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Research Review

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Growing fruit crops organically : challenges and opportunities

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ABSTRACT

Present days' farming is not sustainable in consonance with economics, ecology, equity, energy and socio-cultural dimensions. Indiscriminate use of chemical fertilizers, weedicides and pesticides, especially in fruit production has resulted in various environmental and health hazards along with socio-economic problems. Grower community is trying to find out an alternative sustainable farming system, which is ecologically sound and economically and socially acceptable. Sustainable production is unifying concept, which considers ecological, environmental, philosophical, ethical and social impacts, balanced with cost-effectiveness. Traditional organic production practices, which are based on natural and organic methods of farming offer several effective, feasible and cost-effective solutions to most of the basic problems being faced in conventional production of fruit crops. Organic fruit cultivation helps in climate mitigation, carbon fixation, soil fertility improvement and water conservation. In present scenario, shifting from conventional to organic, maintenance of soil health and insect pest management will be major challenges which can be taken care of with adaptation of complete organic package of practice in fruit production.

Key Words: Soil organic carbon, Biological properties, Biodynamic, Organic matter, Carbon sequestration

Over use of agro-chemicals for 5-6 decades in fruit production has resulted in various environmental and health hazards along with socio-economic problems (Pathak and Ram, 2004). The degenerative effects of intensive agro-chemical based farming practices have forced for alternative system of farming. Though fruit production has continued to increase, but productivity rate per unit area has started to decline. The whole farming community is trying to find out an alternative sustainable farming system, which is ecologically sound, economically and socially acceptable. Organic agriculture is unifying concept, which considers ecological, environmental, philosophical, ethical and social impacts, balanced with cost effectiveness. The answer to the problem probably lies in returning to our own roots. Traditional agricultural practices, which are based on natural and organic methods of farming offer several effective, feasible and cost-effective solutions to most of the basic problems being faced in conventional farming system.

As per FiBl survey (2018), 2.6 million farmers across the world and 178 countries are now growing organically produced commodities on more than 57.8 million ha of agricultural lands. In India, 8,35,200 farmers are engaged in organic production of various crops. Total world trade of organic produce was 90 million US dollars during 2016. In India, total area under organic cultivation is 7.2 million ha which is 0.4% of the total area under organic cultivation. About 4.2 million ha is under wild collection. Sporadic attempts for organic production are now being attempted by some enthusiasts in horticultural and plantation crops like tea, coffee and cardamom in certain pockets in India. By default, many regions in north-eastern states of the country are pursuing organic horticulture which needs to be consolidated and promoted.

Background

India has rich heritage and enjoyed the (golden period) in every sphere of life in ancient times. There used to be record production in many crops and have supremacy in spices, silk fabrics, cotton etc. without use of agro-chemicals. On close observation, it is evident that ancient people used to respect the five ultimate source of energy and they were benevolent to provide free energy to humanity. The Vedic answer is that cosmic

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energy is at root cause of all these mysteries. Like all forms of energies, cosmic energy is invisible and can be observed or felt through effects. One element can be converted into another with the help of the cosmic energy. Enormous amount of energy is available through primitive microorganism in soil and also to living cells of plants. Plants have capacity to produce all the elements needed for their growth, without feeding them with specific elements. Capturing enormous quantity of solar and cosmic energy through micro life in around earth surface could pave the way for sustainable agriculture and food security.

Every activity requires some kind of energy. It was well-known to people in ancient India that solar and cosmic energy is root cause for soil fertility and crop productivity. With the advent of agro-chemicals, slowly there had been shift change in name of higher production. Country initiated copying western countries of agro-chemical based farming and facing the current crises.

Organic production: its relevance to Indian farming

Only 30% of India's total cultivable area is covered with agro-chemicals where irrigation facilities are available and in the remaining 70% of arable land, which is mainly rainfed, negligible amount of agro-chemicals are being used. Farmers in these areas often use organic manures as a source of nutrients that are readily available either in their own farms or in their localities (Ram and Pathak, 2016). The north-eastern region of India provides considerable opportunity for organic farming due to least utilization of agro-chemical based inputs. About 18 million ha of such land is available in NEH region, which can be exploited for organic production. With the vast area under naturally organic/default organic cultivation, India has tremendous potential to grow crops organically and emerge as a major supplier of organic products in the world's organic market (Ram and Pathak, 2016).

The report of the Task Force on Organic Farming appointed by the Government of India also observed that in vast areas of the country, where limited amount of agro-chemicals are used and have low productivity could be exploited as potential areas for organic agriculture. Protecting the decline of soil organic matter is most potent weapon in fighting against unabated soil degradation and imperiled sustainability of agriculture in tropical regions of India, particularly those under the influence of arid, semi-arid and sub-humid climate. Application of organic manure is the only option to improve the soil organic carbon for sustenance of soil quality and future agricultural productivity (Pathak *et al.*, 2010).

The on-farm organic input production with locally available materials normally leads to a reduction in variable input costs under organic management. Expenditure on manures and biopesticide spray is substantially lower than in conventional systems in almost all the cases. In a few cases, a higher input costs due to purchase of compost and other organic manures have been reported (Sellen *et al.*, 1993). The traditional organic farming practices with lower input costs and favourable price premiums can mitigate reduced yields and make organic farms equally and more profitable than conventional farms.

Issues in organic fruit production

- On-farm input generation to make it cost effective
- Quantum production equal or higher what is expected from optimum combination of agro-chemicals
- Continuous improvement in physico-chemical and biological properties of soil
- Improvement in produce quality with respect to nutrition, essential constituents, therapeutic value and storability, and
- Eco-friendly and cost-effective technology.

Fruit crops as carbon sink *vis-a-vis* environmental cleansing

Organic farming practices are so far the most appropriate approach for mitigation and adaptation to climate change it represents a positive example of how farmers can help mitigate climate change and adapt to its predictable and unpredictable impacts (FiBl, 2007). It can serve as a benchmark for allocating development resources to climate change adaptation, or to measure progress in implementing climate related multilateral environmental agreements (FiBl, 2007). Foodgrain crops land and permanent pastures lose soil carbon through mineralization, erosion and overgrazing. Global arable land loss is estimated at 12 million ha per year, which is 0.8% of the global crop land area (1,513 million ha) (Pimentel *et al.*, 1995). If present farming practices remain unchanged, the loss of organic carbon in typical arable soils will be continued and will reach a new steady state at a low level.

The application of improved agricultural techniques (organic farming, conservation tillage, agroforestry), however, stops soil erosion (Bellamy *et al.*, 2005) and converts carbon losses into gains (FiBl, 2007). Consequently, considerable amounts of CO_2 may be removed from the atmosphere. Fruit plants are grown at recommended distance where only basin area receives cultural practices and rest receive minimum tillage (Berner *et al.*, 2005). Therefore, in fruit orchards carbon loss is less than arable land and also sink source for carbon than field crops. Soil carbon increased 981 kg/

Table 1. Carbon sequestration capacity of various fruit crops

Fruit crop	Carbon sequestration (t/ha/year)	Source
Apple	7.96	Qaisar *et al.*, 2018
Cocoa	65	Kongsager *et al.*, 2013
Grape	49.5	Nistor *et al.*, 2018
Oil palm	14.72	Pulhin *et al.*, 2014
Mango	27.254	Chavan and Ganesh. 2012
Coconut	15.73	Magat, 2009
Kiwi	6.3	Holmes *et al.*, 2015
Syzygium sp.	138.541	Anonymous. 2016
Orange	76	Kongsager *et al.*, 2013

ha and 574 kg/ha in manure legume based organic farming system at Rodale experiment, US, (Pimentel *et al.*, 2005). In nine farming system trials in the US (Marriott and Wander, 2006), reported that soil organic carbon concentrations was 14% higher in organic than in conventional system. Different workers have also reported carbon sequestration capacity of various fruit trees (Table 1).

Traditional skills and knowledge have been neglected in conventional/intensive farming system, although they are now being partially recaptured in integrated farming system. Organic production, on the other hand, has always been based on practical farming skills, observation, personal experience and intuitions. Knowledge and experience reduce reliance on external inputs (Ram and Pathak, 2005). This knowledge is important for manipulating complex agro-ecosystems, for breeding locally adjusted seeds and livestock, and for producing on-farm inputs (composts, bio-enhancers, green manure *etc.*) and on-farm produced cheap bio-pesticides. Such knowledge has also been described as a 'reservoir of adaptations' (Tengo and Belfrages, 2004).

Farming practices such as organic productions that preserves soil fertility and maintains or increase organic matter in soils, are in a good position to maintain productivity during abiotic and biotic stresses. Organic farm management may help to stop soil erosion and convert carbon losses into gains (Reganold *et al.*, 1987). Soils under organic management retain more rainwater because of the porous properties of organic matter. These porous properties were described for heavy loamy soils in a temperate climate in Switzerland where soil structure stability was 20-40% higher in organically managed soils than in conventional soils (Mader *et al.*, 2002). The amount of water percolate through the top 36 cm soil was 15-20% more in the organic systems of the Rodale farming systems trial compared to conventional systems.

The organic soils held 8,16,000 liters water/ha in the upper 15 cm layer of soil. It was found that water stored in organic plots was twice than conventional plots during torrential rains (Lotter *et al.*, 2003). Percolation of water in the soil significantly reduced the risk of floods, an effect that could be very important if organic production was practiced on much larger areas. Sequestration of CO_2 in soils is excluded from the Clean Development Mechanism (CDM), although it could take effect quickly, is very cost effective and would promote rural development. Organic production should be included in voluntary CO_2 emissions markets.

Science and apprehensions

An additional strength of organic farming systems is the diversity, including diversity of crops, fields, crop rotation, on-farm input production, intercrops, cover crops and various organic farming practices. The diversity in organic farms provides many ecological services that significantly enhance farm resilience (Bengtsson *et al.*, 2005; Hole *et al.*, 2005). Positive effects of enhanced biodiversity on pest prevention have been shown by several authors (Zehnder *et al.*, 2007; Wyss *et al.*, 2005; Pfiffner *et al.*, 2003). Similar effects of diversified agro-ecosystems on diseases and better utilization of soil nutrients and water are likely to occur (Altieri *et al.*, 2005). Pathak and Ram (2016) and Pathak *et al.* (2010) have given emphasis for on farm production of organic inputs *viz*; composts, bio-enhancers and biopesticides which are good source of nutrients and beneficial microbes. Their proper application can improve soil fertility (Table 2).

Table 2. Improvement in chemical and biological properties of tree basin soil

Constituent	Improvement after organic cultivation			
	Initial	II year	III year	IV year
Organic carbon (%)	0.53	0.80	1.00	1.16
P (ppm)	8.66	8.66	22.66	56.27
K (ppm)	140.00	142.50	202.50	1062.25
Yeast and mould (cfu g^{-1})	1.3×10^4	5.8×10^4	8.5×10^4	8.5×10^4
Bacteria (cfu g^{-1})	3.7×10^6	4.8×10^6	8.0×10^6	3.1×10^8

Apprehensions

- Can crop yield level be maintained in organic farming to feed ever growing population?
- Are there are enough organic wastes available for conversion of entire area of country into organic production?
- Is organically produced foods are more nutritive as compared conventional systems?
- Can insect pest and weed managed by organic means?
- Is organic practices are eco-friendly and cost-effective?
- Are there are enough markets for organic produce?

For sustainable fruit production, one has to change the mindset and conceive a farming system approach, which can enhance the health of rhizosphere and biosphere simultaneously for sustainable production. This evidence get further support from the study published in Times of India by Food Safety and Standards Authority of India under GOI which is summarizes as under:

- Common food items contained residue of banned pesticides beyond the permissible limits;
- Okra, leafy green vegetables such as cabbage and fruits like bananas, oranges and apple that we so relish may be overloaded with some of these harmful pesticides:
- Brinjal tops with the maximum residue limit of banned pesticides which was 860% above legal limit followed by cauliflower and cabbage;
- Rice too had these residue of pesticides such as chlorofeninphos 1324% above maximum residue limit;
- While the level of aldrin in wheat was 21,890 times more than the maximum residues limit.

Strength

About 74% of farmers in India own less than 2 ha land compared to developed countries, this was considered strength because organic farming practices would require low-cost inputs and could be produced on-farm (Reddy and Ram, 2010) which could be managed under family farming. Rabo Bank Survey, 2005 reported that 65% of the total cultivable area in India is organic by default. Therefore, system would facilitate the conversion of these area, to start with, into organic and work within natural systems and cycles at all levels from the soil to plants and animals.

In India, Sikkim has become the first organic state and states like Meghalaya, Mizoram and Nagaland are in queue to declare them as organic states. Organic production represents a very productive food supply system that relies on recycling strategies. Badgley *et al.* (2007) modelled the yields stated in 293 on-farm and on-station production and concluded that, compared to high cost agri-inputs in developed countries, the average yields in organic crop and livestock production are 92% of those in conventional production.

Interestingly, yields from organic production under conditions where water is limited during the growing period, and under subsistence farming, are equal or significantly higher than those from conventional production. A comparison of 133 studies from developing countries concluded that organic crops and livestock yields were 80% higher than conventional (increase in yield was 74% in crops) (Badgley *et al.*,

Table 3. Economic analysis of organic mango production

Treatment	Cost of production (₹/kg)	Yield (kg/ha)	Total production value (₹/ha)	Net profit (₹/ha)	Benefit : cost ratio
FYM (40 kg/tree) + *Azotobacter* + *Azospirillum* + PSB (108 cfu/g) + Mycorrhiza (inoculum)	9.24	6068.33	91025	36436.50	1.67
Biodynamic compost (30 kg/tree) + bio-enhancers (CPP 100 g, BD - 500 and BD 501 as soil and foliar spray)	5.41	10898.67	163480	112298.67	3.19
Neem cake + farmyard manure (20 kg each/tree) + *Azotobacter* + *Azospirillum* + PSB (108 cfu/g)	9.84	8175.33	122630	46056.30	1.60
Vermicompost (30 kg/tree) + *Azotobacter* + *Azospirillum* + PSB (108 cfu/g)	9.27	6955.67	104335	49606.67	1.90
Farmyard manure (40 kg/tree)+ bio-enhancer (Amritpani 5% soil application)	9.16	5795.33	86930	36956.30	1.74
FYM (40 kg/tree) + green manuring (sun hemp) *Azotobacter* + *Azospirillum* + PSB (108 cfu/g)	7.43	8218.33	123275	68938.07	2.26
1000g N P K/tree	11.50	5353.00	80295	24623.11	1.44
CD (5%)	2.04	2565.26	38478.85	38479.04	0.78

2007). In temperate climate region higher yields for maize and soya were recorded in organically managed fields during dry seasons (Hepperly *et al.*, 2005).

The data indicates that techniques inherent to organic farming of investing in soil fertility by means of green manure, leguminous intercropping, composting and recycling of organic and animal wastes could contribute considerably to global food productivity. Further improvements in compost application techniques are also required, however, in organic production systems, nitrous oxide and methane emissions is very less. Ram *et al.* (2017), reported increase in production as well as benefit: cost ratio with biodynamic package of practice compared to recommended dose of fertilizer (Table 3).

In another experiment on organic production of guava cv Allahabad Safeda, Ram and Verma, 2017, reported less energy consumption with organic amendments compared to recommended dose of fertilizers, (Table 4).

Nutrient and insect pest management

Carbon and oxygen, together constitute 88% of plant tissue, derived from carbon dioxide. Photosynthesis allows the integration of carbon and oxygen from CO_2 within the structure of a sugar (Bourguignon, 2011). Hydrogen, which contributes 6% of plant tissues, is derived from the breakdown of rainwater and hydrogen, which is absorbed in the tissues of the plant. Nitrogen is derived from the atmosphere, through microbes that can transform gaseous nitrogen into ammonia. This ammonia directly enters in leguminous plants in the form of amino acids or is converted into nitrates by the soil microbes and then absorbed by other plants (Bourguignon, 2011). The constitutive elements of the plants derived from the soil do not enter in the form of atoms, but in the form of oxides and chelates (Bourguignon, 2011).

These transformations are affected by the soil microbes, which render these elements assimilable by the plants from the mother rocks or humus. Thus, all other soil elements can be absorbed by plants through microbial action. The oxidation of soil elements is often achieved by very specific micro flora. Fifteen oligo-elements can enter in plants in organic form. This statement enables us to nullify the strong notion that plants have purely mineral diet (Reddy and Ram, 2010). Organic fruit production also emphasizes on crop wastes recycling for compost production, crop rotation, cover crops, trap crops, mulching *etc*. In an area, application of biodynamic package of practice for 3 years, improved the physical, chemical and biological properties of soil (Pathak *et al.*, 2010).

Insect pest management in organic farming begins with growing of crops those are naturally resistant to insect pests, or choosing sowing times that prevent insect pests outbreaks (Reddy and Ram, 2010). Careful management in both time and space of planting not only prevents pests, but also increases population of natural predators that can contribute to the reduction of insects, diseases and weeds (Reddy and Ram, 2010). Other methods generally employed for the management of insect pests are: improving soil health to resist soil pathogens and promote plant; growth; rotating crops; encouraging natural biological agents for the management of insect pests and weeds; using physical barriers for protection from insects, birds and animals; modifying habitat to encourage pollinators and natural enemies of pests; and using pheromone attractants and trap pests (Pathak and Ram, 2012).

Table 4. Energy consumption and output in guava production with various organic and inorganic amendments

Particular	30 kg biodynamic compost/ tree (T1)	30 kg biodynamic compost fortified with BD-500 and 100 g cow pat pit/tree (T2)	250 g rhizospheric soil of *Ficus benghalensis*/ tree+5 per cent *Amritpani* + 30 kg organic mulching (T3)	30 kg FYM/ tree + 5 per cent *Pancha-gavya* (T4)	30 kg vermicompost + 250 g Azospirillum culture + 50 g PSB/ tree (T5)	30 kg FYM/ tree (T6)	350 g N, 150 g P_2O_5 and 350 g K_2O/ tree (T7)
Total energy input (MJ)	9653.1	12104.3	5216.9	7427.03	10905.6	7135.37	13523.41
Total output energy (MJ)	37673.9	38287.0	46973.2	36402.2	42340.6	33154.848	47120.76
Energy output-input ratio	3.90	3.16	9.00	4.90	3.88	4.65	3.48
Specific energy (MJ/kg)	0.73	0.897	0.315	0.579	0.731	0.611	0.815
Energy productivity (kg/MJ)	1.375	1.114	3.172	1.727	1.368	1.637	1.228
Energy intensiveness (MJ/₹)	0.254	0.297	0.133	0.201	0.274	0.209	0.318
Net energy yield (MJ/ha)	28020.8	26182.7	41756.2	28975.2	31434.9	26019.5	33597.3

Organically-grown crops have been shown to be more tolerant to insect pest incidence. Plant susceptibility to insect pest has been shown in numerous studies to be associated with high plant N levels (Ramesh *et al.*, 2005). Soil-borne root diseases are generally less severe on organic farms than conventional farms, while there were no consistent differences in foliar diseases between the systems. The successful management of root diseases in organic production systems is likely to be related to the use of long and diverse crop rotations, crop mixtures and regular application of organic amendments (Ramesh *et al.*, 2005). Increased levels of soil microbial activities lead to increased competition and antagonism in rhizosphere, the presence of beneficial root-colonizing bacterial and increased levels of vesicular-arbuscular mycorrhizal colonization of roots have all been identified as contributing factors; in the management of root diseases (Ramesh *et al.*, 2005).

Ram *et al*. (2017) reported that insect pest management in mango cv Mallika was effectively done with spray of biodynamic liquid pesticide and natural sulphur. Before spray, the hopper population was 3.07 / panicle and after the spray the reduction in the hopper population was found up to 15th SMW with 0.95 hoppers / panicle. Second spray was taken up at 14th SMW, as result hopper population reduced to 0.4 hoppers / panicle up to 19th SMW. Powdery mildew was managed with spraying of BD - 501 and 2% natural sulphur (Fig. 1).

Constraints in field application

Most of the soils have become deficient in 7-8 micro nutrients due to repeated application of NPK for a quite long period (Singh, 2008). Organic carbon percentage has also gone down in most of the soils. Soil health management will be most challenging during conversion period and it may take time to bring back the required soil fertility. On the other hand, biological properties of soil have also been deteriorated due to use of agro-chemicals for a long time (Zayad *et al.*, 2000). Soil health management should focus on systematic application of organic manures, bio-enhancers, mulching, crop rotation, intercropping, cover cropping etc.

Agri-inputs availability

Most of off farm and out sourced organic inputs sometimes do not meet the quality standards. Therefore, emphasis should be given for on-farm production of organic inputs, *viz.* composts, bio-enhancers and bio-pesticides (Pathak and Ram, 2013). Besides, due to mechanization in agriculture, livestock population in villages has gone down drastically. A major challenge in organic fruit production is availability of quality organic inputs. Therefore, incentives must be given to the farmers for production of organic inputs on their farms (Ram and Pathak, 2016). There is a need to develop cost-effective local organic input production unit within the communities.

Organic seed and planting material

Non-availability of organically produced seeds and planting material is the key component for promotion of organic farming in fruit crops. Hence major research and development efforts are required to ensure availability of quality seeds and planting material required for organic production. According to "Manu" good seed and good land yields abundant produce.

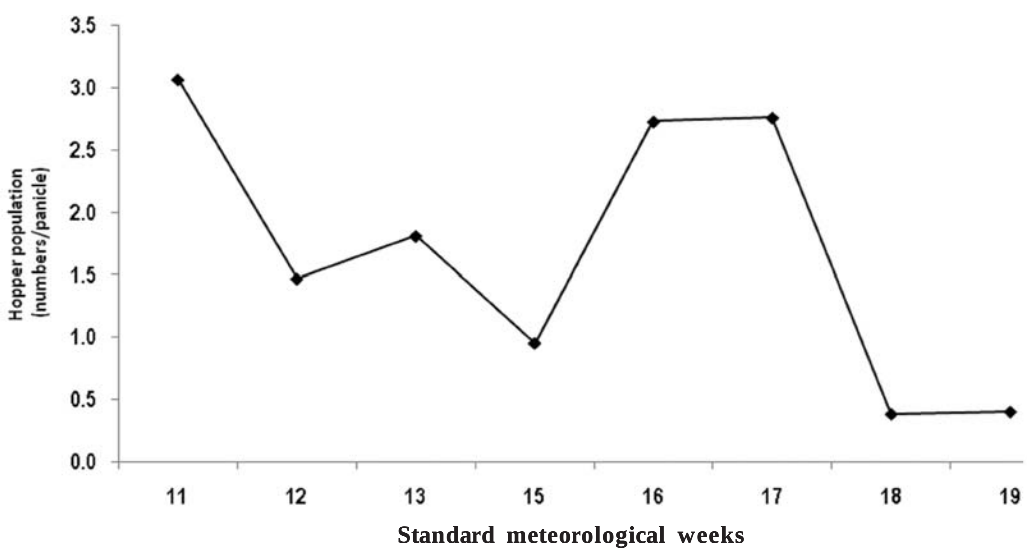

Fig. 1. Mean hopper population in experimental mango orchard before and after spray of biopesticide

Quality of seeds should be true, viable, free from insect pest incidence, weeds, unwanted materials, fairly priced, bold and uniform in size. Local seeds and varieties are better adapted to organic production system. Therefore, emphasis should be given for production of organic seed and planting material for promotion of organic fruit production (Pathak and Ram, 2006).

Insect pest management

Over use of agro-chemicals for a long time, caused damage to bio and rhizosphere which resulted in significant decrease in population of parasites, predators and other beneficial creatures. In such disturbed habitat, management of insect pest may be more challenging during shifting from conventional to organic production. Therefore, prior to opting for organic production, one should require proper training for soil health and insect pest management (Ram and Pathak, 2016).

Insufficient market channels

There are no organized markets for selling of organic produce. Till date, organic production of various crops is demand based and on contractual basis (Mondal, 2018). The farmers who are not members of any organic produce selling agency, cannot sell their produce at premium price in the markets. There is a need to develop buy back system of organic produce to promote organic production in the country. Besides, local infrastructural facilities for value-addition, processing, packaging, logistics, finance etc is to be organized to promote organic production system in the country.

Lack of know-how

Most of the growers are not aware of organic farming practices. They require proper practical training for organic production of fruit crops. There are a number of centrally sponsored schemes for organic production of various crops but very few progressive farmers are aware of those. Proper popularization of these schemes should be done on priority to promote organic farming practices in the country. Besides that, education system from primary/secondary levels should cover agricultural and rural subject's essential to upgrade their knowledge and skills to optimize the use of their resources, know-how for good agricultural practices (GAPs).

Challenges in sustaining quality production

"Healthy soils produce healthy food and healthy food maintains people health" is the primary fundamental principle of organic production systems. Still, nutritional qualities of organically produced foods compared to conventionally produced foods are the matter of discussion. Organic farming recommends that organically-grown foods are nutritionally superior because it contains higher levels of vitamins, minerals, and amino acids. Baranski *et al.* (2014) reported after analyzing 343 studies that food produced according to organic standards can lead to increased intake of nutritionally desirable antioxidants and reduced exposure to toxic heavy metals. Cadmium along with lead and mercury was found to be almost 50% lower in organically produced commodities than conventionally grown one.

Concentrations of total nitrogen were 10%, nitrate 30% and nitrite 87% lower in organic produce compared to conventional one. Professor Leifert (2015) added that organic vs. non-organic debate has rumbled on for decades but the evidence from this study is overwhelming - that organically produced foods are rich in antioxidants and lower in pesticides residues. He also suggested that this study should be a starting point for promotion of organic cultivation in the world.

There has been a number of conflicting reports regarding nutritional quality of organic and conventionally grown commodities in early years. Ram *et al.*, (2017) reported higher yield of mango cv. Mallika over conventional production and significant increase in fruit quality parameters were also recorded. After one year of organic amendments application in mango plantation, improvement in microbial properties of soil, *viz*, total bacterial count, fungal population, actinomycetes, total microbial biomass carbon, phosphorus, nitrogen, urease, alkaline phosphate, fluorescent diacetate, acid phosphate and dehydrogenase activity, were recorded with biodynamic package of practice over to recommended dose of fertilizers (Ram *et al.*, 2017).

Use of agrochemicals has adversely polluted the 3 source of energy, *i.e.* soil, water and environment which has affected soil fertility, crop productivity, produce quality etc. Soil organic carbon content (soil humus) in most of soils has been reduced to > 0.5 per cent. Under these circumstances, maintenance of soil fertility and crop productivity are the major challenges in organic fruit production systems. It is pertinent to record that loss of soil organic carbon is one of the major concerns of its fertility (Bellamy *et al.*, 2005). The soil humus loss on the planet earth might become ecologically dangerous if not focussed now, because humus is the major accumulator of solar energy at the earth surface and is guardian of soil fertility, guaranteeing ecological stability of biosphere (Rozanov, 1990). Yields in organic production systems are comparable to conventional systems are directly related to intensity of farming practices in conventional systems (Reddy and Ram, 2010). Effect of conversion to organic production on yields indicates that:

- In intensive farming systems, organic production decreases yield; the range depends on the intensity of external inputs used before conversion.
- In green revolution areas (irrigated lands); conversion to organic usually leads to almost identical yields.
- In traditional rainfed farming system (with low external inputs), organic production has shown the potentials in increase yields.

Number of studies (FiBl, 2007) has shown that under drought conditions, crops in organic production systems produce significantly higher yields than comparable conventional agricultural crops, often out-yielding conventional crops by 7- 90%. Others have shown that organic systems have less long-term yield variability (Pretty and Hine, 2001). The so called organic conversion effect, in which a yield decline in the first 1- 4 years of conversion to organic agriculture, followed by a yield increase when soils have developed adequate biological activity. Pathak *et al.* (2010) also reported improvement in yield and quality of mango cv. Mallika and Dashehari.

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Research Review

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Sustainable production of tuberose *(Polianthes tuberosa)* through integrated nutrient management : a review

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ABSTRACT

Tuberose (*Polianthes tuberose* L.) is most important cut flower. The recent energy crisis and hike in prices of fertilizers, further necessitate the use of alternate sources, *i.e.* organic manures and biofertilizers. But no single source of plant nutrients either it is chemicals, organic manures or even biofertilizers could meet the entire need of the crop. Therefore, there is a need of integrated nutrient management (INM). This holistic approach has profound effect in improving flower quality and yield. The INM also provides an excellent opportunity to overcome all the imbalances besides sustaining soil health. The paper reviews all the literature on various aspects of tuberose cultivation from INM perspective for better understanding and future strategies for improved flower quality and yield of tuberose.

Key Words: Biofertilizers, Fertilizers, Integrated nutrient management, Manures

Tuberose (*Polianthes tuberosa* L.) is one of the most important bulbous crops cherished for beauty and fragrance of flowers. The use of manures as an organic source occupy an important place in modern agriculture system as they provide a scope for reduction in use of costly chemical fertilizers which can pollute soil in long term use (Singh, 2006). Organic and microbial sources of nutrients have advantage of consistent and slow release of nutrients, maintaining ideal C:N ratio, improvement of water-holding capacity and microbial biomass of soil profile without having any residual effects (Yadav *et al.*, 2010; Hazarika *et al.* 2011; Hazarika *et al.* 2015a). Application of organic manures not only improves the soil physical properties and pH, but also adds essential nutrients to the soil, thus increases the nutrient availability and its ultimate absorption by plant (Hazarika *et al.*, 2014). Similarly, biofertilizers have been considered as a cheap, eco-friendly way of improving soil fertility status (Hazarika *et al.*, 2015a).

INTEGRATED NUTRIENT MANAGEMENT

The integrated plant nutrition systems (IPNS) in growth, yield and quality of banana cultivation was reviewed in detail by Hazarika *et al.* (2015b). The emphasised that a thorough knowledge of the critical levels of different nutrient elements, time and method of application of nutrients is essential to get better growth, yields and quality along with improving soil health. Organic manure have a lots of benefit, apart from the increased yield and return, it also improve soil texture, reduces pollution of soil due to reduced fertilizer application which is beneficial for the present problems of high cost fertilizers and environment pollution (Kumar *et al.*, 2016). Use of organic manures and biofertilizers are environmentally safe and viable alternative of chemical fertilizers and it increases microbial biomass in soil (Selvamani *et al.*, 2011). The use of organic manures and biofertilizers helps in improving quality and quantitative traits of chrysanthemum (Bohra and Kumar, 2014). Similar findings were also reported by Khanna *et al.*, 2016 in China aster. Bio-fertilizers can promote plant growth and productivity has internationally been accepted as an alternate source of chemical fertilizers (Mia, *et al.* 2010). Biofertilizers are supplements of chemical fertilizers as they contribute plant nutrients through biological nitrogen fixation and solubilization of immobile phosphorus and promote synthesis of growth promoting substances like auxins, gibberellins,

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cytokinins and antibiotic metabolites which, in turn, improved resistance against biotic and abiotic stress (Awasthi *et al.*, 1998; Hazarika *et al.* 2015a) and accumulation of dry matter (Wange 1996).

The use of organic manures in conjugation with fertilizers enhances the efficiency of fertilizers, partly supply nutrients and also improve soil physical, chemical and biological properties (Airadevi and Mathad, 2012). In addition, INM improves quality of produce, reducing the cost of production. Chakradahar *et al.* (2018) reported that use of recommended doses of chemical fertilizers along with biofertilizers PSB @ 2 ml / litre + *Azotobacter* @ 25 g / litre + VAM @ 20 g / litre was found effective in improving the vegetative and floral attributes of gladiolus. The INM can consequently be a viable and cost-effective approach for commercially sustainable agriculture (Verma *et al.*, 2011).

VEGETATIVE GROWTH

The growth and development of plants largely depend on proper feeding right from the growth initation. Since tuberose is a heavy feeder crop, INM practices play an important role in its growth and development. Nitrogen and phosphorus are essential for initiating the growth (Bankar and Mukhopadhyay, 1980). An application of 200 kg P_2O_5 / ha recorded maximum vegetative growth (Yadav *et al.*, 1985). The application of NPK @ 250: 200: 200 kg / ha resulted in maximum plant height, number of leaves and shoots in tuberose cv. Double. The leaf length in tuberose cv. Single increased with the application 200: 200: 400 kg / ha NPK (Singh *et al.*, 1996). Likewise, Mohanasundaram *et al.* (2003) reported maximum leaf number as well as length in tuberose with an application of increasing quantity of nitrogen.

Application of 200 kg N / ha increased plant height and number of leaves / plant in tuberose cv. Double (Sharma *et al.*, 2015). In addition, Pal and Biswas (2005) revealed that NPK fertilization significantly increased the leaf area in tuberose. Similarly, a treatment of 30:30:15 g / m^2 of NPK recorded highest vegetative growth (Nair *et al.*, 2000). Higher doses of nitrogen and phosphorus accelerated the sprouting in tuberose (Dahiya *et al.*, 2001). Gupta *et al.*, (2006) found that plant height of tuberose improved with application of phosphorus at 200 kg P_2O_5 / ha. As soon as 200 kg / N / ha was applied 90 and 120 days after planting it resulted in maximum plant height, number of sprouts / bulb, number of leaves and length of longest leaf (Kishore and Singh, 2006).

Swaminathan *et al.* (1999) found that treatments with 30:65:62.5 kg NPK / ha + *Azospirillum* resulted in earliest sprouting of bulbs. The inoculation of VAM in combination with N and P doses were significantly more effective in improving the growth parameters of cv. Double (Singh *et al.*, 2003).

The improved growth might also be due to more absorption and utilization of nutrients due to integrated use of organic and inorganic fertilizers alongwith biofertilizers (Chezhiyan *et al.* 1999). Tuberose var. Single treated with Tricho-compost (3 t / ha) + one-fourth RDF produced maximum plant height, leaf number and plant spread (Naznin *et al.*, 2015). Similarly, Suseela *et al.* (2016) reported that blub planted in plots containing 50% recommended dose of fertilizers in combination with poultry manure 50% recorded significantly less number of days for sprouting and 50% sprouting of bulbs and maximum number of leaves, leaf area index and total chlorophyll content per plant in tuberose *(Polianthes tuberosa)* cv. Suvasini.

FLORAL CHARACTERS AND YIELD PARAMETERS

The quality of flowers is also affected by climatic, geographical and for greater extent by nutritional factors.

Singh and Uma (1996) evaluated the effect of nitrogen levels on floral parameters of tuberose cv. Shringar. Yield and quality were best when 250 kg / ha nitrogen was applied at three splits (basal, 60 and 90 days after planting). While working on tuberose, Swaminathan *et al.* (1999) reported that application of NPK at 120:65:62.5 kg / ha + *Azospirillum* + phospho-bacteria resulted in highest spike length and number of florets / spike. Similarly, Parkash *et al.* (2006) found highest flower number with best tuberose quality and yield attributing parameters with the application of NPK @200: 200: 150 kg / ha. Shivalingappa *et al.* (2001) observed that application of NPK at 75:37.5:50 kg / ha + *Azotobacter* + *Azospirillum* + VAM significantly improved the flower yield.

Integration of farmyard manure (FYM) along with recommended dose of fertilizers produced maximum spike length, number of flowers / spike and number of flowers / m^2 in tuberose (Barman *et al.*, 2003). Munikrishnappa *et al.* (2004) also observed that application of 50% of recommended dose of fertilizer (RDF) along with vermicompost at 5 t / ha improved spike length, rachis length, florets diameter, number of florets / spike and flower yield Padaganur *et al.*, (2005) found that application of vermicompost alone as well as in combination with 50% RDF initiated early flowering. Kukde *et al.* (2006) studied the effect of organic manures and biofertilizers on flowering and yield of tuberose cv. Single. Tuberose bulb treated with *Azotobacter* and phosphate-solubilizing bacteria at 2.5 g / kg of bulb gave highest early opening of first pair of florets, better flower quality and also maximum yield of flowers / ha, followed by application of vermicompost at 10 t / ha.

Significant increase in flower quality and yield contributing characters, *viz*. length and diameter of spike, rachis length, number of florets / spike, number of spikes / plant and yield of florets / ha in tuberose were obtained by implementing INM with the application of vermicompost @ 2 t / ha + *Azotobacter* + PSB (2.5 g / m^2 each) as compared to other treatments (Chopde *et al.*, 2007). The foliar spray of Panchagavya (4%) resulted in minimum days taken to spike emergence and first floret opening and maximum in spike length, number of florets / spike and spike yield / m^2 of cv. Pearl Double (Singh *et al.*, 2007).

In addition, spike length, duration of flowering and number of florets per spike were increased significantly with increasing levels of nitrogen upto 200 kg / ha and biofertilizers (*Azotobacter*, phosphorus solubilizing bacteria and *Azospirillum*) in cv. Double (Yadav *et al.*, 2008). The biofertilizers application with lower N and P doses advanced the flowering indicated complementary role in reducing the use of chemical fertilizers (Chudhary, 2009). Pandhare *et al.* (2009) also found that tuberose yield and yield attributing characters, *i.e.* number of florets / spike / plant, weight of loose flowers / plant and floret size were maximum with the application of 75% recommended N, P and 100% K (*i.e.* 150:225:200 kg / ha) along with pre-planting treatment of bulbs with *Azotobacter* and PSB.

Bulbs of cv. Single treated with PSB @ 2 g / bulb recorded highest spike length, number of spikes / plant and longevity of spike (Lal *et al.*, 2010). Spray of 4% panchgavya with 2% Manchurian mushroom tea improved the floral parameters of tuberose cv. Phule Rajani, *i.e.* duration of flowering, length of spike, weight of spike, number of florets / spike, number of spikes / plant and yield of spikes (Mahawer *et al.*, 2010). Moreover, Bahadoran *et al.* (2011) recorded that soils amended with poultry litter had a positive effect on flowering parameters of tuberose.

Kabir *et al.* (2011) found that flower quality parameters, *viz.* spike length and diameter, number of florets / spike and flower yield greater when plants of cv. Single were supplied with organic fertilizers along with half chemical fertilizers. Among different biofertilizers in combination with chemical fertilizers, NPK @ 10:8:10 + *Azotobacter* recorded highest spike length and number of spikes / clump (Koley and Pal, 2011). Majumder *et al.* (2014) observed significantly longest spike and higher flower yield in tuberose cvs Phule Rajani and Suvasini applied with 75% RDF + FYM (1 kg / m^2 / year) + vermicompost (300 g / m^2) + *Azospirillum* (2g plant / year) + PSB (2 g / plant / year).

Application of phosphorus @ 155 kg / ha increased spike length, spike diameter, number of flowers / spike and flower yield of cv. Double (Amin *et al.*, 2012). Organic fertilizer enriched compost @ 10 t / ha produced maximum spike length, floret number and clump weight of variety Double (Das *et al.*, 2011). In tuberose, grown under the potting media containing sand + leaf recorded maximum floral diameter and number of flowers / spike (Ikram *et al.*, 2012). Kumar *et al.* (2012) reported that application of *Azospirillum* @ 3 g / plot and PSB @ 150 g / plot gave better performance on flowering parameters. Khalaj *et al.*, (2012) observed that plants supplied with 250 kg nitrogen / ha produced highest stalk length, stem diameter and spike length of tuberose. Mahmoodinezhadedezfully and Isvandi (2012) stated the application of phosphorus with different levels of organic manures improved floral characters of tuberose cv. Double.

Taher *et al.* (2013) observed that application of 200 kg / ha N and 10 kg / ha microbial fertilizer containing PSB resulted in highest yield and quantitative traits for tuberose. Wasim *et al.* (2014) stated that PSB was found more effective in quantitative and qualitative spike production of cv. Mexican single. Tuberose bulb grown in plots supplied 10 t cow dung + 250 kg urea + 190 kg TSP + 190 kg MP / ha along with water hyacinth mulch produced maximum flowering plants, length of flower spike, number of spikelets and yield of spike / ha (Mazed *et al.*, 2015). Application of Tricho-compost (3 t / ha) + one-fourth RDF on tuberose var. Single recorded minimum days to flowering, maximum spike length, rachis length, spike weight, florets / spike and yield / ha (Naznin *et al.*, 2015).

Organic manures and biofertilizers like FYM, vermicompost, *Azospirillum* and phosphate solubilizing bacteria and their integration with 75% recommended dose of fertilizers induced higher number of spikes, spike length, rachis length and number of florets in tuberose (Rao *et al.*, 2015). Plants treated with 50% N through Vermicompost + 50% N through urea + P and K (RDF) produced maximum number of flowers / spike (Shirsat *et al.*, 2015). Suseela *et al.* (2016) to study the effect of organic manures, inorganic fertilizers and micronutrients on vegetative and floral characters of tuberose (*Polianthes tuberosa* L.) cv. Suvasini.

POST-HARVEST MANAGEMENT

Khalaj *et al.* (2007) reported that application of nitrogen had no significant effect on vase-life. In post-harvest studies of Cultivar Pearl Double, total number of florets, number of opened florets, lowest floret diameter, water uptake and vase-life were found to be highest in spikes harvested from plots applied with Panchgavya (4%) spray (Singh *et al.*, 2007). Srivastava *et al.* (2007) studied the combined effect of *Azotobacter* and organic manures on post-harvest parameters of cv. Double.

Khalaj *et al.* (2012) observed that plants supplied with 250 kg nitrogen / ha improved vase-life of tuberose cv. Double. Subsequently, highest vase-life and in situ longevity of spikes of cv Double were recorded from plants harvested from plots applied with half RDF + NC @ 1 t / ha + PSB @ 1 g / m^2 + *Azotobacter* @ 1 g / m^2 (Hadwani *et al.,* 2013). Application of organic manures influenced flower longevity due to increased uptake by plants and greater development of water conducting tissue. Application of Pseudomonas @ 40 g / m^2 increased vase life of tuberose spike (Srivastava *et al.,* 2013). The IPM package consisting neem cake 12 q / ha, vermicompost 20 q / ha, *Azotobacter*, PSB and 60% recommended dose of NPK through inorganic fertilizers was found beneficial in getting maximum days taken to open basal floret, vase-life of spike, floret diameter, longevity of opened floret and uptake of water of tuberose cv. Phule Rajani (Meena *et al.,* 2014).

BULB PRODUCTION

High dose of nitrogen and phosphorus caused marked improvement in bulb formation (Bhattacharjee *et al.,* 1979). Subsequently, Khalaj *et al.* (2012) observed that tuberose plants supplied with 250 kg nitrogen / ha produced maximum bulb weight. Wange *et al.* (1995) observed that number of bulblets in tuberose cv. Single increases when applied with *Azospirillum* inoculation. Among different biofertilizers, PSB was found more effective in improving bulb formation in cv. Double (Yadav *et al.,* 2008).

The biofertilizers application with lower N and P doses advanced the sprouting of bulbs (Chaudhary 2009). Inoculation of bulb with *Azotobacter* and PSB at 2.5 g / kg recorded maximum fresh weight of bulb, followed by application of vermicompost @ 10 t / ha (Kukde *et al.*, 2006). Lal *et al.* (2010) recorded improved bulb weight when plants treated with PSB @ 2 g / bulb in cv. Single. Similarly, soils amended with poultry litter (146 g / m^2) produced maximum fresh and dry weight of bulblets (Bahadoran *et al.*, 2011). Organic fertilizer enriched compost @ 10 t / ha produced maximum numbers of bulb in variety Double (Das *et al.,* 2011). Kabir *et al.* (2011) found that application of organic fertilizers along with half dose of chemicals significantly improved bulb length, bulb diameter and bulb yield. Application of phosphorus @ 155 kg / ha improved number of side bulbs, bulb length, bulb diameter and bulb yield in cv. Double (Amin *et al.,* 2012).

Thus, it can be concluded that integrated nutrients management through chemical fertilizers, organic manures and biofertilizers is quite effective in improving vegetative, floral as well as yield-attributing traits in tuberose. The INM approach is helpful in reducing the cost on cultivation, enhancing the yield, maintaining soil fertility and improving the economic stability of flower growers. Tuberose is one of the most important flower crops which are commercially used in perfumery industry. However, research on effect of INM on essential oil content is very meager. So, there is a need to emphasize studies on effect of INM on concrete production.

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Long-term effect of branch bending on fruiting capacity, biomass and xylem vessel anatomical structure of walnut *(Juglans regia)* c.v. Xiangling and Qingxiang

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ABSTRACT

The experiment was conducted to find out the effect of branch bending with ten years on fruiting capacity, biomass and xylem vessel anatomical structure in walnut (*Juglans regia* L.) c.v. Xiangling and Qingxiang trees. Both the percentage of fertile fruits and nut yield were investigated in ten successive years from the trees being planted during 2008. And the biomass of trees and xylem vessel anatomical structure of annual semi-woody branches were measured during 2017. Although the response of both varieties was not similar, branch bending could increase the percentage of fertile fruits and nut yield only in early 3-6 years. In both varieties during ten years, branch bending reduced the trunk diameter above 20 cm ground, the width of vessel, vessel area and vessel total area/xylem transect area, increased the crown area and dry weight of above-ground significantly, but had no effect on above-ground and under-ground fresh weight. There were no more positive effects of branch bending in long-term cultivation of Xiangling and Qingxiang walnuts. It seems that more physiological responses need to be concerned to evaluate the long-term effects of branch bending.

Key Words: Branch bending, Percentage of fertile fruits, Yield, Biomass, Xylem vessel, Vessel area, Crown area.

Walnut (*Juglans regia* L.) trees are most ancient and worldwide commercial forestry with large scale more than 5 600 thousands ha now in China, where it has been cultivated for more than 2 000 years (Chen *et al.*, 2014). And branch-bending practice in cultivation for walnut trees had been referenced from apple after 2000 (Wei *et al.*, 2013). The branch bending could increase walnut tree budding rate, net photo-synthetic rate of leaves, spur formation, yield and root activity in the same year or the next year (Wei *et al.*, 2013; Li *et al.*, 2014a; Li *et al.*, 2014b). Dai (1996) reported the promotional effects of branch bending on young pair trees with timelessness. Branch bending is a widely used cultural practice in orchards (Colaric *et al.*, 2007), which is proved to reduce vegetative growth and increase flower buds and spur formation in apple through redistributing carbon-to-nitrogen (C/N) and hydraulic conductance of sap (Lauri and Lespinasse 2001; Zhang, 2017; Han *et al.*, 2007).

An increase in vegetative growth of plants can lead to a higher growth performance in plant biomass, which is positively correlated with yield (Egli 1997; Rigsby and Board 2003; Board and Modali 2005). The number, diameter, and length of vessels directly determine the xylem hydraulic efficiency and transportation function, thus determining redistribution of material and energy in plants and growth characteristic of plants (West and Brown 1999). It was found that branch bending has an effect on hydraulic conductance of sap (Han *et al.*, 2007). The information regarding shoot architecture of walnut trees was well documented (Wei *et al.*, 2013; Li *et al.*, 2014a, 2014b). However, effect of branch bending on plant vessel system and biomass is not known. Therefore, an experiment was conducted to evaluate the effect of branch bending on percentage of fertile fruits, yield, xylem vessel anatomical structure and biomass and, to analyze the timelessness of branch bending in absence of confounding factors such as rootstock and fertilizer, and water management.

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MATERIALS AND METHODS

The trees of walnut cv. Xiangling and Qingxiang grafted on *Juglans regia* L. were planted in a commercial orchard (31°31′N and 110°50′E) in Baokang country in Hubei province, China, at a spacing of 6 m × 7 m during 2007. The orchard is at an altitude of 810 m with an annual precipitation of 800-1 000 mm and an annual mean temperature of 12-15°C. The soil of orchard had 49.68 g / kg available N, 11.9 g / kg available P, 68.4 g / kg available K, 4.73 mg / g available Fe, 0.29 mg / g g / kg available B, and 1.07 mg / g available Zn. Drip irrigation with fertilizers and other orchard practices including pest control were applied every year.

Bending all one-year-old branches at an angle of 90° in every March from 2008 to 2016 were selected. Four treatments were applied:

Treatment I: Xiangling walnut trees with branch bending.
Treatment II: Xiangling walnut trees without branch bending.
Treatment III: Qingxiang walnut trees with branch bending.
Treatment IV: Qingxiang walnut trees without branch bending.

Each treatment had ten trees with random arrangement in orchards. Percentage of fertile fruits with every tree was calculated in every April and July during 2007 - 2016. Percentage of fertile fruits = number of fruits / number of flowers × 100%. And nut yield of every tree was weighted at the end of September. Trunk diameter above 20 cm ground and crown area were measured in December 2016.

Biomass was measured during January 2017. Three randomly selected trees in every treatment were fully excavated. The roots were rinsed in tap water to clean the soil and then dried with bare cloth. Fresh weight of above-ground and under-ground parts were measured separately. Then they were dismembered to be dried at 60°C for 72 h in a forced-air oven to a constant weight.

Annual semi-lignified branches were randomly selected from the canopy periphery of every tested tree at the end of June 2016. They were fixed for paraffin and xylem vessel extraction. Paraffin and xylem vessel extraction were determined according to Liu *et al.* (2008). The data were subjected to SAS 8.1 with one-way ANOVA. And the means were compared using the least significant difference (LSD) test at $P<0.05$.

RESULTS AND DISCUSSION

Compared with non-branch-bending trees, branch bending could significantly improve percentage of fertile fruits in Xiangling and Qingxiang trees 3-6 years after planting (Fig. 1). The peak of percentage of fertile fruits of Xiangling walnut trees with branch-bending appeared during sixth year. It declined rapidly after eighth year. The percentage of fertile fruits from other three treatments was relatively stable after eighth years. And the successive sequence was treatment IV> treatment II> Treatment III.

The branch bending could make Qingxiang walnut trees to have production one year ahead, but had no effect on Xiangling walnut trees (Fig. 2). Although yield of branch-bending trees were higher than non-branch bending trees of Xiangling walnut 5 years after planting and Qingxiang walnut 7 years after planting, yield with branch-bending treatment of Xiangling walnut trees declined rapidly after 8 years planting. On the contrary, yield of non-branch- bending Qingxiang walnut trees were rising all the time 10 years after planting.

As branch-bending treatments allowing greater percentage of fertile fruits and higher yield in early years based on their more leaf area per unit (Wertheim *et al.*, 2001; Jackson, 1989; Zhang *et al.*, 2017), the response of both varieties was not similar. It seems that branch bending has to be more concerned for long-term effect on walnut trees.

Compared with the biomass in corresponding parts of both varieties, trunk diameter above 20 cm ground,

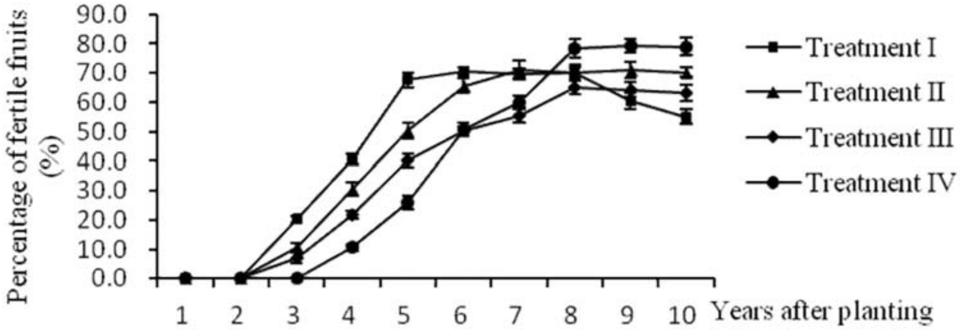

Fig. 1: Percentage of fertile fruits of all treatments during different planting years

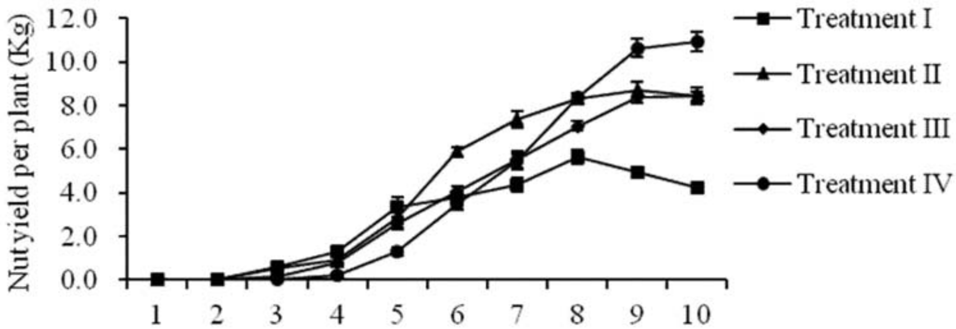

Fig. 2: Nut yield per plant in all treatments during different planting years.

crown area, and DW of above-ground biomass of Qingxiang walnut were higher than Xiangling walnut significantly (Table 1). It means that there are differences in biomass accumulation in different varieties. Compared with non-branch-bending treatment, branch bending treatments of both varieties reduced the trunk diameter above 20 cm ground, but increased the crown area and DW of above-ground biomass significantly. For all that, it had no effect on FW of above-ground biomass and under-ground biomass accumulation. The dry matter accumulated from photosynthesis of branch-bending treatment is more used for crown extension, but less for thickening growth of trunk and root growth comparatively.

The branch-bending treatment significantly reduced the width of vessel, vessel area and vessel total area / xylem transect area of both varieties branches, especially more than 50% decline of vessel total area / xylem transect area of Qingxiang walnut trees (Table 2). Compared with Xiangling trees, branch-bending treatment reduced more significantly length of vessel but increased the vessel density. Still, branch-bending treatment had no effect on xylem area / transect area.

With the prolonging of planting time, smaller increase or even decrease of percentage of fertile fruits and yield with branch-bending treatments in both varieties may be related to nutrient transport of vessel. Adler *et al.* (2008) reported that plants can adapt to environment by adjusting their morphology, physiology, biomass allocation patterns and characteristics of water diversion system, so as to achieve optimal allocation of resources and water balance. This adaptation cause differences in physiological characteristics, internal anatomical structure and external morphological characteristics of plants, which can change the water balance process and water transmission characteristics of plants (Jansen *et al.*, 2011; Markesteijin *et al.*, 2011). The branch-bending treatments

Table 1. Biomass of different treatments after planting over ten years

Treatment	Trunk diameter (cm)	Crown area (m^2)	Above-ground biomass (kg)		Under-ground biomass (kg)	
			Fresh weight	Dry weight	Fresh weight	Dry weight
Treatment I	13.50 ± 0.68d	20.05 ± 0.41c	10.99 ± 0.46b	3.89 ± 0.17d	9.77 ± 0.37b	3.91 ± 0.19b
Treatment II	14.57 ± 0.48c	17.73 ± 0.45d	11.66 ± 0.40ab	4.16 ± 0.15c	10.64 ± 0.49ab	4.34 ± 0.31a
Treatment III	16.23 ± 0.53b	24.28 ± 0.72a	13.00 ± 1.03ab	5.02 ± 0.36b	11.52 ± 0.78a	4.32 ± 0.11a
Treatment IV	18.72 ± 0.72a	22.84 ± 0.30b	14.60 ± 0.47a	5.73 ± 0.13a	11.64 ± 0.62a	4.40 ± 0.09a

Table 2. Comparison of vessel anatomical structure of different treatments after planting over ten years

Treatment	Length of vessel / µm	Width of vessel / µm	Vessel density (number / mm^2)	Vessel area / mm^2	Vessel total area / xylem transect area	Xylem area / transect area
Treatment I	284 ± 62 bc	86.4 ± 21.3 b	23.6 ± 10.0 ab	0.313 ± 0.155 b	0.146 ± 0.072 b	0.33 ± 0.08 a
Treatment II	339 ± 128 ab	119.5 ± 33.1 a	19.2 ± 8.2 bc	0.565 ± 0.286 a	0.231 ± 0.117 a	0.32 ± 0.03 a
Treatment III	238 ± 89 c	52.1 ± 18.6 c	27.6 ± 14.7 a	0.112 ± 0.274 c	0.066 ± 0.044 c	0.29 ± 0.02 ab
Treatment IV	342 ± 76 a	104.3 ± 33.0 a	15.5 ± 9.1 c	0.435 ± 0.237 ab	0.145 ± 0.079 b	0.26 ± 0.03 b

significantly reduced the width of vessel, vessel area and vessel total area / xylem transect area in both varieties, then reduced the water and nutrient transport efficiency, which may be one of the important causes for serious abscission and yield reduction. As the vessel is an important channel for nutrient delivery from the root system (Wang, 2000), the results means that branch-bending treatment significantly reduced the efficiency of root nutrient dredging.

CONCLUSION

Although the response of both varieties was not similar, branch bending could increase the percentage of fertile fruits and nut yield only during early 3-6 years. For both varieties in ten years, branch bending reduced the trunk diameter above 20 cm ground, width of vessel, vessel area and vessel total area / xylem transect area, increased the crown area and dry weight of above-ground significantly, but had no effect on above-ground and under-ground fresh weight. Thus, there were no more positive effects of branch bending in long-term cultivation of Xiangling and Qingxiang walnuts. It seems that more physiological responses need to be concerned to evaluate the long-term effects of branch bending.

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Evaluating stage-wise irrigation water requirement of sweet orange *(Citrus sinensis)* c.v. Sathgudi grown on Alfisols

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ABSTRACT

A field experiment on stage-wise water requirement was conducted on pan evaporation replenishment through drip irrigation system in a 10- year- old bearing sweet orange (*Citrus sinensis* Osbeck) cv. Sathgudi at AICRP Fruits(Citrus), Citrus Research Station, Dr YSR Horticultural University, Tirupati, Andhra Pradesh, during 2012-2017. The treatments comprised : irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (T1), irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (T2), irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (T3), irrigation schedule with 80% ER in stage I to VI (T4) and irrigation schedule with 30% ER in stage I to VI (T5) with four replications in a randomized block design. The maximum canopy volume (20m^3), average number of fruits of fruits (288 fruits / plant) and total soluble solids (10.63°Brix) were recorded at 80-80-80-80-80-80% ER from stage I (January-February) to stage VI (November-December). However, maximum fruit yield (46.91 kg / plant and 13 t / ha), less incidence of dry root rot (8.33%) and highest benefit:cost ratio (1.48) were recorded at 60-80-60-80-60-80% ER in stages I to VI. The reduction in irrigation from 80% ER to 30% ER during any stage resulted in consequent reduction in yield from 13.00 to 10.19 t / ha. Hence, it is recommended that irrigation at 60-80-60-80-60-80% ER from stages I (January-February) to VI (November-December) for better plant growth, fruit yield and quality with efficient utilization of water, besides water saving of 13% per plant and highest benefit with and also low incidence of dry root rot disease (8.33%) for *Ambia bahar* crop of sweet orange under Rayalaseem region of Andhra Pradesh.

Key Words: Stage wise, Drip irrigation, Water requirement, Alfisols, Irrigation schedule

Sweet orange (*Citrus sinensis* Osbeck) cv. Sathgudi is an important commercial cultivar, mainly grown in Rayalaseema region of Andhra Pradesh and adjoing states like Telangana, Karnataka and Tamil Nadu. The main constraint for sweet orange production in Rayalaseema region of Andhra Pradesh is scarcity of water and alkalinity of red calcareous soils. The irrigation resources in the region are limited such as bore well, water storage tanks and rarely canal. Interestingly, the water use of acid lime under different soil moisture regimes was earlier estimated (Shirgure *et al.*, 2000). The irrigation scheduling of acid lime (Shirgure *et al.*, 2000) and pulse irrigation scheduling in Nagpur mandarin (Shirgure, 2012) could give some strong clues for scheduling irrigation in other citrus cultivars, Sathgudi sweet orange being one of them. In citrus production, drip irrigation is gaining popularity owing to better water-use efficiency (Shirgure *et al.*, 2000 b). Harish Kumar *et al.* (2013), Ghosh and Pal (2010), and Panigrahi *et al.* (2012) established usefulness of drip irrigation in citrus for better plant growth and higher production of quality fruits in addition to other economical benefits of cultivation. Very little information is available on drip irrigation water requirement at different phonological stages of sweet orange (Panigrahi and Srivastava 2011). The average annual rainfall is very low (580 mm) during 2012-17. Very less work has been carried out on sweet orange on stage-wise application of irrigation water for quantitative as well as qualitative production. Therefore,

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drip irrigation is one such technology which can help increase irrigation potential by optimizing use of available irrigation water and also by precise management of irrigation quantity along with rate and timing of application.

MATERIALS AND METHODS

The experiment was conducted in 0.3 ha area on bearing (five-years-old) sweet orange trees at experimental farm of AICRP Fruits *(Citrus)*, Citrus Research Station, Dr Y.S.R Horticultural University, Tirupati, Andhra Pradesh, during 2012-2017. The trees were planted in red sandy loam soils at the distance of 6 m × 6 m. The irrigations were scheduled on per cent of pan evaporation replenishment (PER) at various stages of growth and fruit development. The different stages considered are: Stage-I (Jan-Feb: flowering and fruit setting), stage-II (Mar-Apr: marble-size of fruit growth), stage-III (May-Jun: fruit enlargement), Stage-IV (Jul-Aug: fruit enlargement), Stage-V (Sept-Oct: fruit saturation) and stage-IV (Nov-Dec: harvesting). The treatments were irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (T_1), irrigation schedule with 40% ER in stage I, III, V and 60% ER in stages II, IV and VI (T_2), irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (T_3), irrigation schedule with 80% ER in stage I to VI (T_4) and irrigation schedule with 30% ER in stage I to VI (T_5) with four replications in a randomized block design. The daily weather data recorded was used for irrigation scheduling based on evaporation.

The soil type was sandy loam with 10% of clay content and taxonomically classified as Alfisols (Typic Rhodustalf) . 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 were observed as 9% and 3%, respectively. While, water-holding capacity of 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 cm^3 volume.

Based on the average weekly open pan evaporation, irrigation quantities were calculated taking into account of pan factor (0.7), crop factor (0.75), spacing at 6 m × 6 m 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 ($N:P_20_5:K_20$) along with basal application of 40 kg FYM and 8 kg neem cake per plant per year as per the package of practices. The monthly precipitation, mean temperature and relative humidity for 2012-2017 is also presented (Table 1).

The biometric parameters of plants (plant height and tree spread) were recorded in January, from 2012-2017. 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 also carried out as per were (Ranganna, 1986). The data on fruit yield and quality attributing to different irrigation schedules for 5 years were analysed through analysis of variance method (Panse and Sukhatme, 1995).

Water-use efficiency (WUE) was calculated as the ratio between the fruit yield (t / ha) and total volume of water applied (cm) in each treatment. The observations on root rot incidence prior to harvesting were recorded in each irrigation treatment. Root rot incidence (%) in

Table 1. Monthly rainfall, evaporation, mean temperature and relative humidity at CRS, Tirupati (2012-2017)

Month	Total rainfall (mm)	Mean evaporation (mm)	Mean temperature (°C)		Mean RH (%)	
			Max	Min	Max	Min
Jan	47.20	3.83	30.04	17.31	87.84	50.68
Feb	55.50	5.17	32.40	17.72	84.30	39.92
Mar	124.50	6.19	35.88	21.58	84.00	36.27
Apr	208.30	7.01	38.92	24.96	74.28	32.71
May	445.00	7.41	39.34	26.65	64.47	35.60
Jun	522.10	7.27	37.00	26.48	66.53	39.87
Jul	783.20	6.22	35.23	25.92	71.18	42.38
Aug	949.80	5.68	34.60	24.88	75.60	47.80
Sept	990.20	4.67	33.27	23.62	82.90	54.25
Oct	1007.50	4.48	32.82	22.45	84.23	54.08
Nov	1243.30	4.68	30.55	21.25	86.55	65.30
Dec	606.20	3.28	29.53	18.70	85.65	57.10

each treatment was calculated by counting number of diseased trees and total number of trees in each treatment and the ratio was expressed as per cent disease incidence.

Economics of drip irrigation method was worked out to compute the net returns and benefit:cost ratio. For this purpose, life period of polyvinyl chloride (PVC) items was considered as 10 years and that of 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 cultivator in cash throughout the crop period for carrying various horticultural operations. Total operational cost of system is operating cost plus interest on operational cost at the rate of 12%. These expenses were inurred 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 ₹ 30,000 / t.

RESULTS AND DISCUSSION

Biometric growth parameters

The effect of different drip irrigation scheduling combinations based on per cent evaporation replenishment influenced the biometric growth of 10 year-old trees. The pooled mean (2012-17) data on biometric growth parameters of sweet orange revealed that out of various growth parameters (Table 2), only canopy volume produced a significant response in relation to irrigation treatments ranging from 15.60 to 20 m^3. The highest average canopy volume (20 m^3) was recorded in irrigation schedule with 80% ER during stage I-VI. Maximum canopy growth by application of irrigation at 80 ER% at all growth stages might have been due to higher and frequent irrigation schedules, resulting in more photosynthesis and dry-matter production. Similar increase in growth by application of irrigation water at 80 ER% to all growth stages were reported by Balaganvi and Kumathe (2004) in acid lime and Shirgure *et al.* (2014) in Nagpur mandarin and Pawar *et al.*(2017) in Mosambi sweet orange.

The average canopy volume of was medium in irrigation schedule with 40% ER in stage I, III, V and 60% ER in stages II, IV and VI (19.04 m^3), followed by irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (18.71m^3), and irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (17.01m^3). The lowest plant canopy (15.60 m^3) was observed in irrigation schedule with 30% ER in stage I to VI during 2009 - 2012 . The lowest plant height (2.51 m) and stock girth (36.50 cm) were observed in irrigation schedule with 30% ER in stage I to VI during 2012-2017.

Fruit yield and quality

The pan evaporation based drip irrigation scheduled based on pan evaporation replenishment in six different stages had a profound effect on yield and fruit quality of sweet orange during 2012-2017. The sweet orange fruits were harvested during first fortnight

Table 2. Pooled mean analysis of stage-wise application of irrigation water on growth, yield and quality of sweet orange at Tirupati (2012-17)

Treatment	Plant height (m)	Scion girth (cm)	Canopy volume (m^3)	Fruits / tree	Fruit weight (g)	Fruit yield (kg / tree)	Fruit yield (t / ha)	Dry root rot (%)
T_1	2.57	38.26	17.01	242.01	164.77	38.64	10.71	25.00
T_2	2.79	40.58	19.04	265.75	166.81	42.08	11.66	16.67
T_3	2.56	39.83	18.71	283.13	173.54	46.91	12.99	8.33
T_4	2.67	40.78	20.00	288.16	170.30	46.29	12.82	16.67
T_5	2.51	36.50	15.60	227.45	164.88	36.79	10.19	33.33
CD @ 5%	NS	NS	3.07	45.31	NS	6.46	1.79	--
SE(m)±	0.07	1.20	1.03	15.25	3.35	2.17	0.60	--
CV (%)	6.88	7.51	13.99	14.30	4.88	12.63	12.63	--

T_1, 30-40-30-40-30-40% ER; T_2, 40-60-40-60-40-60% ER; T_3, 60-80-60-80-60-80% ER; T_4, 80-80-80-80-80-80% ER; T_5, 30-30-30-30-30-30% ER of September. The average number of fruits / plant, yield, TSS, juice content, and acidity were analysed and pooled mean values were presented. The number of fruits / plant, fruit yield, total soluble solids (TSS) were significant (Table 2). But highest average fruit weight (173.54 g) was observed in drip irrigation schedule with 60% ER in stage I, III, V and 80% ER in stages II, IV and VI followed by irrigation schedule with 80% ER in stage I to VI (170.3g).

The average number of fruits / plant ranged from 227 to 288 in different drip irrigation scheduling treatments. The highest number of fruits / plant (288 fruits / plant) was in drip irrigation schedule with irrigation schedule with 80% ER in stage I to VI and at par irrigation schedule with 60% ER in stageI, III, V and 80% ER in stages II, IV and VI (283 fruits / plant). Whereas, medium number of fruits were recorded in irrigation schedule with 40% ER in stage I, III, V and 60% ER in stages II, IV and VI (266 fruits / plant) and irrigation schedule with 30% ER in stage I, III, V and 40% ER in stages II, IV and VI (242 fruits / plant). The lowest number of fruits / plant was with irrigation schedule with 30% ER in stage I to VI (227 fruits / plant), may be due to lower soil moisture content with 30% ER drip irrigation schedule during critical growth and fruit development stages.

The average fruit yield was 10.19 - 12.99 t / ha in all the combinations of pan evaporation replenish-ment drip irrigation schedules. However, highest fruit yield was in drip irrigation schedule with 60% ER in stage I, III, V and 80% ER in stages II, IV and VI (46.91 kg / plant and 12.99 t / ha) and at par with irrigation schedule with 80% ER in stage I to VI (46.29 kg / plant and 12.82 t / ha). The drip irrigation schedules based on ER maintained higher as well as continuous soil moisture during growth and development of fruits, which helps mobilization of nutrients and food materials to growing fruits, resulting in maximum fruit yield.

Fruit yield were medium inirrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (42.08 kg / plant and 11.66 t / ha), followed by irrigation schedule with 30% ER in stage I, III, V and 40% ER in stages II, IV and VI (38.64 kg / plant and 10.71 t / ha). The lowest fruit yield was with irrigation schedule with 30% ER in stage-I to VI (36.79 kg / plant and 10.19 t / ha) is attributed to lower soil moisture available with 30% irrigation schedule during critical fruit growth development period. The reduction in irrigation from 80% ER to 30% ER during any stage resulted in reduction in yield from 13 to 10.19 t / ha.

Table 3. Pooled mean analysis of stage-wise application of irrigation water on fruit quality

Treatment	TSS (°Brix)	Juice (%)	Acidity (%)	TSS: acid ratio
T_1	9.88	40.93	0.74	13.35
T_2	9.89	41.15	0.75	13.18
T_3	10.19	40.18	0.71	14.35
T_4	10.63	43.39	0.69	15.40
T_5	9.73	39.89	0.77	12.63
CD @ 5%	0.56	NS	NS	--
SE(m)±	0.19	1.15	0.03	--
CV%	4.56	6.83	8.83	--

Juice and acidity content in fruits were not significantly differ among the treatments (Table 3). The total soluble solids content was significantly improved due to drip irrigation and it was significantly highest (10.63°Brix) with maximum juice per cent (43.39%) and low acidity (0.69%) at 80% drip irrigation schedule at all the stages. The application of irrigation water at 80 ER % at all the growth stages enhanced photosynthetic rate and auxin production which in turn improved fruit quality of sweet orange. This is in conformity with those of Shirgure *et al.* (2001), Shirgure and Srivastava (2013) and Pawar *et al.* (2017). The moderate fruit quality was observed with 60% ER in stage I, III, V and 80% ER in stages II, IV and VI, irrigation schedule with 40% ER in stage I, III, V and 60% ER in stages II, IV and VI, followed by irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI. The lower TSS (9.73°Brix), juice (39.89%) and high acidity (0.77%) was observed in drip irrigation schedule with 30% ER in stage-I to VI.

Table 5. Cost analysis for stage-wise water requirement in sweet oange cv. Sathgudi at Tirupati centre.

Treatment	Total expenditure (₹ / ha)	Pooled mean yield (t / ha)	Gross return (₹ / ha)	Net profit (₹ / ha)	B:C ratio
T_1	261550	10.71	321300	59750	1.23
T_2	262018	11.66	349800	87782	1.34
T_3	263588	12.99	389700	126112	1.48
T_4	260420	12.82	384600	124180	1.48
T_5	258388	10.19	305700	47312	1.19

Higher TSS

Acidity ratio is indicator of sweetness of fruits. If TSS : acidity ratio is high means that fruits have more TSS (total soluble solids) and less acidity. This ratio was analysed and highest TSS to acidity ratio (15.40) was found in drip irrigation schedule with 80% ER in all I-VI stages, followed by irrigation schedule with 60% in combination to 80% ER in stage I-VI (14.35). The lowest TSS to acidity (12.63) was observed in drip irrigation schedule with 30% ER in stage I-VI. The similar fruit yield and quality were observed (Shirgure *et al.* 2000b, 2003d, Srivastava and Singh 2009) and (Shirgure *et al.* 2004a, 2004b).

Irrigation scheduling and water requirements at different stages

Various pan evaporation based irrigation schedules using drip irrigation system varied the water-use of bearing sweet orange (Table 4). The variation in water applied for different treatments was due to variation in pan evaporation and rainfall pattern, as quantity of water applied was based on pan evaporation. Highest water requirement (5707 l/plant/year) was recorded with 80% ER in stages I-VI, followed by irrigation schedule with 60% ER in stages I, III and V and 80% ER in stages II, IV and VI. (4950 l/plant/year). However, highest fruit yield was recorded in drip irrigation schedule with T_3 at 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (46.91 kg/plant and 12.99 t/ha) with 4950 l/plant/year there by saving 13% (757 l/plant/year) irrigation water compared to 80% ER in stages I-VI (46.29 kg/plant and 12.82 t/ha). Though water use with 80% ER at all stages was more, but it did not increase the fruit yield. This may be due to loss of water in root zone. The lowest water quantity was recorded in irrigation with 30% ER in all six stages (2140 l/plant/year). Similar results were also observed (Shirgure *et al.* 2000b, Srivastava and Malhotra 2014) and (Shirgure *et al.* 2004).

The irrigation water-use efficiency for different treatments was computed from fruit yield and water applied (Table 4). The irrigation water-use efficiency in drip irrigation treatments with 30% ER in all six stages was maximum (1.71 t/ha-cm), followed by drip irrigation with 30% ER in stage I, III, V and 40% ER in stages II, IV and VI (1.56 t/ha-cm), 40% ER in stage I, III, V and 60% ER in stages II, IV and VI (1.19 t/ha-cm) and with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (0.94 t/ha-cm). The water-use efficiency was lowest in 80% ER in stages I-VI (0.81 t/ha-cm), indicating with highest water application it recorded the lowest water use efficiency. However, when taking WUE as an evaluation criterion, there was no difference

Table 4. Average monthly water quantity applied (l/plant) in different irrigation schedules and various stages of sweet orange during the year (2012-2017)

Treatment	Water quantity applied (l/plant)												Irrigation water (l/plant/year)	Total irrigation water (cm/plant/year)	Yield (t/ha)	WUE (t/ha-cm)
	Stage I		Stage II								Stage VI					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec				
T_1	124	248	6.87	10.71	1.56	317	251	118	42	76	148	0.00*	2475	6.87	10.71	1.56
T_2	165	330	9.79	11.66	1.19	423	377	177	56	101	222	0.00*	3523	9.79	11.66	1.19
T_3	248	495	13.75	12.99	0.94	635	503	236	84	152	295	0.00*	4950	13.75	12.99	0.94
T_4	330	661	15.85	12.82	0.81	846	503	236	112	203	295	0.00*	5707	15.85	12.82	0.81
T_5	124	248	5.94	10.19	1.71	317	188	89	42	76	111	0.00*	2140	5.94	10.19	1.71

*No irrigation water

in WUE between the 80% and the 60% treatments, while both WUE values were lower than the WUE under 30% treatment. It was also observed that sweet orange plants irrigated with 30 and 40% ER were more prone to dry root rot causing Fusarium fungal infection than that 60 and 80% ER (Table 2). The most water-stressed treatment (T_5) had highest WUE, but high dry root rot incidence (33.33%) was noticed.

Maximum net profit of ₹ 1,26,112 / ha with B: C ratio of 1.48 was recorded when sweet orange crop were irrigated with 60% ER in stage I, III, V and 80% ER in stages II, IV and VI (Table 5). However, in drip irrigation with 80% ER in stages I-VI the net returns of ₹ 124180 / ha was obtained with B:C ratio of 1.48, while lowest of ₹ 47312 / ha with B:C ratio of 1.19 was recorded with 30% ER in all six stages.

CONCLUSION

For taking *ambe bahar* in sweet orange in Andhra Pradesh, water stress was given in December. The highest fruit yield can be achieved with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI with low incidence of dry root rot disease (8.33%). This irrigation treatment not only helps in efficient utilization of water besides water saving of 13%per plant, but also supports the economic development of farmers in Andhra Pradesh.

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Future changes in mean temperature and total precipitation and climate suitability of yam (*Dioscorea* spp.) in major yam-growing environments in India

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ABSTRACT

The experiment was conducted to project climatic changes in major yam-growing environments and also calibrated and evaluated the eco crop model to study the impact of 2030 climate change on yam climate suitability in major yam-growing environments in India. The current climate and future climate projections of 22 GCMs from the SRES-A1B emission scenario were used. The projected change in annual mean temperature and total annual precipitation in yam-growing areas ranged from 0.9 to 1.3°C and from 9 to 128 mm respectively. The calibrated data were used to constrain the eco crop model to find out the suitability of current and future climatic conditions. The results of projected climate change over the Indian yam-growing areas using 22 GCMs of SRES-A1B emission scenario revealed that change in suitability will be in the range of -2.04 to 23.5 per cent.

KEY WORDS: Climate change; Mean annual temperature; Total annual precipitation; Eco crop model; Overall suitability, Eco crop model

The rapid population growth over past 61 years (from 350 million in 1950 to 1110 million in 2011) had a huge impact on food demand in India. Many studies have predicted significant impacts from climate change for the Indian agriculture (Aggarwal, 2007; Swaminathan and Kesavan, 2012; Senapati *et al*., 2013). Tuber crops over past many years have created a niche in food security of millions of people, especially in tropical and subtropical regions of the world, as they form the third most important food crop after cereals and legumes (James George, 2004). Yam (*Dioscorea* spp.) is the third most important tropical root crop after cassava (*Manihot esculenta* Crantz.) and sweet potato (*Ipomoea batatas* L. Lam.). Yams grow better in areas having 1000-1500 mm of well-distributed rainfall over a period of 6-7 months in cropping season (Onwueme, 1975). Moisture stress also delays tuber initiation in water yam (Onwueme, 1975). Though yams are very important crops in food and nutritional security of backward, hilly and tribal population in many districts in our country, so far no study has been conducted to find out the effect of future climate on the change in suitability of these crops in major yam-growing environments in India. Therefore, an experiment was conducted to develop a presence point map of yams in India based on available information and expert knowledge, to assess the projected climatic changes in major yam-growing environments, to calibrate eco crop model for yams under Indian conditions and to model the suitability of current yam-growing areas to study the impact of future climate (2030) on climate suitability of yams in India.

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MATERIALS AND METHODS

Current climate data

For current climate data, we used the World Clim dataset (Hijmans *et al*., 2005), freely available from the website http://www.WorldClim.org. The World Clim data were prepared by compiling monthly averages of climate as measured at different weather stations from a large number of global, regional, national, and local sources for the period of 1950-2000, then interpolated the data using thin-plate smoothing spline algorithm (Hutchinson, 1995) and created global climate surfaces for monthly precipitation and minimum, mean and maximum temperature. The data downloaded for this study were at the resolution of 30 arc-seconds, restricted to India. These datasets were used to analyze the projected climatic changes for cassava-growing regions and to assess the impact on cassava climate suitability.

Future climate data

The future climate projections were also downloaded from the website http://www.WorldClim.org. Future data downloaded was monthly time series of maximum, minimum and mean temperature, and total monthly precipitation for SRES-A1B emission scenarios of 21st century simulations from 22 different coupled global climate models (GCMs) used in IPCC Fourth Assessment Report (IPCC, 2007) for the period 2030s. The data downloaded were at the resolution of 30 arc-seconds restricted to India.

Map of yam

We identified principal regions where yam is cultivated currently. We extracted the geographic coordinates (latitude and longitude) of yam-growing regions in India at 2.5 minute spatial resolution using the district boundary shape file of each growing areas. All the spatial analysis was carried out using ArcGIS 10.0 software. We used this point shape file to extract climate data from India grid to study the projected climatic changes in yam-growing areas and to calibrate the eco crop model for suitability analysis in Diva GIS.

Projected climatic changes

The original monthly means of mean temperature and total monthly precipitation data from current and future predictions were used to calculate the predicted GCM-specific changes in total annual precipitation (mm) and annual mean temperature (°C) for each state of our study area in areas where the crop is grown. The individual GCM predicted changes of total annual precipitation and annual mean temperature were plotted as bar graph. The average prediction by 22 GCMs was plotted as box plots using Excel 2007.

Model description

The basic mechanistic model (eco crop), uses environmental ranges as inputs to determine the main niche of a crop and then produces a suitability index as output. The model was originally developed by Hijmans *et al.* (2001) and named eco crop since it was based on the FAO-eco crop database (FAO, 2000).

In the model, there are two ecological ranges for a given crop, each one defined by a pair of parameters for each variable (temperature and rainfall). First, the absolute range, defined by TMIN-C and TMAX-C (minimum and maximum absolute temperatures at which the crop can grow, respectively) for temperature, and by RMIN-C and RMAX-C (minimum and maximum absolute rainfall at which the crop grows, respectively) for precipitation; and second, optimum range, defined by TOPMIN-C and TOPMAX-C (minimum optimum and maximum optimum temperatures, respectively), and ROPMIN-C and ROPMAX-C (minimum optimum and maximum optimum rainfall, respectively). An additional temperature parameter is used (TKILL) to illustrate the effect of a month's minimum temperature.

The model performs two different calculations separately, one for precipitation and the other for temperatures and then calculates the interaction by multiplying them. We used the eco crop model to study the impact of climate change on yam in India.

Model calibration

The calibration of eco crop model for yam was done following the procedure given by Villegas *et al.* (2013). Present study selected yam in India for testing the parameter selection process due to several reasons.

Determination of ecological parameters

For each of the data points in crop dataset, we extracted the corresponding values (from the current climate dataset) for maximum and minimum temperature and total precipitation variables and for each of the 12 months of the year. Then, for each of 12 potential growing seasons (assuming all months are equally likely to be the first month of growing season), we calculated the average maximum and minimum temperatures and total precipitation. For each point, we then calculated the mean (ME), mode (MO), maximum (MX) and minimum (MN) of all growing seasons for each variable and each point.

All the parameter sets were then used to drive the eco crop model. For each of the 12 potential growing seasons, we performed 2 runs of the model, one using the minimum temperature parameter set and the other using the maximum temperature parameter set; both of them use the same precipitation parameter set. We then combined the resulting suitability surfaces obtained from the maximum and minimum temperatures parameter sets as given below:

$$SUIT_{TOTALK} = \begin{cases} \mathrm{SUIT_{TMINK}} & \mathrm{SUIT_{TMINK}} \neq 0;\ \mathrm{SUIT_{TMAXK}} = 0 \\ \mathrm{SUIT_{TMAXK}} & \mathrm{SUIT_{TMINK=0;\ SUIT_{TMAXK}}} \neq 0 \\ \dfrac{(\mathrm{SUIT_{TMINK}})^2 + (\mathrm{SUIT_{TMAXK}})^2}{\mathrm{SUIT_{TMINK}} + \mathrm{SUIT_{TMAXK}}} & \mathrm{SUIT_{TMINK}} \neq 0;\ \mathrm{SUIT_{TMAXK}} \neq 0 \end{cases}$$

The suitability calculation is done on pixel basis. The $\mathrm{SUIT_{TOTALK}}$ is the total suitability of the kth growing season. $\mathrm{SUIT_{TMINK}}$ is the suitability of the pixel of the kth growing season, as calculated with the minimum temperature parameter set; $SUIT_{TMAXK}$ is the suitability of the pixel of the kth growing season, as calculated with maximum temperature parameter set. In this way, a total of 36 suitability surfaces are finally produced. From these, one with most accurate distributed prediction is chosen by examining the predictions against the known distribution of the crop (You *et al.*, 2007; You *et al.*, 2009; Monfreda *et al.*, 2008).

Modeling crop suitability

Crop suitability modeling involves the evaluation of model and usage of selected ecological parameter set(s) to run the model using certain climate scenario(s). In this study, we used current climate scenario and 22 different future climate scenarios. All the suitability analysis was carried out by using DivaGIS and ArcGIS softwares.

We first performed a suitability prediction with the EcoCrop model for current climatic conditions using derived ecological parameters and then projected the model on to each of the 22 different GCMs (future climate data). For each projection, change in suitability was calculated on a pixel basis and the following impact matrices were derived for yam-growing regions for each GCM specific predictions.

- The overall suitability change (average % change of all pixels)
- The average suitability change in positively impacted areas (areas increasing suitability)
- The average suitability change in negatively impacted areas (areas decreasing suitability)

The results are displayed in tables and the change in suitability predictions by 22 GCMs were averaged and represented as box plot.

RESULTS AND DISCUSSION

Map of yams

A point shape file of presence points of yams in India was prepared and the map is shown in Fig. 1. A total of 7910 point locations were identified as yam presence points covering 13 states in India, viz. Andhra Pradesh, Assam, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Tamil Nadu, Odisha and Tripura. From these 13 states, 44 districts were identified as current growing areas of yams in India. No statistical data is available about yam distribution in India, though considerable portion of the country depend up on this crop as a subsidiary food, mainly by the poor, tribal people of Odisha (Nedumchehiyan *et al.*, 2012). So, gathering expert knowledge on known cultivation areas was the only way to prepare the database and the map of presence points of yams in India.

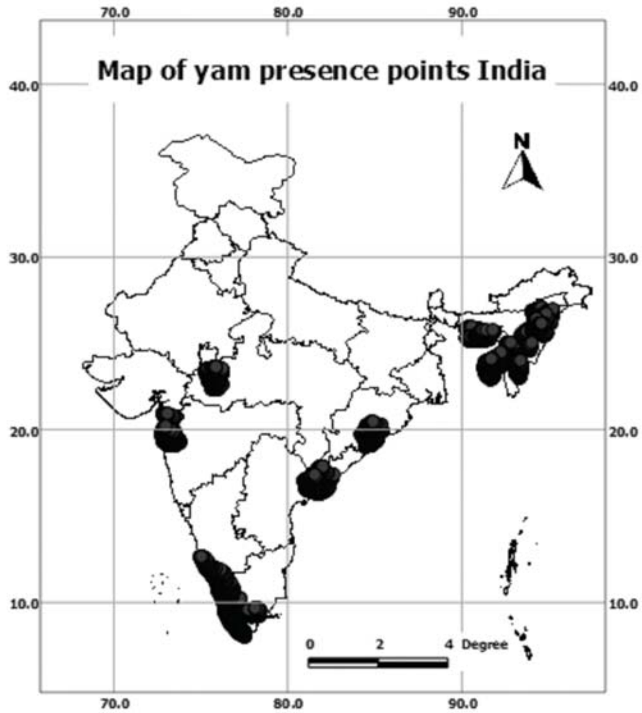


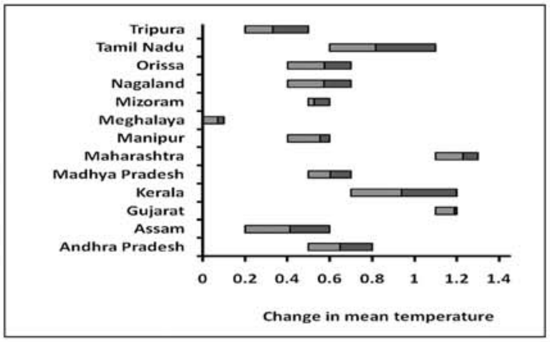
Fig. 1: Map of yam presence points in India

Change in annual mean temperature

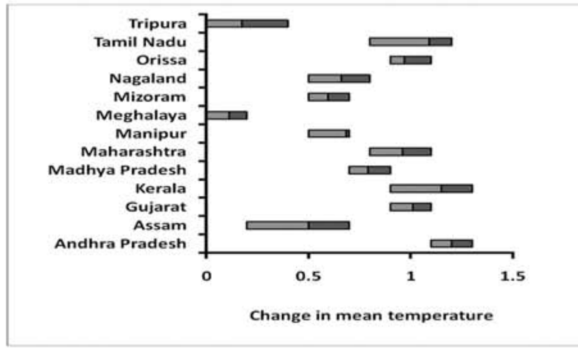
The individual GCM predicted change in mean temperature ranged from -0.06 to 1.28°C predicted by the NCAR-CCSM3.0 and MIROC3.2-HIRES respectively. Minimum and maximum changes in annual mean temperature in all yam-growing areas ranged from -0.7 (NCAR-CCSM3.0) to 1.9°C (GISS-MODEL-ER and NCAR-PCM1). Only one GCM (NCAR-CSSM3.0) predicted a decrease in annual mean temperature. All major yam-growing states predicted increase in annual mean temperature by 2030 with values ranging from 0.9-1.1°C for Andhra Pradesh, 0.9-1.0°C for Kerala and Meghalaya, and from 1.0-1.1°C for Odisha. All the 14 districts in Kerala and two in Tamil Nadu have 0.9°C increase in mean temperature, whereas East Godavari and West Godavari districts in Andhra Pradesh and two districts of Odisha (Ganjam and Nayagargh) have 1°C increase in mean temperature by 2030.

Individual GCM predicted changes in annual mean temperature are shown in Fig. 2. The average of the 22 different GCMs showed that by 2030, all the major yam-growing regions in India will have an increase in their annual mean temperature and predicted increase ranged between 0.9 and 1.3°C (Fig. 3). The mean temperature change in India by 2030 is shown in figure 3.4. The highest increase was observed in the Indore and Khandwa districts of Maharashtra (1.3°C). About 63 per cent of the yam-growing districts showed an increase in annual mean temperature of 0.9°C. Out of

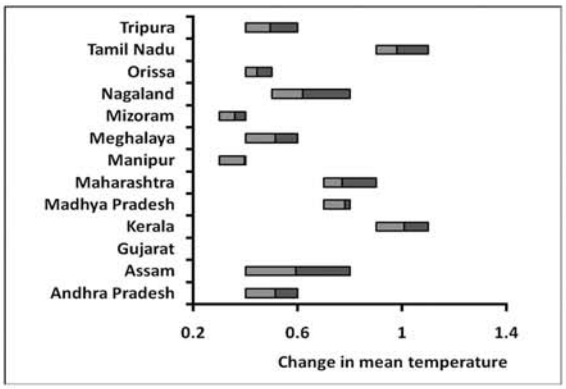
CCCMA-CGCM3.1 (T47)



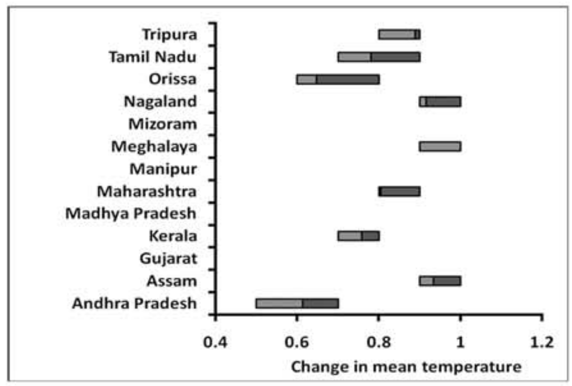
CCCMA-CGCM3.1 (T63)



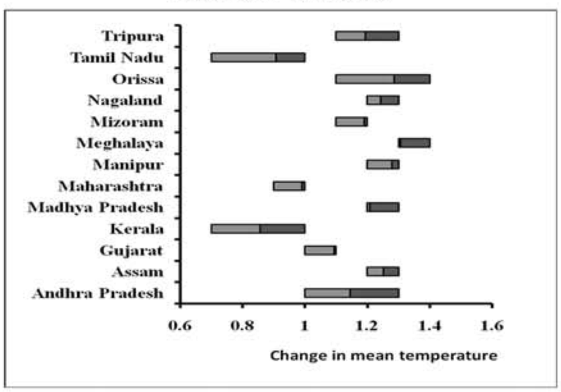
CNRM-CM3



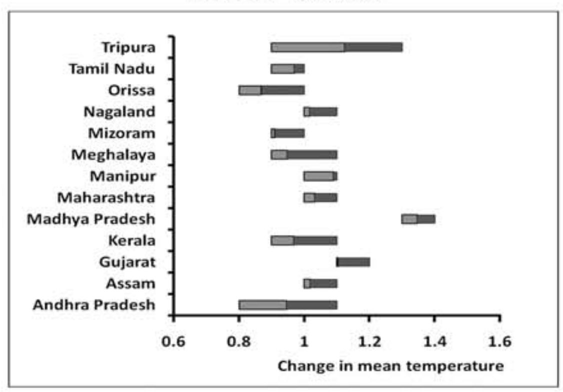
CSIRO-MK3.0



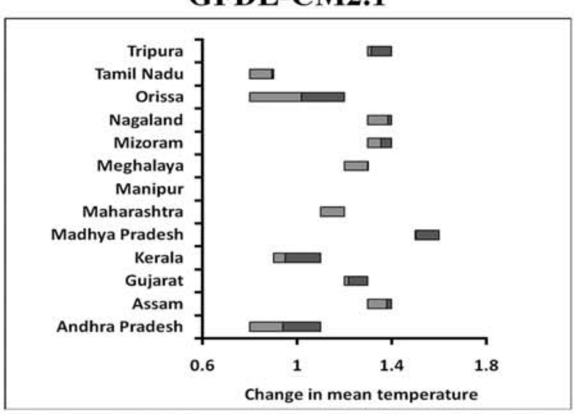
CSIRO-MK3.5



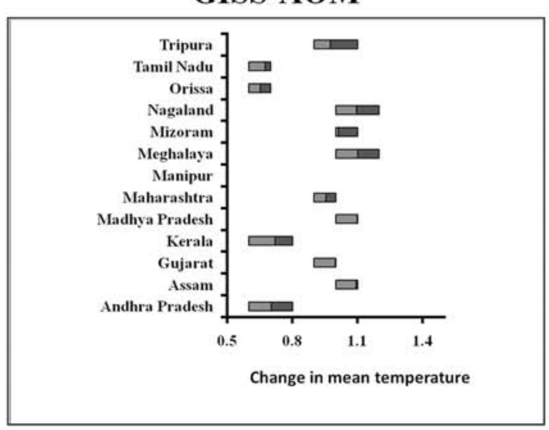
GFDL-CM2.0



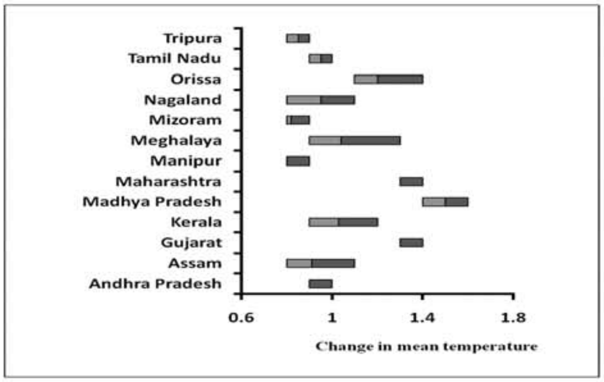
GFDL-CM2.1



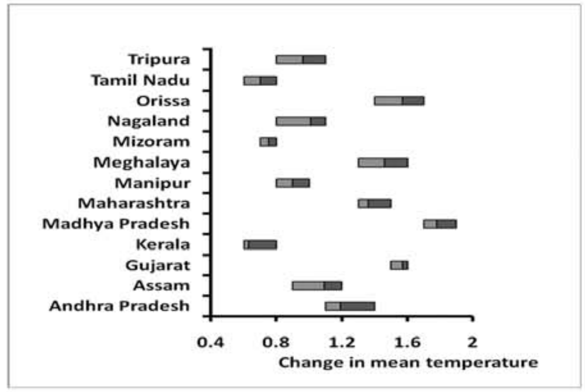
GISS-AOM



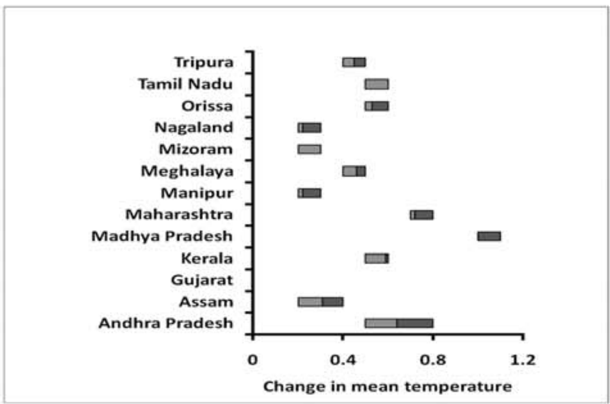
GISS-MODEL-EH



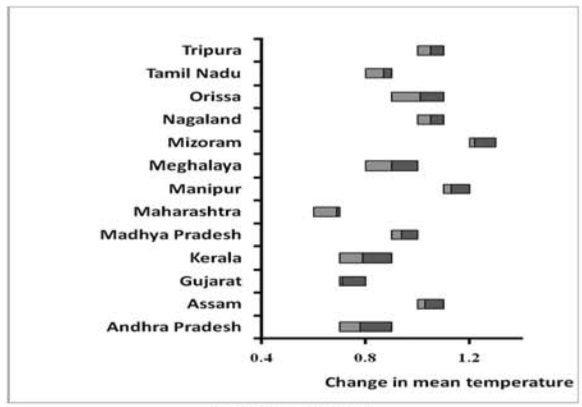
GISS-MODEL-ER



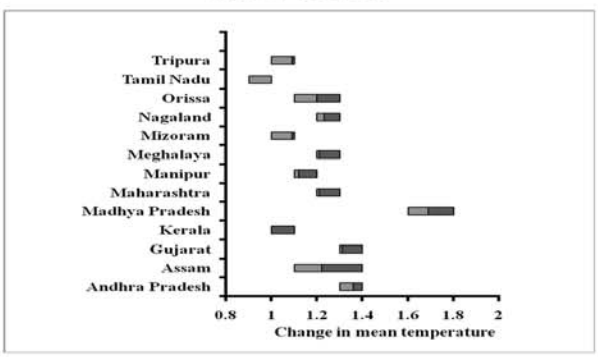
IAP-FGOALS1.0-G



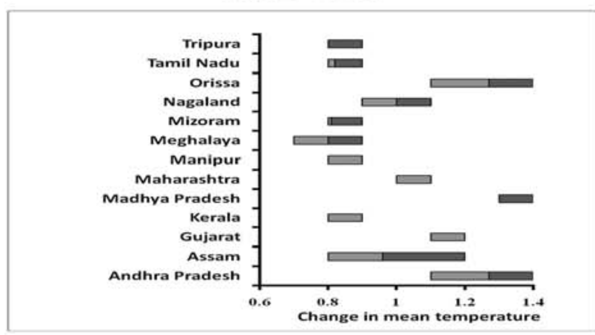
INGV-ECHAM4



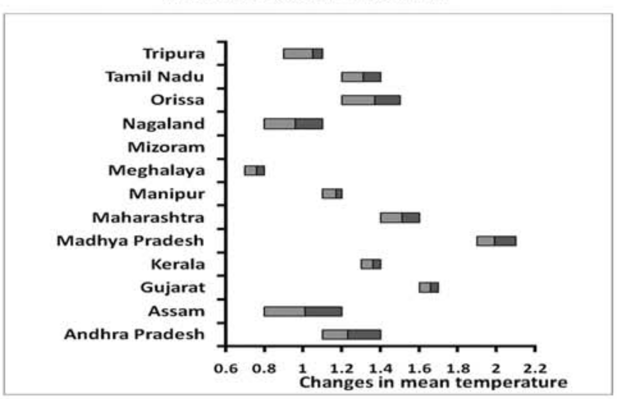
INM-CM3.0



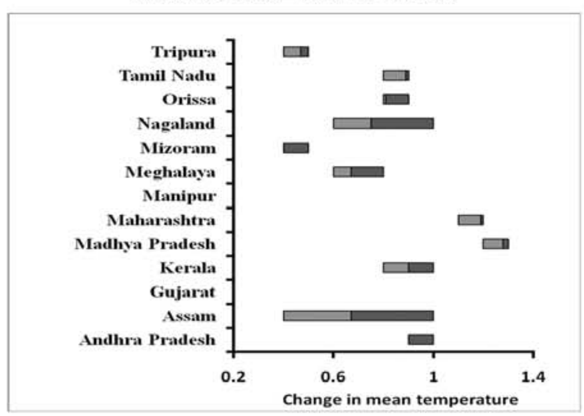
IPSL-CM4



MIROC3.2-HIRES



MIROC3.2-MEDRES



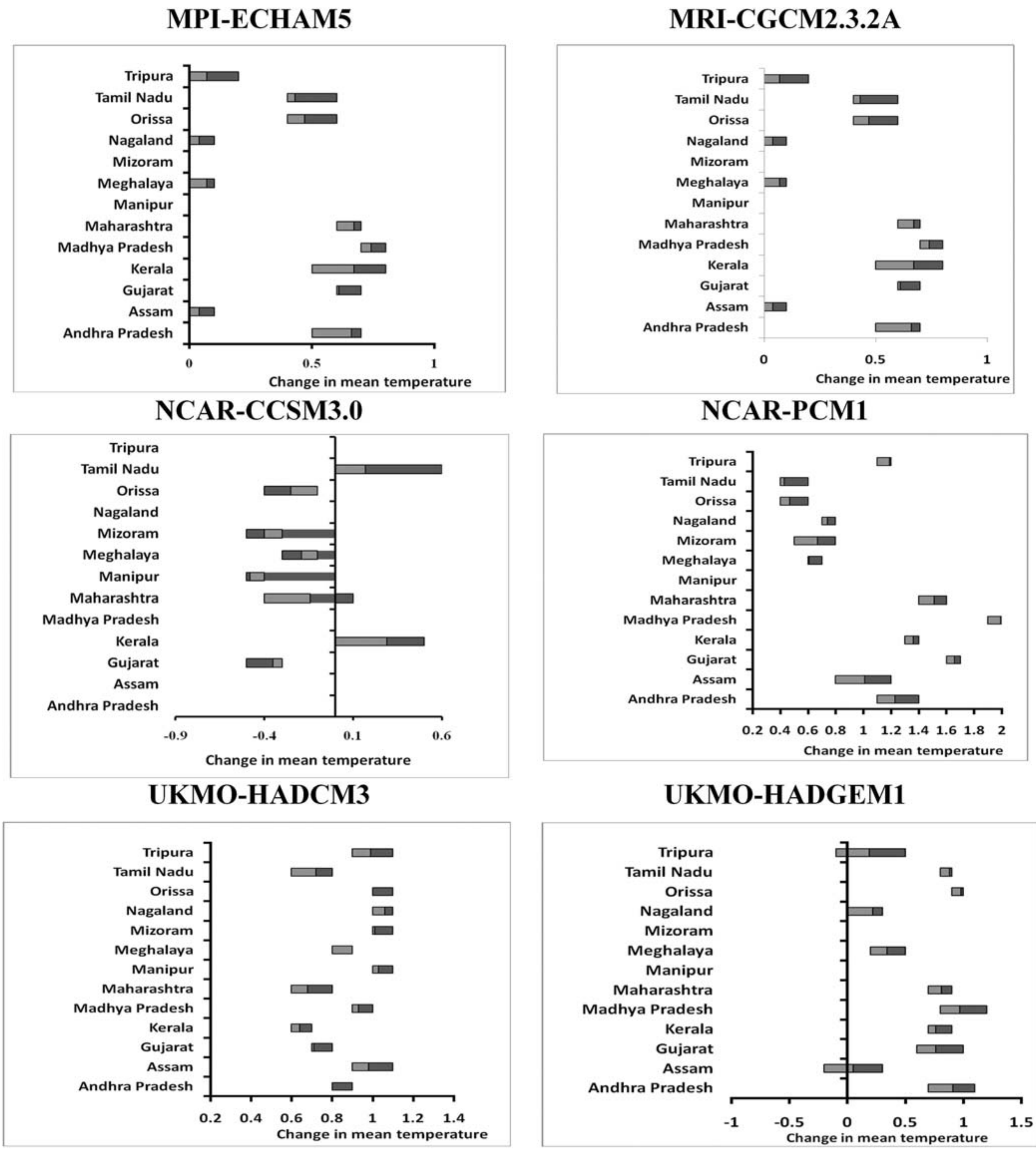


Fig. 2: Individual GCM predicted changes in annual mean temperature (°C) for yam-growing states in India ▭ Minimum, ▭ maximum, mean.

the 44 districts identified as current growing areas of yam, 20 per cent of the districts showed an average increase of 1-1.1°C in their annual mean temperature, 13 per cent districts showed 0.9-1.1°C increase and the remaining 6 per cent of districts showed 1.1-1.4°C increase in their annual mean temperature.

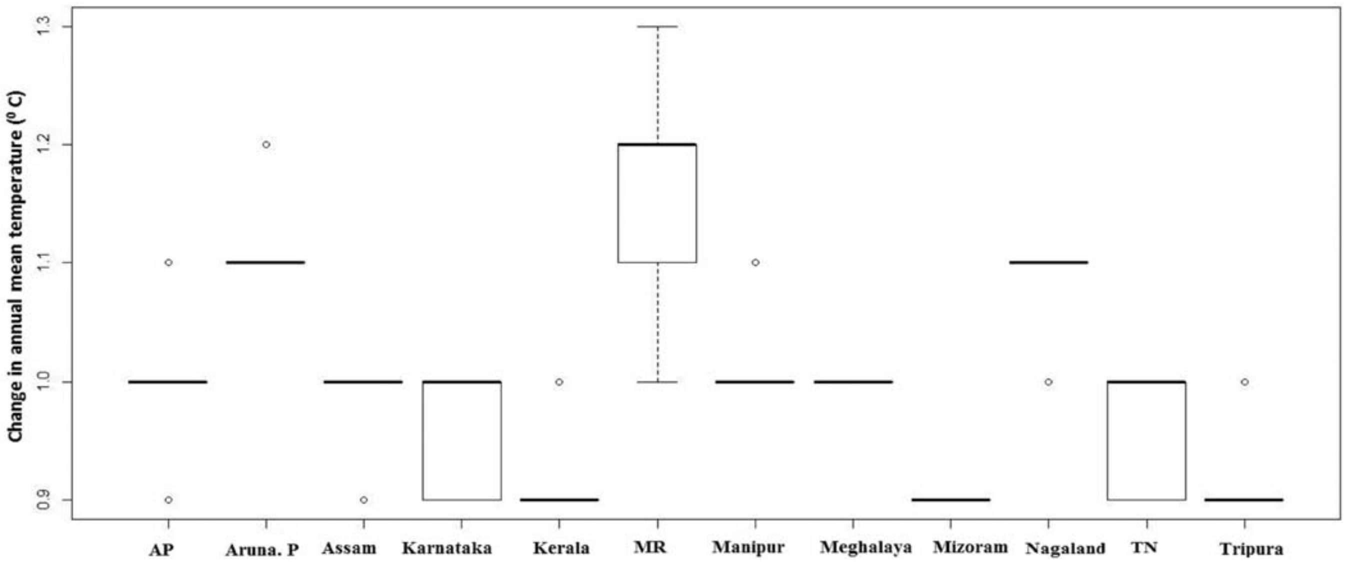


Fig. 3: Annual mean temperature change by 2030 for cassava-growing states of India

Change in total annual precipitation

The individual GCM predicted change in precipitation ranged from -360-18 mm predicted by the GCMs, UKOMO- HADGEMI and CCMA-CGCM3-1-T47 respectively. The mean value of one GCM (CCMA-CGCM3-1-T47) was positive and ranged from 116.95-242 mm, indicating that annual precipitation will increase by 2030. Minimum and maximum changes in annual precipitation in all yam-growing areas ranged from -86.99 (IAP-FGOALS1.0G) to 970 mm (GISS-MODEL-EH). All the major yam-growing states will increase their precipitation by 2030 with values ranging from 12-19 mm with a mean value of 12.6 mm for Andhra Pradesh, 5-53 mm with mean value of 20.96 mm for Kerala, 96-138 mm with a mean value of 120.66 mm for Meghalaya and from 23-61 mm with a mean value of 36.81 mm for Tamil Nadu. Precipitation change in major yam-growing districts ranged from 5.0 (Malapuram district of Kerala) to 138 mm (East Godavari district of Andhra Pradesh). Precipitation increase in Kerala ranged from 5.0 (Malapuram) to 53 mm (Thiruvananthapuram).

The individual GCM predicted changes in total annual precipitation are plotted and shown in Fig. 4. The mean change of the 22 GCMs showed an increase in total annual precipitation in all major growing regions of yam in India (Fig. 5). The change in total annual precipitation in India by 2030 is shown in Fig. 7. Predicted changes (average of 22 GCMs) in annual precipitation for the major yam growing regions ranged between 9 and 128 mm / year with the minimum increase in the Wayanad district of Kerala (9 mm) and the maximum increase was observed in the South Garo Hills and West Garo Hills of Meghalaya (>100 mm). In the districts of Kerala, Tamil Nadu and Odisha, the annual increase in precipitation ranged from 8-53 mm (Kerala), 23-61mm (Tamil Nadu) and 9.87-11.86 mm (Odisha) respectively. The annual increase in precipitation in the districts of Meghalaya ranged from 96 mm of South Garo Hills to 138 mm of West Garo Hills by 2030. In other yam growing areas, the precipitation change was in the range of 7-13 mm (Gujarat), 17-26 mm (Maharashtra), 9-14 mm (Madhya Pradesh), 68-78 (Manipur), 82 - 101 mm (Nagaland) and 55-75 mm for Tripura.

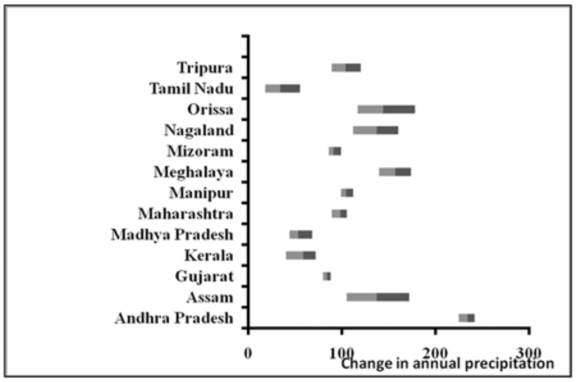
Model calibration and parameterization

The selected parameter set to calibrate the eco crop model was given in Table 1. The dataset indicates that the crop would die at a temperature ≤ 3°C, and is not suited for temperature below 10°C, the crop grows optimally in the range of 21-33°C and will not grow if temperature above 42°C. In the case of precipitation,

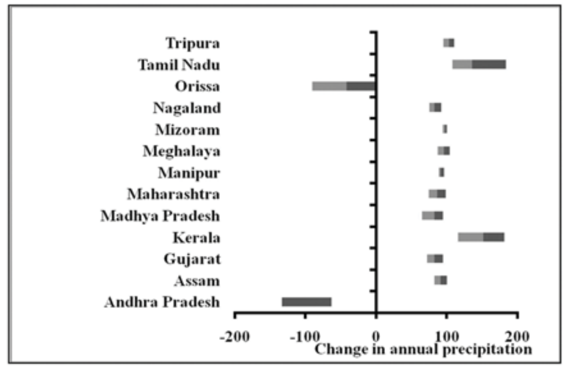
Table 1. Selected parameter set for calibrating eco crop model

Parameter	Calibrated value
Tkill	3°C
Tmin	10°C
Topmin	21°C
Topmax	33°C
Tmax	42°C
Rmin	300 mm
Ropmin	1000 mm
Ropmax	2000 mm
Rmax	3200 mm

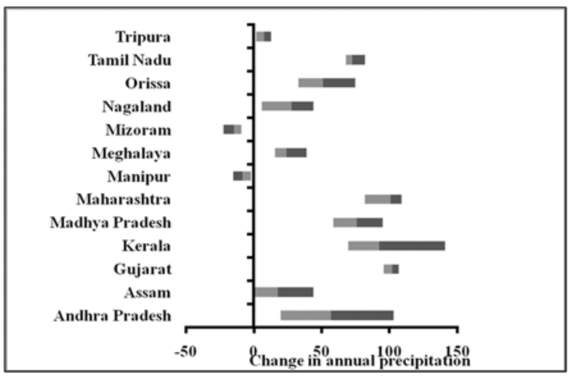
CCCMA-CGCM3.1 (T47)



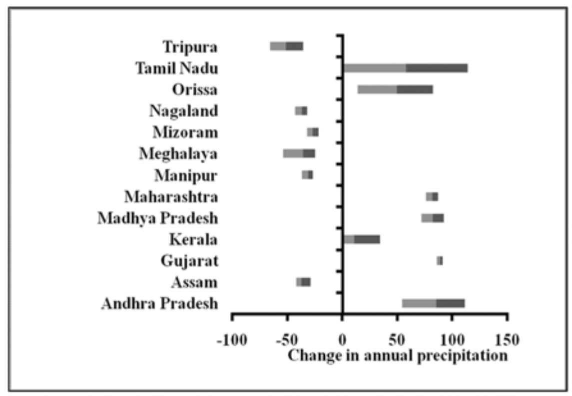
CCCMA-CGCM3.1 (T63)



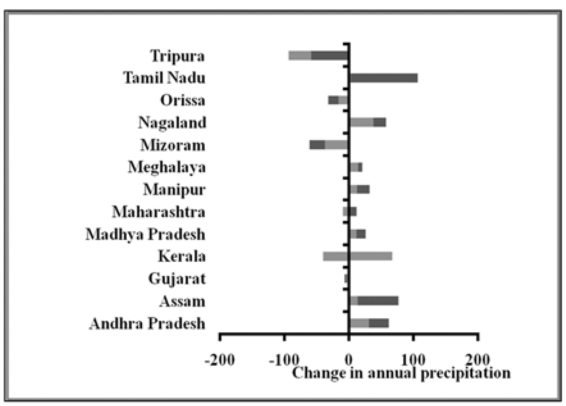
CNRM-CM3



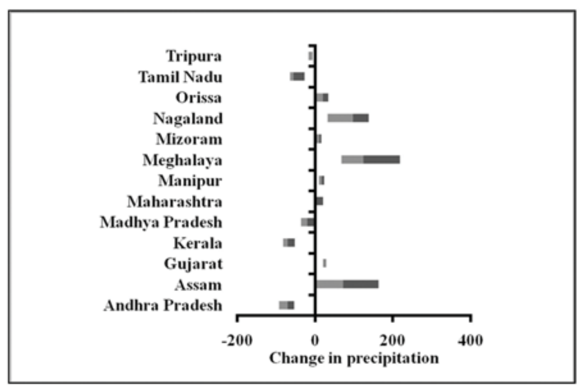
CSIRO-MK3.0



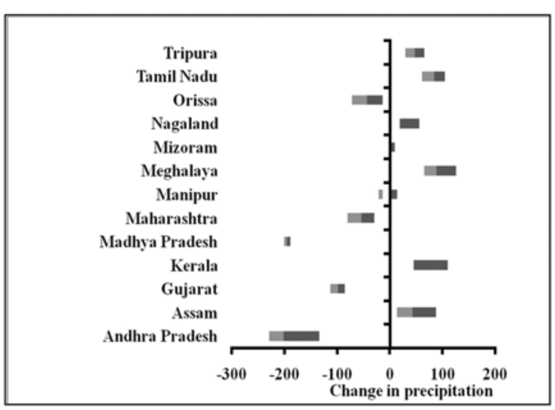
CSIRO-MK3.5



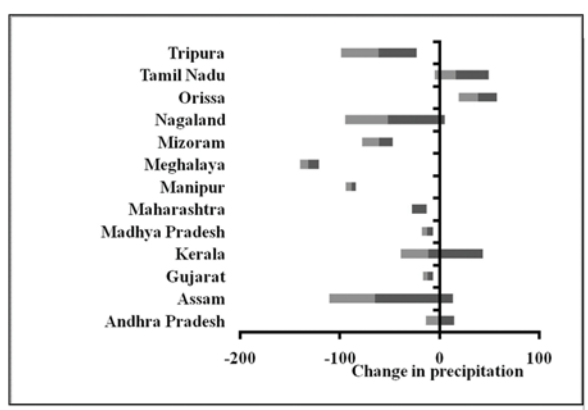
GFDL-CM2.0

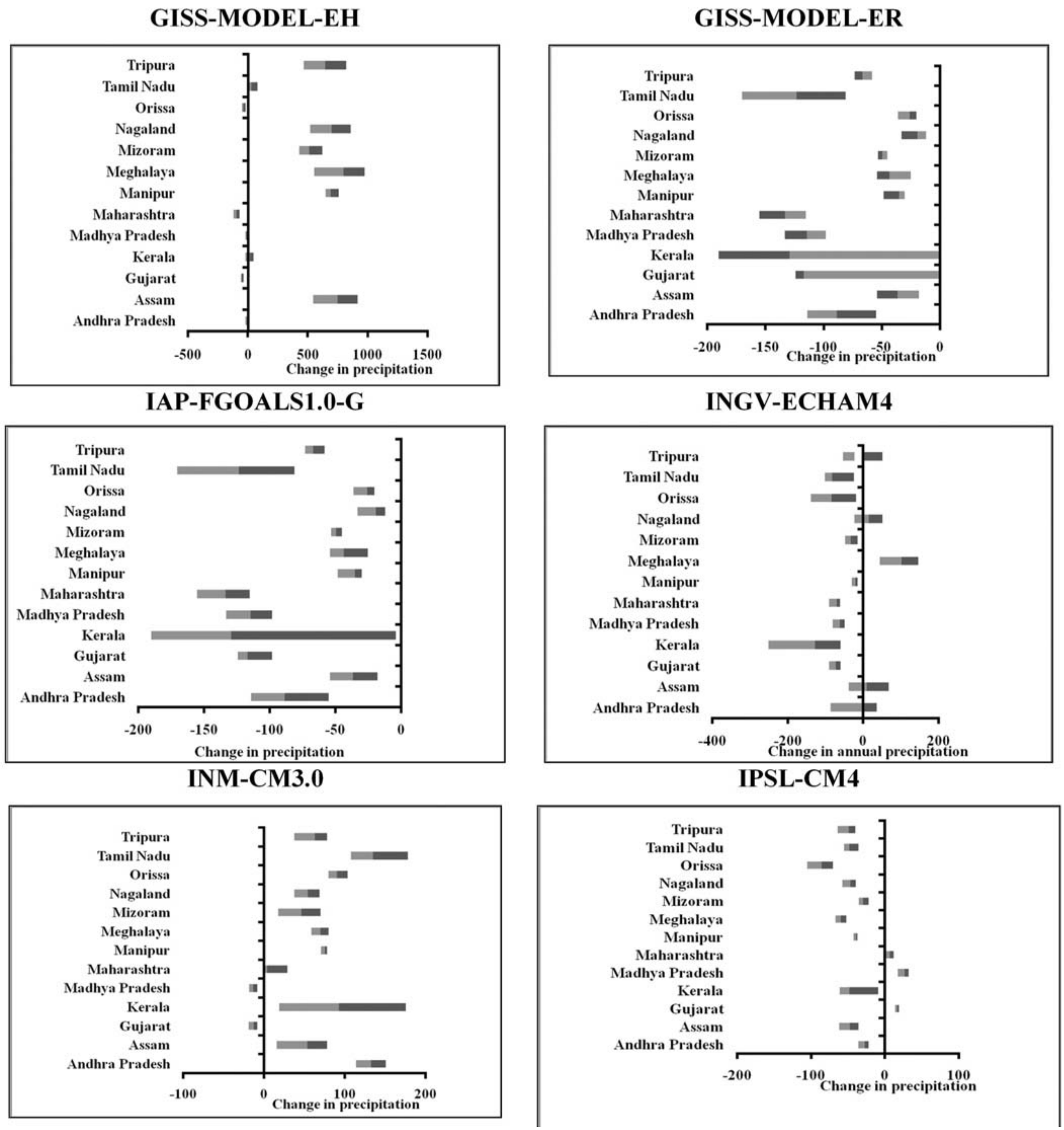


GFDL-CM2.1



GISS-AOM

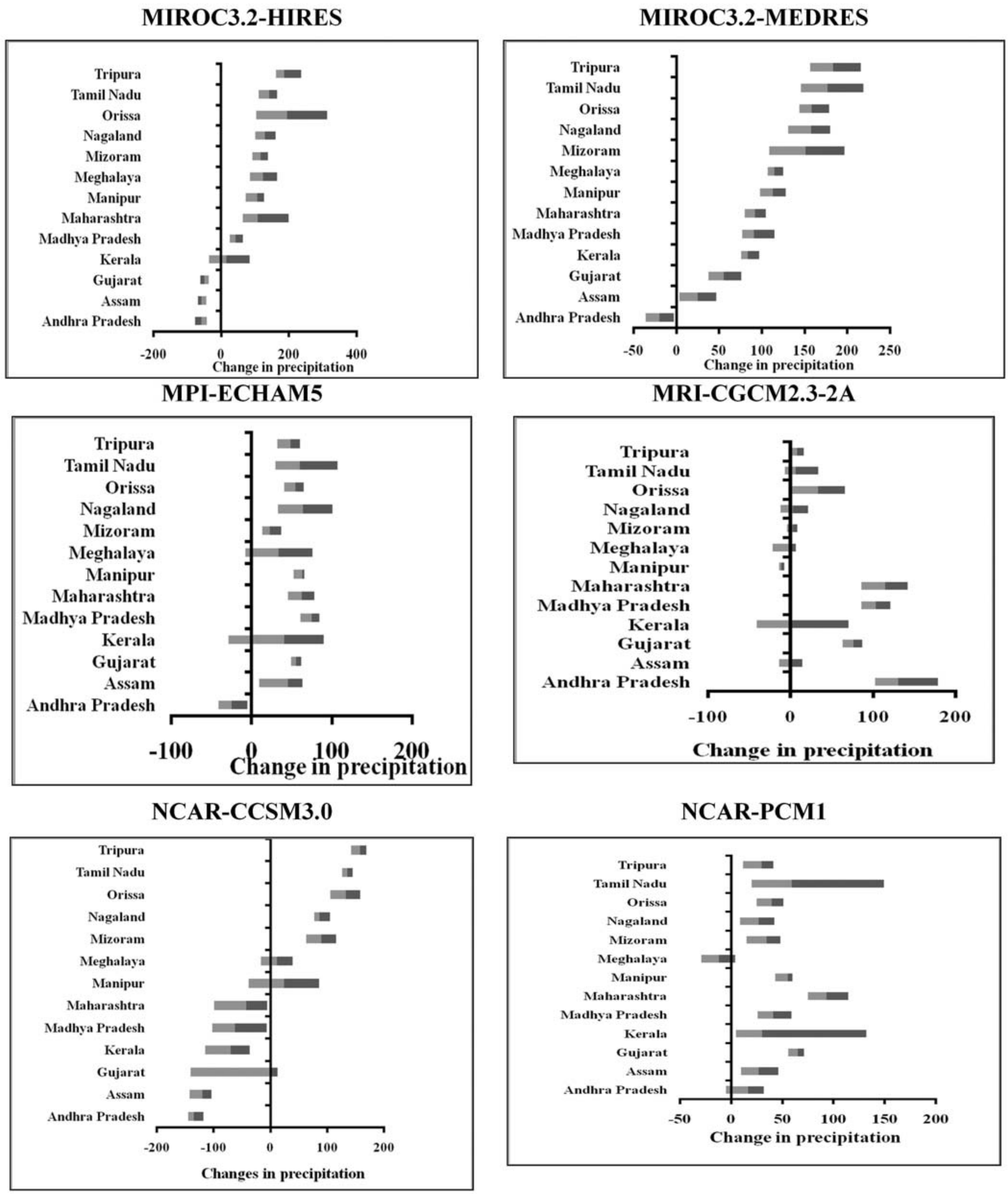




the crop will harmfully stressed if the total precipitation during the growing season is less than 300 mm (drought stress) or above 3200 mm (excess water) and grows optimally in the range of 1000-2000 mm precipitation.

Current suitability and model evaluation

The results on climate current suitability of yams in different parts of the country showed highly suitable (80-100%) areas for growing yam in the southern states of Kerala, Andhra Pradesh, Odisha, Maharashtra, Gujarat, and Madhya Pradesh, Mizoram, Manipur and Tripura. The current climate suitability predicted for Tamil Nadu is in the range of 40-80 per cent. The current suitability ranged from 20-100 per cent with 80-100 per cent suitability in the East Godavari and West Godavari districts of Andhra Pradesh. Current climate suitability of yam-growing regions of India is given in the Fig. 6.



Future predictions

The future predictions on yam climatic suitability showed that, on an average, yams production in India will be favoured by climate change or there will not be much decrease in yams climatic suitability by 2030 (Fig. 7). The future suitability predictions in major growing

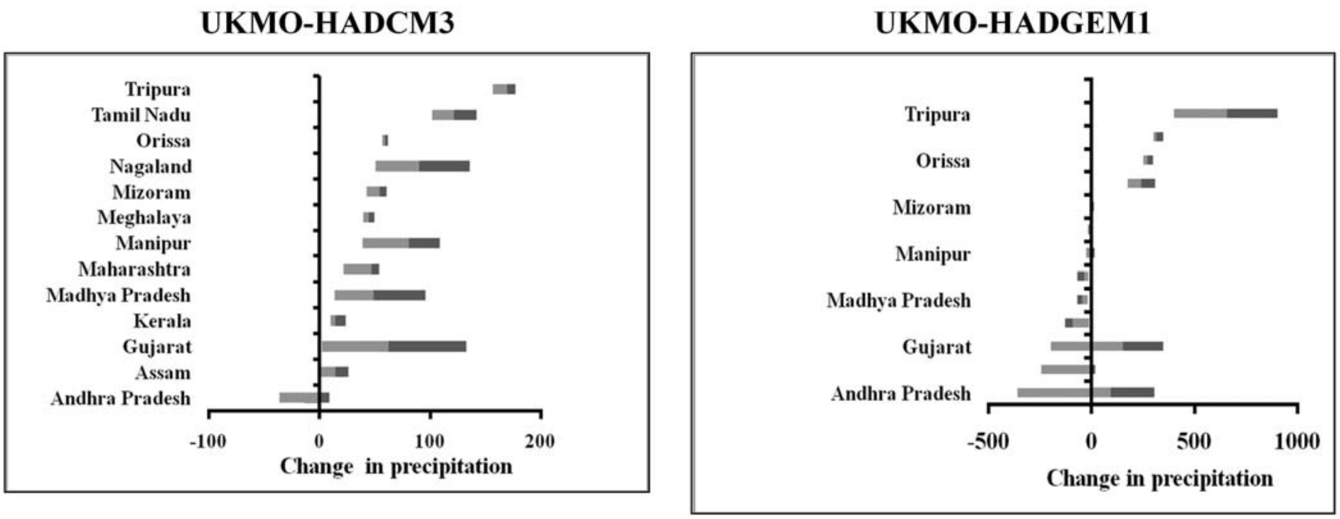


Fig. 4: Individual GCM predicted changes in annual precipitation (in mm) for yam growing states of India. Minimum, Maximum, Mean

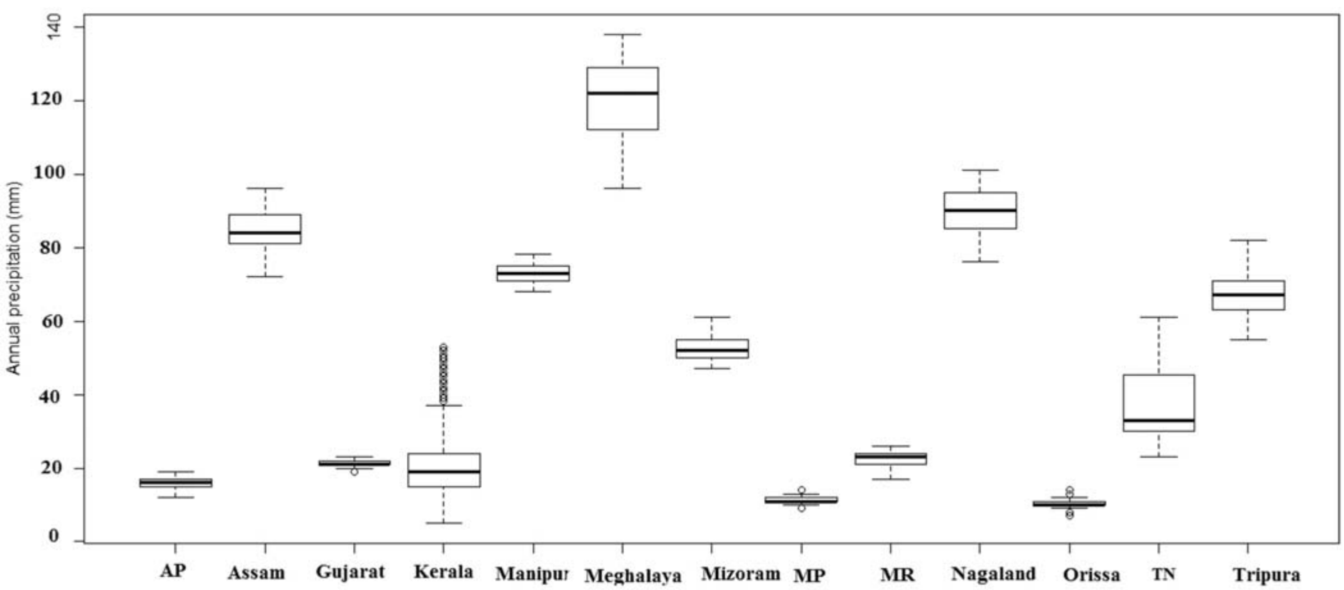


Fig. 5: Total annual precipitation change by 2030 for yam growing states of India

areas were almost similar as in the current suitability predictions. The 14 districts of Kerala, 2 districts of Andhra Pradesh and 1 district of Gujarat have the similar future suitability predictions. An increase in suitability range of 80-100 per cent was observed in north-eastern states like Tripura, Assam, Meghalaya and Nagaland. A marked increase of suitability of yam was observed in Tamil Nadu in 2030.

The individual GCM predicted changes in suitability is presented in Table 2. The overall suitability change in yam-growing regions ranged between -30.30 (NCAR-PCMI) to 3.0% (CSIRO-MK3.0) with suitability change in positively and negatively impacted areas ranged from 4.0 to 19.49 per cent and from -16 to 16.19 per cent respectively. According to predictions by the GCMs, CSIRO-MK3.5, GFDL-CM2.0, GFDL-CM2.1, GISS-MODEL-EH, GISS-MODEL-ER, IAP-FGOALS1.0-G, UKMO-HADGEM1, MRI-CGCM3.2A, NCAR-CSSM3.0, NCAR-PCMI, UKMO-HADCM3 the overall suitability change for yam-growing areas was negatively ranging from -30.0 to -1.0. The negative suitability change predicted by other GCMs ranged from -69.40 to 16.19 per cent and positive change in suitability ranged from 4.0 to 19. 49 per cent showed in Table 2.

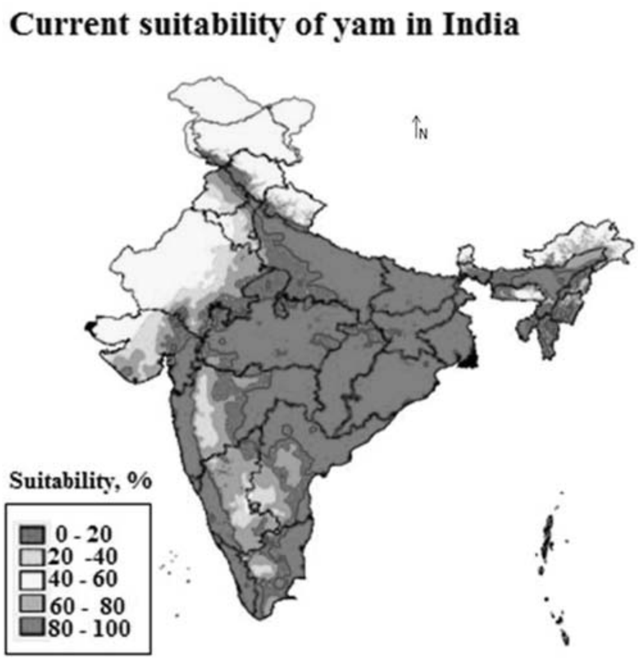


Fig. 6: Current suitability of yam in India predicted by eco crop model

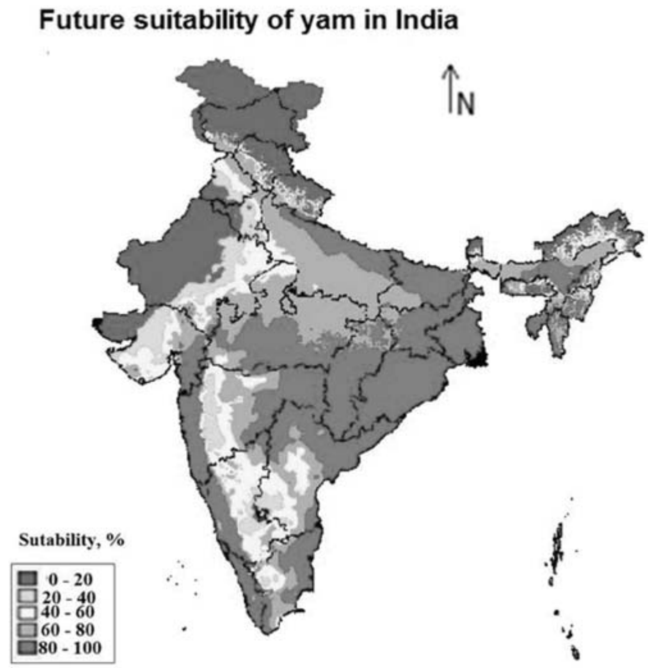


Fig. 7: Future suitability of yam (average of 22 GCMs) in India predicted by eco crop model

Table 2. Regional changes in yam suitability for individual GCMs

GCM	OSC*	SCPIA*	SCNIA*
CCCMA-CGCM3.1 (T47)	0.18	4.00	-5.00
CCMA-CGCM3.1 (T63)	-1.00	4.00	-5.00
CNRM-CM3	-7.00	7.00	-16.00
CSIRO-MK3.0	3.00	8.00	-4.00
CSIRO-MK3.5	2.00	8.00	-4.00
GFDL-CM2.0	1.00	8.89	-5.20
GFDL-CM2.1	-8.00	9.00	16.19
GISS-AOM	2.80	8.83	-1.97
GISS-MODEL-EH	-2.90	9.00	-13.00
GISS-MODEL-ER	-1.00	6.95	-12.97
IAP-FGOALS1.0-G	-1.80	4.16	-9.93
INGV-ECHAM4	1.49	9.58	-7.94
INM-CM3.0	2.25	9.22	-2.96
IPSL-CM4	1.28	4.89	-5.22
MIROC3.2-HIRES	1.45	10.06	-7.42
MIROC3.2-MEDRES	1.24	8.90	-8.51
MPI-ECHAM5	0.01	3.79	-3.43
MRI-CGCM2.3.2A	-0.32	5.27	-4.04
NCAR-CCSM3.0	-0.32	5.27	-4.04
NCAR-PCM1	-30.30	19.49	-69.94
UKMO-HADCM3	-4.27	4.95	-16.56
UKMO-HADGEM1	-4.74	10.47	-8.81

OSC*, overall suitability change; SCPIA*, suitability change in positively impacted area; SCNIA*, suitability change in negatively impacted area

The average change in suitability by 22 GCMs are presented as box plot as shown in Fig. 8 and the average suitability prediction by the GCMs are shown in Fig. 9. Suitability changes in yam-growing states ranged between -14.0 per cent (Madhya Pradesh) and 23.5 percent (Nagaland). No severe impacts were observed in most of yam growing regions by 2030. The predicted changes were negative for Andhra Pradesh (-5%), Odisha (-1.0%), but the values are negligible. The suitability changes in Kerala, Tamil Nadu and Andhra Pradesh were in the range of -2 to 7.18 per cent, -3 to 8.82 per cent and -3.0 to 5.86 per cent respectively.

The average suitability change was observed highest in the North Eastern region of India compared to other states. Here change in suitability range predicted as -10.72 to 16.0 per cent (Meghalaya), -13.36 - 23.5 per cent (Nagaland), -6.81- 17.9 per cent (Mizoram), and for Tripura (-13.72- 9.09%). The most suitable region for the yam cultivation is north-eastern region of India by 2030 as per the present study because the change in suitability was reported higher in those regions. In the case of south Indian states like Kerala and Andhra Pradesh, the average change suitability was reported as negative. Suitability of yam cultivation in Tamil Nadu will increase by an average change in suitability 4.66%. In other growing areas, -13.31 to -1.54 per cent for Maharastra and Gujarath (-3.86 - 0%). Kerala is having the suitability change in the range of -14.59 to 7.18 per cent.

This study was aimed to find out the projected

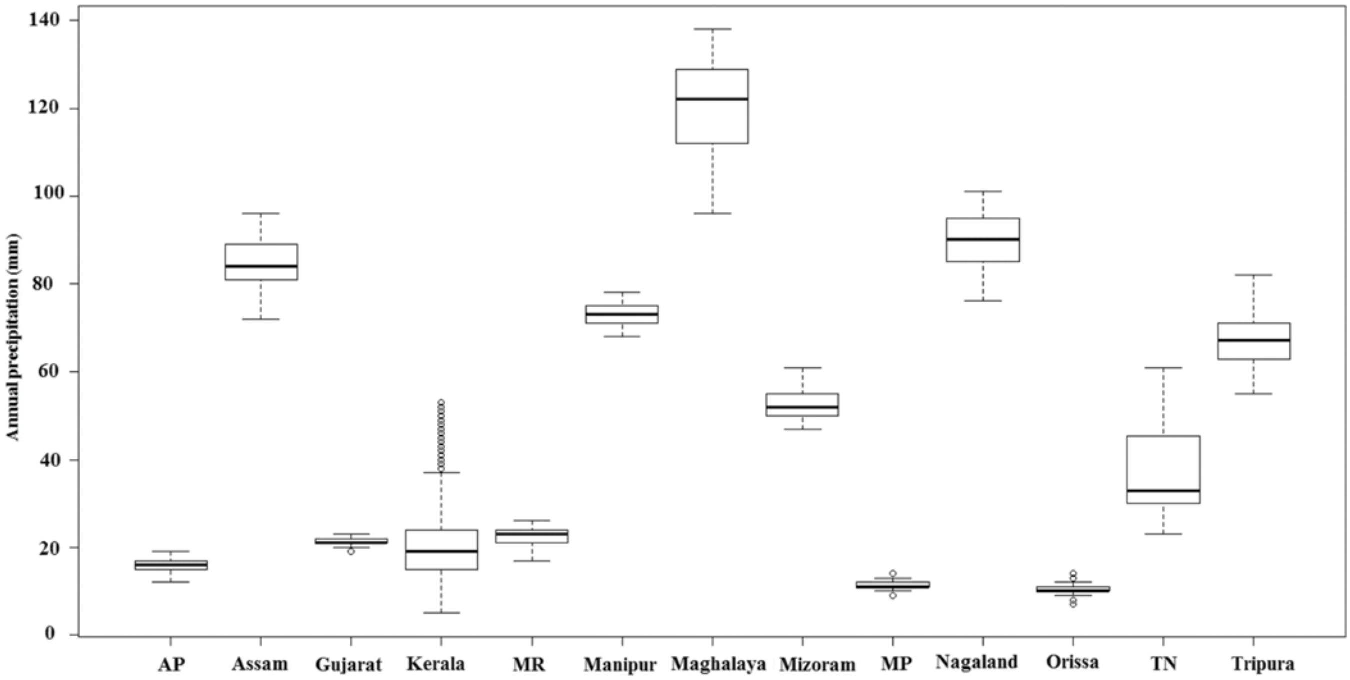


Fig. 8: Average change in suitability in major yam-growing regions in India

climatic changes in yam-growing regions of India, and to calibrate the eco crop model for yam to study the impact of yam to 2030 climate in India. The climate change projection in major yam-growing areas in India showed that annual mean temperature and total annual precipitation will increase by 2030. Out of the 22 GCMs studied, only one GCM predicted that temperatures will remain reduced in most of the current yam-growing areas. Annual mean temperature change in major yam-growing districts ranged from 0.9 to 1.3°C. The highest increase was observed in Indore and Khandwa districts of Maharashtra (1.3°C).

Predicted changes (average of 22 GCMs) in annual precipitation for major yam-growing regions ranged between 9 and 128 mm / year with the minimum increase in Wayanad district of Kerala (9 mm) and maximum increase was observed in South Garo Hills and West Garo Hills of Meghalaya (>100 mm). Out of the 22 GCMs studied, only one GCM, viz. CCMA- CGCM3.1 (T47) predicted an increase in annual precipitation in all yam-growing areas with a range of 33.98 (Tamil Nadu) to 234.54 mm (Andhra Pradesh), and also only one GCM predicted a decrease in annual precipitation by 2030 in all yam-growing areas with values range from -133 (Maharastra) to -19.17 mm (Nagaland), whereas the remaining GCMs showed varying precipitation changes.

The IPCC (Intergovernmental Panel on Climate Change) estimated that earth will warm by 1.4 to 5.8°C during the current century (IPCC, 2007) and the average

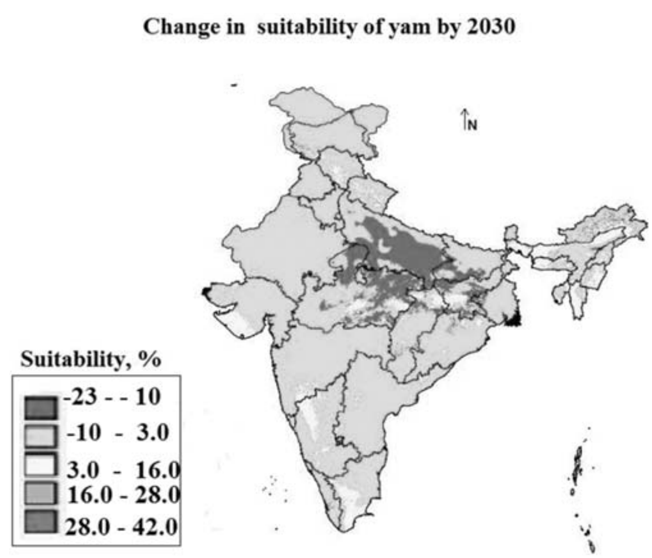


Fig. 9: Predicted changes in cassava suitability as average of the 22 GCMs

mean temperature will increase by 1 - 2°C during this century (Swaminathan and Kesavan, 2012). The continued emissions of greenhouse gases will cause further warming and changes in all components of climate system. An increase in temperature from 0.7 to 1.3°C in future in cassava-growing regions in Asia was earlier reported by Ceballos *et al.* (2011). An increase in precipitation by 2020 in some Asian countries was also reported by Beebe *et al.* (2011). Mendelsohn *et al.* (1994) predicted positive impact on agriculture from climate change like increased temperatures and higher carbon dioxide levels. Senapati *et al.* (2013) reported 10 - 15 per cent increase in monsoon precipitation in many regions in India and a decrease in precipitation (5-25%) in drought-prone central India. A decrease in number of rainy days along with an increase in heavy precipitation days in monsoon season are expected to increase the vulnerability of Indian agriculture because in India, agriculture is highly sensitive to monsoon variability as 65 per cent of the cropped area is rainfed (Chang, 1987).

The overall suitability change predicted by individual GCMs in cassava-growing regions ranged between -30.0 and 3.0%. The changes in suitability as an average of 22 GCMs for major cassava-growing states were observed to be from -2.04 to 23.5%. Jarvis *et al.* (2012) reported a positive impact of cassava in Africa to 2030 climate with a suitability change of -3.7 to 17.5%. The results of our study reported prominent increase of suitability to yam cultivation will observe in some yam-growing regions like Tamil Nadu, Mizoram and Tripura in 2030. A ten per cent increase is the excellent suitability of white yam-growing areas in Nigeria is expected by 2050 due to climate change is predicted using the 18 SRES models for emission scenario A2 (Sonder *et al.*, 2010). The results showed that 2030 climate will maintain yam production in almost all yam-growing states in India. There are different studies which showed a substantial increase in area of cassava suitability in different parts of the world (Liu *et al.*, 2008; Lobell *et al.*, 2008; Ceballos *et al.*, 2011; Jarvis *et al.*, 2012).

CONCLUSION

This study examined the projected climatic changes in major yam-growing environments of India which have identified based on expert knowledge and from literature review; and also calibrated and evaluated the eco crop model, of FAO to study the impact of 2030 climate on yam climate suitability in major yam-growing environments of India. The climate change projection in major yam-growing areas in India showed that annual mean temperature and total annual precipitation will increase by 2030. Using the calibrated data, predictions were made for current and future climatic conditions using the eco crop model and resulting suitability maps showed that the most current yam-growing areas have almost similar suitability in future climatic conditions and increased future suitability is seen for some of the region like Tamil Nadu. Analysis of change in suitability of yam-growing area agreed that there will be less consequence to current growing area. India has a potential to change the agriculture conditions by effective inclusion of new or unexplored crops with renowned agroclimatic adaptation, in this perspective whilst other crops fail yams happen to a key resource for Indian food security.

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Effect of foliar application of chemicals on quality and yield economics of garlic *(Allium sativum)* var. GG-4

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ABSTRACT

An experiment was conducted to find out the effect of foliar application of chemicals on quality and yield economics of garlic (*Allium sativum* L.) var. GG-4 during *rabi* season of 2015-16 at Regional Horticultural Research Station, Navsari Agricultural University, Navsari. The experiment was laid out in a randomized block design with three replications and nine treatments. The quality parameters like TSS (%) and ascorbic acid (mg/100 g) were significantly influenced by foliar application of 100 ppm citric acid + 300 ppm thiourea (T_8) with maximum value of 44.77% and 17.02 mg/100 g, respectively, whereas maximum storage days (179.33 days) were also observed in the same treatment. Moreover, sulphide content showed non-significant affect among different treatments. The maximum net return of ₹ 2,28,415 with a benefit: cost ratio (4.29) was obtained when plants were treated with 100 ppm citric acid + 300 ppm thiourea (T_8).

Key Words: Chemicals, Foliar spray, Quality, yield economic, TSS, Ascorbic acid, Thiourea

Garlic (*Allium sativum* L.) is one of the most important spices belonging to the family Amaryllidaceae. It is grown in 2.48 lakh ha with a total production of 12.59 lakh tonnes and productivity of 5.1 tonnes/ha. In Gujarat, it occupies an area of 39.20 thousand ha with a total production of 277.46 thousand tonnes, productivity being 7.07 tonnes/ha (NHB, 2014). The adoption of non-scientific and monocropping cultivation techniques of paddy, sugarcane and other horticultural crop required excessive amount of fertilizers and irrigation which have resulted into twin problem of waterlogging and secondary salinization which leads to drastic reduction in yield of crops under south Gujarat condition (NAU, 2003). Since garlic is a more remunerative crop, it requires less irrigation water (45-50%) as compared to summer paddy and sugarcane, it can fit in prevailing multicropping system in south Gujarat. Therefore, an experiment was conducted by using urea, thiourea, citric acid etc. under south Gujarat condition.

MATERIALS AND METHODS

The experiment was conducted at RHRS farm, ASPEE Collage of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, during 2015-16. The experiment was laid out in a randomized block design with three replications and nine treatments, *viz.* 1% urea (T_1), 2% urea (T_2), 50 ppm citric acid (T_3), 100 ppm citric acid (T_4), 200 ppm thiourea (T_5), 300 ppm thiourea (T_6), 50 ppm citric acid + 200 ppm thiourea (T_7), 100 ppm citric acid + 300 ppm thiourea (T_8) and the control (T_9). The experimental plot was thoroughly prepared by ploughing and harrowing before sowing of garlic cloves and applied required quantity of FYM (20 t/ha) as well as inorganic fertilizers (50-50-50 kg NPK/ha). The required quantity of clove (500 kg/ha) for experimental area was worked out and sowing of cloves at 20 cm × 15 cm was carried out during first week of December (2015). The first foliar spray of chemicals was applied 30 days after sowing (DAS) and second at 60 DAS. The quality parameters like storage days, TSS (%), ascorbic acid (mg/100 g) and sulphide content were recorded after six month of storage of tagged bulbs from each treatment.

RESULTS AND DISCUSSION

It was observed that TSS (44.72%) and ascorbic acid (17.02 mg/100g) were significantly influenced by

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Table 1. Effect of foliar application of chemicals on quality parameters of garlic var. GG-4

Treatment	Storage life (days)	TSS (%)	Ascorbic acid (mg/ 100g)	Diallylsulfide		Allicin		Diprophylthio-sulphinate		dimethylthio-sulphinate	
				Standard Rf.	Obtained Rf.	Standard Rf.	Obtained Rf.	Standard Rf.	Obtained Rf.	Standard Rf.	Obtained Rf.
T_1	169.00	40.00	14.34	0.05	0.05	0.45	0.44	0.45	0.26	0.30	0.19
T_2	170.33	40.23	14.79	0.05	0.04	0.45	0.40	0.45	0.30	0.30	0.15
T_3	176.67	38.25	16.15	0.05	0.05	0.45	0.43	0.45	0.26	0.30	0.17
T_4	177.67	39.93	16.31	0.05	0.05	0.45	0.35	0.45	0.31	0.30	0.17
T_5	170.33	42.62	15.99	0.05	0.06	0.45	0.46	0.45	0.35	0.30	0.19
T_6	172.00	43.40	16.02	0.05	0.05	0.45	0.45	0.45	0.30	0.30	0.17
T_7	178.67	43.86	16.46	0.05	0.06	0.45	0.44	0.45	0.31	0.30	0.17
T_8	179.33	44.72	17.02	0.05	0.05	0.45	0.36	0.45	0.34	0.30	0.17
T_9	155.67	36.45	13.04	0.05	0.04	0.45	0.38	0.45	0.34	0.30	0.18
SE. M±	1.64	0.40	0.31		0.004		0.027		0.019		0.009
CD (5%)	4.92	1.20	0.94		NS		NS		NS		NS
CV (%)	1.65	1.68	3.51		12.24		11.37		11.09		8.84

Table 2. yield economics of garlic var. GG-4 as influenced by foliar application of different chemicals

Treatment	Marketable yield (kg/ha)	Treatment cost (₹/ha)	Operational cost (₹/ha)	Total cost of cultivation (₹/ha)	Gross return (₹)	Net return (₹/ha)	Benefit : cost ratio
T_1	5080	5	53150	53155	203200	150045	2.82
T_2	5600	9	53150	53159	224000	170841	3.21
T_3	4480	3	53150	53153	179200	126047	2.37
T_4	5020	6	53150	53156	200800	147644	2.78
T_5	5540	20	53150	53170	221600	168430	3.17
T_6	5750	30	53150	53180	230000	176820	3.32
T_7	6320	23	53150	53173	252800	199627	3.75
T_8	7040	35	53150	53185	281600	228415	4.29
T_9	3470	0	53150	53150	138800	85650	1.61

Selling price g, 40/kg; FYM, 570/tonne; Urea, 6.20/kg; MOP, 15.60/kg
SSP, 6.30/kg; Citric acid, 80/kg; Thiourea, 140/kg; Labour cost, 150/head
Ploughing, 250/hr; Harrowing, 200/hr; Planking, 200/hr; Seed rate, 500 kg/ha

foliar application of 100 ppm citric acid + 300 ppm thiourea (T_8) after six month of storage (Table 1). The increase in quality attributes might be due to foliar application of citric acid and thiourea which supply adequate amount of essential nutrients to plants which play major role in quality improvement through desirable enzymatic changes taking place during growth period of plants and enhanced quality of bulbs. Similar results were reported by Haldar *et al.* (2014) in garlic and Meena *et al.* (2015) in coriander. The maximum storage life (179.33 days) was also noticed in the same treatment. The reason may be due to combined application of citric acid and thiourea.

Citric acid plays a role in post-harvest longevity of bulbs, whereas thiourea molecule is good donor of sulphur atom in biological reactions (Haldar *et al.*, 2014). Sulphide content of cloves was found to be non-significant with foliar application of different chemicals. This may be because that garlic need more sulphur fertilizers for production of sulphur compounds. However, experiment was conducted with less amount of sulphur resulted into less availability of sulphur for proper production of sulphur compound. Contrary findings were reported by Zinzala *et al.* (2017).

Different treatments registered more or less a good value of benefit : cost ratio. Foliar application of citric acid 100 ppm along with thiourea 200 ppm (T_8) achieved the marketable bulb yield of 7.04 t/ha and recorded the maximum net return of ₹ 2,28,415 with highest benefit:cost ratio (4.29:1) (Table 2). Similar results were found by Haldar *et al.* (2014) in garlic and Shanu *et al.* (2013) in coriander. Thus, it can be concluded that foliar application of 100 ppm citric acid along with 300 ppm thiourea on garlic var. GG-4 gave better response to increase quality of bulbs with maximum net return and highest benefit : cost ratio.

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Impact of post-harvest treatment on shelf-life and quality of mango *(Mangifera indica)* cv. Langra

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ABSTRACT

The experiment was conducted on six thousand fruits of mango (*Mangifera indica* L.) cv. Langra at Fruit Research Station Kuthulia, Rewa, Madhya Pradesh, during 2012 to find out the effect of post-harvest treatment on their shelf-life and quality. The treatments comprised MH- (1000 ppm), GA3 (250 ppm), hot water (50 $\pm$ °C), potassium permanganate, silver nitrate (1%), wax emulsion coating (6%), neem oil, perforated polythene and the control. The data were recorded on two parameters, viz. physical and chemical at an interval of 4 days for a total period of 12 days during storage. The maximum stone weight (12.68 g) was observed in hot water (50 $\pm$ °C), while minimum stone weight (11.89 g) was noted in perforated polythene (11.89%). The pulp thickness was maximum due to potassium permagnate (1.43 cm). The maximum TSS was showed by potassium permanganate (19.51°Brix). While minimum TSS (17.58°Brix) was noted in the control. The maximum shelf-life at room temperature was recorded in potassium permanganate (13.87 days), while minimum shelf-life was at room temperature in the control. The maximum acidity was found in potassium permanganate (0.44%), while minimum acidity(0.35%) was recorded with hot water (50 $\pm$ 2°C).

Key Words: Shelf-life, Potassium permanganate, Silver nitrate, Pulp, Perforated polythene.

Mango (*Mangifera indica* L.) utilized for human consumption. Fruit pulp predominates in water, carbohydrates, fibers, organic acids, fats, minerals, tannin and vitamin. The ripe fruit pulp contains about 11.8 per cent carbohydrates, 4800 IU of vitamin A and 13 mg / 100 mg ascorbic acid. Qualities as well as storability of mango fruits depend much on pre-harvest treatments. Scare application of plant growth regulators and chemicals during developmental stages results in poor storability due to increased rate of respiration and irregular biochemical function of fruit cell. Post-harvest losses in mango are estimated in the range of 25 - 40 per cent. To ensure quality and shelf-life of mango fruits with pre-harvest spray of chemicals and plant growth regulators have been tried by several workers. The post-harvest losses can be minimized by extension of shelf-life through checking the rate of transpiration and respiration, microbial infection and protection membranes from disorganization. This could be achieved by using plant growth regulators, chemical hot water and different materials after harvesting. Therefore, an experiment was conducted to find out the effect of post-harvest treatments on shelf-life and quality of mango.

MATERIALS AND METHODS

The experiment was conducted on six thousand fruits mango cv. Langra at Fruit Research Station Kuthulia, Rewa, Madhya Pradesh, during 2012. Twenty fruits were considered as a treatment replicated thrice in a randomized block design. The chemicals were MH (1000 ppm), GA3 (250 ppm), and hot water (50 $\pm$ 2°C), potassium permagnate, silver nitrate (1%), wax emulsion coating (6%), neem oil perforated polythene and the control. The data were recorded on two parameters, viz. physical and chemical at an interval of 4 days for a total period of 12 days during storage. The average fruit weight (gm), fruit length (cm), fruit girth, pulp weight (gm), stone weight (gm), pulp colour, specific gravity, volume of fruit (m), peel thickness (cm), pulp thickness (cm), spoilage, TSS. (°Brix), acidity (%), total sugar (%), sugar acidity ratio, loss in weight (%), shelf-life (days) at room temperature and shelf-life of fruits at two days interval were recorded. The length

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of selected fruits was measured and average length per fruit was measured with the help by variety cub par in cm. Twenty ripe fruits were randomly selected and removed the pulp from ripe fruits and weighted with the triple of electric balance. The pulp weight was measured in percentage. The weight of stone of the same fruits was measured and stone percentage was calculated as per standard formula (stone percentage = weight of stone / weight of fruits × 100). The specific gravity was calculated as per the formula given below.

$$\text{Stone percentage} = \frac{\text{Total weight of fruit}}{\text{Total volume of replaced water by fruits}} \times 100$$

Twenty fruits were randomly selected and fruit place in a glass jar full of water and the volume of replaced water was measured with the help of measuring cylender. The spoilage in fruits in different treatments were counted 5, 10 and 15 day after storage and percent of the spoilage fruit was recorded as per formula (spoilage (%) = number of spoilage fruit at 5, 10 and 15 day / total number of fruits stored × 100). Percentage of physiological weight loss of fruit was calculated with the help of following formula.

$$\text{Physiological weight loss}(\%) = \frac{\text{W1} - \text{W2}}{\text{W1}} \times 100$$

where, W1= initial weight of fruit

W2= weight after 5, 10 and 15 days of storage

The TSS of juice was measured by hand refractometer of 0-32°Brix range.After measure the sugar and acidity of fruit the sugar and acidity ratio measured by total divided by total acidity the sugar.

RESULTS AND DISCUSSION

The maximum fruit weight was recorded in MH (1000 ppm) (232.90 g), while minimum fruit weight was found in the control (212.03 g). These findings are confounded with Sandhu and Subhadra Bandhu (1992) observed that pre-harvest spray of GA_3, Vipul and Bavistin at a different concentration result at increase in fruit weight. The result of effect of length of fruit shows that various treatment significantly. The maximum fruit length was recorded in wax emulsion coating (10.79 cm), while minimum length of fruit (9.55 cm) was found in silver nitrate (40 ppm). The maximum girth of fruit was noted with hot water (7.13 cm), while minimum girth of fruit was recorded in the control (6.59 cm). The maximum pulp weight (72.66 g) was noted in MH (100 ppm), while minimum pulp weight (71.69 g) was recorded in the control. The maximum stone weight (12.68 g) was showed with hot water while minimum stone weight (11.89 g) was noted in perforated polythene.

The maximum specific gravity (1.09) of fruit was noted in MH (1000 ppm), while minimum specific gravity of fruit was found in the control (0.022). The maximum peel thickness (0.20 cm) was recorded with GA_3 and MH. While, minimum peel thickness (0.17 cm) was noted in calcium nitrate, neem oil, forted polythene and the control. The maximum pulp thickness was shown potassium permanganate (1.43 cm), while minimum pulp thickness was recorded in wax emulsion coating (1.35 cm). All treated fruits by various treatments more effective in pulp color that showed dark yellow color after 15 days except neem oil, perforated polythene and control that showed brownish yellow color after 15 days of storage.

Physiological loss in weight (PLW) was significantly increased in all the treatments with the advancement of storage period and the increasing trends in weight loss percentage was found maximum in fruits with untreated as the control. The losses in fruit weight and moisture content of peel were mainly caused by fruit transpiration in which water moved out and resulted in wilted rind and a shriveled appearance (Table 1). The findings are conformed to Wills *et al.* (2007). Variation of nutrients is also corroborated by earlier report of Bhalerao *et al.* (2013), who reported that seasonal variation of nutrients in leaves of mango was stable up to 1 June in growth and development of mango fruits.

The maximum TSS showed potassium dpermanganate (19.51 °Brix). While, minimum TSS was noted in the control (17.58 °Brix). These findings are conformed to Gautam *et al.* (2003) noted the TSS of mango fruits treated with potassium permanganate (17.31). The metabolic breakdown of organic acid into carbon dioxide and polysaccharides into water soluble sugar might be a reason for an increase in the sugar content. The findings of Raffo *et al.* (2002) also indicated that starch is completely hydrolyzed into soluble sugar such as glucose, fructose and sucrose as ripening progresses. The result of effect of shelf-life at (days) room temperature after ripening indicates that various treatment significant. The maximum shelf-life (day) room temperature was recorded in potassium permanganate (13.87 day), while minimum shelf-life in (5.97, day) room temperature was found in control. The findings are conformed to those of Singh *et al.* (1993) noted allthe treatments delayed ripening and improved fruit quality during storage. Control fruit could be stored for only 6 days (Table 2).

The result on spoilage of fruits indicates that various treatment significantly affected fruits. Patel and Patil (2016) also reported that different organics and coating, application of 80% N through neem cake +*Azotobacter* + PSB (50 g each / tree) and 5% Acacia gum coating were found to be most beneficial for improving quality and shelf-life of mango fruits. The maximum spoilage of fruit was noted in the control (75.39, 94.44 and 100.00%).

Table 1. Effect of various treatments on fruit characters

Treatment	Average fruit weight (g)	Average fruit length (cm)	Average fruit girth (cm)	Pulp weight (g)	Stone weight (g)	Pulp color			Specific gravity	Volume of fruit (ml)	Peel thick-ness (cm)	Pulp thick-ness (cm)	Effect on physiological loss in weight		
						5 days	10 days	15 days					5 days	10 days	15 days
MH (1000 ppm)	232.90	10.47	7.07	72.66	12.03	WY	Y	DY	1.09	213.53	0.20	1.41	6.05	12.09	18.17
GA (250 ppm)	228.10	10.36	6.90	72.42	12.16	WY	Y	DY	1.03	208.13	0.20	1.41	7.52	14.68	22.35
Hot water (50 ± 2 °C) 5 minut	221.73	10.04	7.13	71.94	12.68	WY	Y	DY	1.03	198.70	0.18	1.41	9.63	19.26	28.89
Potassium permanganate (6%)	223.83	10.20	6.74	72.21	12.06	WY	Y	DY	1.02	204.57	0.19	1.43	3.15	6.18	9.33
Silver nitrate (40 ppm)	222.30	9.55	6.77	72.06	11.98	WY	Y	DY	1.03	199.57	0.18	1.39	4.12	8.24	12.36
Calcium nitrate (1%)	224.93	10.13	7.07	72.20	12.08	WY	Y	DY	1.02	202.80	0.17	1.37	8.61	17.23	25.84
Wax emulsion coating (6%)	229.97	10.79	6.91	72.26	12.17	WY	Y	DY	1.02	205.70	0.18	1.35	5.42	10.83	16.32
Neem oil pure	219.17	9.97	6.82	72.04	12.02	Y	DY	BY	1.08	198.53	0.17	1.39	11.51	23.03	35.06
Perforated polythene 300 gauge	221.63	9.87	6.71	71.95	11.89	Y	DY	BY	1.01	197.97	0.17	1.38	10.61	21.16	31.83
Control	212.03	9.73	6.59	71.69	11.93	Y	DY	BY	0.022	187.30	0.17	1.38	14.34	28.68	43.02
S Em(±)	1.3427	0.198	0.121	0.124	0.173				0.065	2.337	0.008	0.108	0.083	0.216	0.362
CD (5%)	3.896	0.576	0.352	0.360	0.503					6.781	0.024	0.031	0.273	0.629	1.052

Table 2. Effect of various treatments on nutritional qualities of fruits

Treatment	Effect of various treatment on Spoilage (day)			Acidity (%)	Total sugar (%)	TSS	Sugar acidity ratio	Shelf-life in (day) room temperature after ripening	Effect of various treatments on shelf life					
	5 days	10 days	15 days						2 days	4 days	6 days	8 days	11 days	15 days
MH (1000 ppm)	24.60	65.87	69.83	0.38	17.11	18.64	46.12	10.65	100	80.90	52.33	33.27	18.97	4.73
GA (250 ppm)	34.92	69.83	74.60	0.37	17.32	18.85	48.13	9.27	100	71.40	52.43	38.03	42.73	9.42
Hot water (50 ± 2 0C) 5 minut	60.31	80.15	84.92	0.35	17.35	18.19	48.43	8.33	100	66.63	52.33	28.50	4.73	0.0
Potassium permanganate (6%)	0.00	38.03	47.60	0.44	17.35	19.51	48.31	13.87	100	85.95	65.03	47.57	28.50	14.23
Silver nitrate (40 ppm)	9.52	42.80	57.10	0.40	17.35	18.13	47.93	13.78	100	80.96	64.63	42.80	28.50	9.47
Calcium nitrate (1%)	45.23	75.39	80.15	0.36	17.26	18.38	45.59	9.13	100	80.70	66.63	42.80	23.73	0.0
Wax emulsion coating (6%)	14.28	52.38	61.90	0.39	17.31	18.55	45.99	10.80	100	76.17	57.10	42.80	28.50	9.43
Neem oil pure	69.83	89.68	94.44	0.40	17.35	18.08	43.53	13.17	100	71.40	52.33	28.50	4.73	0.0
Perforated polythene 300 gauge	65.07	84.92	89.68	0.37	17.35	17.73	48.60	6.93	100	76.17	57.10	42.80	28.50	4.73
Control	75.39	94.44	100.00	0.39	17.45	17.58	45.97	5.97	100	61.87	42.80	19.0	4.73	0.0
S Em(+)	2.713	4.907	3.7555	0.026	0.0916	0.191	1.569	5.65		4.058	4.379	5.882	6.088	3.867
CD (5%)	7.874	14.240	10.899	0.055	0.266	0.553	4.553	NS		11.777	12.708	17.070	17.669	11.223

While, minimum spoilage of fruits was found in potassium permanganate (0.00, 38.03 and 47.60%) at 5, 10 and 15-day interval. These findings are confirmed with Gautam *et al.* (2003). It is due to strengthens defense system through enhancing activities of antioxidant enzymes that improve the resistance in treated fruits against the fungal attack.

The potassium per manganese silica gel treatment and ZECC storage was most effective in delaying in spoilage of fruit. The result of effect of shelf-life at 2-day interval showed that various treatment significantly. The maximum shelf-life at 2-day interval of the fruit was noted in potassium permanganate (100, 85.95, 65.03, 47.57, 28.50 and 14.23). While, minimum shelf-life at 2-day interval of fruits was recorded in the control (100, 61.87, 42.80, 19.0, 4.73 and 00.00) at 2, 4, 6, 8, 11 and 15-day interval. These finding are confirmed with Narayan *et al.* (1996) was noted most effective in extending self-life increase it to 8, 12 and 23 days in different treatments. The result presents on acidity show that various treatment significantly. The maximum acidity was found in potassium permanganate (0.44%), while minimum acidity (0.35%) was recorded in hot water (50 $\pm$ 2°c). Thus, it is concluded that potassium permanganate (6%) showed better results in delaying the changes in physico-chemical properties, extending shelf-life of mangoes.

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Effect of different types of mulches on growth, yield and quality of okra *(Abelmoschus esculentus)* cv. GAO-5

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ABSTRACT

The experiment was conducted in summer season 2017 at Agriculture Experimental Station, NAU, Paria (Gujarat) to assess the effect of different types of mulches on growth, yield and quality parameters of okra [*Abelmoschus esculentus* (L.) Moench] cv. GAO-5. The growth, yield and quality were studied under inorganic and organic mulch and compared with the control. The experiment was laid out in a randomized block design with three replications and nine treatments. The results reveled that among all the treatments silver polythene mulch: 50 micron showed significantly highest germination per cent (89.87%), number of branches/plant (3.13), plant height at final picking (114.93 cm), total dry biomass of plant (123.97 g/plant), marketable pod length (11.01 cm), number of pods/plant (15.15), pod weight (12.30 g), pod yield (0.188 kg/plant and 13.81 t/ha). The minimum days required for 50% flowering (37.00 days) and first picking (42.00 days) were noted under silver polythene mulch: 50 micron. The quality parameter such as ascorbic acid (mg/100g) and fibre content (%) were found non-significant by different mulching treatments.

Key Words: Growth, Yield, Quality, Mulch, Summer season, Plant height, Germination

Okra {*Abelmoschus esculentus* (L.) Moench} is herbaceous hairy annual plant, belonging to Malvaceae family. It is grown during rainy and summer seasons. In summer season, temperature is high and this time moisture in soil is important. In view of conserving soil moisture reducing the weed growth and maintaining congenial soil physical environment mulches are more effective (Nagalakshmi *et al.*, 2002). Mulch increased soil temperature and high soil moisture, proper root growth, better uptake of nutrients, increased CO_2 level and absence of weeds growth in field were responsible for creating favourable microclimate around plant, which ultimately induced better vegetative growth. The use of plastic mulch helps conserving water by reducing evaporation from soil surface, controlling weed growth and reducing soil compactness (Tarara, 2000). Since mulches improve yield of many crops, an experiment was conducted to find out its effect on increasing the yield of okra.

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MATERIALS AND METHODS

An experiment was conducted at Agriculture Experimental Station, NAU, Paria (Gujarat), during summer season of 2017. The experiment was laid out in a randomized block design in nine treatments with three replications. The treatment consists of: T_1 (black polythene mulch: 25 micron), T_2 (black polythene mulch: 50 micron), T_3 (silver polythene mulch: 25 micron), T_4 (silver polythene mulch: 50 micron), T_5 (red polythene mulch: 25 micron), T_6 (red polythene mulch: 50 micron), T_7 (paddy straw mulch: 5 tons/ha), T_8 (sugarcane trash: 10 tons/ha) and T_9 (control).

Mulch were spread in plot before two days of sowing as per the treatment. Plastic mulch was laid by cutting into pieces of 3m × 3m to cover plot area. For the purpose of seed sowing holes were made in plastic at the recommended spacing. Paddy straw and sugarcane trash mulch of 10 cm thickness were spread in plot. The pods were harvested at alternate days and observation were taken from selected five plant.The growth, yield and quality parameters were recorded. Quality parameters such as ascorbic acid and fiber content were measured by method detailed by Ranganna (1997). Irrigation, weeding and plant-protection measures were done as and when required. The data were analysed statistically using standard method as suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The results reveled that different types of mulching materials significantly influenced the growth parameters over the control. The maximum germination per cent (89.87 %), number of branches / plant (3.13), plant height at final picking (114.93 cm) and total dry biomass of plant (123.97 g / plant) were recorded in silver polythene mulch : 50 micron (Table 1). Improvement in growth parameter due to plastic mulches improved moisture conservation and availability, which ultimately leads to improved plant growth and increased dry matter of plant. Warm soil temperature and proper moisture availability influenced by mulches that present during entire growth period of okra plant which is responsible for creating favourable conditions for plant growth. Which enhancement in photosynthesis and metabolic activities. Similar finding were confirmed by Bhatt *et al.* (2011).

The minimum days to 50% flowering (37 days) and days to first picking advanced (42 days) with treatment T_4 (silver polythene mulch: 50 micron) compared to the control (Table 2). Silver polythene mulch induced early

Table 1. Effect of different type of mulches on growth and quality parameters of okra

Treatment	Germination (%)	Number of branches / plant	Plant height at final picking (cm)	Total dry biomass (g / plant)	Ascorbic acid (mg / 100g)	Fibre content (%)
T_1 : black polythene mulch (25 micron)	61.60	2.20	91.07	107.53	11.36	1.83
T_2 : black polythene mulch (50 micron)	68.91	2.87	105.47	116.37	11.70	2.00
T_3 : silver polythene mulch (25 micron)	65.94	2.60	100.23	112.80	11.69	1.90
T_4 : silver polythene mulch (50 micron)	71.51	3.13	114.93	123.67	12.27	2.17
T_5 : red polythene mulch (25 micron)	59.02	1.87	84.17	87.23	10.97	1.83
T_6 : red polythene mulch (50 micron)	65.89	2.00	89.73	97.83	11.33	2.00
T_7 : paddy straw mulch (5 t / ha)	58.68	1.67	80.00	84.73	10.72	1.63
T_8 : sugarcane trash (10 t / ha)	58.15	1.60	76.80	84.76	10.45	1.77
T_9 : control	57.01	1.47	73.43	65.70	10.54	1.70
SEm.(±)	1.714	0.152	5.114	3.607	0.398	0.118
CD (5%)	5.14	0.46	15.33	10.82	NS	NS
CV (%)	4.72	12.23	9.77	6.39	6.14	10.96

Table 2. Effect of different type of mulches on yield parameters of okra

Treatment	Days to 50% flowering	Days to first picking	Number of pods / plant	Marketable pod length (cm)	Pod weight (g)	Pod yield (kg / plant)	Pod yield (t / ha)
T_1	41.67	46.67	13.79	9.94	11.53	0.161	11.85
T_2	38.67	43.67	14.60	10.70	12.10	0.177	13.15
T_3	39.00	44.33	14.13	10.54	11.96	0.172	12.52
T_4	37.00	42.00	15.15	11.01	12.30	0.188	13.81
T_5	42.33	47.67	13.51	8.43	11.17	0.152	11.20
T_6	42.00	47.33	13.57	9.00	11.29	0.153	11.39
T_7	44.67	49.33	12.94	8.15	11.07	0.143	10.62
T_8	45.33	50.67	12.75	8.06	10.96	0.143	10.57
T_9	50.00	55.33	12.64	7.68	10.29	0.132	9.76
SEm.(±)	1.489	1.456	0.419	0.367	0.388	0.006	0.454
CD (5%)	4.46	4.37	1.26	1.10	1.16	0.02	1.36
CV (%)	6.10	5.32	5.30	6.84	5.89	6.75	6.75

flowering by increasing water-use efficiency and fertilizer-use efficiency (Singh *et al.* 2009). The treatment T_4 (silver polythene mulch: 50 micron) recorded highest number of pods / plant (15.15), marketable pod length (11.01 cm) and pod weight (12.30 g), pod yield / plant (0.19 kg) and pod yield / ha (13.81 tons) (Table 2).

Plants under polythene mulch produce larger fruit and yield because of better plant growth due to favorable hydro-thermal regime of soil and complete weed-free environment. Furthermore, extended retention of moisture and availability of moisture also lead to a higher uptake of nutrient for proper growth and development of plants, resulted in higher growth of plants as compared to the control. Nikolic *et al.* (2012) reported that highest number of fruits / plant was recorded in plants grown on plastic mulch than organic mulch and the control. The present findings are in agreement with those of Hudu *et al.* (2002), Nagalakshmi *et al*. (2002), Rajbir Singh (2005), Aruna *et al.* (2007) and Sathiyamurthy *et al.* (2017).

The ascorbic acid content and fiber contentwere found non-significant among various mulch treatments (Table 1). Similar results confirmed to those of Sunanda (2004) and Arekar (2012). Thus, it was concluded that silver polythene mulch (50 micron) was found the best as compared to others. Silver polythene mulch: 50 micron (T_4) was beneficial for seed germination per cent, number of branches / plant, plant height at final picking, total dry biomass, early flowering, first picking, pod length, pod weight, number of pods / plant, pod yield (kg / plant and t / ha) with higher B:C ratio. Ascorbic acid content and fiber content not influenced by mulch treatment. Application of silver mulch: 50 micron can be suggested to obtained maximum growth, yield, quality as well as higher B:C ratio in okra cultivation under south Gujarat conditions.

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Analysis of salinity stress on biomass yield in ornamental tree species

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ABSTRACT

An experiment was conducted to study the response of subtropical ornamental tree species to five salinity levels, 0, 3, 4, 5 and 6 dS/m. Salinity effect was evaluated on the basis of changes in biomass under different salinity treatments. Different concentrations of NaCl were applied from May 2015 to October 2015 and different parameters were recorded at the end of October 2015. Aggravated salinity stress caused significant (P<0.05) reduction in all the quantified parameters. The highest salinity showed more detrimental effect compared to the control as well as lower salinity levels. At low level of salinity (0, 3, 4 dS/m), root fresh, dry weight and root length of *Callistemon lanceolatus* and *Acacia auriculiformis* slightly increased as compared to the control, whereas in *Koelreutaria paniculata* and *Putranjiva roxburghit*, biomass and root length decreased as salt concentration increased. Fresh and dry weight of stem and leaves increased as salt concentration increased in *Callistemon lanceolatus* and *Acacia auriculiformis*, whereas in *Koelreutaria paniculata* and *Putranjiva roxburghit*, it decreased.

Key Words: Saline water, Fresh weight, Dry weight, Root length, Ornamental trees, Salinity stress, Biomass

Salinity is major abiotic stresses that adversely affect crop productivity and quality (Ouda, 2008) with increasing effect on socio-economic fabric and health, especially of farming communities. Plants grown in saline soils face two major problems: osmotic and ionic stress (Silva *et al.,* 2008). The osmotic effects can be observed immediately after salt application, resulting in inhibited cell expansion and cell division, as well as stomatal closure and inhibition of growth of new leaves (Munns, 2003). Long time exposure to salinity results in ionic stress, which may direct to premature senescence of adult leaves, reducing photosynthetic area (Cramer and Nowak, 1992). In Punjab, south western area is mostly affected by ground water salinity and hence in this area, water level is raising, causing waterlogged conditions. Ground water in many regions of Punjab contain high amount of dissolved salts having EC between 2 and 7 dS/m (Shakya and Singh 2010). Salinity and poor quality irrigation water are most prevalent issue in arid and semi-arid regions, so there is requirement to select plants that can tolerate saline water and make arid and semi-arid regions green. Therefore an experiment was conducted to find out the effect of saline water on biomass yield of a few ornamental tree species.

MATERIALS AND METHODS

One-year-old seedlings of four ornamental trees *viz., (Acacia auriculiformis), (Callistemon lanceolatus), (Koelreutaria paniculata)* and *(Putranjiva roxburghii)* were grown in 10" earthen pots containing soil: FYM (2:1) during first week of April 2015. After 30 days of planting, i.e. on first week of May, different concentrations of NaCl , AR (analytical reagent), *i.e.* 0 mM, 30 mM (1.75g/l of water/pot), 40 mM (2.34g/l of water/pot), 50 mM (2.92g/l of water/pot) and 60 mM (3.51g/l of water/pot) were given with irrigation water and EC of media was maintained according to different concentrations of salt. Concentration of NaCl was gradually increased in irrigation water till it reached to desired salinity of each treatment.

The irrigation water volume was determined by adding the leaching amount to water consumed by plants, *i.e.* 1 litre/pot. Before starting the experiments, the doses were standardized and EC of soil was maintained as 0.75, 1.00, 1.25, 1.50 dS/m at 30, 40, 50

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and 60 mM NaCl. Fresh weight and dry weight of stem, leaves, roots and root length of all the ornamental trees were recorded during October 2015. The experiments were conducted as per the treatments in a factorial completely randomized design (CRD) with three replications comprising one pot per replication. The statistical analysis was performed using SAS software version 9.4 and salt treatment, tree means and salt treatment × tree, interaction were compared using Duncan Multiple Range Test (DMRT) at 5% level of significance (Duncan 1955).

RESULTS AND DISCUSSION

High salinity level negatively affected root length in ornamental trees. In *Acacia auriculiformis* and *Callistemon lanceolatus*, root length increased with salt treatment up to 40 mM NaCl and after that decreased, whereas in *Koelreutaria paniculats* and *Putranjiva roxburghii*, root length decreased as the level of salinity in irrigation increased. Among different tree species, maximum increase (44.04%) in root length was recorded in *Callistemon*, followed by *Acacia* (20.12 %) at 40 mM NaCl as compared to the control. Increase in root length under salinity may be due to ability of these two species to extract more water from soil. As a consequence, increase in water uptake capacity allowed the ion dilution to prevent toxicityin cytosol (Chelli-Chaabouni *et al.*, 2010). Decrease in root biomass of *Dalbergia sissoo* and rooting percentage and root length of *Papulus teemula* has been reported earlier with increased salinity (Singh *et al.*, 1996, Evers *et al.*, 1997).

Among different salt treatments, highest mean fresh weight (20.98 g) was recorded when tap water was given and lowest (8.30g) at highest concentration (60 mM) of salt, irrespective of different tree species. In *Acacia* and *Callistemon*, fresh weight of roots increased up to 40 mM NaCl and per cent increase was 20.12 and 44.04 % respectively as compared to the control and thereafter at 50 and 60 mM, fresh weight decreased (Table 1 and fig. 1). In *Koelreutaria* and *Putranjiva*, fresh weight decreased as salt concentration in water increased and decrease was maximum (72.16%) in *Koelreutaria,* followed by Putranjiva (70.15 %).

The increase in fresh weight of stems and leaves with increase of salinity levels was recorded in *Acacia* and *Callistemon* compared with the control (Tables 2 and 3, Figs 2 and 3), whereas in *Koelreutaria* and *Putranjiva,* fresh weight of stems and leaves decreased as salt concentration in soil increased. Salinity-induced fresh weight reduction is a common phenomenon for most of the cultivated crop plants and trees. Behzadifar *et al.* (2013) described high significant reduction of fresh weight of *Catharanthus roseus* at 8 dS m salinity, whereas an increase in fresh weight in *Pennisetum alopecuroides*

Table 1. Effect of different concentration of NaCl on fresh weight (g) of roots of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	36.62 cd	33.06 d	58.77 a	30.52 de	20.98 a
30 mM NaCl	41.85 bc	44.80 b	31.36 de	24.26 ef	15.94 b
40 mM NaCl	43.99 b	47.62 b	25.70 ef	19.62 fg	16.35 b
50 mM NaCl	35.07 d	32.19 d	22.11 fg	16.10 g	10.79 c
60 mM NaCl	33.43 d	30.78 de	16.96 g	9.11 h	8.30 d
Mean	12.65 c	19.48 a	16.36 b	9.39 d	

The different letters in each column are significantly different at $P \leq 0.05$ by Duncan's Multiple Range test (DMRT)

Table 2. Effect of different concentration of NaCl on fresh weight (g) of stem of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	27.23 j	37.39 g	87.40 a	18.22 k	42.56 a
30 mM NaCl	30.92 i	40.96 f	60.16 b	13.37 l	36.36 b
40 mM NaCl	32.73 hi	43.63 ef	56.21 c	11.46 lm	36.01 b
50 mM NaCl	34.43 gh	46.44 e	29.92 ij	8.90 mn	29.92 c
60 mM NaCl	36.05 g	50.15 d	12.32 l	6.85 n	26.34 d
Mean	32.27 c	43.71 b	49.20 a	11.76d	

The different letters in each column are significantly different at $P \leq 0.05$ by Duncan's Multiple Range test (DMRT)

Table 3. Effect of different concentration of NaCl on fresh weight (g) of leaves of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	24.49 g	25.26 fg	44.49 a	18.63 h	28.22 a
30 mM NaCl	37.35 c	28.75	31.96 d	14.91 hi	28.24 a
40 mM NaCl	40.40 bc	30.52 de	27.51 efg	12.69 ij	27.78 ab
50 mM NaCl	43.06 ab	36.67 c	14.06 i	11.47 ij	26.32 b
60 mM NaCl	46.43 a	40.03 bc	11.88 ij	9.39 j	26.93 ab
Mean	38.34 a	32.24 b	25.97 c	13.41 d	

Different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range test (DMRT)

Table 4. Effect of different concentration of NaCl on dry weight (g) of roots of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	14.07 gh	19.32 cd	34.95 a	15.58 efg	10.02 a
30 mM NaCl	15.13 efg	21.15 bc	16.79 defg	10.70 hi	9.35 a
40 mM NaCl	17.99 cdef	24.32 b	14.52 fg	8.55 ijk	9.47 a
50 mM NaCl	9.37 ij	18.40 cde	8.70 ijk	6.69 jk	6.49 b
60 mM NaCl	6.69 jk	14.23 gh	6.84 jk	5.43 k	4.80 c
Mean	4.55 c	12.89 a	7.25 b	7.38 b	

Different letters in each column are significantly different at P?0.05 by Duncan's Multiple Range test (DMRT)

Table 5. Effect of different concentration of NaCl on dry weight (g) of stem of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	8.21 jk	19.19 eg	26.29 c	7.80 jk	15.37 a
30 mM NaCl	10.37 ij	23.61 de	21.35 ef	6.29 kl	15.40 a
40 mM NaCl	11.84 i	25.56 cd	16.99 gh	5.73 kl	15.03 a
50 mM NaCl	15.08 h	29.15 b	10.11 ij	4.81 l	14.79 a
60 mM NaCl	15.92 h	38.66 a	4.42 l	4.01 l	15.75 a
Mean	12.28 c	27.23 a	15.83 b	5.72 d	

Different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range test (DMRT)

Table 6. Effect of different concentration of NaCl on dry weight (g) of leaves of ornamental tree species

Treatment	*Acacia auriculiformis*	*Callistemon lanceolatus*	*Koelreutaria paniculata*	*Putranjiva roxburghii*	Mean
0 mM NaCl	18.67j	19.53 hij	36.45 a	10.12 k	21.19 a
30 mM NaCl	19.37 ij	21.66 ghi	28.07 cd	6.62 lm	18.93 b
40 mM NaCl	20.30 ghij	26.32 de	21.92 fgh	5.69 mn	18.56 bc
50 mM NaCl	22.36 fg	30.42 c	10.85 k	4.72 mn	17.09 cd
60 mM NaCl	24.41 ef	33.48 b	8.98 kl	3.66 n	17.63 d
Mean	21.02 b	26.28 a	21.25 b	6.14 d	

Different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range test (DMRT)

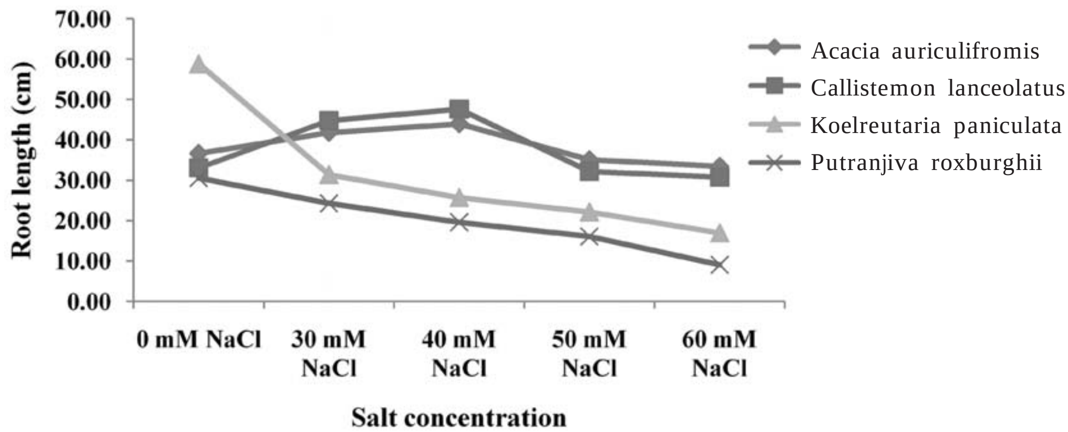

Fig. 1: Root length of different tree species under different concentration of salt

Fig. 2: Salt stressed leaves of *Acacia, Callistemon, Koelreutaria* and *Putranjiva* in field

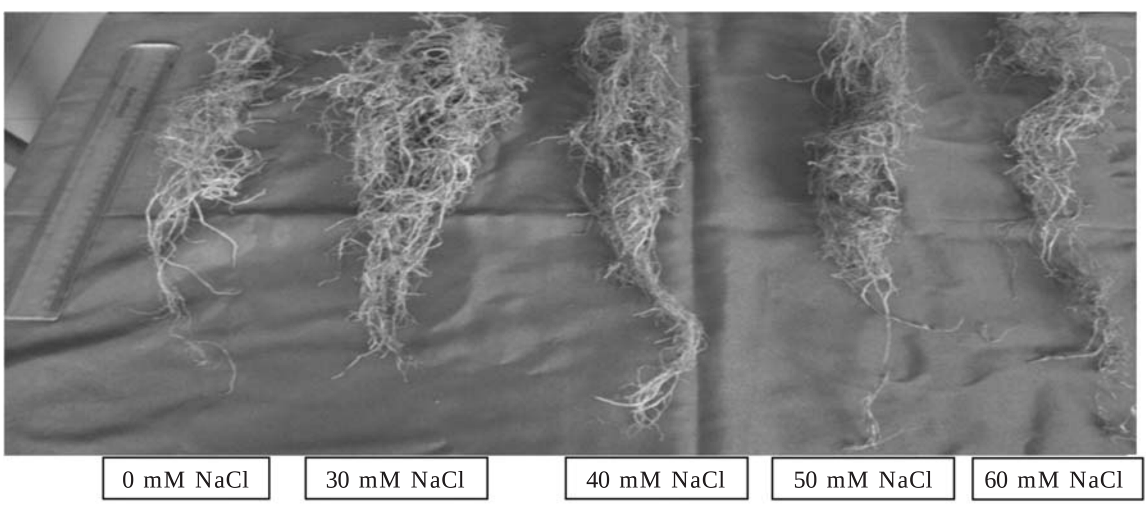

Fig. 3: Effect of different concentration of NaCl on root growth of *Acacia auriculiformis*

at 100 mM salinity has been reported by Mane *et al.* (2011)a.

Dry-matter contents significantly reduced by NaCl-induced salinity stress in *Koelreutaria* and *Putranjiva* with an increase of salinity levels except Acacia and Callistemon, in which dry weight increased at 30 and 40 mM NaCl and decreased thereafter. The increase in dry-matter content in Pennisetum alopecuroides at 100 mM salinity was also reported by Mane *et al.* (2011)b. Such stimulation in dry matter production under the effect of salinity might be due to accumulation of inorganic ions and organic solutes for osmotic adaptation, while a decrease in dry-matter content at the highest salinity levels might be due to inhibition in

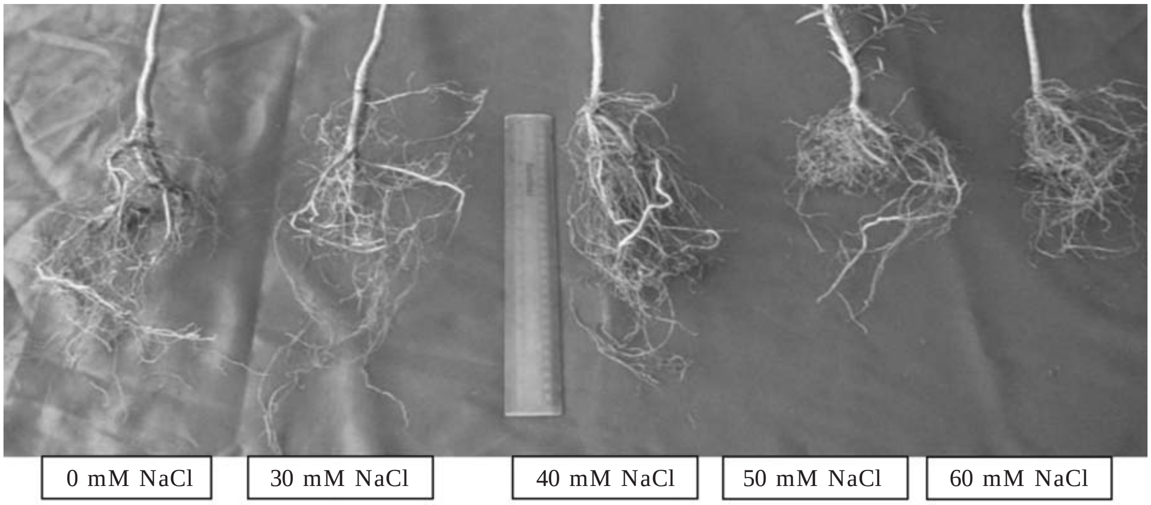

Fig. 4: Effect of different concentration of NaCl on root growth of *Callistemon lanceolatus*

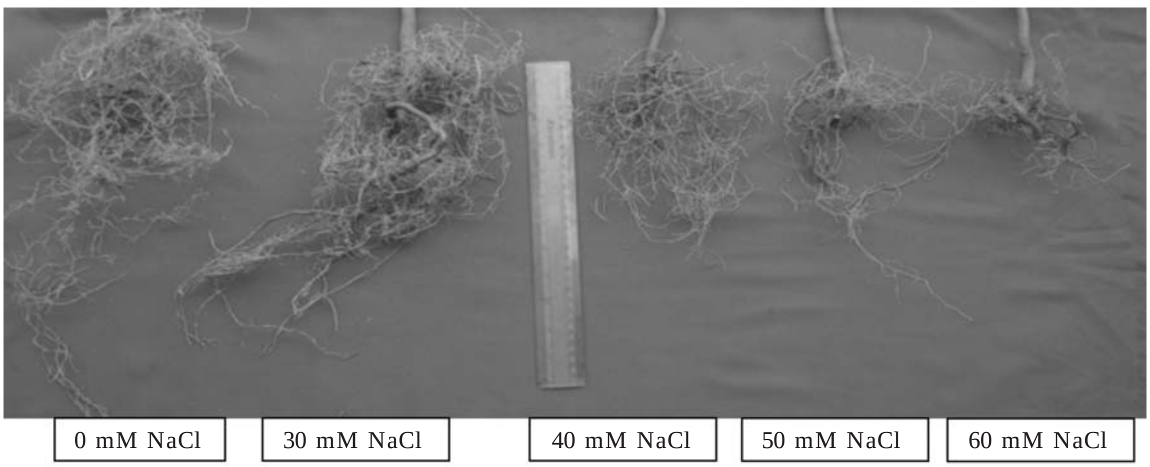

Fig. 5: Effect of different concentration of NaCl on root growth of *Koelreutaria paniculata*

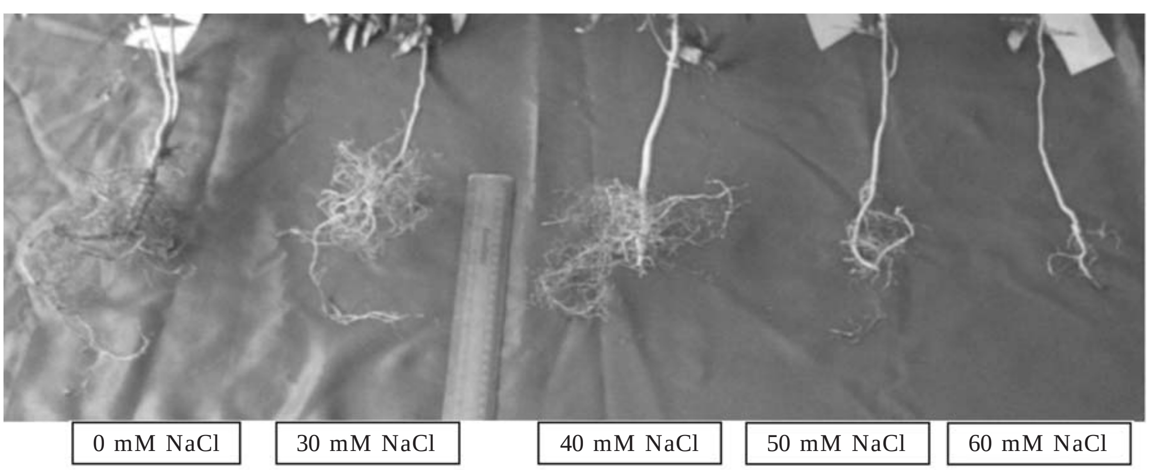

Fig. 6: Effect of different concentration of NaCl on root growth of *Putranjiva roxburghii*

hydrolysis of reserved foods and their translocation to growing shoots.

Climate change and industrialization deteriorate the environment, rising sea level and severe soil and water salinity, resulting in unsuitable existence for many important plant species. Though there has been a significant variation among four tree species for measured parameters but *Callistemon sp.* and *Acacia sp.* proved as salt-tolerant plants. Salt stress at higher concentration was harmful to vegetative growth of *Koelreutaria* and *Putranjiva* since root length, fresh and dry weight of roots, leaves and stem decreased significantly, thereby proving them as sensitive ones.

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Evaluation of physico-chemical and sensory properties of jam and jelly prepared from paniol *(Flacourtia jangomos)* fruits

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ABSTRACT

The experiment was conducted to evaluate physico-chemical and sensory properties of value-added products of paniol [*Flacourtia jangomos* (Lour.) Raeush] fruits, in the Laboratory, Department of Horticulture, B N College of Agriculture, Biswanath, Chariali, during 2014-2016. The factorial complete randomized design in replicate was followed. The products were stored at ambient and refrigerated conditions and analysed qualitatively at 30 days interval. The result showed that storage condition and storage duration significantly influenced the physico-chemical characteristics of jam and jelly. The TSS, acidity, reducing sugar and total sugar were in increasing trend, whereas ascorbic acid and anthocyanin content were in decreasing trend with increase in storage periods. The TSS content of jam ranged from 68 to 68.70%, acidity 0.85 to 1.01%, total sugar 6.39 to 7.07%, ascorbic acid 4.85 to 3.51 mg/100g and anthocyanin content 3.50 to 1.33mg/100g. Similarly, TSS jelly ranged from 65 to 66.08%, acidity 0.85 to 1.09%, total sugar 6.78 to 7.17% ascorbic acid 4.67 to 3.46mg/100g and anthocyanin content 3.61-1.35mg/100g. There was no significant interaction effect of storage duration and storage condition in jam and jelly during the storage period. The overall sensory score for colour, flavour and taste/texture were highest in jelly (24.40) than that of jam (21.74) at the end of storage period. Sensory evaluation results revealed that paniol jam and jelly kept under refrigerated condition remain organoleptically acceptable to consumers for 6 months.

Key Words: Physico-chemical, Sensory properties, Jam Jelly, Value-added products, Storage, Acidity, Reducing sugar

Paniol [*Flacourtia jangomos* (Lour.) Raeusch] is one of the most important indigenous fruits found in wild state in different tropical and subtropical parts of the country. It belongs to the family Flacourtiaceae and it is also known as "Indian plum". The fruits are eaten to overcome biliousness, nausea and diarrhoea. Powdered, dried leaves are employed to relieve bronchitis and coughs (Shukla and Kumar, 2009). Fruits become unmarketable due to shrivelling and loss of scarlet colour shortly after harvest (Nath *et al.*, 2009; George *et al.*, 1999). Thus, quick disposal of fruits is of great importance. The alternate source may be processing of fruits into pulp and then processed into value-added products. However, efforts have been made for development of value-added products by Khurdiya and Roy (1985), Kannan and Thirumaran (2004) in jamun, Chakraborty *et al.* (2008) in underutilized fruits and Chakraborty *et al.* (2011) in minor fruits. There is always a demand for new nutritious and innovative food products. Therefore, an experiment was conducted to make its value-added products.

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MATERIALS AND METHODS

The fruits were collected from Dhupdhora area of Goalpara district of Assom. After collection, they were washed properly with water and weighed and boiled in pressure cooker for about 30 minutes. The pulp was extracted by passing through a fine stainless sieve size of 4mm to 38 microns. After extraction of pulp, fruit jam was prepared with required amount of sugar, i.e. in a 1:1 ratio. The prepared jam was transferred to sterilised glass bottles and sealed the cap.

For jelly, fruits were washed properly with water, boiled in a pressure cooker and after that they were tied in a muslin cloth and juice was extracted. After extraction of juice, jelly was prepared with required amount of sugar, i.e. in a 1:1 ratio and transferred to sterilised glass bottles and sealed the cap.

Paniol fruit jam and jelly were stored at two storage conditions [ambient temperature(20-25°C) and refrigerated temperature(4 ± 1°C)] for 6 months. The biochemical analyses of stored products were done at 30 days interval. Observation on biochemical parameters like TSS by hand refractometer; titratable acidity was estimated by using standard method of AOAC (1980); total and reducing sugar was estimated as per Lane and Eyon method (1928); ascorbic acid was determined by visual titration method described by Freed (1966) and anthocyanin was determined by method described by Srivastava and Kumar (2007). The data on changes in chemical composition of paniol jam and jelly during storage was statistically analyzed by the standard procedure of Factorial completely randomized design (Panse and Sukhatme, 1985). There were 3 replications in each of the following methods.

RESULTS AND DISCUSSION

There was a significant increase in TSS content with increase in storage period of jam and jelly. It ranged from 68 to 68.70 per cent in jam and from 65 to 66.08 per cent in jelly during 60 days of storage period. Storage conditions significantly affected the TSS content of jam. Among storage conditions, ambient condition showed higher TSS content (68.62 and 65.85%) than refrigerated condition (68.33 and 65.50%) in paniol jam and jelly. The TSS content of jelly increased more rapidly from an initial level 65 per cent peaking to 66.30 per cent under ambient condition at 60 days of storage. Similarly, TSS content of jelly increased from initial level to 65.87 per cent under refrigerated condition.

The interaction between storage conditions and storage duration showed non-significant effect on TSS content of jam and jelly. Both the samples stored under refrigerated condition were stable up to 6 months, whereas under ambient condition it remained stable up to 60 days of storage. The increase of TSS content might be due to increase in total soluble sugars produced and pectin substances into similar substances. This trend of increase in TSS during storage has also been reported by Swamy and Banik (2011) in guava squash, Prasad and Mali (2006) in ber jam.

The storage conditions significantly influenced the acidity of jam and jelly. The higher acidity (1.06%) was observed in jam stored under ambient condition than that of refrigerated condition (0.90%). The acidity content of both jam and jelly increased significantly throughout the storage period. At beginning of storage, acidity level of jam was 0.853 per cent. It increased to 1.01 per cent and in case of jelly, acidity increased to peak level (1.09%) at 60 days of storage.

The interaction between storage conditions and storage duration had non-significant effect on acidity of jam, whereas significant effect on acidity of jelly. However, jelly stored under ambient condition had higher acidity level as compared to refrigerated condition. The acidity of jelly ranged from 0.81 to 1.11 per cent under ambient condition. The increase in acidity might be due to oxidation of alcohol and aldehyde during processing and was influenced by storage temperature, higher the temperature greater the increase in acidity. The results were in conformity with the work of Sarkar *et al.* (2015) on tomato pulp and Ashaye and Adeleke (2009) on roselle jam.

Higher reducing sugar (5.34%) was noted at ambient condition over refrigerated condition (5.04%) in jam. The reducing sugar content of jam increased gradually with the progress of the storage periods. The reducing sugar increased from initial level to 5.27 per cent during storage of 60 days.

The interaction between storage conditions and storage duration significantly affected the reducing sugar of jam. It increased from 4.75 to 5.49 per cent in ambient condition (S_1) and 4.75 to 5.07 per cent in refrigerated condition (S_2). In jelly, storage conditions and duration had non-significant effect on reducing sugar content which varied from 5.54 to 5.93 per cent during 60 days of storage. Changes in values of reducing sugars might be due to hydrolysis of non-reducing sugars, resulting into their increase. Similar findings were reported by Vidhya and Narain (2011) in wood apple jam and fruit bar, Prasad and Mali (2006) in ber jam during storage.

Total sugar content of jam and jelly significantly increased with increase in storage period. Total sugar of jam increased from 6.39 to 7.06 per cent, whereas total sugar of jelly ranged from 6.78 to 7.17 per cent at 60 days of storage. Total sugar of jam was significantly affected by the storage duration. The maximum total sugar (7.06%) was recorded at 60 days of storage. Similarly, at ambient condition total sugar retention was more (6.97%) than that of refrigerated condition (6.74%). The interaction between storage conditions and duration had no significant effect on total sugar of jam. The difference in total sugar content of jelly at both storage conditions was non-significant but storage duration had significant effect on total sugar content of jelly. The increase in total sugar during storage period might be due to solubilisation of pulp constituents and hydrolysis of polysaccharides including pectin and starch materials (Bal *et al.*, 2014).

Level of ascorbic acid decreased gradually from 4.85 mg per 100 g to 3.51 mg per 100 g in jam and 4.67 to 3.46 mg per 100 g in jelly during the storage period. The ascorbic acid content of both the samples decreased gradually during storage. The storage conditions significantly influenced the ascorbic acid content of jam. The jam stored at ambient condition had lower ascorbic acid (3.74 mg / 100 g) than that of refrigerated condition (3.87 mg / 100 g). Storage duration significantly influenced the ascorbic acid content of jam. The level of ascorbic acid content of jam was higher at 30 days of storage than at 60 days of storage.

The interaction between storage conditions and duration had significant effect on ascorbic acid content of jam and it decreased the level of ascorbic acid from 4.85 to 3.39 mg per 100 g. There was non-significant effect of storage duration and their interaction with storage duration in jelly. However, storage duration significantly affected ascorbic acid content of jelly during storage. The decline in ascorbic acid concentration could be due to thermal degradation during processing and subsequently oxidation in storage as ascorbic acid is the least stable vitamin and it is highly sensitive to oxidation and leaching into water soluble media during storage. The ascorbic acid present in pulp gets destroyed during prolonged heating at high temperature (Ahmed *et al.*, 2011).

There is a significant decrease in anthocyanin content of jam and jelly. The anthocyanin level of fresh jam was 3.61 mg per 100 g, which decreased significantly to 1.35 mg per 100 g during the storage period of 60 days. As the storage duration advanced, anthocyanin content in jelly reduced from 3.50 to 1.33 mg per 100 g. A significant difference was observed between the storage conditions of jam. The anthocyanin retention of jam was more in refrigerated condition (2.37 mg / 100 g) as compared to ambient condition (1.85 mg / 100 g). Duration of storage significantly influenced the anthocyanin of jam. The rate of decrease in anthocyanin content was more after 30 days of storage.

The interaction between storage conditions and duration significantly influenced the anthocyanin content of jam, which ranged from 3.61 to 1.05 mg per 100 g. The anthocyanin content of jelly was significantly influenced by storage periods but there was no significant effect of interaction between storage conditions and duration on anthocyanin content of jelly. Anthocyanin pigments are very sensitive to temperature, and a combined time / temperature process can greatly reduce the content of anthocyanin pigments in final product. The results obtained with jam and jelly stored at different storage conditions are in accordance with the previous reports (Bof Jeusti *et al.*, 2012; Garcia Viguera *et al.*, 1999).

Sensory evaluation is one of the most important criteria for acceptability of any food product by the consumer. The value-added products prepared were stored at ambient as well as refrigerated condition. Accordingly, products stored under refrigerated condition were evaluated for qualities but products stored under ambient condition were not in acceptable condition for sensory evaluation after 2 months of

Table 1. Effect of storage conditions and storage duration on TSS (%) content of paniol jam and jelly during storage

Duration (days)	TSS content of jam (%)			TSS content of jelly (%)		
	S_1	S_2	Mean	S_1	S_2	Mean
Initial (fresh processed)	68.00	68.00	68.00	65.0	65.0	65.00
30	68.37	68.13	68.25	65.40	65.13	65.26
60	68.87	68.53	68.70	66.30	65.87	66.08
Mean	68.62	68.33		65.85	65.50	
LSD (5%)	D = 0.19	S = 0.19	D x S = NS	D = 0.33	S = 0.33	D x S = NS

Table 2. Effect of storage conditions and storage duration on acidity (%) content of paniol jam and jelly during storage

Duration (days)	Acidity content of jam (%)			Acidity content of jelly (%)		
	S_1	S_2	Mean	S_1	S_2	Mean
Initial(fresh processed)	0.85	0.85	0.85	0.81	0.81	0.81
30	1.03	0.86	0.94	1.06	0.85	0.95
60	1.09	0.94	1.01	1.11	1.09	1.09
Mean	1.06	0.90		1.08	0.97	
LSD (5%)	D = 0.05	S = 0.05	D x S = NS	D = 0.06	S = 0.06	D x S = 0.08

Table 3. Effect of storage conditions and storage duration on total (%) sugar content of paniol jam and jelly during storage

Duration (days)	Total sugar content of paniol jam (%)			Total sugar content of paniol jelly (%)		
	S_1	S_2	Mean	S_1	S_2	Mean
Initial (fresh processed)	6.39	6.39	6.39	6.78	6.78	6.78
30	6.77	6.54	6.65	6.98	6.91	6.94
60	7.18	6.94	7.06	7.16	7.20	7.17
Mean	6.97	6.74		7.07	7.05	
LSD (5%)	D = 0.13	S = 0.13	D x S = NS	D = 0.19	S = NS	D x S= NS

Table 4. Effect of storage conditions and storage duration on ascorbic acid (mg/100g) content of paniol jam and jelly during storage

Duration (days)	Ascorbic acid content of paniol jam (mg/100g)			Ascorbic acid content of paniol jelly (mg/100g)		
	S_1	S_2	Mean	S_1	S_2	Mean
Initial (fresh processed)	4.85	4.85	4.85	4.67	4.67	4.67
30	4.09	4.10	4.09	4.08	4.11	4.09
60	3.39	3.63	3.51	3.35	3.57	3.46
Mean	3.74	3.87		3.72	3.84	
LSD (5%)	D = 0.02	S = 0.02	D x S = 0.03	D = 0.14	S = NS	D x S= NS

S_1, Ambient condition; S_2, refrigerated condition; D, duration

Table 5. Effect of storage conditions and storage duration on anthocyanin (mg/100g) content of paniol jam and jelly during storage

Duration (days)	Anthocyanin content of paniol jam (mg/100g)			Anthocyanin content of paniol jelly (mg/100g)		
	S_1	S_2	Mean	S_1	S_2	Mean
Initial (fresh processed)	3.61	3.61	3.61	3.50	3.50	3.50
30	2.66	3.08	2.87	2.55	2.66	2.60
60	1.05	1.66	1.35	1.29	1.38	1.33
Mean	1.85	2.37		1.92	2.02	
LSD (5%)	D = 0.40	S = 0.40	D x S = NS	D = 0.36	S = NS	D x S = NS

S_1, Ambient condition; S_2, refrigerated condition; D, duration

storage due to microbial spoilage. The sensory qualities included colour, flavour and texture/taste.

Among products, higher score was observed in jelly for colour, flavour and taste. Thus, both products were in acceptable condition till the end of storage period under refrigerated condition. The highest mean score obtained in jelly, indicated the preference due to its colour, flavour and taste after 6 months of storage. The decline in colour score might be due to change in colour attributed to Maillard reaction and enzymatic browning, ascorbic acid degradation and polymerisation of anthocyanin with other phenolics (Garcia *et al.*, 1999).

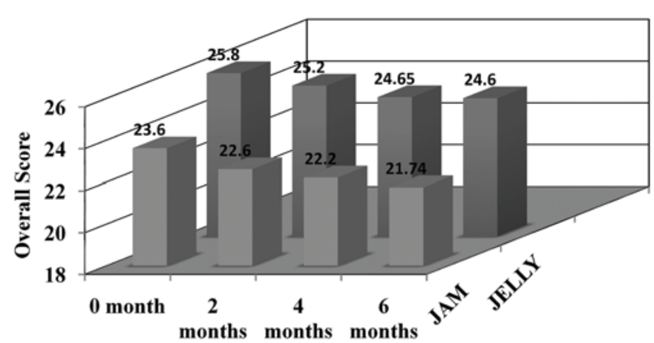

Fig. 1: Sensory evaluation of paniol jam and jelly

Change in flavour is the most sensitive index for quality deterioration during storage followed by colour (Eckerie *et al.*, 1984). With respect to taste score, which decreased during storage might be due to fluctuations in acids, sugar / acid ratio (Rathore *et al.*, 2007).

CONCLUSION

Thus, it was concluded that various value-added products like jam and jelly could be prepared from paniol fruit, which stored well for 2 months under ambient condition and up to 6 months under refrigerated condition but we did not show the remaining analysis of refrigerated one as we will not be able to perform the statistical analysis without ambient conditions data. Products were microbiologically safe from consumption point of view after doing all microbial analysis using different medias. Paniol fruits being perishable in nature, it cannot be stored for a long period or sold outside the production area. Thus, its diversified and innovative products need to be explored.

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*Original not seen

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Effect of various levels of IBA and stem cutting sizes on propagation of dragon fruit *(Hylocereus polyrhizus)*

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ABSTRACT

The experiment was conducted using two-factor CRD with IBA concentrations (0, 250, 500, 750 and 1000 ppm) and stem cuttings of stems (5, 10 and 15 cm) lenth of dragon fruit *(Hylocereus polyrhizus)* plant replicated thrice at Department of Horticulture, Nagaland University,SASRD, Medziphema, during 2016-17. The shoot growth and establishment of stem cuttings in field were best achieved with the application of IBA 1000 ppm even with smaller-sized cuttings of stems, while total nitrogen and protein content (%) were more with lower concentration of IBA (250 ppm). The cutting size of 15 cm recorded good shoot and root development even without the application of IBA. There was cent per cent survival of stem cuttings after one year of their planting.

Key Words: Dragon fruit, IBA, Stem cuttings, Propagation, Concentration, Root development, Planting

Dragon fruit (*Hylocereus* sp.) is a perennial climbing cactus belonging to family Cactaceae. In India, very few farmers in Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu have taken up its cultivation. The total area under dragon fruit cultivation may be less than 100 acres in India. It may be propagated from seed, however fruit and stem characteristics are variable and the time from planting to fruit production may be up to 7 years and true-to-type plants cannot be obtained in this process due to cross-pollination (Andrade *et al.*, 2005). The use of stem cuttings is widespread to produce true-to-type as well as large number of plantlets of dragon fruit. Indole butyric acid (IBA) has high ability to promote root initiation and is most widely used auxin to stimulate rooting of cuttings (Ahmad *et al.*, 2016). Since dragon fruit or pitaya is a newly- introduced crop in Nagaland, Mizoram and Manipur, there is a scarcity of planting material to cater to farmers. Therefore, an experiment was conducted to standardize the size of stem cuttings for propagating successfully.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of SASRD, N.U, Medziphema Campus, Nagaland, during 2016-2017 under naturally- ventilated polyhouse. The experiment was laid out in two- factor completely randomized design with three replications. Factors include; stem length (5, 10 and 15 cm) and IBA levels (0, 250, 500, 750 and 1000 ppm). Shoots of similar size and age were selected from mother plants and detached using clean secateurs. These were cut into the required sizes and basal cut ends were dipped in 0.5% Bavistin (Carbendazim) solution for 10 seconds and allowed to cure in a cool dry place for two days. The different concentrations of IBA were prepared after measuring the amount in a digital balance (Denver, MXX-123).

The IBA was first dissolved using a few drops of absolute alcohol and made up the volume as per requirement with distilled water. Polybags of 20 cm × 12.7cm size were filled with media substrate of finely prepared top soil and well-decomposed manure in equal ratio. The basal cut end of cured cuttings were dipped into the respective solutions of IBA for 10 minutes and planted using a dibbler up to 2 cm depth in polybags. Thereafter, irrigation water was applied till the soil media was well moistened. The physical parameters of growth were recorded at monthly interval. The total nitrogen content was estimated by Kelplus Distillation System, Pelican Equipment as described by Blake (1965) using the formulae:

$$\text{Nitrogen (\%)} = \frac{(14 \times 0.1\text{N HCl} \times \text{Burette reading} \times 100)}{(\text{sample weight} \times 1000)}$$

Protein content was estimated using the formulae:

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Protein (%) = Nitrogen (%) × 6.25

The various observations thus recorded were analyzed by analysis of variance method (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

The concentration of IBA 1000 ppm produced earliest primary shoots and greatest number of primary and secondary shoots at seven months after planting while days taken for secondary shoot emergence was found to be earliest with IBA 750 ppm (Table 1). Similar results were obtained by Dhruve *et al.* (2018), Balaguera-Lopez *et al.* (2010) in dragon fruit. Early shoot emergence in cuttings might be due to the supply of respiratory substrates to glycolytic enzymes which leads to release of energy and helps in early sprouting of dormant buds. The cutting length did not show any significant variation on days to first shoot emergence. In general, earliest shoot emergence and highest number of secondary shoots was recorded in 15 cm cutting size. These results confirm the study made by Ahsan-Ullah *et al.* (2015).

The treatment with 1000 ppm IBA also produced greatest length (5.83 - 37.40 cm) in primary shoots on all days of observation up to seven months and greatest length for secondary shoots in six and seven months (10.35 and 26.18 cm respectively). The present findings concur with those of Seran and Thiresh (2015) who reported that higher concentration of IBA (6000 ppm) gave maximum length of shoots (9.5 cm) in dragon fruit after two months of planting. Yeshiwas *et al.* (2015) also reported that rose cuttings treated with 1000 ppm of IBA had showed significant positive effects on shoot length. The cutting size of 15 cm produced greater length of primary shoots (5.25-32.56 cm) and secondary shoot at six and seven months (7.71 cm and 24.63 cm respectively). The smallest cutting size produced shorter primary and secondary shoot on all days of observation (Table 2).

The maximum fresh and dry weight of shoot was found significantly highest with 250 ppm of IBA treatment. The lowest fresh weight of shoot (37.50 g) was found in treatment with IBA 500 ppm while lowest dry weight was obtained from the control treatment. Similar results were observed by Stancato *et al.* (2003) with propagation of *Rhipsalis grandiflora* Haw, where lower concentrations of IBA gave more dry weight of shoot. Longer cutting sizes (15 cm) produced significantly greater fresh and dry weight of shoot which progressively lessened with smaller cutting sizes. The present findings corroborate with that of Balaguera-López *et al.* (2010) who reported that larger cutting size (60 cm) gave maximum fresh and dry weight of shoot in dragon fruit.

The highest total nitrogen content (2.89%) was recorded with IBA treatment of 250 ppm, which was significantly higher than all the other treatments. This was followed by the control cuttings (2.56%) and IBA

Table 1. Vegetative characteristics of cuttings as influenced by IBA and cutting length of dragon fruit

Treatment	Primary shoots		Secondary shoots	
IBA (ppm)	Days to emergence	Number at seven months	Days to emergence	Number at seven months
0	55.04	11.58	174.07	8.17
250	49.91	18.62	169.51	10.13
500	50.22	13.60	167.24	11.57
750	48.19	13.05	166.59	12.44
1000	41.83	23.89	166.70	24.33
S E m (±)	1.871	0.108	0.591	0.119
CD (5%)	6.243	0.360	1.972	0.398
Cutting size (cm)				
5	51.77	16.31	167.51	11.49
10	48.33	18.67	169.79	10.87
15	47.01	12.87	169.17	16.48
S E m (±)	1.450	0.083	0.458	0.092
CD (5%)	NS	0.279	1.527	0.308
Interaction IBA × cutting size				
S E m (±)	3.24	0.09	1.023	0.206
CD (5%)	NS	0.30	3.415	0.689

Table 2. Length of primary and secondary shoots (cm) as affected by IBA and stem sizes

Treatment	Months after planting						
IBA (ppm)	3	4	5	6	*	7	*
0	4.02	7.20	15.81	25.20	3.80	31.10	14.47
250	3.75	8.40	16.91	26.31	9.21	30.76	19.84
500	3.97	8.57	20.78	26.17	6.52	33.10	22.39
750	3.26	8.83	15.60	21.19	5.72	25.68	18.15
1000	5.83	10.94	21.51	28.56	10.35	37.40	26.18
S E m (±)	0.325	0.329	0.696	0.725	0.38	0.772	0.54
CD (5%)	1.238	1.098	2.322	2.419	1.28	2.575	1.81
Cutting size (cm)							
5	2.80	8.04	13.29	24.75	6.21	30.31	16.55
10	4.45	9.00	18.64	25.52	7.45	31.96	19.45
15	5.25	9.34	22.45	26.19	7.71	32.56	24.63
S E m (±)	0.252	0.255	0.539	0.561	0.30	0.598	0.42
CD (5%)	1.090	0.851	1.799	NS	0.99	1.995	1.40
Interaction IBA × cutting size							
S Em (±)	0.56	0.57	1.20	1.25	0.67	1.34	0.94
CD (5%)	1.63	1.90	4.02	4.19	2.22	4.46	3.13

*secondary shoots from 6 and 7 month

500 ppm (2.50%) which were statistically at par while the lowest observed in IBA 1000 ppm treatment (2.26%). The highest protein content of shoot (18.30%) was also observed in IBA 250 ppm which was significantly higher than all other treatments followed by the control treatment (16.15%) and IBA 500 ppm (15.60%) which were statistically same. The lowest protein content of shoot (14.25%) was recorded with IBA 1000 ppm (Table 3).

Treatments with 750 ppm IBA produced significantly highest number of roots closely followed by IBA 1000 ppm. The lowest number of roots was

Table 3. Qualitative characteristics of shoot in cuttings as influenced by different treatments

Treatment	Weight of shoot (g)		Total nitrogen content (%)	Protein content (%)
IBA (ppm)	Fresh	Dry		
0	44.17	2.83	2.56	16.15
250	106.33	7.89	2.89	18.30
500	37.50	3.00	2.50	15.60
750	74.33	4.72	2.31	14.43
1000	60.11	3.33	2.26	14.25
S E m (±)	0.621	0.401	0.073	0.499
CD (5%)	2.071	1.337	0.244	1.664
Cutting size (cm)				
5	45.37	2.30	2.50	15.86
10	57.07	3.97	2.52	15.88
15	91.03	6.8	2.49	15.51
S E m (±)	0.481	0.310	0.057	0.386
CD (5%)	1.604	1.035	NS	NS
Interaction IBA × cutting size				
S Em (±)	1.075	0.694	0.127	0.864
CD (5%)	3.587	2.315	0.423	2.882

Table 4. Qualitative characteristics of roots as influenced by various treatments

Treatment	No. of roots	Root length (cm)	Longest root length (cm)	Root fresh weight (g)	Root dry weight (g)	Total nitrogen content (%)	Protein content (%)
IBA (ppm)							
0	11.48	7.51	12.43	0.85	0.15	1.57	9.81
250	11.96	11.46	15.87	0.82	0.22	2.07	12.82
500	8.27	6.89	12.92	0.77	0.24	1.44	8.84
750	17.48	10.40	18.45	0.90	0.28	1.52	9.48
1000	16.92	12.77	21.85	1.30	0.37	1.37	8.55
S E m (±)	0.051	0.381	0.549	0.093	0.052	0.124	0.776
CD (5%)	0.167	1.270	1.831	0.312	0.175	0.415	2.590
Cutting size (cm)							
5	9.62	7.73	15.54	0.86	0.25	1.48	9.27
10	11.57	11.39	17.25	0.79	0.25	1.67	10.37
15	18.55	10.29	16.12	1.13	0.27	1.62	10.06
S E m (±)	0.039	0.295	0.425	0.072	0.040	0.096	0.601
CD (5%)	0.131	0.984	1.419	0.242	NS	NS	NS
Interaction IBA × cutting size							
S Em (±)	0.039	0.659	0.951	0.162	0.091	0.215	1.345
CD (5%)	0.131	2.200	3.172	0.541	NS	NS	NS

found with IBA 500 ppm followed by the control treatments. These finding sare supported by Fathi and Ismailpor (2000) who reported that auxin enhances the root formation in cuttings. Similar results were reported by Elobeidy (2006), Salleh (2007), Balaguera-López *et al.* (2010), Seran and Thiresh (2015), Ahmad *et al.* (2016) and Dhruve *et al.* (2018) in dragon fruit. Further, they also reported that higher concentrations of IBA was found effective in increasing number of roots. The maximum root length (12.77 cm) was found with IBA 1000 ppm closely followed by IBA 250 ppm (11.46 cm) which were statistically same.

The lowest (6.89 cm) was found with IBA 500 ppm. It has been observed that higher concentration of IBA and medium cutting sizes (10 cm) produced maximum root length (Table 4). The increase in root length was in dose dependent manner barring the treatment with IBA 500 ppm. The 15 cm cuttings produced maximum number of roots (18.55) which was significantly highest, however longer roots were observed in 10 cm cutting size. The present findings corroborates with that of Elobeidy (2006) who reported that IBA consistently improved the root length in dragon fruit *(H. undatus).* Salleh (2007) also reported. Tha 1000 ppm of IBA gave maximum root length in cuttings of *H. polyrhizus*. Similar findings were reported by Balaguera-López *et al.* (2010) and Ahmad *et al.* (2016).

The highest fresh and dry weight of root was found with IBA 1000 ppm. There was corresponding increase in root fresh and dry weight with increase in number of roots. Higher concentration of IBA also helps in rapid cell division and cell elongation in cambial tissue which may have given greater fresh weight of root per cuttings and also greater cutting sizes showed significant influence on developing roots which might be due to presence of larger amount of stored material for enhancing their growth and development. Similar findings were reported by Balaguera- López *et al.* (2010), Seran and Thiresh (2015), Ahmad *et al.* (2016) and Dhruve *et al.* (2018).

Further, higher concentration of IBA also gave more dry weight of root in dragon fruit cuttings. The total nitrogen and protein content of root (2.07 and 12.82% respectively) was found to be significantly highest with treatment of IBA 250 ppm, followed by the control (1.57 and 9.81% respectively). While the lowest total nitrogen and protein content of root (1.37 and 8.55% respectively) was found with IBA treatment of 1000 ppm. It may be interesting to note that treatments with IBA 250 ppm produced less number of roots but more number of primary and secondary shoots were developed. These may have resulted in more accumulation of endogenous nitrogen and protein content in roots. Larger cutting sizes were found to produce more number of roots and fresh and dry root weight. The nitrogen and protein content in roots did not vary significantly due to cutting sizes although medium sized cuttings (10 cm) fared slightly better.

In a correlation studies (data not shown), it was observed that the total nitrogen content of root exhibited significant positive correlation with fresh weight of shoot, dry weight of shoot, protein content of shoot, total nitrogen content of shoot at 0.05 level of significance, whereas protein content of root was positively correlated at 0.01 level of significance. The protein content of root exhibited significant positive correlation with fresh weight of shoot, dry weight of shoot and protein content of shoot at 0.05 level of significance.

Thus, application of IBA 1000 ppm on stem cuttings produced good rooting and shoot growth. All the cutting sizes were found to initiate good rooting and establish well in the field, however larger cuttings of 10 - 15 cm had an edge over 5 cm cuttings in early root and shoot development. It may be recommended that smaller cuttings of 5 cm may be treated with IBA at 750 or 1000 ppm for successful multiplication of dragon fruit plants.

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