ORGANIC PREPARATIONS AND BIOSTIMULANTS FOR MOISTURE STRESS MITIGATION IN CONTAINER GROWN OKRA (*Abelmoschus esculentus* (L.) Moench)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench)** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
^0C	Degree Celsius
%	Per cent
µ	Micro
BC Ratio	Benefit cost ratio
CD(0.05)	Critical difference at 5 per cent level
cm	Centimetre
cm^3	Cubic centimetre
CRD	Completely randomized design
DAP	Days after planting
$dS\ m^{-1}$	Deci Siemens per meter
EC	Electrical conductivity
et al.	Co- workers/ co- authors
Fig.	Figure
$Fruit^{-1}$	Per fruit
FYM	Farm yard manure
G	Gram
ha	Hectare
ha^{-1}	Per hectare
INM	Integrated nutrient management
K	Potassium
KAU	Kerala Agricultural University

kg	Kilogram
L	Litre
LAI	Leaf area index
MAP	Month after planting
mg	Milli gram
mm	Millimetre
No.	Number
N	Nitrogen
NS	Non significant
Plant $^{-1}$	Per plant
P	Phosphorus
RH	Relative humidity
RWC	Relative water content
Sack^{-1}	Per sack
SG	Soluble granule
SEm	Standard error of means
t ha^{-1}	Tonnes per hectare
UV	Ultra violet
viz.	Namely
WP	Water productivity
WUE	Water use efficiency

Introduction

1. INTRODUCTION

Kerala is blessed with abundance of rivers, lakes, streams and ponds, but many of the water resources dry up during summer months and severe drought is experienced. This phenomenon is mainly due to weather anomalies and developmental pressures resulting from the changes in land use and life style of the people. The monsoon period between June and November contribute to 95 percent of the annual rainfall in the State leaving the remaining six months practically dry. Water scarcity in summer is mainly due to lowering of water tables resulting from the drying of rivers and water resources which adversely affect drinking water availability. Water is one of our precious natural resources which is becoming scarce and every indication is that it will become more so in the future.

In Kerala, vegetables are cultivated in 31,449 ha, with a total production of 8.25 lakh tonnes and by the end of 12^{th} Five Year Plan, the requirement of vegetables for the State was estimated as 38.62 lakh tonnes based on population projections (GOK, 2013). Since the current vegetable production in the State is not sufficient to meet the requirement of the population, various efforts are being made through the line departments and other agencies to bridge the gap between demand and the production. Cluster based vegetable development is one such initiative to boost vegetable production in the State. Promotion of urban vegetable clusters, terrace cultivation of vegetables and homestead vegetable cultivation have been identified as major components of vegetable development scheme in the State.

Urban agriculture faces unique challenges, the important one being limited availability of land and water coupled with smaller growing areas. Majority of the population in urban areas of Kerala is dependent on tap water for their domestic usage and the per capita tap water availability in Kerala is limited. These factors point out the need for integrating water efficient practices to the urban agriculture for reducing the water demand for irrigation.

Plants can respond to abiotic stress by altering the biochemical profile of their tissues and producing a diverse array of secondary metabolites. It is widely believed that the synthesis of many secondary metabolites in plants is part of the defence response to stress conditions. Many investigators have explained the mechanisms of drought tolerance and plant responses under stressed condition and osmotic adjustment and lipid peroxidations are reported to be the major physiological mechanisms associated with drought tolerance in vegetables.

Plant biostimulants contain substances and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality (Calvo *et al.*, 2014). Biostimulants are widely used in many agricultural practices, particularly high value vegetable and fruit tree production systems. These substances however differ from anti transpirants which reduce the water loss from plants by reducing transpiration which may also adversely affect the photosynthetic rate, growth and yield. Few reports are available on the use of naturally occurring leaf extracts as biostimulants for mitigation of stressful condition especially moisture stress. Moringa (*Moringa oleifera*) leaf extract contains growth enhancing substances like zeatin, a source of cytokinin, which reduces the adverse effect of drought stress by delaying leaf senescence and scavenging reactive oxygen species. Application of biostimulants such as yeast extract and humic acid help to improve the nutrient uptake and impart tolerance to abiotic stress. They can directly or indirectly influence the physiological activities in plant growth and yield. Humic acid is an organically charged biostimulant that significantly affects plant growth and development and increases crop yield and mitigate the drought effect. Yeast is a natural source of many growth substances, cytokinins, many of the nutrient elements as well as organic compounds such as proteins, carbohydrates, nucleic acids and lipids and is reported to reduce the drought stress in many crops. The beneficial influence of spraying organic compounds like citric acid and salicylic acid on mitigating moisture stress effect is evident from the literature. Being organic in nature, these compounds are preferred by urban and peri urban farmers who give more importance to organic or safe to eat vegetable production.

With this background the present study was carried out with the following objectives;

- To evaluate the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance in container grown okra.
- To assess the impact of the different organic preparations and biostimulants on growth, yield and irrigation requirement of container grown okra

Review of literature

2. REVIEW OF LITERATURE

Okra popularly known as lady's finger or bhindi is one of the most important vegetables of tropical and subtropical climate. Okra can be grown on all types of soils, but the light soils ranging from sandy loam to loam are best suited. This vegetable is rich in dietary fibre, vitamin C, vitamin A, vitamin B_6, calcium and magnesium and is widely preferred by the people of Kerala including the urban dwellers.

Availability of water is a unique challenge in the urban agriculture scenario of the State wherein majority of the population is dependent on tap water for their domestic usage. Mean while, the promotion of urban vegetable clusters, terrace cultivation of vegetables and homestead vegetable cultivation have been identified as major components of vegetable development programme in the State and hence there is a need for integrating water efficient practices to the urban agriculture for reducing the water demand for irrigation.

Plants can respond to abiotic stress by altering the biochemical profile of their tissues and producing a diverse array of secondary metabolites. Application of biostimulants and certain organic preparations having biostimulant action are known to improve the nutrient uptake and impart tolerance to abiotic stress. Being organic in nature, these compounds are likely to be preferred by urban/peri urban farmers who give more importance to organic or safe to eat vegetable production.

Many investigators have explained the mechanism of drought tolerance and plant responses under stressed condition and also the stress mitigation effects of organic preparations and biostimulants. In this chapter, a detailed review of research work done on the effect of moisture stress, the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance and their effect on growth, yield and irrigation requirement of the crop have been presented.

2.1 EFFECT OF MOISTURE STRESS

2.1.1 Effect of moisture stress on growth and growth attributes

An adequate water supply and relatively moist soils are prerequisites during the total growing period for higher yield. Efficient use of limited water resources and better growth under limited water supply are desirable traits for crops in drought environments.

Several workers have reported the effects of moisture stress on growth and growth attributes in okra. Sankar *et al.* (2007) reported that when 5 varieties of okra were subjected to moisture stress by irrigating at 60 per cent of field capacity from 30-70 Days After Sowing (DAS), the root length, shoot length, total leaf area, fresh weight and dry weight were drastically reduced in all the varieties. According to Sankar *et al.* (2008), there was varietal difference in the moisture stress effect on okra cultivars and though the dry weight was reduced in all the varieties, the variety JK Haritha had highest reduction (78.44 per cent) over the control when moisture stress was imposed by watering at 60 per cent of field capacity. In their study, the Leaf Area Duration (LAD) was also reduced under moisture stress and the highest reduction (94.64 per cent) was in variety JK Haritha. In sandy soils of Egypt, levels of irrigation was found to affect the growth of okra and biometric parameters such as plant height, fresh weight, stem diameter, number of branches, number of leaves, leaf area per plant were low with lower levels of irrigation (El-Kader *et al.*, 2010). Altaf *et al.* (2015) found that drought reduced the plant height and number of leaves in okra and the plant could survive only low levels of drought. According to Kwajaffa *et al.*, (2015), when irrigation was given at 25, 50, 75 and 100 per cent field capacity in okra, the number of leaves per plant and leaf area increased with increasing soil moisture content and growth attributes were affected at grater soil moisture depletion. There was a reduction in plant height at 25 per cent and 50 per cent levels of soil moisture contents compared to 75 per cent and 100 per cent levels.

Increasing or decreasing the irrigation interval also found to have influence on growth and growth attributes of okra. El- Kader *et al*. (2010) reported that number of leaves and stems per okra plant decreased when subjected to moisture stress condition and highest number of leaves and stems per plant were obtained with shortest irrigation interval. In another study conducted by Hussein *et al*. (2011) in okra, the average plant height and stem dry weight were reduced with higher irrigation interval of 30 days imposing severe stress compared to 12, 18 or 24 days interval. In an investigation on irrigation interval in okra, Aliyu *et al*. (2016) observed that the plant height was decreasing when irrigation interval was increased from 5 or 8 days to 11 days which was attributed towards increased moisture stress condition reducing the rate of cell enlargement and plant growth. In their study, irrigation at 11 days interval produced lesser number of leaves and required more days for 50 per cent flowering. In a recent study, Singh *et al*. (2016) reported that when moisture stress was imposed by giving irrigation at 9 days interval in okra, the dry matter accumulation per plant at 30, 60 and 90 days after planting were reduced drastically compared to the unstressed condition with 5 day irrigation interval.

. Moisture stress was found to affect the growth and growth attributes of several other crops. In an early study, Boyer (1970) reported that increased rate of leaf senescence and reduction in leaf area could be attributed towards the occurrence of water stress and low levels of soil moisture content in corn, soybean and sunflower. Gamze *et al*. (2005) in his investigation on pea found that under drought stress, germination percent is decreased, average time necessary for germination is increased, radical and plumule length, fresh and dry weight of radical and plumule are reduced. Benjamin and Nielsen (2006) found that in the relative root distribution in soyabean was not much affected by water stress but in chickpea and field pea, root distribution was significantly affected by growing deeper into the soil. Hamidou *et al.* (2007) found that there was a decrease in root volume in various genotype of cowpea in vegetative stage during moisture stress condition. In a study conducted by

Rouphael *et al.* (2008) in water melon, the shoot dry matter of both grafted and ungrafted plants was found to decrease linearly with increase in water stress. Ranawake *et al.* (2011) reported that water stress significantly affected the flowering and pod filling stage of mung bean 6 Weeks After Planting (WAP). Only number of leaves was significantly affected when the stress applied at 8 WAP and all the measured parameters other than length of tap root and number of nodules per plant were significantly affected by drought stress at 3 WAP.

2.1.2 Effect of moisture stress on yield attributes and yield

2.1.2.1 Effect of moisture stress on yield attributes

Several workers have reported the effect of irrigation interval and moisture stress on yield attributes in okra. Ahmed (2002) pointed out that flowering and fruiting stages are most sensitive for yield development in okra that are influenced by the soil moisture content. Hussein *et al.* (2011) reported that fruit yield in okra was reduced with a wider irrigation interval of 30 days compared to 12 days interval and small fruit weight was recorded (3.32 and 3.05 g in 2007 and 2008 respectively) with 30 days irrigation interval compared with 12 days interval recording higher fruit weight (5.79 g and 4.66 g in 2007 and 2008 respectively). Aliyu *et al.* (2016) reported that the number of pods per plant in okra was reduced to 6.3 when irrigation interval was increased to 11 days from 5 days and 8 days which produced higher number of pods per plant (15.7 and 10.6 respectively). In their experiment, the average pod weight was reduced to 13.30 g, pod length was decreased to 3.8 cm with 11 days irrigation interval while higher values were recorded with 5 and 8 days irrigation interval. According to Singh *et al.* (2016), when moisture stress was induced by 9 day irrigation interval in okra, it resulted in lowest number of pickings and fruits per plant (9 and 15.33 respectively) when compared to the unstressed condition with 5 days irrigation interval which produced the maximum number of pickings and fruits per plant (11 and 17 respectively).

Moisture stress induced through the depletion of available soil moisture significantly influence the yield attributes of plants. Nahar and Ullah (2011) reported that the flower and fruit characteristics of tomato plants i.e. flower per cluster, fruit per cluster, cluster per plant, fruit stalk length, fruit length and diameter and average fruit weight, are affected by soil moisture depletion and in their study, all the flower and fruit characters were significantly affected by water stress and the highest values were obtained at 70 per cent field capacity (slight stress) followed by severe stress (40 per cent field capacity) and control (100 per cent field capacity). Kwajaffa *et al.* (2015) reported that in okra the mean fruit fresh weight, fruit length and fruit dry weight were lower when irrigation was given at 25 or 50 per cent field capacity compared to 75 or 100 per cent field capacity, while the fruit diameter showed a quadratic response at a peak of 50 per cent soil moisture content.

2.1.2.2 Effect of moisture stress on yield

Several workers have reported the effects of moisture stress on yield of okra. In an experiment to study the effect of water stress at vegetative, flowering and pod filling stage of three okra cultivars, Mbagwu and Adesipe (1987) reported that reduction in fruit yield occurred when moisture stress was imposed at flowering stage of variety "Kano Dwarf" and "Wgu Early" and pod filling stage of variety "Lady Finger". In all the varieties, moisture stress at flowering and pod filling stage resulted in 70 per cent reduction in fruit yield while lowest reduction in fruit yield occurred with moisture stress at vegetative stage. Sankar *et al.* (2008) reported that when moisture stress was induced in 5 varieties of okra by watering at 60 per cent field capacity, the harvest index decreased at 70 Days After Sowing in all the varieties. Atoyoby *et al.* (2009) reported that in okra, there were significant differences in yield with level of irrigation and the yield followed in the order 80 per cent >60 per cent >100 per cent of applied irrigation regimes at 100 per cent, 80 per cent and 60 per cent of field capacity. In their study, the low yield obtained with 100 per cent field capacity was attributed towards the tendency to supply water above the moisture content at field capacity. Pravisya and Jayaram (2015) also reported similar results in okra wherein the biomass and fruit yield were reduced under moisture stress condition.

Widening the irrigation interval is reported to affect the economic yield in vegetables by imposing the moisture stress. Kirnak *et al.* (2002) reported that in brinjal, the water stress treatment receiving 80 per cent replenishment of open pan evaporation at 8 days interval and 70 per cent replenishment at 12 days interval reduced the marketable fruit yield and fruit size compared to well watered treatment or light stress at 4 days interval with 90 per cent replenishment of pan evaporation. Aliyu *et al.* (2016) observed that okra fruit yield was drastically reduced to 1.66 t ha^{-1} with11days irrigation interval compared to 8 days and 5 days irrigation interval producing the yield of 3.42 and 4.30 t ha^{-1} respectively. Singh *et al.* (2016) reported that, the yield of okra in g $plant^{-1}$ and kg ha^{-1} were lowest with the stressed condition wherein irrigation interval was 9 days (138.73 g and 7007 kg respectively) compared to the unstressed condition producing 188.38 g and 9516 kg respectively.

2.1.3 Effect of moisture stress on plant nutrient status, nutrient uptake and quality

Early workers like El Rahman (1973) reported that the deficiency in soil moisture results in a considerable rise in the nitrogen content of the plant which reaches in some cases double the value at optimum water supply. In his study, there was a tendency towards increase in crude fibre content with increase in soil moisture and the nutritive value of plants as determined by the total available carbohydrates, total nitrogen, Ca, Mg; and P contents were highly influenced by soil moisture conditions. According to another basic study, Kiegle *et al.* (2000) reported that the water deficiency causes a decrease in the flow of nutrients to stem cells from other tissues and organs and such a decrease leads to the occurrence of nutrient deficiencies in different tissues. They further pointed out that the water scarcity leads to a decrease in the concentration of Ca in tissues and ultimately Ca ion transport mobility is restricted in the xylem and phloem.

Many workers have reported the effects of moisture stress on nutrient uptake in okra. While studying the effect of water stress at vegetative, flowering and pod filling stage of three okra cultivars, Mbagwu and Adesipe (1987) reported that moisture stress increased the uptake of nitrogen and potassium in all okra cultivars. El-Kader *et al.* (2010) reported that in okra, nitrogen uptake was 173 per cent and 273 per cent respectively for higher irrigation levels (I_2- 1798.2 m^3 $acre^{-1}$ and I_3-2397.6 m^3 $acre^{-1}$) compared to lower irrigation level (I_1 .1198.8 m^3 $acre^{-1}$). The P uptake was 103 per cent and 213 per cent while the K uptake was 88 per cent and 85 per cent in I_2 and I_3 respectively when compared to I_1.

The nutrient content and uptake in several other crops are affected by the moisture stress. In an experiment on the effect of water stress in rice, maize and soybean, Tanguilig *et al.* (1987) reported that the nutrient uptake under water stress conditions was influenced by the capacity of roots to absorb nutrients than by transpiration. Transport of nutrients to shoots may occur even at reduced transpiration and the continued uptake of K which allows osmotic adjustment may be responsible for the ability of maize and soybean to grow better under water stressed condition than rice. Jyothi (1995) found that when yard long bean was irrigated at 75 per cent field capacity, throughout the crop growth there was remarkable increase in the uptake of N, P and K. According to Cakmak (2005), increase in severity of drought stress result in corresponding increase in K demand to maintain photosynthesis and protect chloroplasts from oxidative damage. The workers like Nasri *et al.* (2008) and Dasgan and Koc (2009) reported that potassium plays an important role in regulating the stomatal oscillations and osmoregulation under drought in particular and higher uptake and accumulation of K under drought is regarded as a better strategy to cope with drought.

. Moisture stress can influence quality of produce besides uptake and accumulation of nutrients. Nahar and Gretzmatcher (2002) reported that uptake of nitrogen, sodium, potassium, sulphur, calcium and magnesium were significantly reduced by water stress in tomato plants and the highest concentration of nitrogen was found at 100 per cent field capacity (1.47 per cent) and the lowest at 40 per cent (1.10 per cent) field capacity. In their study, the moisture stress significantly influenced the uptake of potassium and its concentration was the highest at 100 per cent field capacity. Moisture stress treatments in this experiment did not significantly influence the uptake of phosphorous and its concentration showed a slight decrease as the moisture content got reduced from 100 to 40 per cent field capacity. In this trial, significant increases in glucose, fructose, sucrose in fruits were noticed which indicated the tendency of the crop to adjust osmotically to the water stress. According to Rouphael *et al.* (2008), when moisture stress was given by decreasing the irrigation rate from 1.0 to 0.5 evapotraspiration, the fruit K content and Mg content increased quadratically and linearly respectively in water melon and there was no difference in fruit dry matter and Total Soluble Solids (TSS) contents compared with full irrigation treatment. Based on a study conducted on bread wheat, Hammad and Ali (2014) reported that water stress treatments affected both NPK content and uptake and maximum reduction in contents were observed in high stress treatment which recorded about 22.11 per cent, 29.73 per cent and 15.98 per cent of N, P, and K contents respectively.

2.1.4 Effect of moisture stress on physiological aspects of plants

Plants grown under moisture stress show variations in physiological processes. Moniruzzaman *et al.* (2007) reported that during water deficit, many morphological features and physiological processes associated with plant growth and development are affected in okra. According to Naveed *et al.* (2009), drought stress affect photosynthesis, respiration, the membrane stability index and nutrient metabolism and there by reduces plant growth.

Relative water content and leaf water potential are important physiological parameters affected by moisture stress. Yamasaki and Dillenburg (1999) observed that relative water content is an appropriate physiological measure of plant water status under water stress condition. Rouphael *et al.* (2008) reported a decline in leaf water status and photosynthetic rate under moisture stress in water melon. Sibomana *et al.* (2013) noted that decreased leaf water potential leads to stomatal closure and ultimately results in low transpiration in tomato.

Moisture is found to influence the content of photosynthetic pigment in many plants. Talebi (2011) evaluated the effect of water stress on chlorophyll content and canopy temperature on different genotype of durum wheat. He found that genotype with high yield in well watered condition had also low canopy temperature and high chlorophyll content. He concluded that wheat genotype which maintained high transpiration rate and photosynthetic rate having low canopy temperatures produced high yield as well. Atlaf *et al.* (2015) reported that drought reduced the photosynthetic pigments in okra and maximum reduction in growth, morphology and photosynthetic pigment was found in higher level of drought (50 per cent depletion) than lower level. In their study, drought affected okra at early stage than the middle stage and drought upto 50 per cent depletion of available moisture was found to be fatal to the plants. Pravisya and Jayaram (2015) reported that the total chlorophyll content and relative water content decreased in okra when stress was imposed by not irrigating for 3 days consecutively. The decrease in protein content was greater in untreated water stressed plants compared to unstressed plants.

Osmotic Adjustment (OA) could play a significant role in maintaining turgor potential and turgor-related processes, such as opening of the stomata, photosynthesis, shoot growth and extension of roots in deeper soil layers. Based on a study on tomato varieties, Rao and Bhatt (1992) reported better osmotic adjustment in tomato cvs. Arka Saurabh, Pusa Early Dwarf and Sioux, thereby relatively higher yields in these cultivars under moisture deficit condition. Under moisture stress, aminoacids such as proline and other secondary metabolites accumulate in plants. According to Pagter *et al.* (2005) proline accumulates in leaves of drought-stressed plants and it function as an osmolyte or osmoprotectant and also they have multiple functions in stress adaptation, recovery and signalling. According to Abdalla and El-Khoshiban (2007), water stress raised the content of each of absicisic acid (ABA), carotenoids; direct reducing sugars (DRS), proline, sucrose and the concentration of both sodium and iron and the activities of both hydrolytic (invertase, á and B-amylase) and oxidative enzymes (peroxidase, polyphenol oxidase and IAA- oxidase) in the shoots and roots. Sankar *et al.* (2007) reported that when moisture stress was imposed in five varieties of okra, by irrigating at 60 per cent field capacity, the amino acid content in roots was increased and there was varietal variation in accumulation of amino acid. The glycine betaine content also showed an increase under stressed condition and the okra variety JK Haritha had 51 and 60 per cent higher glycine betaine content at 50 and 70 days after sowing respectively compared to the unstressed control plants. In their experiment, the proline content in roots, stem and leaves were found to have increased in all stages of growth under moisture stress condition. In another study, Szabados and Savoure (2009) pointed out that proline plays a more complex role in conferring drought tolerance than in acting as a simple osmolyte.

Many workers have reported oxidative stress and damage under moisture stress. Shohael *et al.* (2006) have shown that lipid peroxidation may be involved in the initiation of secondary metabolites and the accumulation of secondary metabolites arises from a need to protect membrane lipids from oxidative stress. According to Zhu *et al.* (2009), oxidative damage generated by drought stress in the plant tissue is alleviated by a concerted action of both enzymatic and non-enzymatic antioxidant systems.

The stomatal closure in plants is another physiological mechanism influenced by the moisture stress. According to Siddique *et al.* (2001), the increase in temperature probably occurs under moisture stress due to the decrease in plant transpiration caused by the closure of stomata, this being the main cooling mechanism for plants. Sankar *et al.* (2008) observed that the Net Assimilation Rate (NAR) and mean transpiration rate decreased in okra varieties under moisture stress compared to unstressed plants which indicated the stomatal closure factor during increased level of stress. Turan *et al.* (2009) reported that during water stress, plants respond by closing their stomata to protect themselves from excessive water loss. According to Hussein *et al.* (2011), percentage of opened stomata in both leaf sides of okra was lower than the closed stomata with shortage of water supply in 24 days irrigation interval. In their study, the stomata in the lower surface of okra leaves were completely opened in plants exposed to relatively high soil water stress with 30 days irrigation interval compared to 12 days interval. Sibomana *et al.* (2013) noted that the stomatal conductance decreased with increased level of moisture deficit.

Water Use Efficiency (WUE) is a critical characteristic of drought-tolerant species and is a water-saving strategy of plants in arid regions. However, there are many relative physiological traits affecting leaf WUE expressing wide variations under normal and water stress conditions. Intrinsic water use efficiency (iWUE) estimated as a ratio of photosynthesis/transpiration has been recognized as a measure of carbon gain per unit of water loss and found to be inversely proportional to the ratio of intercellular and ambient CO_2 concentrations (Martin *et al.*, 1992). Since higher rates of leaf photosynthesis are often associated with faster crop growth rates, a combination of higher photosynthesis and improved WUE may play a vital role for yield enhancement of crops under drought stress conditions (Parry *et al.*, 2005). According to Sankar *et al.* (2008), there was genotypic difference in WUE among okra cultivars and okra variety JK Haritha recorded highest WUE in stressed condition followed by variety Mahyco, Sakthi 101, Saloni F and SPBH 1.

2.2 EFFECT OF ORGANIC PREPARATIONS AND BIOSTIMULANTS

2.2.1 Effect of organic preparations and biostimulants on moisture stress mitigation

Biostimulants are derived from natural or biological sources and can enhance plant growth, development and yield when applied in small quantities. Apart from having capacity to induce stress tolerance, they can act as growth promoters. Many of the organic preparations also can act as natural biostimulants inducing stress tolerance and favouring the plant growth.

Vrikshayurveda is the vedik literature written by ancient scholars outlining systematic and indigenous agricultural practices (Nalini, 1996). As outlined in the *Vrikshayurveda*, the organic extract using cow dung, water, molasses and starch was sprayed at 10 per cent concentration to the tea plantations under Parry Agro Industries at Assam to evaluate its efficiency as a biostimulant for inducing drought tolerance. Though severe drought was experienced without rains for 45 days during peak cropping season, the plantations survived the stress situation. The quality of the produce was also not affected by high temperature ranging from 42- 44^{0}C (Deora, 2008).

Recent studies indicate that there is a relationship between accumulation of organic acids such as citric acid and drought tolerance in plants. Levi *et al.* (2011) reported that accumulation of organic acids including citric acid could contribute to the capacity of cotton lines to cope with drought situation. El- Tohamy *et al.* (2013) pointed out that the foliar application of citric acid ameliorated the negative effects of drought compared to control in beans.

A laboratory experiment conducted by Maqbool (2010) in maize indicated that, when the grains were soaked in diluted concentrations of sorghum extract for 12 hours and sown in washed sand for 7 days and then submitted to drought, the emergence of seedlings was delayed with increased dilutions, and the minimum germination was observed with soaking in 2 ml L^{-1} sorghum extract; and the most effective dilution under drought was 0.75 ml L^{-1}. Al-Hussaini and Alsaadawi (2013) reported that spraying 2.5 or 5 per cent sorghum water extract was effective in mitigating the drought effect in mung bean. Maqbool and Sadiq (2017) opined that although high concentrations of *sorgaab* (sorghum water extract) reduced the growth of plants, it might alleviate the adverse effects of drought, if applied at the low concentration and diluted concentrations of *sorgaab* can be utilized as a natural source for improving drought resistance in maize both at germination and later growth stages.

Humic acid is an organically charged biostimulant that significantly affects plant growth and development. Rasaei *et al.* (2013) pointed out the beneficial effect of humic acid spraying in mitigating the drought effect in chick pea by improving leaf area and soluble sugars. Moghadam *et al.* (2014) reported that foliar application of humic acid at 300 and 450 ppm improved the yield components and grain yield in corn even on withholding irrigation

Yeast is a natural source of many growth substances, cytokinins, many of the nutrient elements as well as organic compounds such as proteins, carbohydrates, nucleic acids and lipids (Barnet *et al.*, 1990). According to Yeo *et al.*, (2000), yeast extracts contain trehalose-6-phosphate synthase which is a key enzyme for trehalose bio synthesis and the production of trehalose not only affect plant development but also improves drought tolerance. In another study, Hammad and Ali (2014) reported that foliar application of yeast extract as a biostimulant at 3 or 6 g per litre concentration significantly reduced the drought stress in bread wheat. The leaf water deficit, osmotic potential and proline content were favourably influenced by the yeast application.

Moringa (*Moringa oleifera*) leaf extract is a potential source to mitigate the deleterious effects of drought in maize (Makkar and Becker, 1996). According to Ali *et al.* (2011), moringa leaf extract contains growth enhancing substances like zeatin, a source of cytokinin, which reduced the adverse effect of drought stress by delaying leaf senescence and scavenging reactive oxygen species in maize. Zaki and Radi (2015) observed that the high level of zeatin makes moringa leaves extract (MLE) more effective as a natural compound promoting plant tolerance under stress conditions. In a recent study, Hanafy (2017) reported that the moringa leaf extract could trigger the activation of physiological compounds in soybean plants to alleviate the oxidative damage causing by drought, leading to improvements in physiological and biochemical aspects for the plant growth under drought conditions and therefore can be used to alleviate the adverse effect of water stress.

Salicylic acid is a signaling or messenger molecule in plants and induces plant tolerance against various biotic and abiotic stresses (Horvath *et al.*, 2007). Baghizadeh and Hajmohammadrezaei (2011) observed that ascorbic acid and salicylic acid decrease effects and damages of drought stresses on okra germination and seedlings growth. According to the pot culture study conducted by Al- Razak *et al.* (2015), the foliar spraying of salicylic acid at two concentrations (50 and 100 mg L^{-1}) counteracted the adverse effect of water stress in fenugreek. In this study, spraying at 100 mg L^{-1}concentration was found to be more effective and it promoted the synthesis of proline which in turn helped in maintaining turgor in plant cells exposed to water stress. In general, adding salicylic acid and ascorbic acid significantly relieved the harsh effects of drought on okra germination and growth parameters and were able to enhance the drought tolerant ability of the plant.

In Kerala Agricultural University, research works on inducing drought tolerance or mitigating drought effect using biostimulants are meagre. Anitha *et al.* (2004) reported the beneficial effect of thiourea application in improving the productivity of cowpea under rain fed condition. Soaking the seeds in 500 ppm thiourea solution followed by 2 sprays increased the seed yield under rainfed situation. Menon and Savithri (2015) studied the benefits of seed hardening, antitranspirant spray and mulching for mitigating water stress in vegetable cowpea. They have reported that the lime water (2 per cent) spraying as antitranspirant resulted in highest pod yield.

2.2.2 Effect of organic preparations and biostimulants on plant growth and yield

Many of the organic preparations and biostimulants are found to be promoting the growth and yield in plants.

In an experiment comparing the effects of organic farming, conventional farming and *vrikshayurveda* product *kunapajala* in tomato, Deshmukh *et al.* (2012) observed that the number of leaves per plant, leaf area and biomass were highest with the *kunapajala* treatment. In an experiment with organic preparations based on cow dung, Gopakkali and Sharanappa (2014) reported that application of enriched biodigested liquid manure (EBDLM) at 100 kg N equivalent ha^{-1} + 3 sprays of panchagavya (3 per cent) recorded the highest plant height (42.3 cm), leaves per plant (8.1), leaf diameter (1.46 cm), leaf-area index (4.26), total dry matter production per plant (7.59 g), fresh weight of bulb (143.7 g) and, bulb yield (42.8 tonnes per ha) in onion. Sarkar *et al.* (2014) reported the beneficial effect of spraying of *Vrikshayurveda* products in improving the vegetative characters and yield in chilli, tomato and cowpea. The biomass production of shoot and root were found to have enhanced and the combination of *panchagavya* and *kunapajala* was found to be the best treatment resulting in efficient photosynthetic activity and yield. In their study, the yield increase was to the tune of 115 per cent in tomato and 127 per cent in cowpea.

Jaafari and Hadavi (2012) noted that spraying of citric acid increased the leaf width, length and dry yield in basil. According to El-Tohamy *et al.* (2013), vegetative growth parameters like fresh weight of plants, number of branches per plant, number and weight of pods were improved by the citric acid applications in beans. Talebi *et al.* (2014), reported in a study conducted on the flowering plant Gaziana that the citric acid spraying increased the root fresh weight significantly at 100 and 300 mg L^{-1} concentration and both the plant height and peduncle length were significantly increased in all applied levels of citric acid compared to control treatment. The root to shoot ratio was also increased significantly with 300 mg L^{-1} concentration of citric acid compared to all other treatments.

Al-Hussaini and Alsaadawi(2013) reported that in mung bean, application of 2.5 per cent and 5 per cent sorghum water extract significantly improved seed yield, dry weight and number of seeds per pod under stressed condition. The study conducted by Iqbal (2014) indicated that the sorghum water when applied in small quantity as foliar spray increased the growth and yield of a number of crops. According to Maqbool and Sadiq (2017), when *sorgaab* (sorghum water) was applied in different concentrations on maize, all the dilutions enhanced the shoot length and the root length was favoured by 1.75 ml L^{-1} and 2.00 ml L^{-1} concentration of *sorgaab* respectively. Shoot fresh and dry weights of maize increased in ascending order with *sorgaab* dilutions and the lower concentrations advanced root fresh and dry biomass due to the production of root hairs as compared to others levels.

Bama (2009) reported that foliar application of humic acid upto a concentration of 1.5 per cent increased the grain yield in rice. Rasaei *et al.* (2013) observed that when humic acid was sprayed at the early vegetative stage in chick pea it increased the leaf area. According to Moghadam *et al.* (2014), foliar application of humic acid at 300 and 450 ppm concentration improved the yield components and grain yield in corn even on withholding irrigation

It is known that yeast is considered as a natural source of cytokinins that stimulate cell division and enlargement as well as the synthesis of proteins, nucleic acids and chlorophyll (Fathy and Farid, 1996). El -Tohamy *et al.* (2008) reported that the foliar application of yeast extract increased vegetative growth of eggplant. The study conducted in pea by Asmaa *et al.* (2013) indicated that spraying of 2 per cent yeast extract increased all the vegetative yield parameters, green pod yield and pod quality. According to Hammad and Ali (2014), spraying yeast extract at the rate of 6 g L^{-1} increased the growth characters and yield in wheat. Favourable influence of yeast extract spraying on the yield of garlic was pointed out by Shalaby and El-Ramady (2014).

According to Foidle *et al.* (2001), foliar application of moringa leaf extract resulted in significant growth promotion and yield in melon, peanut, corn, sorghum, onion and sugarcane. Foliar application of moringa leaf extract improving the growth and yield of pea plants was pointed out by Mishra *et al.* (2013). The moringa leaf juice contains a growth regulating substance called zeatin which is natural plant hormone. It is also rich in natural cytokinin along with other minerals, phytohormones and other natural salts which increase the yield of crops when applied exogenously (Iqbal, 2014).

Beneficial effect of spraying salicylic acid on tomato was reported by Javaheri *et al.* (2014). In their study, the number of fruits per panicles, fruit number, fruit weight and fruit diameter were improved by the spraying of salicylic acid. Amira and Qados (2015) reported that application of salicylic acid improved the growth of capsicum plants under stress. In a study on sugar beet, Merwad (2015) observed that foliar spraying of salicylic acid increased the fresh shoot and root weight by 12 and 14 per cent respectively. In this study, when salicylic acid was sprayed along with potassium it produced the highest root length, root diameter, shoot and root yield.

2.2.3 Effect of organic preparations and biostimulants on plant nutrient content, uptake and quality

In an experiment on the efficacy of cow dung based liquid organic preparations in onion, Gopakkali and Sharanappa (2014) reported that application of enriched biodigested liquid manure (EBDLM) at 100 kg N equivalent ha^{-1} + 3 sprays of panchagavya (3 per cent) recorded the highest ascorbic acid (26.1 mg per 100 g), total soluble solid (14.4 per cent), reducing sugar (3.98 per cent), non-reducing sugar (9.05 per cent) and total sugar (13.03 per cent).

Ghazijahani *et al.*(2014) observed that foliar spraying of citric acid and salicylic acid in combination improved the root acquisition of sulphur and boron in sweet basil (*Ocimum basilicum* L.). Citric acid is also considered to facilitate plant P uptake (Ryan *et al.*, 2014).

Maqbool and Sadiq (2017) reported that when sorghum water extract was sprayed on maize plants in different concentrations, the uptake of K by leaf and roots were favourably influenced. In their trial, elevated nitrate-N content was noticed in leaves and roots with foliar spraying of sorghum water extract.

Celik *et al.*(2011) reported that foliar applications of humic acid had a statistically significant effect on Cu, Zn, and Mn uptake by the maize plants and greatest Cu and Na uptakes were obtained from the 0.1 per cent humic acid treatment. Osman *et al.* (2013) observed that foliar spraying of humic acid significantly increased uptake of N, P and K in wheat grain. In another study on humic acid spraying in wheat, Ehsan *et al.* (2014) noticed maximum uptake of N, P and K (93, 22 and 30 kg ha^{-1} respectively) in grain with humic acid spraying (40 g per litre) along with application of 150 kg Nha^{-1}. In their study, maximum uptake of 105, 16 and 101 kg ha^{-1} N, P and K were registered in the straw with the above treatment.

Hammad and Ali (2014) reported that spraying of yeast @ 6 g L^{-1} as a biostimulant increased the N, P and K content in wheat through increased absorption by roots, translocation and accumulation in plant tissue. In their study application of yeast was also found to increase the total soluble sugars, total carbohydrates and phenols in plants.

Basra and Lovatt (2016) observed that, the foliar and root applied moringa leaf extract increased the fruit concentrations of soluble sugars, protein, antioxidants, and lycopene in cherry tomato compared with fruit from untreated control plants. Hanafy (2017) reported that uptake and accumulation of N, P and K in soybean plants were significantly higher with the spraying of moringa leaf extract.

According to a study conducted by Wang *et al.* (2011), salicylic acid is involved in the regulation of uptake of several plant beneficial elements such as Mn Ca, Cu, Fe, P and Zn and thereby minimize oxidative stress. Merwad (2015) reported that potassium nutrition combined with foliar spraying of salicylic acid significantly increased the N, P and K content and uptake in sugar beet. The highest values of N, P and K contents of sugar beet (3.67 per cent, 0.48 per cent and 4.47 per cent, respectively) and N, P and K uptake (194.2, 25.6 and 236.1 kg ha^{-1}) respectively) were obtained with a K-fertilisation rate of 200 kg ha^{-1} combined with salicylic acid (1000 ppm) spraying.

2.2.4 Effect of biostimulants and organic preparations on physiological aspects of plants

. Water stress can lead to reduction in plant growth by reducing photosynthesis and stomatal conductance, and can inhibit photosynthesis pigments. The application of biostimulants and organic reparations can influence the physiological aspects of plants thus modifying the effects of moisture stress.

Bio organic studies conducted by Deshmugh *et al.* (2012) to find the effect of cow dung based organic preparation *kunapajala* in tomato indicated that highest relative water content (RWC), osmotic potential (OP) of cell sap, total chlorophylls, chlorophyll stability index, carotenoids and xanthophylls and lowest percentage of membrane injury were noticed in the leaves under kunapajala treatment. The treatment also resulted in higher soluble proteins, total carbohydrates, polyphenol, proline, glycine betain and ascorbic acid. The antioxidant property of tomato leaf was highest with kunapajala treatment compared to conventional farming as revealed by activity of enzymes viz. catalase, peroxidase, polyphenol oxidase, IAA oxidase and super oxide dismutase.

A study conducted by Sun and Hong (2011) indicated that spraying of citric acid induced the defense mechanisms by increasing the activities of antioxidant enzymes and thus improving the plant growth under stress conditions. According to El-Tohamy *et al.* (2013), application of citric acid at 1.5 g per litre concentration improved the relative water content, chlorophyll content, productivity and quality parameters of bean plants under moisture stress.

According to Al-Hussaini and Alsaadawi (2013), in mung bean spraying of sorghum extract on plants under drought stress treatment increased the chlorophyll content by 16.7 per cent over plants of control treatment alone and maximum chlorophyll content was recorded in plants sprayed with 5 per cent sorghum water extract. Maqbool and Sadiq (2017) reported that when different concentrations of *sorgaab* were sprayed on maize, the total chlorophyll content and the ratio of chlorophyll A and B were greater at higher dilutions. Higher transpiration and photosynthetic rates were observed when concentrations from 0.75 ml L^{-1} to 1.50 ml L^{-1} were sprayed under drought. In their study, slight reduction in water use efficiency, elevation in sub-stomatal CO_2 content and increased stomatal conductance were noticed with lower concentrations of extract.

Humic acid is an organically charged biostimulant that significantly affects plant growth and development and increases crop yield. Abbas (2013) reported biostimulants such as humic acid and yeast extract effect the photosynthetic pigment, phytohormone and enzyme activity which in turn increased vegetative growth of faba bean plant. In another study Meganid *et al.* (2015) reported that spraying of humic acid at the rate of 3 g per litre increased the relative growth rate and chlorophyll content in beans

Hammad and Ali (2014) reported that in wheat, spraying of yeast extract to the plants under moisture stress increased the relative water content, osmotic potential and membrane integrity. There was a significant increase in peroxidase and phenoloxidase activity and significant increase in total chlorophyll and carotinoid. There was also an increase in total soluble solids, total carbohydrates and total phenols but the proline content was found to reduce with the application of yeast extract at the rate of 6 g per litre.

Moringa (*Moringa oleifera*) leaf extract contains growth enhancing substances like zeatin, a source of cytokinin, which reduced the adverse effect of drought stress by delaying leaf senescence and scavenging reactive oxygen species in maize (Ali *et al*., 2011). Abdulla (2013) recorded that spraying of moringa leaf extract in 3 per cent concentration increased the photosynthetic rate, stomatal conductance, total sugars, total protein and reduced peroxidase and superoxide dismutase enzymes associated with moisture stress condition in leafy vegetable *Eruca vesicaria* subsp. *sativa.* Hanafy (2017) reported that spraying of moringa leaf extract on drought stressed soybean plants caused significant increases in non-enzymatic antioxidants (ascorbic acid, tocopherol and reduced glutathione), enzymatic antioxidants (glutathione reductase, superoxide dismutase and ascrobate peroxidase), oxidative damage (lipid peroxidation) and osmolyte compounds (proline, total soluble sugars and total phenols). The photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments) were also found to have increased in this study.

Larque (1978) documented that the exogenous application of salicylic acid has an antitranspiration effect on bean plants by causing a reduction in stomatal conductance. Pancheva *et al*. (1996) demonstrated that a 7-day treatment of barley seedlings with salicylic acid decreased the rate of photosynthesis and the activity of rubisco, an enzyme responsible for CO_2 fixation in most plants. In an experiment with two linseed varieties, Bakry *et al*. (2012) reported that salicylic acid increased the proline and free amino acid content in both varieties compared to the corresponding control plant.

2.3 CHEMICAL PROPERTIES OF ORGANIC PREPARATIONS AND BIOSTIMULANTS

Citric acid is a six carbon organic acid, having a central role in citric acid cycle in mitochondria that creates cellular energy by phosphorylative oxidation reactions (Ghazijahani *et al*., 2014). According to Miyazawa (2016), citric acid can stimulate the scavenging of reactive oxygen species in plants and thus reduce the oxidative stress.

In a study on the leaf chemistry of sorghum, Khatir *et al*. (2013) reported that the *Sorghum bicolour* leaves have a dry matter content of 96.80 per cent, fat content of 0.673 per cent, protein content of 17.86 per cent, fibre content of 13.60 per cent, ash content of 32.81 per cent and Nitrogen Free Extract content of 30.24 per cent Won *et al*. (2013) reported that, phenolic compounds are the characteristic chemicals present in sorghum leaf extract and three phenolic compounds such as *p*-hydroxybenzoic acid, *p*-coumaric acid, and *trans*-cinnamic acid are present in leaf extract. The *p*-hydroxybenzoic acid content in crude extracts of sorghum shoots ranged from 48.95 to 2.4 μg mg^{-1} with 15 DAS (Days after seeding) foliage to 2.4 μg mg^{-1} with 105 DAS foliage. The other two phenolic compounds also followed the similar trend.

Humic acid has several biochemical effects such as increase in respiration rates, cell membrane permeability, root cell elongation, potassium and phosphate uptake, photosynthesis and synthesis of proteins and hormones (Saruhan *et al*., 2011). In another study Gao and Li (2012) reported that the humic acid as biostimulant had a pH of 6.2, nitrate N content of 92 mg kg^{-1}, ammoniacal N content of 5.3 mg kg^{-1}, phosphorus content of 4mg kg^{-1} and potassium content of 10 mg kg^{-1}.

Several workers have reported that yeast is a rich source of phytohormones especially cytokinins, vitamins, enzymes, amino acids and minerals (Barnett *et al.*, 1990; Fathy and Farid, 1996 ; Khedr and Farid, 2000).

Moringa leaves are extremely rich in vitamins (A, B, C), essential minerals (K, Ca, Fe), antioxidants (Ascorbate, Phenolics), proteins and growth hormone zeatin (Foidle *et al.*, 2001). In another study, Nambiar *et al.* (2005) reported that moringa leaves are potential source of vitamin A and C, iron, calcium, beta-carotene, riboflavin, antioxidant and phenolic acid. While analyzing the biochemical composition of moringa leaf extract, Yasmeen (2011) reported that it has a total soluble protein content of 1.40 mg g^{-1} and enzymatic antioxidants (super oxide dismutase, peroxidase and catalase) content of 191.86, 21.99 and 7.09 IU min^{-1} mg^{-1} protein respectively. In this study, the chemical composition of moriga leaf extract also included 8.19 mg g^{-1} total phenols, 0.36 m mole g^{-1} ascorbic acid, 1.93 per cent N, 0.18 per cent P, 2.19 per cent K, 2.43 per cent Ca, 0.012 per cent Mg, 38.33 mg kg^{-1} Zn, 3.50 mg kg^{-1} Cu, 544.0 mg kg^{-1} Fe, 49.67 mg kg^{-1} Mn, and 21.33 mg kg^{-1} B.

Salicylic acid (SA) is one of the most readily available plant growth regulating materials, which is also effective in other forms of acetyl SA and methyl salicylate in the plant. It can also induce alternative oxydase enzyme activity in mitochondria that are involved in stress alleviation mechanism (Raskin, 1992).

The review of literature indicated the effects of moisture stress on growth, yield, nutrient uptake, quality and physiological processes in plants. Various studies also pointed out the influence of application of organic preparations and biostimulants on moisture stress mitigation, growth, productivity and physiological processes in plants along with a brief account of their chemical properties.

Materials and methods

3. MATERIALS AND METHODS

The field experiment entitled "Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench) was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during July to October 2016 to evaluate the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance and to assess their impact on growth, yield and irrigation requirement of okra in urban homesteads. The details of materials used and the methods adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani situated at 8.5° North latitude and 76.9° East longitude and at an altitude of 29 m above mean sea level. The experiment was conducted in rain shelter with a partial shade of 50 per cent.

3.1.1 Season

The field experiment was conducted during the period July to October 2016.

3.1.2 Weather condition

3.1.2.1 Weather condition in open area

The weekly average of the weather parameters viz. maximum and minimum temperature, relative humidity, rainfall and evaporation received during the cropping period collected from the Meteorological Observatory, College of Agriculture, Vellayani are given in Appendix I and illustrated in Fig. 1. The mean maximum temperature ranged between 31.1°C-32.3°C and mean minimum temperature ranged between 24.1°C-25.2°C during the crop season. The mean maximum relative humidity ranged between 88 per cent to 95 per cent, while the mean minimum relative humidity ranged between 74 to 80.4 per cent. A total rainfall of 51.2 mm was recorded during the crop period. Daily evaporation in open condition ranged between 3.3 mm to 4.6 mm.

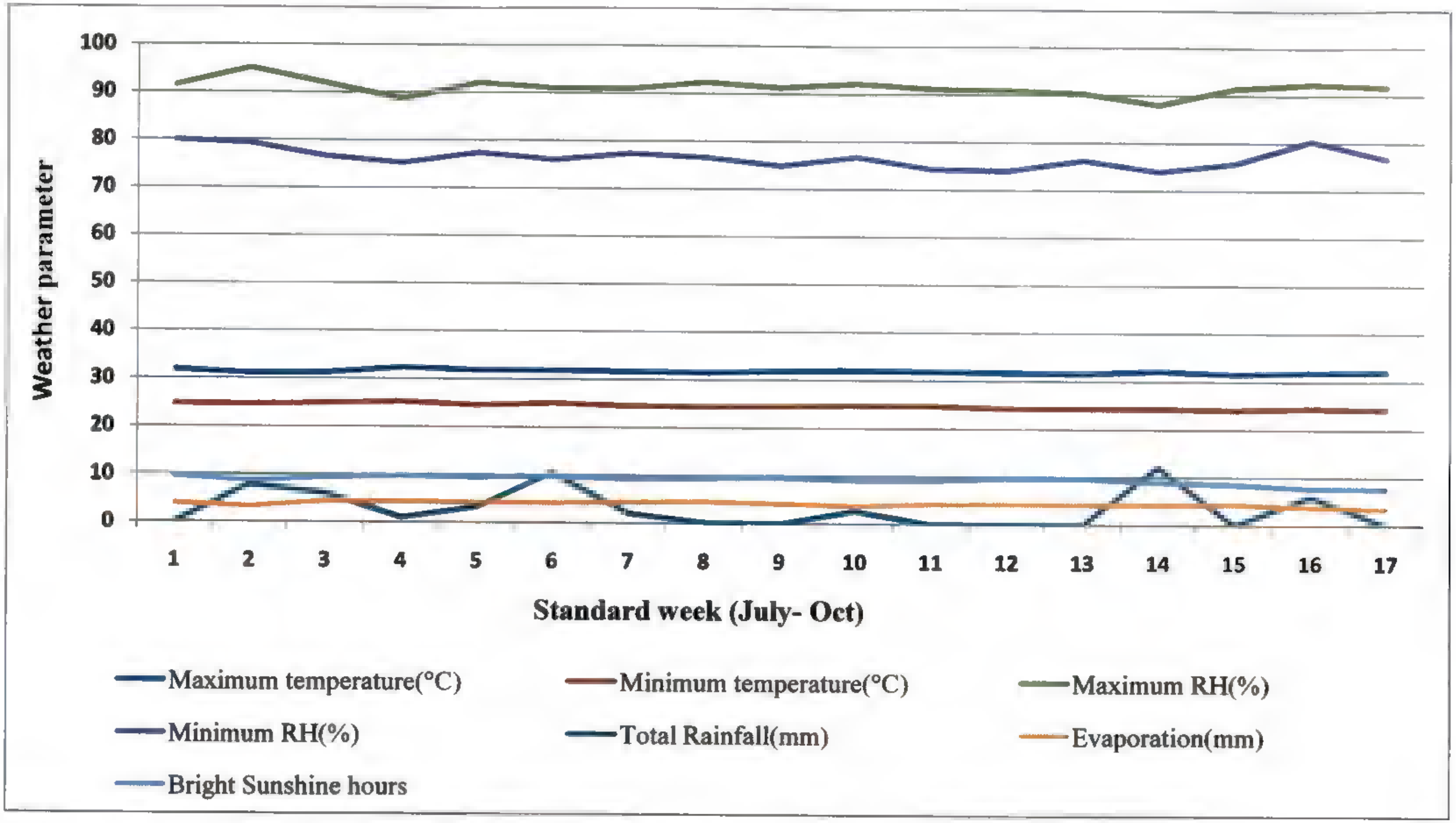

Fig. 1. Weather parameters during the crop period in open condition

3.1.2.2 Weather condition in rain shelter

Maximum and minimum temperature in rain shelter was recorded by using air temperature thermometer and relative humidity was measured using hygrometer. Evaporation under rain shelter condition was measured by using locally fabricated can evaporimeter and the weekly average of the weather parameters calculated are given in Appendix II and illustrated in Fig. 2. The mean maximum temperature in rain shelter ranged between 31.1 °C - 32.3 °C and mean minimum temperature ranged between 26.2 °C-27.4 °C during the crop season. The mean maximum relative humidity ranged between 79.2 to 85.5 per cent, while the mean minimum relative humidity ranged between 65.86 to 71.58 per cent. The daily evaporation in the rain shelter during the cropping period ranged between 3 mm to 4.2 mm.

3.2 MATERIALS

3.2.1 Potting mixture

The growth media used in the experiment was normal potting mixture (cow dung, soil and sand in 1:1:1 ratio). Well decomposed farm yard manure containing 0.51 per cent N, 0.64 per cent P_2O_5 and 0.31 per cent K_2O was used in potting mixture. The soil used in the potting mixture was laterite red loam belonging to order oxisol of Vellayani series. The important physico-chemical properties of the potting mixture and the method of analysis are presented in Table 1.

Table 1. Physico-chemical properties of the potting mixture used in experiment

Sl.No	Parameters	Content	Methods adopted
	A. Physical properties		
1	Bulk Density (Mg m^{-3})	1.11	Core method (Gupta and Dakshinamoorthi, 1980)
2	Particle Density (Mg m^{-3})	2.64	Pycnometer method (Black, 1965)
3	Porosity (per cent)	58.00	
4	Field capacity (per cent)	23.00	Pressure plate membrane apparatus (Hillel, 1971)
5	Permanent wilting point	9.00	

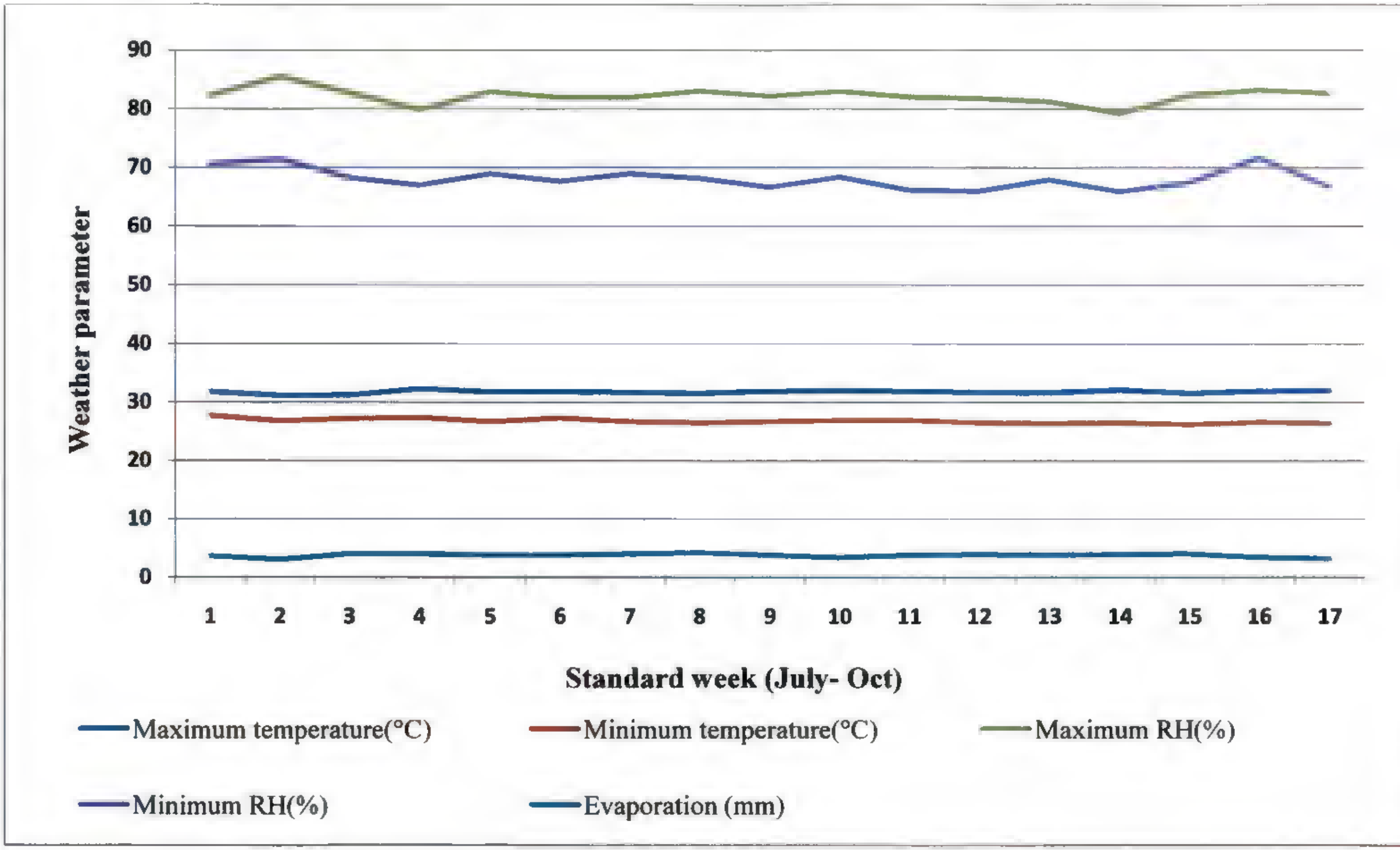

Fig. 2. Weather parameters during the crop period in rainshelter

	(per cent)			
	B. Chemical composition			
Sl.No	Parameters	Content	Rating	Methods adopted
1	Soil reaction (pH)	6.21	Slightly acidic	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)
2	Electrical conductivity(dSm^{-1})	0.213	Normal	Digital conductivity meter (Jackson, 1973)
3	Organic carbon (per cent)	0.8	High	Walkley and Black rapid titration method (Jackson, 1973)
4	Available N (per cent)	0.015	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available P_2O_5 (per cent)	0.004	High	Bray colorimetric method (Jackson, 1973)
6	Available K_2O (per cent)	0.014	High	Ammonium acetate method (Jackson, 1973)

3.2.2 Cultivar

The cultivar of okra used for the study was Varsha Upahar released by Chaudhary Charan Singh, Haryana Agricultural University, Hissar by inter varietal hybridization between 'Lam Selection 1' and 'Parbhani Kranthi' following pedigree selection in 1996. It is an early high yielding variety tolerant to Yellow Vein Mosaic Disease.

3.2.3 Seeds

Seeds of variety Varsha Upahar were obtained from the Instructional Farm, College of Agriculture, Vellayani.

3.2.4 Plastic sack

The plants were raised in uniform sized 1400 linear UV stabilized woven plastic sacks (diameter 40 cm and height 42 cm) having 25 kg capacity.

3.2.5 Manures and fertilizers

Urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

3.3 METHODS

3.3.1 Design and Layout

Design : Completely Randomised Design

Treatments : 9

Replication : 3

Variety : Varsha Upahar

Spacing : 60 cm x 30 cm

3.3.1.1 Treatments

T_1 : Spraying of fermented cow dung water mixture (10 per cent)

T_2 : Spraying of citric acid (0.2 per cent)

T_3 : Spraying of sorghum water extract (5 per cent)

T_4 : Spraying of humic acid (1 per cent)

T_5 : Spraying of yeast extract (2 per cent)

T_6 : Spraying of moringa leaf extract (3 per cent)

T_7: Spraying of salicylic acid (100 ppm)

T_8 : Spraying of water

T_9 : No stress treatment (daily irrigation to field capacity and no spraying)

Plate 1. General view of the experiment plot

Plate 2. Visual symptom of wilting

3.3.1.2 Making of organic preparations and biostimulants

Fermented cow dung water mixture (*Vrikshayurveda* product) : About 25 kg fresh cow dung, 0.167 kg cane jaggery and 0.333 L of rice water (starch) were placed in a nylon bag. The bag was tied and suspended in a 17 L bucket filled with water. The mixture in the bag was allowed to ferment for 36 to 48 hrs and was used for foliar spraying with 10 per cent concentration (Deora, 2008).

Citric acid : Citric acid anhydrous (99 per cent purity) was used for preparing 0.2 per cent solution and foliar spraying with 0.2 per cent solution was done (El-Tohamy *et al.*, 2013).

Sorghum water extract : Mature sorghum plant (stem and leaf) was air dried for several days and chopped into pieces of about 1 cm long. About 300 g of chopped material was added to 3000 ml of boiling distilled water for 5 minutes, shaken for 10 minutes by hand and allowed to stand for 1 hour. Sorghum debris was removed by filtering through muslin clothes and the extract was taken. Concentration of 5 per cent was made by diluting 5 ml of extract with 100 ml of distilled water (Al-Hussaini and Alsaadawi, 2013).

Humic acid : Humic acid powder having 98 per cent purity was used to prepare 1 per cent solution (Rasaei *et al.*, 2013).

Yeast extract: A quantity of 20 g of dry yeast was dissolved in 1 L of water to which 20 g of sugar was added (yeast and sugar in 1:1 proportion) and kept for 24 hours in a warm place to prepare 2 per cent yeast extract (Marzauk *et al.*, 2014).

Moringa leaf extract : Young shoots and tender branches of moringa were grinded with a little water at the rate of 1 L water for 10 kg fresh material. The extract was sieved through muslin cloth, centrifuged for 15 minutes and then diluted to 3 per cent concentration (Yasmeen *et al.*, 2013).

Salicylic acid : Salicylic acid having 99 per cent purity was used for preparing 100 ppm solution (Al- Razak *et al.*, 2015).

3.3.1.3 Treatment application

Treatment application (T_1 to T_8) was done by foliar spraying at 20, 40, 60 and 80 DAP (Days After Planting).

3.3.2 Crop management

3.3.2.1 Preparation of Plastic sacks

Uniform sized sacks having 25 kg capacity were taken and sacks were filled with 10 kg of potting mixture. Five sacks were selected for each treatment per replication.

3.3.2.2 Sowing

Two seeds were dibbled in each sack at a depth of 3-5 cm. Gap filling was done within a week followed by thinning two weeks later so as to retain one plant per sack.

3.3.2.3 Application of fertilizers

N, P_2O_5 and K_2O were applied as per KAU package of practices recommendations (KAU, 2011) for okra. A uniform quantity of 1.95 g of urea, 3.15 g of rajphos and 2 g of muriate of potash per sack was applied to all the plants. Urea was given in two spilt doses, half at the time of planting and remaining half one month after planting. Rajphos and muriate of potash were applied as basal dose at the time of planting.

3.3.2.4 After cultivation

First weeding was done 20 days after planting and subsequent weedings at 10 days interval. Staking was done for each plant at three weeks after emergence.

3.3.2.5 Irrigation

3.3.2.5.1 Standardization of seepage losses

Seepage loss from the potting mixture filled plastic sack was standardized by collecting the amount of water lost by horizontal seepage and vertical seepage through the plastic sack. The water was collected in a plastic basin, kept under the sack and the quantity of water collected was taken into account in calculating the quantity of irrigation water to be applied.

3.3.2.5.2 Determination of field capacity

Field capacity was determined by using the Pressure Plate Membrane Apparatus as per the procedure outlined by Hillel (1971). The available moisture content at field capacity was converted to volume to find out the quantity of water required to bring the potting mixture to field capacity.

3.3.2.5.3 Measurement of evaporation under rain shelter condition

Daily evaporation was recorded from the sacks under rain shelter condition using locally fabricated can evaporimeter having a dimension of 14.3 cm height, 10 cm diameter and covered with 6/20 size mesh (Reddy and Reddy, 1995).

3.3.2.5.4 Computation of irrigation requirement

Uniform daily irrigation was given to all the treatments for the first 20 days to bring the potting mixture to field capacity. The schedule of irrigation for the treatments in detail is given in Appendix III. For treatments T_1 to T_8, irrigation was withheld after 20 days of planting and irrigated only when plant showed temporary wilting symptoms. For T_9, daily irrigation was given throughout the cropping period to bring the potting mixture to field capacity. The quantity of water applied per irrigation for treatments T_1 to T_9 is shown in Appendix IIIa. The quantity of water to be applied to bring the potting mixture to field capacity was worked out using the following relationship;

$ET_{crop} = Kc \times ET_0$

Where ET_{crop} = Crop evapotraspiration

Kc = Crop coefficient

ET_0 = Evapotranspiration (FAO, 1977)

The ET_0 under the rain shelter was standardized using can evaporation data. Measured quantity of water was applied for each irrigation covering the seepage losses.

3.3.2.5.5 Computation of irrigation interval

Measured quantity of irrigation water was applied only when the plants showed temporary wilting symptoms for treatments T_1 to T_8 and irrigation intervals were calculated for each irrigation, mean value was calculated and expressed as days. Irrigation interval in days for each irrigation is indicated in Appendix III b.

3.3.2.6 Plant protection

Spraying of Quinalphos 0.05 per cent was given against jassid infestation.

3.3.2.7 Harvest

The crop was harvested for vegetable purpose from 45^{th} day onwards as per the treatment. Maturity of the fruit was determined by visual appearance (usually 7 days after flowering).

3.4 OBSERVATIONS

3.4.1 Growth and growth attributes (at monthly interval)

3.4.1.1 Plant height

Plant height was measured from the base to the terminal bud and the average was worked out from each and expressed in cm at monthly interval.

3.4.1.2 Leaves plant $^{-1}$

The number of leaves was noted at monthly interval from each sack and average was calculated.

3.4.1.3 Leaf area index

Leaf area of two observational plants from each treatment was measured at flowering stage (45 DAS) by graph paper method and the mean value was expressed in cm^2.

Leaf area index was then computed using the equation:

$$LAI = \frac{\text{Total Leaf area}}{\text{Land area}}$$

3.4.1.4 Root-shoot ratio

Fresh and dry weight of the roots and shoot were taken and the root - shoot ratio was calculated.

3.4.1.5 Root volume

Root volume was recorded by water displacement method. The roots of sample plant were washed free of adhering soil with a low jet of water. The roots were immersed in 1000 ml measuring cylinder containing water and the rise in water level was recorded. Displacement in volume of the water was taken as measure of the volume of root measured (Novoselov, 1960) and expressed in cm^3.

3.4.2 Yield attributes and yield

3.4.2.1 Fruits plant $^{-1}$

Total number of fruits obtained from each plant was counted and the mean value was worked out.

3.4.2.2 Fruit weight

The weight of individual fruit harvested from each plant was measured and the mean was worked out in g fruit $^{-1}$.

3.4.2.3 Length of fruit

The length of individual fruit harvested from each plant was measured and the mean worked out and expressed in cm.

3.4.2.4 Number of pickings

Number of picking of fruits from each treatment during total crop period was recorded.

3.4.2.5 Fruit yield

Total weight of fruits from each observation plant at different harvests were worked out and expressed as fruit yield in kg plant $^{-1}$.

3.4.3 Incidence of pests and diseases

Incidence of pests and diseases during the crop period were recorded treatment wise. No disease incidence was noticed in the crop, however jassid infestation was observed on 2 plants and since the infestation was very mild, scoring was not done.

3.4.4 Plant and fruit analysis

3.4.4.1 N, P and K contents of plants

Samples were collected at harvest, chopped, sundried and oven dried (70±5°C) to a constant weight. Samples were ground to pass through a 5 mm mesh in a Willey Mill and required quantity of samples were digested and used for nutrient analysis.

3.4.4.1.1 N Content

Nitrogen content in plant sample was estimated by modified microkjeldhal method (Jackson, 1973).

3.4.4.1.2 P Content

Phosphorus content in the plant sample was determined colorimetrically (Piper, 1967).

3.4.4.1.3 K Content

Potassium content in the plant samples was determined by flame photometer method and expressed in percentage (Piper, 1967).

3.4.4.2 Fruit analysis

3.4.4.2.1 Crude protein content

The nitrogen content of the fruit from 6^{th} harvest was determined and the value was multiplied by the factor 6.25 to obtain protein content of fruits and values were expressed as percentage (Simpson *et al.*, 1965)

3.4.4.2.2 Crude fibre content

The crude fibre content was determined by the acid-alkali treatment and expressed as percentage as per the procedure outlined by Sadasivam and Manickam (1992).

3.4.4.2.3 Ascorbic acid content

The ascorbic acid content of the fruit was determined by titrimetric method (Sadasivam and Manickam, 1992) and expressed as mg 100 g^{-1} on fresh weight basis.

3.4.5 Dry matter production

The weight of fruits from each harvest and that of observational plant which was uprooted at final harvest were recorded. Samples of fruits at each harvest and plant at final harvest were separately chopped and oven dried to constant weight at 80^0C. The total dry matter production of plant was calculated and expressed in g $plant^{-1}$.

3.4.6 Uptake of NPK at final harvest

The uptake of N, P and K were calculated by multiplying the nitrogen, phosphorus and potassium content of the sample with total dry matter production of the plant. The uptakes were expressed in g plant^{-1}

3.4.7 Moisture studies

3.4.7.1 Water use efficiency

Water use efficiency was calculated by using the formula

$$\text{WUE (g L}^{-1}\text{)} = \frac{\text{Yield}}{\text{Total quantity of water used}}$$

(Stanhill, 1987)

3.4.7.2 Water productivity

Water productivity was estimated using the formula proposed by Kijne *et al.* (2003) and expressed as g L^{-1}.

$$\text{Water productivity (WP)} = \frac{\text{Total biomass}}{\text{Total water utilized}}$$

3.4.8 Physiological studies

3.4.8.1 Stomatal count (45 DAP)

Stomatal count refers to the number of stomata per unit area of leaf. A thick mixture of thermocol and xylene was prepared and this was smeared on both surface of leaves and allowed to dry. It was pealed gently after drying and the peel was observed under microscope and counted using a 40 x objective and 10 x eyepiece. The field of the microscope was measured using a stage micrometer and stomatal frequency per unit area was calculated (Wolf *et al.*, 1979).

3.4.8.2 Proline content (45 DAP)

Proline content of the plant samples was estimated by the procedure outlined by Bates *et al.* (1973) and expressed in μ moles g^{-1} fresh weight.

3.4.8.3 Chlorophyll content (45 DAP)

Chlorophyll content was analysed by Dimethyl Sulphoxide method (Yoshida *et al.*, 1976) and the intensity of colour was read in spectrophotometer and expressed in mg g^{-1}.

3.4.8.4 Relative leaf water content (1 week after treatment application)

Leaf discs were taken from the top most fully expanded leaf of the observational plant and the fresh weight, turgid weight and dry weight were measured. Turgid weight was taken by immersing the disc in water for 3 hours and the samples were then oven dried at a temperature of 70±5°C for three consecutive days till constant weight was reached and the dry weight was measured (Barr and Weatherley, 1962).

$$\text{RLWC (per cent)} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

3.4.9 Potting mixture analysis

A composite sample of potting mixture was collected before the experiment and potting mixture from each treatment was collected after the experiment and the following physico-chemical analysis were done.

3.4.9.1 Bulk density

Bulk density was determined by undisturbed core method (Gupta and Dakshinamoorthy, 1980) and expressed in Mg m^{-3}

3.4.9.2 Particle density

Particle density was determined by Pycnometer method (Black, 1965) and expressed in Mg m^{-3}

3.4.9.3 Porosity

Porosity was determined by undisturbed core method (Gupta and Dakshinamoorthy,1980) and expressed in percentage.

3.4.9.4 pH

The pH of the potting mixture samples were determined by preparing soil solution in 1:2.5 ratio and using pH meter with glass electrode (Jackson, 1973).

3.4.9.5 Electrical Conductivity

Conductivity meter was used to determine electrical conductivity of potting mixture samples and expressed as dSm^{-1}.

3.4.9.6 Organic carbon content

Organic carbon content of the potting mixture before and after the experiment was determined by Walkely and Black rapid titration method (Jackson, 1973) and expressed in percentage.

3.4.9.7 Available N

Available nitrogen content in the potting mixture before and after the experiment was estimated by Alkaline permanganate method (Subbiah and Asija, 1956) and expressed in percentage.

3.4.9.8 Available P

Available phosphorus content in the potting mixture before and after the experiment was determined by Bray colorimetric method (Jackson, 1973) and expressed in percentage.

3.4.9.9 Available K

Available potassium content in the potting mixture before and after the experiment was estimated by Ammonium acetate method (Jackson, 1973), using flame photometer and expressed in percentage.

3.5 ECONOMIC ANALYSIS

Economics of cultivation was worked out for the experiment by taking into account the cost of cultivation and prevailing market price of okra.

Net income and benefit: cost ratio were calculated as follows:

$$\text{Net income} = \text{Gross income} - \text{Total expenditure}$$

$$\text{Benefit: cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.6 STATISTICAL ANALYSIS

The data generated from the experiment were subjected to statistical analysis using Analysis of Variance technique (ANOVA) as applied to Completely Randomised Design (Panse and Sukhatme, 1985) and the significance was tested using F test (Snedecor and Cohran, 1967). Wherever F values were significant, critical differences were worked out at five per cent and one per cent probability levels. The treatment effect was noted as 'NS' when not significant.

Results

4. RESULTS

The study entitled "Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during 2016 to 2017. The objective of the study was to evaluate the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance and to assess their impact on growth, yield and irrigation requirement of okra in urban homesteads. The field experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani during July to October 2016 in containers which were housed in a rain shelter. The results of the experiment are presented in this chapter.

4.1 GROWTH AND GROWTH ATTRIBUTES

4.1.1 Plant Height

The result on the effects of organic preparations and biostimulants on plant height are presented in Table 2.

Spraying of organic preparations and biostimulants did not influence the plant height of okra at 1 MAP and 2 MAP. However it was significantly affected by the treatments at 3 MAP. Spraying of moringa leaf extract-3 per cent (T_6) produced taller plants (72.33 cm) compared to other organic preparations and biostimulants which was significantly higher than the plant height produced with spraying of 5 per cent sorghum water extract-T_3 (66.56 cm) and 1 per cent humic acid-T_4 (66.83 cm) which were on a par with each other. The treatment T_6 however did not differ from spraying of fermented cow dung water mixture-10 per cent (T_1), spraying of citric acid-0.2 per cent (T_2), spraying of yeast extract-2 per cent (T_5), spraying of salicylic acid-100 ppm (T_7) or spraying of water (T_8) which produced the plant height of 70.20, 70.96, 68.56, 68.81 and 68 cm respectively. The no stress treatment (T_9)

Table 2. Effect of organic preparations and biostimulants on plant height of okra at monthly interval, cm

Treatments	Plant height		
	1 MAP	2 MAP	3 MAP
T_1 - Spraying of fermented cow dung water mixture (10%)	28.74	51.80	70.20
T_2 - Spraying of citric acid (0.2 %).	28.11	50.60	70.96
T_3 - Spraying of sorghum water extract(5%)	27.56	49.53	66.56
T_4 - Spraying of humic acid (1%)	25.58	50.49	66.83
T_5 - Spraying of yeast extract (2%)	27.36	48.26	68.56
T_6 - Spraying of moringa leaf extract (3%)	29.50	53.30	72.33
T_7 - Spraying of salicylic acid (100 ppm)	29.05	51.50	68.81
T_8 - Spraying of water	28.56	49.50	68.00
T_9 - No stress treatment	31.40	58.23	77.23
SEm (±)	2.93	4.00	2.37
CD (0.05)	NS	NS	4.990

MAP : Months After Planting

however produced the tallest plants (77.23 cm) compared to the application of organic preparations and biostimulants which was also on a par with the T_6.

4.1.2 Leaves plant^{-1}

The result on the effects of organic preparations and biostimulants on leaves plant^{-1} are shown in Table 3.

Spraying of organic preparations and biostimulants did not have any significant effect on leaves plant^{-1} at 1 MAP, 2 MAP or 3 MAP.

4.1.3 Leaf area index

Leaf area index at 45 DAP was highest (0.66) with spraying of moringa leaf extract 3 per cent (T_6) followed by spaying of humic acid 1 per cent (T_4) and spraying of citric acid 0.2 per cent (T_2) among biostimulants. However spraying of water (T_8) produced the lowest LAI of 0.52. Compared to the application of biostimulants, the no stress treatment produced the highest LAI of 0.76.

4.1.4 Root-shoot ratio

The result on the effects of spraying of organic preparations and biostimulants on root-shoot ratio of okra at final harvest is presented in Table 4.

The treatments could not significantly influence the root-shoot ratio of plants at harvest.

4.1.5 Root volume

The result on the effects of spraying of organic preparations and biostimulants on root volume of plants at final harvest is indicated in Table 4.

Among the organic preparations and biostimulants, spraying of moringa leaf extract-3 per cent (T_6) recorded significantly higher root volume (76.53 cm^3) when compared to spraying of salicylic acid-100 ppm (51.03 cm^3), spraying of water (53.03 cm^3), spraying of fermented cow dung water mixture-10 per cent (53.83 cm^3) or

Table 3. Effect of organic preparations and biostimulants on leaves plant^{-1} in okra, nos

Treatments	Leaves plant^{-1}		
	1 MAP	2 MAP	3 MAP
T_1 - Spraying of fermented cow dung water mixture (10%)	6.18	9.10	9.68
T_2 - Spraying of citric acid (0.2%)	6.08	7.33	9.03
T_3 - Spraying of sorghum water extract (5%)	6.00	7.96	10.14
T_4 - Spraying of humic acid (1%)	5.64	8.03	9.26
T_5 - Spraying of yeast extract (2%)	5.90	8.32	10.36
T_6 - Spraying of moringa leaf extract (3%)	6.12	8.83	11.43
T_7 - Spraying of salicylic acid (100 ppm)	6.47	7.98	10.06
T_8 - Spraying of water	5.90	7.46	9.63
T_9 - No stress treatment	6.28	9.16	13.33
SEm (±)	0.51	0.41	0.93
CD (0.05)	NS	NS	NS

MAP : Months After Planting

Table 4. Effect of organic preparations and biostimulants on leaf area index, root-shoot ratio and root volume in okra

Treatments	Leaf area index (45DAP)*	Root - shoot ratio at final harvest	Root volume at final harvest (cm^3)
T_1 - Spraying of fermented cow dung water mixture (10%)	0.59	0.21	53.83
T_2 - Spraying of citric acid (0.2%)	0.61	0.15	63.00
T_3 - Spraying of sorghum water extract(5%)	0.57	0.21	57.70
T_4 - Spraying of humic acid (1%)	0.62	0.24	71.60
T_5 - Spraying of yeast extract (2%)	0.58	0.19	64.60
T_6 - Spraying of moringa leaf extract (3%)	0.66	0.18	76.53
T_7 - Spraying of salicylic acid (100 ppm)	0.56	0.21	51.03
T_8 - Spraying of water	0.52	0.18	53.03
T_9 - No stress treatment	0.76	0.20	97.80
SEm (±)	-	0.07	4.95
CD (0.05)	-	NS	10.430

DAP : Days After Planting

* not statistically analysed

spraying of sorghum water extract (57.70 cm^3) which were on a par each other. Spraying of moringa leaf extract-3 per cent (T_6) however did not vary from spraying of humic acid-1 per cent (T_4), yeast extract- 2 per cent (T_5) or citric acid-0.2 per cent (T_2) which produced the root volume of 71.60, 64.60 and 63.00 cm^3 respectively which were on a par each other. The no stress treatment however resulted in significantly higher root volume at final harvest compared to the application of organic preparations and biostimulants.

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Fruits plant^{-1}

The result on the influence of spraying of organic preparations and biostimulants on number of fruits plant^{-1} is presented in Table 5.

Different treatments could not influence the number of fruits plant $^{-1}$ in container grown okra.

4.2.2 Fruit weight

The result on the effect of spraying of organic preparations and biostimulants on average fruit weight is given in Table 5.

Spraying of sorghum water extract-5 per cent (T_3) recorded the highest fruit weight (19.20 g fruit^{-1}) among the organic preparations and biostimulants which was statistically on a par with all other treatments except no stress treatment (T_9) which produced significantly higher average fruit weight (25.34 g fruit^{-1}) compared to the spraying of organic preparations, biostimulants and water.

4.2.3 Length of fruit

The result on the effect of spraying of organic preparations and biostimulants on length of fruit is given in Table 5.

The treatments did not significantly influence the length of fruit in container grown okra.

4.2.4 Number of pickings

The result on the effect of spraying of organic preparations and biostimulants on number of pickings is given in Table 5.

Different treatments could not significantly affect the number of pickings in okra.

4.2.5 Fruit yield

The result on the effect of spraying of organic preparations and biostimulants on fruit yield $plant^{-1}$ is given in Table 5.

Spraying of citric acid-0.2 per cent (T_2) or humic acid-1 per cent (T_4) produced significantly higher fruit yield (0.25 kg $plant^{-1}$) than with spraying of sorghum water extract-5 per cent (T_3), moringa leaf extract-3 per cent (T_6), salicylic acid-100 ppm (T_7) or water (T_8) which recorded a fruit yield of 0.19, 0.19, 0.20 and 0.20 kg $plant^{-1}$ respectively which did not significantly vary each other. The treatments T_2 and T_4 were however on a par with treatments T_1 (spraying of fermented cow dung water mixture-10 per cent) and T_5 (spraying of yeast extract-2 per cent) each of which produced a fruit yield of 0.22 kg $plant^{-1}$. The no stress treatment however recorded significantly higher fruit yield (0.31 kg $plant^{-1}$) compared to other treatments.

4.3 INCIDENCE OF PESTS AND DISEASES

Jassid infestation was noticed on two plants and since infestation was very mild scoring was not done. No disease incidence was noticed in the crop.

4.4 PLANT AND FRUIT ANALYSIS

4.4.1 Crude protein content

Table 5. Effect of organic preparations and biostimulants on fruits plant^{-1}, fruit weight, length of fruit, number of pickings and fruit yield in okra

Treatments	Fruits Plant^{-1} (nos)	Fruit weight (g fruit^{-1})	Length of fruit (cm)	No of pickings	Fruit yield (kg plant^{-1})
T_1 - Spraying of fermented cow dung water mixture (10%)	12.40	16.56	12.29	6.66	0.22
T_2 - Spraying of citric acid (0.2 %)	14.00	18.85	13.19	7.67	0.25
T_3 - Spraying of sorghum water extract (5%)	12.43	19.20	12.41	5.81	0.19
T_4 - Spraying of humic acid (1%)	12.00	19.08	13.50	6.23	0.25
T_5 - Spraying of yeast extract (2%)	11.83	19.16	13.43	6.80	0.22
T_6 - Spraying of moringa leaf Extract (3%)	10.33	17.19	13.33	5.90	0.19
T_7 - Spraying of salicylic acid (100 ppm)	11.26	16.61	12.31	6.23	0.20
T_8 - Spraying of water	10.33	16.47	12.81	5.50	0.20
T_9 - No stress treatment	15.00	25.34	15.16	9.26	0.31
SEm (±)	1.41	1.74	0.84	1.30	0.06
CD (0.05)	NS	3.65	NS	NS	0.043

The result on the effect of spraying of organic preparations and biostimulants on crude protein content of fruit is presented in Table 6.

Different treatments could not significantly influence the crude protein content of okra fruits.

4.4.2 Crude fibre content

The result on the effect of spraying of organic preparations and biostimulants on crude fibre content in fruit is presented in Table 6.

Among the different organic preparations and biostimulants, spraying of sorghum water extract-5 per cent (T_3) recorded the highest crude fibre content (7.22 per cent) which was significantly higher than the content recorded with spraying of 10 per cent fermented cow dung water mixture-T_1 (6.08 per cent), 3 per cent moringa leaf extract-T_6 (6.32 per cent), no stress treatment-T_9 (6.65 per cent) or spraying of 100 ppm salicylic acid-T_7 (6.76 per cent). The T_3 treatment was however on a par with spraying of 0.2 per cent citric acid (T_2), 1 per cent humic acid (T_4), 2 per cent yeast extract (T_5) and water (T_8) which recorded a crude fibre content of 6.96, 7.15, 7.09 and 6.87 per cent respectively. The T_2 treatment (spraying of citric acid) also did not statistically vary from spraying of salicylic acid (T_7), spraying of water (T_8) and no stress treatment (T_9) which recorded a crude fibre content of 6.76, 6.87 and 6.65 per cent respectively. The crude fibre content was lowest (6.08 per cent) with spraying of 10 per cent fermented cow dung water mixture (T_1) which was on a par with spraying of 3 per cent moringa leaf extract (T_6) which recorded a crude fibre content of 6.32 per cent. Spraying of salicylic acid-100 ppm (T_7) did not differ from no stress treatment (T_9) with respect to the crude fibre content of fruit and the T_7 and T_9 treatments produced a crude fibre content of 6.76 and 6.65 per cent respectively.

Table 6. Effect of organic preparations and biostimulants on crude protein, crude fibre and ascorbic acid content of fruits in okra

Treatments	Crude protein Content (per cent)	Crude fibre Content (per cent)	Ascorbic acid content (mg100 g⁻¹)
T_1 - Spraying of fermented cow dung water mixture (10%)	18.77	6.08	19.83
T_2 - Spraying of citric acid (0.2%)	17.60	6.96	17.75
T_3 - Spraying of sorghum water extract (5%)	22.28	7.22	15.03
T_4 - Spraying of humic acid (1%)	21.23	7.15	15.60
T_5 - Spraying of yeast extract (2%)	22.21	7.09	20.44
T_6 - Spraying of moringa leaf extract (3%)	20.46	6.32	20.32
T_7 - Spraying of salicylic acid (100 ppm)	21.22	6.76	19.80
T_8 - Spraying of water	19.92	6.87	16.37
T_9 - No stress treatment	22.27	6.65	18.43
SEm (±)	1.53	0.20	1.52
CD (0.05)	NS	0.419	3.180

4.4.3 Ascorbic acid content

The result on the effect of spraying of organic preparations and biostimulants on ascorbic acid content of fruit is presented in Table 6

Highest ascorbic acid content of 20.44 mg 100 g^{-1} was recorded with spraying of 2 per cent yeast extract (T_5) which was significantly higher than the ascorbic acid content recorded with spraying of water (T_8), 1 per cent humic acid (T_4) and 5 per cent sorghum water extract (T_3) producing 16.37, 15.60 and 15.03 mg 100 g^{-1} ascorbic acid respectively in fruit. The T_5 treatment was however on a par with T_6 (spraying of 3 per cent moringa leaf extract), T_1 (spraying of 10 per cent fermented cow dung water mixture), T_7 (spraying of 100 ppm salicylic acid), T_9 (no stress treatment) and T_2 (spraying of 0.2 per cent citric acid) which produced an ascorbic acid content of 20.32, 19.83, 19.80, 18.43 and 17.75 mg 100 g^{-1} respectively. The T_2 treatment however was on a par with T_3, T_4 and T_8 which produced an ascorbic content of 15.03, 15.60, and 16.37 mg 100 g^{-1} respectively. Ascorbic acid content in fruit was lowest (15.03 mg 100 g^{-1}) with spraying of 5 per cent sorghum water extract (T_3) which did not differ from T_4 (15.60 mg 100 g^{-1}) and T_8 (16.37 mg 100 g^{-1}).

4.4.4 Nitrogen content

4.4.4.1 Nitrogen content in plant

The result on the effect of spraying of organic preparations and biostimulants on nitrogen content in plant is presented in Table 7

Nitrogen content in plant was the highest (3.39 per cent) with the spraying of salicylic acid-100 ppm (T_7) which was significantly higher than the nitrogen content recorded with spraying of 10 per cent fermented cow dung water mixture-T_1 (2.59 per cent), 5 per cent sorghum water extract-T_3 (2.85 per cent), water-T_8 (2.83 per cent), 1 per cent humic acid-T_4 (3.04 per cent), or 3 per cent moringa leaf extract-T_6 (3.08 per cent). The T_7 treatment however was on a par with T_2 (spraying of 0.2 per cent citric acid), T_5 (spraying of 2 per cent yeast extract) and T_9 (no stress treatment) which

Table 7. Effect of organic preparations and biostimulants on total N, P and K content in okra, per cent

Treatments	N		P		K	
	Plant	Fruit	Plant	Fruit	Plant	Fruit
T_1 - Spraying of fermented cow Dung water mixture (10%)	2.59	3.03	0.34	0.35	2.36	2.63
T_2 - Spraying of citric acid (0.2 %)	3.19	2.81	0.44	0.30	2.20	2.13
T_3 - Spraying of sorghum water extract (5%)	2.85	3.56	0.38	0.33	2.33	2.41
T_4 - Spraying of humic acid (1%)	3.04	3.39	0.40	0.34	1.90	2.35
T_5 - Spraying of yeast extract (2%)	3.09	3.55	0.46	0.23	2.04	2.17
T_6 - Spraying of moringa leaf extract (3%)	3.08	3.27	0.41	0.26	2.02	1.90
T_7 - Spraying of salicylic acid (100 ppm)	3.39	3.39	0.35	0.31	1.94	2.20
T_8 - Spraying of water	2.83	3.18	0.31	0.30	1.99	2.24
T_9 - No stress treatment	3.27	3.56	0.33	0.29	2.48	1.61
SEm (±)	0.157	0.23	0.02	0.04	0.13	0.21
CD (0.05)	0.307	NS	NS	NS	0.270	0.43

produced a nitrogen content of 3.19, 3.09 and 3.27 per cent respectively in plant. Nitrogen content in okra plant was lowest with T_1 (2.59 per cent) which did not statistically vary from the N content recorded with T_3 (2.85 per cent) and T_8 (2.83 per cent).

4.4.4.2 Nitrogen content in fruit

The result on the effect of spraying of organic preparations and biostimulants on nitrogen content in fruit is presented in Table 7.

Different treatments could not significantly influence the nitrogen content of okra fruit.

4.4.5 Phosphorus content

4.4.5.1 Phosphorus content in plant

The result on the effect of spraying of organic preparations and biostimulants on phosphorus content in plant is presented in Table 7.

Different treatments had no significant effect on phosphorus content in plant.

4.4.5.2 Phosphorus content in fruit

The result on the effect of spraying of organic preparations and biostimulants on phosphorus content in fruit is presented in Table 7.

Different treatments did not significantly influence the phosphorus content of okra fruit.

4.4.6 Potassium content

4.4.6.1 Potassium content in plant

The result on the effect of spraying of organic preparations and biostimulants on potassium content in plant is presented in Table 7

Among different organic preparations and biostimulants, highest potassium content in plant (2.36 per cent) was produced by spraying of fermented cow dung water mixture-10 per cent (T_1) which was significantly superior to spraying of 1 per cent humic acid (1.90 per cent), 100 ppm salicylic acid (1.94 per cent), water (1.99 per cent), 3 per cent moringa leaf extract (2.02 per cent) and 2 per cent yeast extract (2.04 per cent). The T_1 treatment however was on a par with no stress treatment (T_9), spraying of 5 per cent sorghum water extract (T_3) or spraying of 0.2 per cent citric acid (T_2) which recorded a potassium content of 2.48, 2.33 and 2.20 per cent respectively in plant.

4.4.6.2 Potassium content in fruit

The result on the effect of spraying of organic preparations and biostimulants on potassium content in fruit is presented in Table 7.

Highest potassium content in fruit (2.63 per cent) was recorded by spraying of fermented cow dung water mixture-10 per cent (T_1) which was significantly higher than potassium content recorded with no stress treatment (1.61 per cent), 3 per cent moringa leaf extract (1.90 per cent), 0.2 per cent citric acid (2.13 per cent) and 2 per cent yeast extract (2.17 per cent). The treatment T_1 did not statistically differ from spraying of salicylic acid-100 ppm (T_7), water (T_8), humic acid-1 per cent (T_4) or sorghum water extract-5 per cent (T_3) which produced a potassium content of 2.20, 2.24, 2.35 and 2.41 per cent respectively in fruit.

4.5 DRY MATTER PRODUCTION AND UPTAKE

4.5.1 Total dry matter production

The result on the effect of spraying of organic preparations and biostimulants on total dry matter production is shown in Table 8.

Among different organic preparations and biostimulants, highest total dry matter production was observed (58.85 g $plant^{-1}$) with spraying of citric acid-0.2 per cent (T_2) which was significantly higher than the dry matter produced with spraying of humic acid-1 per cent (T_4), moringa leaf extract-3 per cent (T_6) and water (T_8) which were 45.24, 46.04 and 44.71 g plant^{-1} respectively. The T_2 treatment was however on a par with T_1 (spraying of cow dung water extract-10 per cent), T_3 (spraying of sorghum water extract-5 per cent), T_5 (spraying of yeast extract-2 per cent) and T_7 (spraying of salicylic acid-100 ppm) which produced a dry matter yield of 52.83, 55.40, 49.73, and 55.62 g plant^{-1} respectively. The no stress treatment however out yielded all other treatments, recording the highest dry matter production of 85.71 g plant^{-1}.

4.5.2 Uptake of nitrogen, phosphorus and potassium

4.5.2.1 Uptake of nitrogen

The result on the effect of spraying of organic preparations and biostimulants on uptake of nitrogen is indicated in Table 8.

Nitrogen uptake was the highest (1.55 g plant^{-1}) with spraying of moringa leaf extract-3 per cent (T_6) which was significantly higher than the uptake recorded with spraying water (1.07 g plant^{-1}), sorghum water extract-5 per cent (1.15 g plant^{-1}) and fermented cow dung water mixture -10 per cent (1.21 g plant^{-1}). The T_6 treatment was however on a par with spraying of yeast extract-2 per cent (1.30 g plant^{-1}), humic acid-1 per cent (1.40 g plant^{-1}), citric acid-0.2 per cent (1.44 g plant^{-1}) and salicylic acid-100 ppm (1.46 g plant^{-1}).

The uptake of nitrogen was significantly higher (2.59 g plant^{-1}) with no stress treatment (T_9) compared to the application of organic preparations and biostimulants

4.5.2.2 Uptake of phosphorus

The result on the effect of spraying of organic preparations and biostimulants on uptake of phosphorus is indicated in Table 8.

Table 8. Effect of organic preparations and biostimulants on total dry matter production, uptake of nitrogen, phosphorus and potassium in okra, g plant^{-1}

Treatments	Total dry matter production	Uptake		
		Nitrogen	Phosphorus	Potassium
T_1 - Spraying of fermented cow dung water mixture (10%)	52.83	1.21	0.12	1.05
T_2 - Spraying of citric acid (0.2 %)	58.85	1.44	0.14	0.99
T_3 - Spraying of sorghum water extract (5%)	55.40	1.15	0.11	0.83
T_4 - Spraying of humic acid (1%)	45.24	1.40	0.14	0.93
T_5 - Spraying of yeast extract (2%)	49.73	1.30	0.09	0.82
T_6 - Spraying of moringa leaf extract (3%)	46.04	1.55	0.14	0.89
T_7 - Spraying of salicylic acid (100 ppm)	55.62	1.46	0.14	0.96
T_8 - Spraying of water	44.71	1.07	0.10	0.76
T_9 - No stress treatment	85.71	2.59	0.22	1.55
SEm (±)	2.96	0.12	0.03	0.16
CD (0.05)	10.868	0.285	0.064	0.363

Uptake of phosphorus was the highest (0.14 g plant^{-1}) with spraying of citric acid-0.2 per cent (T_2), humic acid-1 per cent (T_4), moringa leaf extract-3 per cent (T_6) or salicylic acid-100 ppm (T_7) which statistically did not differ from all other treatments except the no stress treatment.

The uptake of phosphorus was however significantly higher (0.22 g plant^{-1}) with no stress treatment (T_9) than the uptake recorded with spraying of organic preparations and biostimulants.

4.5.2.3 Uptake of potassium

The result on the effect of spraying of organic preparations and biostimulants on uptake of potassium is presented in Table 8.

The potassium uptake was the highest (1.05 g plant^{-1}) with the spraying of cow dung water mixture-10 per cent (T_1) and the lowest (0.76 g plant^{-1}) with spraying of water (T_8) which were on a par with all other treatments except the no stress treatment.

The uptake of potassium was however significantly higher (1.55 g plant^{-1}) with no stress treatment (T_9) compared to the uptake recorded with spraying of organic preparations and biostimulants.

4.6 WATER USE STUDIES

4.6.1 Water use efficiency

Effect of organic preparations and biostimulants on water use efficiency in container grown okra is presented in Table 9.

Among different organic preparations and biostimulants, the water use efficiency was the highest (13.17 g L^{-1}) with spraying of 0.2 per cent citric acid (T_2) which was significantly higher than the water use efficiency recorded with spraying of 3 per cent moringa leaf extract (10.10 g L^{-1}), water (10.12 g L^{-1}), sorghum water extract-5 per cent (10.27 g L^{-1}) and salicylic acid-100 ppm (10.47 g L^{-1}). The T_2

Table 9. Effect of biostimulants and organic preparations on water requirement, water use efficiency and water productivity of okra

Treatment	Water requirement (L plant^{-1})	Water use efficiency (g L^{-1})	Water productivity (g L^{-1})
T_1 - Spraying of fermented cow dung water mixture (10%)	19.06	11.82	2.77
T_2 - Spraying of citric acid (0.2%)	19.04	13.17	3.08
T_3 - Spraying of sorghum water extract (5%)	19.19	10.27	2.35
T_4 - Spraying of humic acid (1%)	19.18	12.69	2.88
T_5 - Spraying of yeast extract (2%)	19.06	11.47	2.60
T_6 - Spraying of moringa leaf extract (3%)	19.13	10.10	2.90
T_7 - Spraying of salicylic acid (100 ppm)	19.09	10.47	2.99
T_8 - Spraying of water	19.26	10.12	2.32
T_9 - No stress treatment	22.78	13.19	3.60
SEm (±)	0.05	1.09	0.27
CD (0.05)	0.128	2.280	0.560

treatment was however on a par with T_1 (spraying of fermented cow dung water mixture-10 per cent), T_4 (spraying of humic acid-1 per cent), T_5 (spraying of yeast extract-2 per cent) and T_9 (no stress treatment) which recorded the water use efficiency values 11.82, 12.69, 11.47 and 13.19 g L^{-1} respectively.

4.6.2 Irrigation requirement

Effect of organic preparations and biostimulants on irrigation requirement in container grown okra is presented in Table 9.

The irrigation requirement of container grown okra was the lowest (19.04 L $plant^{-1}$) with spraying of 0.2 per cent citric acid (T_2) which was significantly lower than the irrigation requirement resulted from spraying of 1 per cent humic acid (19.18 L $plant^{-1}$), 5 per cent sorghum water extract (19.19 L $plant^{-1}$), spraying of water (19.26 L $plant^{-1}$) and no stress treatment (22.78 L $plant^{-1}$). The T_2 treatment however was on a par with T_1 (spraying of fermented cow dung water mixture-10 per cent), T_5 (spraying of yeast extract-2 per cent), T_6 (spraying of moringa leaf extract-3 per cent) and T_7 (spraying of salicylic acid-100 ppm) which recorded an irrigation requirement of 19.06, 19.06, 19.13 and 19.09 L $plant^{-1}$ respectively. Irrigation requirement was however the highest for no stress treatment (22.78 L $plant^{-1}$).

4.6.3 Water productivity

Effect of organic preparations and biostimulants on water productivity in container grown okra is presented in Table 9.

Among different organic preparations and biostimulants tried, spraying of 0.2 per cent citric acid (T_2) recorded the highest water productivity (3.08 g L^{-1}) which was significantly higher than the water productivity produced by spraying of sorghum water extract-5 per cent (2.35 g L^{-1}) and spraying of water (2.32 g L^{-1}). The T_2 treatment was however statistically on a par with all other treatments including the no stress treatment.

4.6.4 Irrigation interval

Effect of organic preparations and biostimulants on irrigation interval in container grown okra is given in Table 10. The mean values of irrigation interval with respect to different treatments are presented.

Irrigation interval was the highest (5.5 days) with spraying of 0.2 per cent citric acid which was followed by spraying of fermented cow dung water mixture-10 per cent or salicylic acid-100 ppm (5.2 days), spraying of moringa leaf extract-3 per cent (4.8 days), spraying of humic acid- per cent (4.6 days), spraying of yeast extract-2 per cent (4.4 days) and sorghum water extract-5 per cent (4.1 days). Irrigation interval was the lowest (3.2 days) with spraying of water (T_8) when compared to the application of organic preparations and biostimulants.

4.7 PHYSIOLOGICAL STUDIES

4.7.1 Chlorophyll content

Effect of organic preparations and biostimulants on chlorophyll content of leaf tissue is presented in Table 11.

Spraying of salicylic acid-100 ppm (T_7) recorded significantly higher chlorophyll content (1.58 mg g^{-1}) compared to the spraying of fermented cow dung water mixture-10 per cent (0.92 mg g^{-1}), sorghum water extract-5 per cent (1.02 mg g^{-1}), humic acid-1 per cent (1.09 mg g^{-1}), moringa leaf extract-3 per cent (1.09 mg g^{-1}), water (1.26 mg g^{-1}) and yeast extract-2 per cent (1.27 mg g^{-1}). The T_7 treatment was however on a par with spraying of citric acid-0.2 per cent (T_2) and no stress treatment (T_9) each recording a chlorophyll content of 1.30 mg g^{-1}.

Table 10. Effect of organic preparations and biostimulants on irrigation interval of container grown okra, days

Treatments	Irrigation Interval*
T_1 - Spraying of fermented cow dung water mixture (10%)	5.2
T_2 - Spraying of citric acid (0.2 %).	5.5
T_3 - Spraying of sorghum water extract (5%)	4.1
T_4 - Spraying of humic acid (1 %)	4.6
T_5 - Spraying of yeast extract (2%)	4.4
T_6 - Spraying of moringa leaf extract (3 %)	4.8
T_7 - Spraying of salicylic acid (100ppm)	5.2
T_8 - Spraying of water	3.2
T_9 - No stress treatment	-

* not statistically analysed

Table 11. Effect of organic preparations and biostimulants on chlorophyll content, stomatal count and proline content in okra at 45 DAP

Treatments	Chlorophyll content (mg g^{-1})	Stomatal count (no cm^{-2})	Proline content (µmoles g^{-1})
T_1 - Spraying of fermented cow dung water mixture (10%)	0.92	665.84	11.07
T_2 - Spraying of citric acid (0.2%)	1.30	619.07	7.49
T_3 - Spraying of sorghum water extract (5%)	1.02	743.33	7.14
T_4 - Spraying of humic acid (1%)	1.09	605.25	11.07
T_5 - Spraying of yeast extract (2%)	1.27	526.92	6.22
T_6 - Spraying of moringa leaf extract (3%)	1.09	641.51	12.41
T_7 - Spraying of salicylic acid (100 ppm)	1.58	716.92	7.15
T_8 - Spraying of water	1.26	593.76	8.64
T_9 - No stress treatment	1.30	741.52	4.04
SEm (±)	0.12	93.90	4.41
CD (0.05)	0.284	NS	NS

4.7.2 Stomatal count

Effect of organic preparations and biostimulants on stomatal count of okra is presented in Table 11.

Different treatments did not influence the stomatal count of okra.

4.7.3 Proline content

Effect of organic preparations and biostimulants on proline content of okra is presented in Table 11.

The proline content was not influenced by the application of organic preparations and biostimulants in okra.

4.7.4 Relative leaf water content

Effect of organic preparations and biostimulants on relative leaf water content of okra at different stages is presented in Table 12.

The relative leaf water content 1 week after I^{st} spraying (at 20 DAP) was significantly influenced by the treatments. Spraying of sorghum water extract-5 per cent (T_3) recorded highest relative leaf water content at this stage (93.46 per cent) which was significantly higher than the value recorded with spraying of water (78.16 per cent) and yeast extract-2 per cent (80.53 per cent). The T_3 treatment was however on a par with all other treatments except T_8 and T_5.

The relative leaf water content 1 week after 2^{nd} spraying (at 40 DAP) and 3^{rd} spraying (at 60 DAP) were not significantly influenced by the treatments.

The treatments however significantly influenced the relative leaf water content recorded at 1 week after 4^{th} spraying (at 80 DAP) and highest value (89.33 per cent) was recorded with T_6 (spraying of moringa leaf extract-3 per cent) which was significantly higher compared to the leaf water content recorded with spraying of water-T_8 (80.13 per cent) and yeast extract -T_5 (83.63 per cent). The T_6 treatment

Table 12. Effect of organic preparations and biostimulants on relative leaf water content in okra, per cent

Treatments	I week after I[st] spraying	1 week after 2[nd] spraying	1 week after 3[rd] spraying	1 week after 4[th] spraying
T_1 - Spraying of fermented cow dung water mixture (10%)	90.80	89.80	87.20	87.06
T_2 - Spraying of citric acid (0.2%).	91.86	89.56	91.60	88.76
T_3 - Spraying of sorghum water extract (5%)	93.46	89.76	80.46	85.23
T_4 - Spraying of humic acid (1%)	85.66	89.80	85.00	87.53
T_5 - Spraying of yeast extract (2%)	80.53	88.53	86.23	83.63
T_6 - Spraying of moringa leaf extract (3%)	87.10	89.50	84.26	89.33
T_7 - Spraying of salicylic acid (100 ppm)	91.40	83.06	89.10	86.73
T_8 - Spraying of water	78.16	90.66	84.40	80.13
T_9 - No stress treatment	92.83	91.50	92.60	93.29
SEm (±)	4.55	2.49	4.08	2.18
CD (0.05)	9.554	NS	NS	4.580

was however on a par with all other treatments except T_8 and T_5 with respect to relative leaf water content at this stage.

4.8 POTTING MIXTURE ANALYSIS

4.8.1 pH

Effect of organic preparations and biostimulants on pH of the potting mixture after the experiment is presented in Table 13.

Different treatments did not significantly influence the pH of the potting mixture after the experiment. There was a general decline in pH compared to the initial value.

4.8.2. Electrical conductivity

Effect of organic preparations and biostimulants on electrical conductivity of the potting mixture after the experiment is presented in Table 13.

The electrical conductivity of the potting mixture after the experiment was not significantly influenced by the application of biostimulants and organic preparations.

4.8.3 Organic carbon content

Effect of organic preparations and biostimulants on organic carbon content of the potting mixture after the experiment is presented in Table 13.

Organic carbon content of the potting mixture after the experiment was the highest (1.18 per cent) with the spraying of 1 per cent humic acid (T_4) which was significantly higher than the content recorded with the spraying of salicylic acid-100 ppm (0.79 per cent), yeast extract-2 per cent (0.84 per cent), moringa leaf extract-3 per cent (0.87 per cent), and no stress treatment (0.91 per cent). The T_4 treatment was however on a par with spraying of fermented cow dung water mixture-10 per cent (T_1), sorghum water extract-5 per cent (T_3), spraying of water (T_8) and citric acid-

Table 13. Effect of organic preparations and biostimulants on pH, electrical conductivity and organic carbon content of potting mixture after the experiment in okra

Treatments	pH	Electrical conductivity (dSm^{-1})	Organic carbon (per cent)
T_1 - Spraying of fermented cow dung water mixture(10%)	4.58	0.38	1.11
T_2 - Spraying of citric acid (0.2%).	4.49	0.32	0.98
T_3 - Spraying of sorghum water extract (5%)	4.57	0.33	1.06
T_4 - Spraying of humic acid (1%)	4.85	0.31	1.18
T_5 - Spraying of yeast extract (2%)	4.83	0.41	0.84
T_6 - Spraying of moringa leaf extract (3%)	4.76	0.24	0.87
T_7 - Spraying of salicylic acid (100 ppm)	4.81	0.27	0.79
T_8 - Spraying of water	5.03	0.31	0.89
T_9 - No stress treatment	4.81	0.22	0.91
SEm (±)	0.25	0.09	0.11
CD (0.05)	NS	NS	0.249
Initial status	6.21	0.213	0.80

0.2 per cent (T_2) which recorded the organic carbon content of 1.11, 1.06, 1.02 and 0.98 per cent respectively.

4.8.4 Available nitrogen, phosphorus and potassium content

Effect of organic preparations and biostimulants on available nitrogen, phosphorus and potassium content of the potting mixture after the experiment is presented in Table 14.

The available nitrogen, phosphorus or potassium content of the potting mixture after the experiment was not significantly influenced by the treatments.

4.9 ECONOMICS OF CULTIVATION

4.9.1 Cost of cultivation

Effect of organic preparations and biostimulants on cost of cultivation is presented in Table 15.

Among the biostimulants the lowest cost of cultivation (₹8.4 $sack^{-1}$) was recorded with spraying of sorghum water extract-5 per cent (T_3) and spraying of moringa leaf extract-3 per cent (T_6) and the highest cost of cultivation (₹14.4 $sack^{-1}$) was recorded with spraying of 1 per cent humic acid (T_4) followed by spraying of yeast extract 2 per cent (₹13.1 $sack^{-1}$).

4.9.2 Net returns

Effect of organic preparations and biostimulants on net returns is presented in Table 15.

Among different organic preparations and biostimulants, highest net returns (₹ 3.15 $sack^{-1}$) was obtained by spraying of citric acid-0.2 per cent (T_2) which was significantly higher than the net returns recorded with spraying of humic acid-1 per cent (₹ -2.22 $sack^{-1}$), yeast extract-2 per cent (₹ -2.16) and fermented cow dung water mixture-10 per cent (₹ 0.61$sack^{-1}$). The T_2 treatment was also on a par with spraying

Table 14. Effect of organic preparations and biostimulants on available N, P and K content of potting mixture after the experiment, per cent

Treatments	Available N	Available P	Available K
T_1 - Spraying of fermented cow dung water mixture (10%)	0.015	0.004	0.005
T_2 - Spraying of citric acid (0.2%)	0.018	0.005	0.005
T_3 - Spraying of sorghum water extract (5%)	0.015	0.006	0.003
T_4 - Spraying of humic acid (1%)	0.012	0.006	0.005
T_5 - Spraying of yeast extract (2%)	0.013	0.007	0.004
T_6 - Spraying of moringa leaf extract (3%)	0.019	0.005	0.005
T_7 - Spraying of salicylic acid (100 ppm)	0.012	0.006	0.005
T_8 - Spraying of water	0.017	0.006	0.004
T_9 - No stress treatment	0.010	0.005	0.003
SEm (±)	1.91	0.001	0.001
CD (0.05)	NS	NS	NS
Initial status	0.015	0.004	0.015

of moringa leaf extract-3 per cent(T_6), water (T_8), sorghum water extract-5 per cent (T_3) and salicylic acid-100 ppm (T_7) which recorded the net returns 1.26, 1.33, 1.47, and 1.50 ₹ sack^{-1} respectively.

The no stress treatment however recorded the highest net returns (₹6.62 sack^{-1}) compared to the organic preparations and biostimulants application.

4.9.3 Benefit : cost ratio

Effect of organic preparations and biostimulants on benefit: cost ratio is presented in Table 15.

Highest of benefit: cost ratio of 1.33 was recorded with the spraying of citric acid-0.2 per cent (T_2) which was significantly higher than the ratio recorded with all other treatments among the organic preparations and biostimulants. The no stress treatment (T_9) however resulted in the highest benefit: cost ratio (1.78) when compared to the application of organic preparations and biostimulants.

Results of the study indicated the influence of organic preparations and biostimulants on moisture stress tolerance, yield attributes and yield, quality and uptake, water use and economics of cultivation of container grown okra in urban home stead condition.

Table 15. Effect of organic preparations and biostimulants on cost of cultivation, net returns and benefit: cost ratio of cultivation of container grown okra

Treatments	Cost of cultivation (₹ sack $^{-1}$)*	Net returns (₹ sack $^{-1}$)	Benefit: cost ratio
T_1 - Spraying of fermented cow dung water mixture (10%)	10.65	0.61	1.05
T_2 - Spraying of citric acid (0.2%)	9.4	3.15	1.33
T_3 - Spraying of sorghum water extrac(5%)	8.4	1.47	1.17
T_4 - Spraying of humic acid (1%)	14.4	-2.22	0.84
T_5 - Spraying of yeast extract (2%)	13.1	-2.16	0.83
T_6 - Spraying of moringa leaf extract (3%)	8.4	1.26	1.15
T_7 - Spraying of salicylic acid (100 ppm)	8.5	1.50	1.17
T_8 - Spraying of water	8.4	1.33	1.15
T_9 - No stress treatment	8.4	6.62	1.78
SEm (±)	-	1.06	0.02
CD (0.05)	-	2.227	0.244

* not statistically analysed

Discussion

5. DISCUSSION

The study entitled "Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench) was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during 2016 and 2017 with an objective to find out the effect of organic preparations and biostimulants on inducing moisture stress tolerance and to assess their impact on growth, yield and irrigation requirement of okra in urban homesteads. The results of the experiment are discussed in this chapter.

5.1 GROWTH AND GROWTH ATTRIBUTES

Spraying of organic preparations and biostimulants significantly influenced the plant height of okra only at 3 MAP. Spraying of moringa leaf extract (T_6) produced taller plants compared to other organic preparations and biostimulants, which was significantly higher than the plant height produced with spraying of 5 per cent sorghum water extract or 1 per cent humic acid (Fig 3). The spraying of moringa leaf extract was also on a par with no stress treatment with respect to plant height at 3 MAP. The spraying of moringa leaf extract also produced highest LAI at 45 DAS. Moringa leaves are extremely rich in vitamins, essential minerals such as K, Ca and Fe, antioxidants such as ascorbate and phenolics, proteins and growth hormone zeatin and foliar application of moringa leaf extract was found to accelerate the growth of tomato, peanut, corn and wheat at early vegetative growth stage (Foidle *et al.*, 2001). The plant growth hormone zeatin present in moringa leaf extract could have enhanced the crop growth and productivity under drought stress. Similar results were reported by Mishra *et al.* (2013) in pea and Hanafy (2017) in soybean where the foliar application of moringa leaf extract improved the plant growth parameters including shoot length.

Root volume at the final harvest was influenced significantly by spraying of organic preparations and biostimulants and the highest root volume was observed

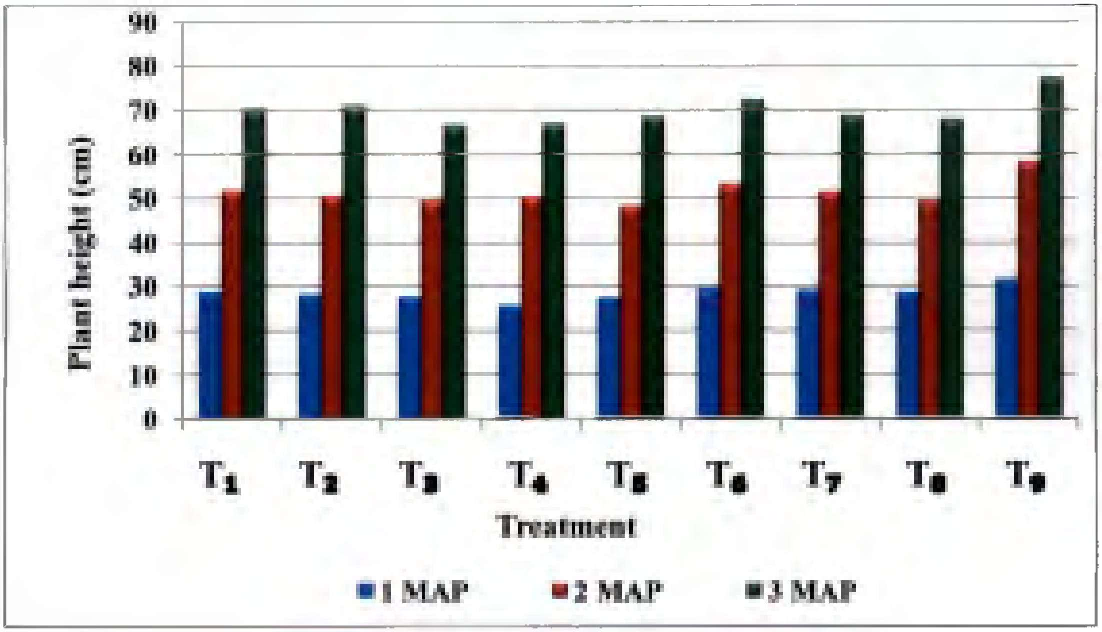

Fig. 3. Effect of organic preparations and biostimulants on plant height of okra, cm

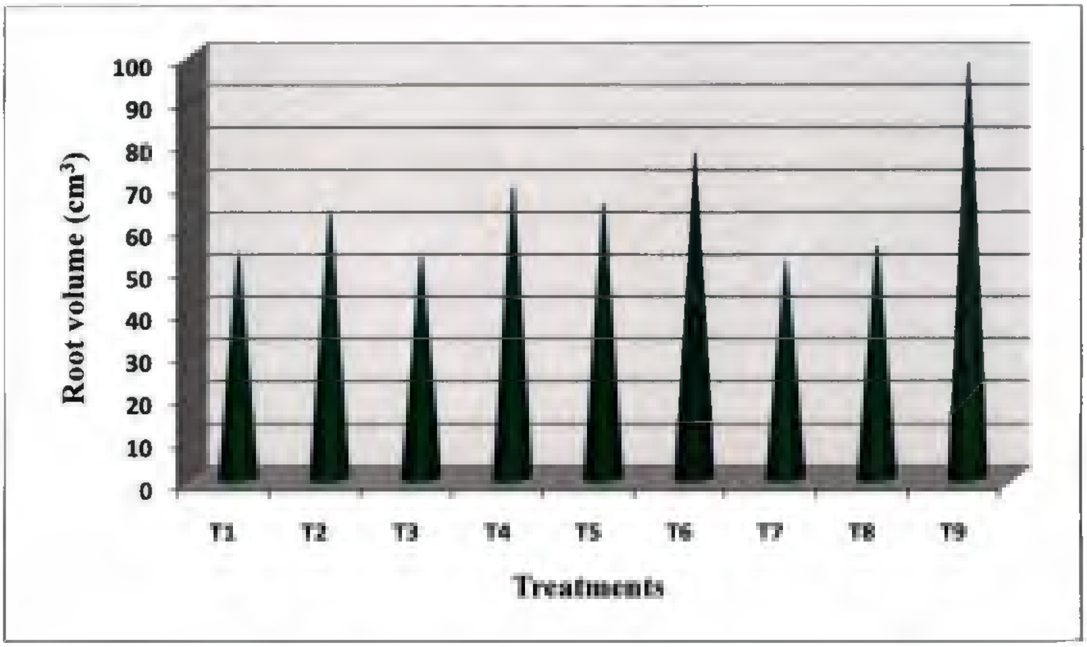

Fig 4. Effect of organic preparations and biostimulants on root volume of okra at final harvest, cm^3

with spraying of moringa leaf extract (T_6) as shown in Fig 4. The increase in root volume might be due to the stimulatory effect of zeatin which is a plant growth hormone belonging to cytokinin present in the moringa leaf extract (Foidle *et al.*, 2001). Early workers like Fuglie (1999) had reported the favourable influence of foliar application of moringa leaf extract on number of roots in several crops. This is also in agreement with the findings of Culver *et al.* (2012) wherein there was an increase in root dry matter of tomato by spraying of moringa leaf extract.

5.2 YIELD ATTRIBUTES AND YIELD

A perusal of the data shown in Table 5 revealed that organic preparations and biostimulants had a positive influence on yield characters like fruit weight and fruit yield plant^{-1}.

Among the organic preparations and biostimulants, spraying of sorghum water extract- 5 per cent (T_3) recorded the highest fruit weight (Fig 5) though it did not statistically vary from other organic preparations and biostimulants. The no stress treatment (T_9) however produced significantly higher average fruit weight compared to the spraying of organic preparations, biostimulants or water. Alsaadawi *et al.* (2007) identified several phenolic acids in sorghum extract, some of which have antioxidant properties and thus can modulate the crop growth and productivity under drought stress. The presence of such growth promoting substances would have promoted the average fruit weight which is an yield attribute in okra. Many other workers have also indicated the growth promoting effect of sorghum water extract under drought stress. The study conducted by Iqbal (2014) indicated that the sorghum water when applied in small quantity as foliar spray increased the growth and yield of a number of crops. Lower concentrations of sorghum water extract (*sorgaab*) improving the yield parameters of maize was recently pointed out by Maqbool and Sadiq (2017).

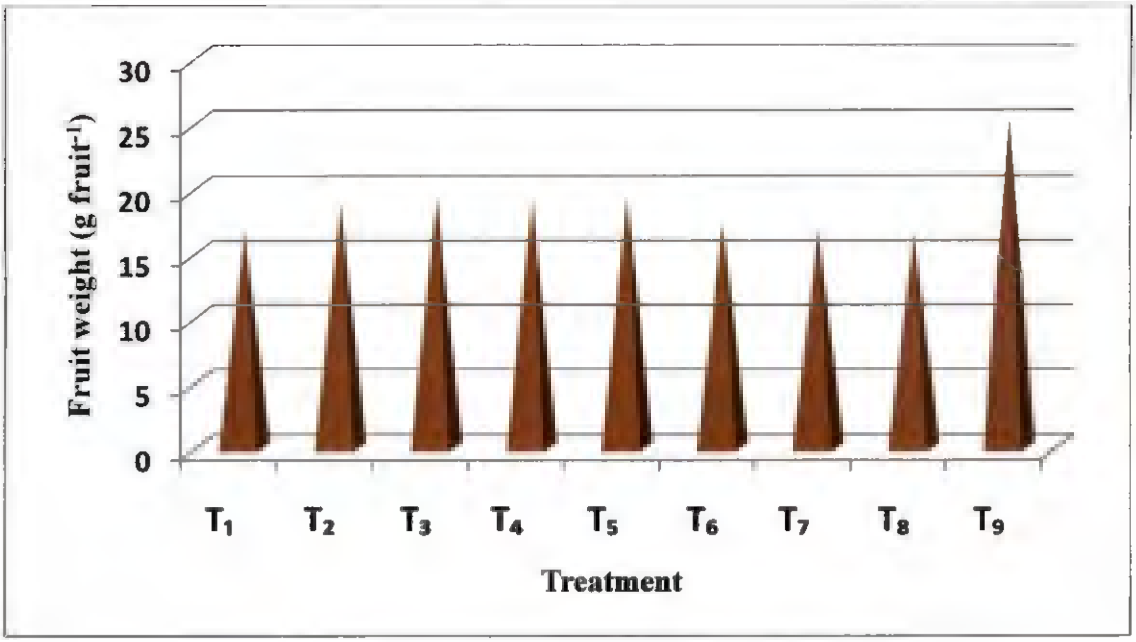

Fig. 5.Effect of organic preparations and biostimulants on fruit weight in okra, fruit^{-1}

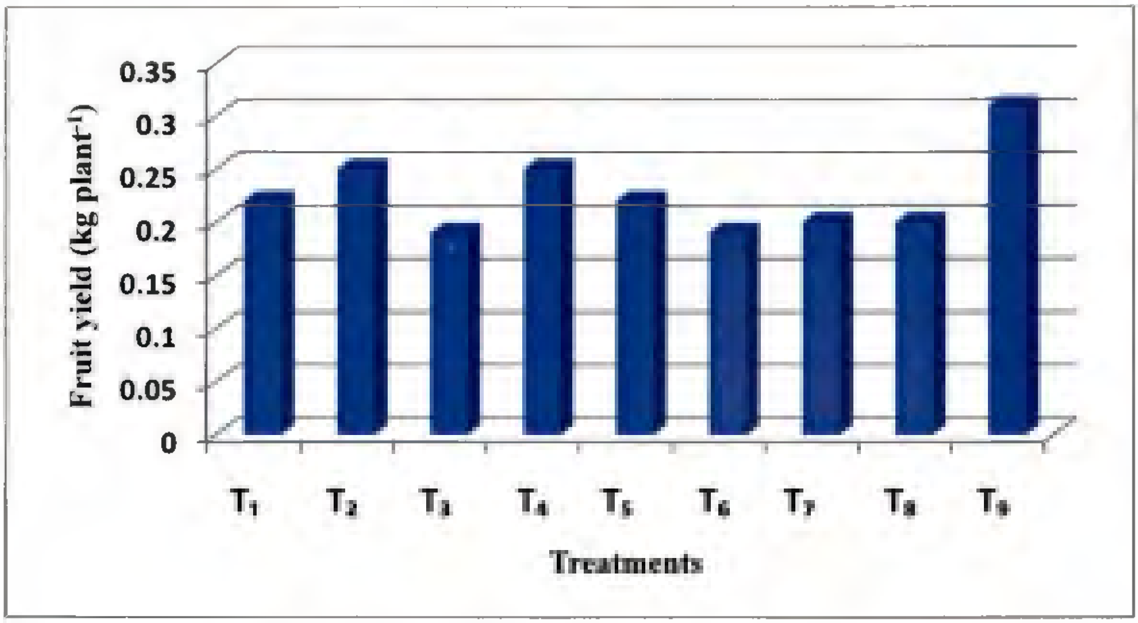

Fig .6.Effect of organic preparations and biostimulants on fruit yield of okra, plant-^{1}

9-1

Among the organic preparations and biostimulants, spraying of citric acid- 0.2 per cent (T_2) or humic acid- 1 per cent (T_4) produced significantly higher fruit yield compared to other biostimulants (Fig 6). The no stress treatment however recorded significantly higher fruit yield (0.31 kg plant^{-1}) compared to other treatments. According to El- Tohamy *et al.* (2013), citric acid contributes to osmotic adjustment in drought situation and helps in minimizing the injury caused by dehydration to plant tissue. In another study investigating the effect of citric acid spraying on hydrogen peroxide generation and accumulation, which is a major component of Reactive Oxygen Species (ROS), Miyazawa (2016) reported that citric acid can stimulate the reactive oxygen species scavenging activities in cabbage plants by lowering the production of hydrogen peroxide and this could have reflected in production of higher yield even under drought stress.

Humic acid is an organically charged biostimulant that significantly affects plant growth and development and increases the crop yield. While analyzing the physiological effects of humic acid in higher plants, Nardi *et al.* (2002) reported that the humic substances can act at the level of the plasma membrane, positively influence the uptake of some nutrients and display a hormone like activity. This growth promoting effect of humic acid might have reflected in the yield even under moisture stress in the present study. Similar results were reported by Moghadam *et al.* (2014) in corn wherein the foliar application of humic acid at 300 and 450 ppm improved the yield components and grain yield even on withholding irrigation through increased leaf water retention, photosynthetic and antioxidant metabolism.

5.3 PLANT ANALYSIS AND UPTAKE STUDIES

The quality parameters such as the crude fibre and ascorbic acid content were significantly influenced by spraying of organic preparations and biostimulants. Among the different organic preparations and biostimulants, spraying of sorghum water extract-5 per cent (T_3) recorded highest crude fibre content (7.22 per cent) in fruits which was significantly superior to spraying fermented cow dung water mixture or moringa leaf extract or salicylic acid or the no stress treatment (Fig 7). As reported by Elangovan *et al.* (1983), the crude fibre content of okra fruits could be as high as 13.1 to 14.3 per cent in different genotypes and since the crude fibre content obtained with T_3 treatment is much below this reported range it could be still considered as a desirable trait without any effect on succulence and fruit quality. Won *et al.* (2013) reported that, phenolic compounds are the characteristic chemicals present in sorghum leaf extract and three phenolic compounds such as *p*-hydroxybenzoic acid, *p*-coumaric acid, and *trans*-cinnamic acid are present in leaf extract. The association of phenolic compounds with dietary fibre has been suggested by Caudillo *et al.* (2008). Spraying of sorghum water extract rich in phenolic compounds would have favoured the production of crude fibre in okra fruits. Exogenous application of sorghum water extract increasing the crude fibre content and decreasing the palatability of fodder sorghum was previously reported by Ahmad *et al.* (2016).

Highest ascorbic acid content of 20.44 mg 100 g^{-1} was recorded with spraying of 2 per cent yeast extract (Fig 7) which was significantly higher than the ascorbic acid content recorded with spraying of water, 1 per cent humic acid and 5 per cent sorghum water extract. According to Shafeek *et al.* (2015), yeast is one of the richest source of high quality protein namely the essential amino acids and contains the essential minerals and trace elements namely calcium, cobalt, iron etc. and is the best source of the B-complex vitamins such as B_1, B_2, B_6 and cytokinins. These constituents could have modified the biochemical reactions within the plants leading to the higher ascorbic acid content. Further more in a basic study on production of ascorbic acid by yeast cells, Brandurardi *et al.* (2008) concluded that the yeast cells contain erythro-ascorbic acid which is a structurally similar compound with similar chemical properties as that of L-Ascorbic acid and the biosynthesis of the yeast cells could produce L-ascorbic acid which acts as a scavenger to reactive oxygen species

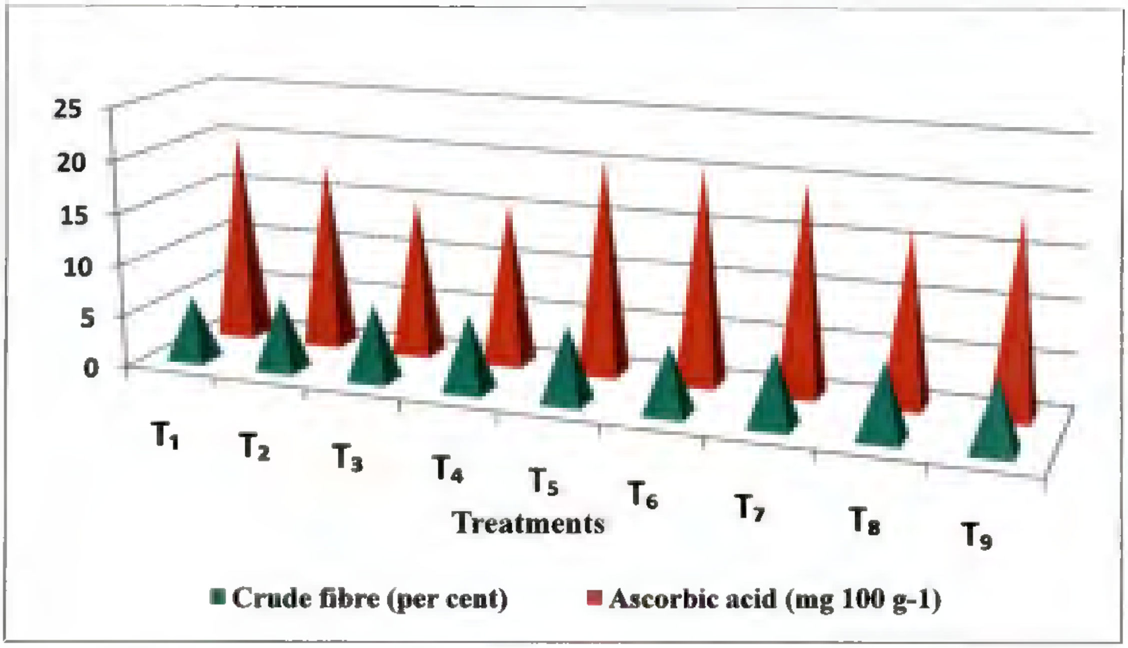

Fig. 7. Effect of organic preparations and biostimulants on crude fibre and ascorbic acid content of okra fruits

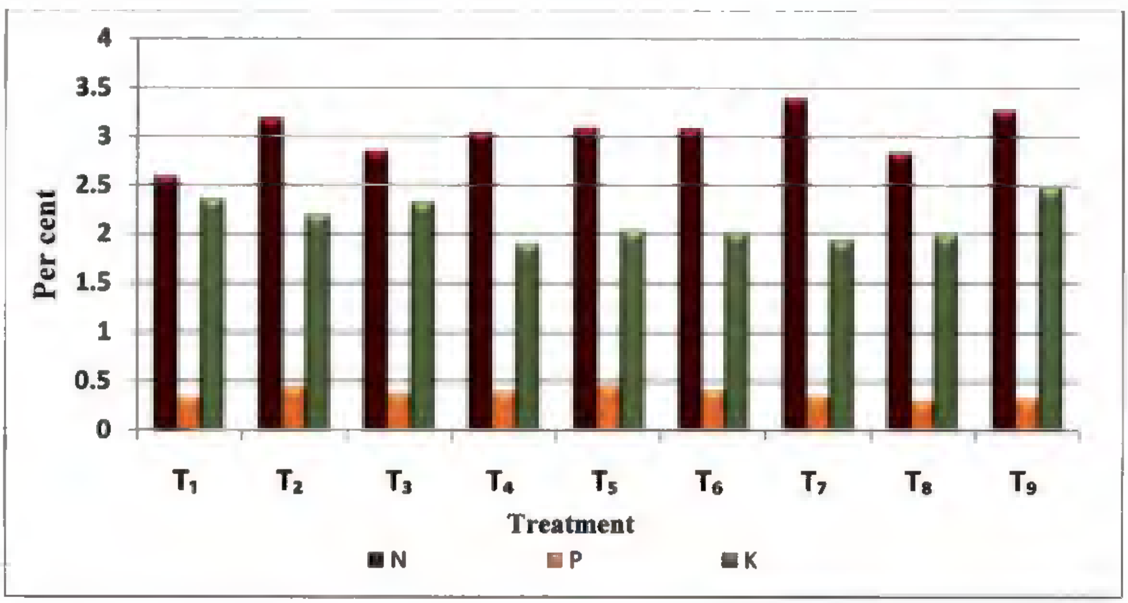

Fig 8. Effect of organic preparations and biostimulants on N, P and K content in okra plant, per cent

under stressed condition. Spraying of yeast extract producing higher ascorbic acid content was reported by Yamada *et al*. (1997) in tomato, Fawzy (2010) in lettuce and Shafeek *et al*. (2014) in capsicum.

The treatments could not exert any significant effect on crude protein content of the fruit. The non significant effect of the nitrogen content of fruits might have caused a similar effect on crude protein content.

Nitrogen content in plant was the highest (3.39 per cent) with the spraying of salicylic acid-100 ppm (T_7) which was significantly higher than the nitrogen content recorded with spraying of 10 per cent fermented cow dung water mixture (T_1), 5 per cent sorghum water extract (T_3), water (T_8), 1 per cent humic acid (T_4) or 3 per cent moringa leaf extract (T_6). Salicylic acid contributes to accumulation of free amino acid under stress possibly by maintaining an enhanced level of abscisic acid in the plants (El-Tayeb, 2005). This increase in amino acids in the plant tissue under stress could be related to protein fraction and the nitrogen content. Spraying of salicylic acid enhancing the plant nitrogen content was previously reported by Amira and Qados (2015) in capsicum and Merwad (2015) in sugar beet.

The nitrogen content in fruits, phosphorus content in both plant and fruit were not significantly affected by the treatments.

Among different organic preparations and biostimulants, spraying of fermented cow dung water mixture-10 per cent (T_1) resulted in the highest potassium content in plant as well as fruits (Fig 8 and 9). In plants, T_1 treatment however was on a par with no stress treatment (T_9) and in case of fruit, T_1 was significantly higher than no stress treatment. A number of physiological mechanisms could be accounted for the moisture stress tolerance in plants and during drought stress, potassium plays a major role in physiological and structural mechanisms of drought tolerance in plants (Wang *et al*., 2013). Higher K contents in plants and fruit are indicating the fact that the moisture stress tolerance imparted by the spraying of cow dung water extract

(Deora, 2008) might be due to the increased uptake and accumulation of potassium in plant parts. The study conducted by Gore and Sreenivasa (2011) clearly revealed that the plant nutrient concentrations (N, P and K) were the highest with the application of liquid organic manures (*Panchagavya* and *Beejamrutha*) and there was significant improvement in the growth and yield with the combined application of liquid organic manures.

Among different organic preparations and biostimulants, highest total dry matter production was observed with spraying of citric acid-0.2 per cent (T_2) which was significantly higher than the dry matter produced with spraying of humic acid -1 per cent (T_4), moringa leaf extract-3 per cent (T_6) and water (T_8). According to Sun and Hong (2011), when citric acid was exogenously applied it induced defense mechanisms by increasing the activities of antioxidant enzymes and significantly improved the plant growth under stress conditions. Higher dry matter production noticed with the citric acid application could be related to its favourable influence on antioxidant enzyme activity. Similar results are observed by El-Tohamy *et al.* (2013) in beans.

Nitrogen uptake was the highest with spraying of moringa leaf extract- 3 per cent (T_6) which was significantly higher than the uptake recorded with spraying water, sorghum water extract- 5 per cent and fermented cow dung water mixture - 10 per cent (Fig 10). According to Emongor (2015), the active growth enhancing substances in moringa leaf extract are reported to be zeatin, dihydrozeatin and isopentyladenine which are natural (endogenous) cytokinins and the cytokinins can stimulate the growth, cell division, nutrient uptake and partitioning. The higher nitrogen uptake resulted from the spraying of moriga leaf extract could be due to the favourable influence of cytokinins. Spraying of moringa leaf extract at 4 per cent concentration significantly increasing the nitrogen uptake in wheat plants was reported by Merwad and Fattah (2017).

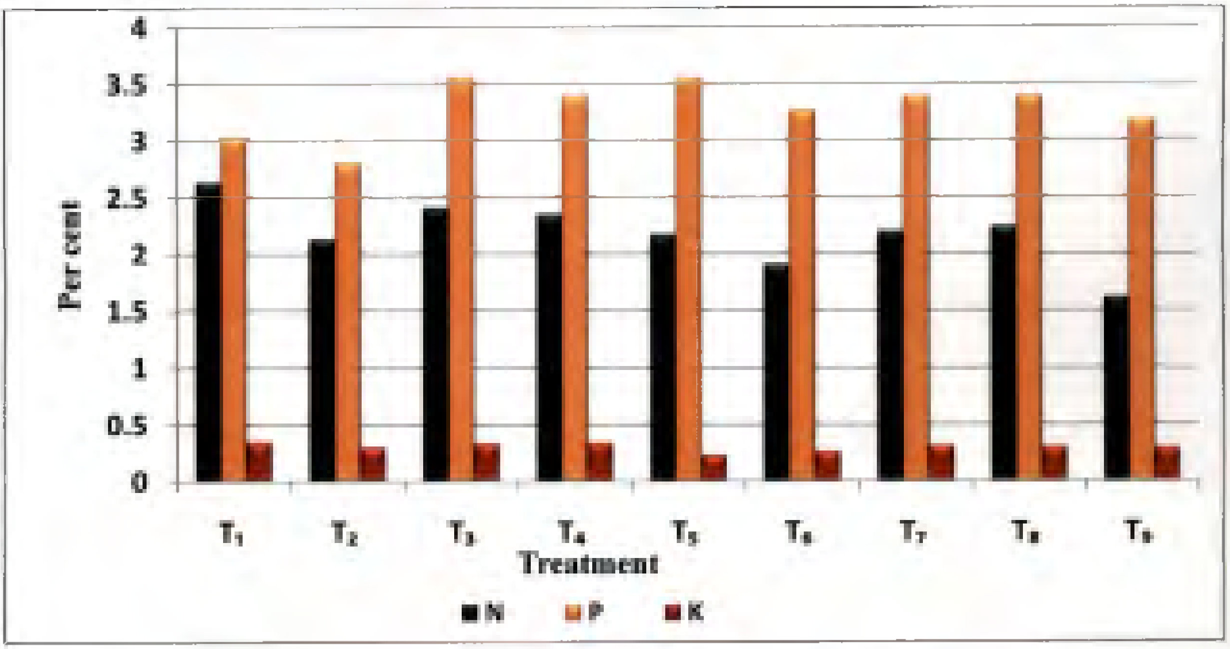

Fig 9. Effect of organic preparations and biostimulants on N, P and K content in okra fruit, per cent

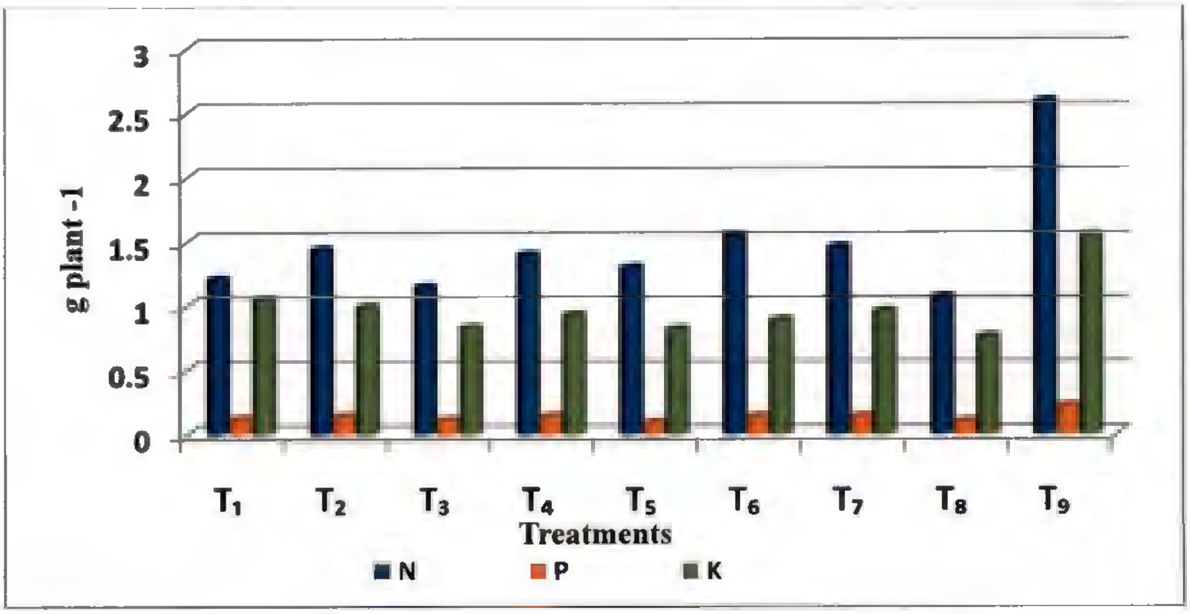

Fig.10. Effect of organic preparations and biostimulants on uptake of nitrogen, phosphorus and potassium in okra, g plant^{-1}

Uptake of phosphorus was the highest (0.14 g plant^{-1}) with spraying of citric acid-0.2 per cent (T_2), humic acid - 1 per cent (T_4), moringa leaf extract- 3 per cent (T_6) or salicylic acid-100 ppm (T_7) which statistically did not differ from all other treatments except the no stress treatment. Citric acid is known to mobilize the phosphorus (Jones *et al.*, 2003) and is considered to facilitate phosphorus uptake in plants (Ryan *et al.*, 2014). Recent report on spraying of moringa leaf extract in increasing the phosphorus uptake of soybean was put forth by Hanafy (2017).

Potassium uptake was the highest (1.05 g plant^{-1}) with the spraying of cow dung water mixture - 10 per cent (T_1) and the lowest with spraying of water (T_8) which were on a par with all other treatments except the no stress treatment. The higher potassium uptake observed with the application of cow dung water extract to the moisture stressed plants might be due to the specific effect of this biostimulant on inducing drought tolerance through accelerating the potassium uptake.

The uptake N, P and K were however significantly higher with no stress treatment (T_9) compared to the uptake recorded with spraying of organic preparations and biostimulants. This is invariably due to the availability of sufficient amount of moisture in the root zone which easily mobilizes the nutrients and help in improving the uptake as reported by early workers like Metwally and Pollard (1959). Another reason for increased nutrient uptake might be the increased root growth, higher root volume and dry matter production associated with the no stress treatment which is in agreement with the findings of Haase and Rose (1994). Uptake of nutrients favoured by higher soil moisture regime has been previously reported by Jyothy (1995) in yard long bean and Nahar and Gretzmatcher (2002) in tomato.

5.4 WATER USE STUDIES

A perusal of the data shown in Table 9 revealed that the spraying of organic preparations and biostimulants showed significant difference in water use characters like water use efficiency, water productivity, irrigation requirement and irrigation interval.

Water use efficiency is a parameter influenced by yield and water requirement. Among different organic preparations and biostimulants, the water use efficiency was the highest (13.17 g L^{-1}) with spraying of 0.2 per cent citric acid (T_2) which was also on a par with the water use efficiency produced with no stress treatment (13.19 g L^{-1}) as depicted in Fig 11. Spraying of citric acid (0.2 per cent) which had the lowest irrigation requirement produced higher yield compared to other biostimulants and it would have reflected in its water use efficiency. From this result, it could be inferred that daily irrigation is not necessary in okra as it results in more water consumption leading to more leafiness. Moreover, in urban homesteads daily irrigation raises the irrigation requirement and disrupts the water economy. The moisture stress mitigation effect of citric acid was previously reported by several workers. According to Miyazawa (2016), citric acid can stimulate reactive oxygen species scavenging activities and lower the reactive oxygen species and the oxidative stress. In drought situation citric acid also contributes to osmotic adjustment and helps in minimizing the injury caused by dehydration to plant tissue (El- Tohamy *et al.*, 2013). These physiological mechanisms could have helped in producing reasonable higher yield at the expense of less water. These findings are in agreement with the reports of Mehanna *et al.* (2013) who noticed that spraying canola plants with 300 ppm citric acid decreased the harmful effect of the moderate water stress and increased water use efficiency.

Irrigation requirement of okra was the lowest (19.04 L $plant^{-1}$) with spraying of 0.2 per cent citric acid (T_2) which was significantly lower than that with spraying of 1 per cent humic acid, 5 per cent sorghum water extract, spraying of water or no stress treatment (Fig 11). Recent studies indicated that there is a relationship between accumulation of organic acids such as citric acid and drought tolerance in plants. Levi *et al.* (2011) reported that accumulation of organic acids including citric acid could contribute to the capacity of cotton lines to cope with drought situation. While studying the physiological processes of drought tolerance associated with citric acid application in beans, El-Tohamy *et al.* (2013) pointed out that application of citric acid at 1.5 g L^{-1} concentration improved the relative water content through its contribution in improving water status due to osmotic adjustment during drought conditions. This could have resulted in saving of water in drought situation. As expected, irrigation requirement of container grown was highest with no stress treatment.

Among different organic preparations and biostimulants tried, spraying of 0.2 per cent citric acid (T_2) recorded the highest water productivity (3.08 g L^{-1}). Water productivity is expressed as the ratio of total biomass produced to the total water used. As discussed earlier, irrigation requirement was the lowest with citric acid spraying while the dry matter production was higher compared to other biostimulants which could have resulted in higher water productivity.

Irrigation interval was the highest with spraying of 0.2 per cent citric acid which was followed by spraying of fermented cow dung water mixture-10 per cent or salicylic acid-100 ppm, moringa leaf extract-3 per cent, humic acid- 1 per cent, yeast extract-2 per cent and sorghum water extract- 5 per cent. The results indicated that with spraying of citric acid plants maintained turgidity for more days (5.5 days) even on withdrawing irrigation, which signifies the usefulness of this biostimulant in urban agriculture. The lowest irrigation interval was noticed with water spraying (3.2 days) which indicated that the plants wilted quickly on withholding irrigation. This further supports the role of biostimulants in inducing moisture stress tolerance in water scarce situation which is supported by Deora (2008), Baghizadeh and Hajmohammadrezaei (2011), Al-Hussaini and Alsaadawi (2013), El-Tohamy *et al.* (2013), Rasaei *et al.* (2013), Hammad and Ali (2014) and Hanafy (2017) in various crops.

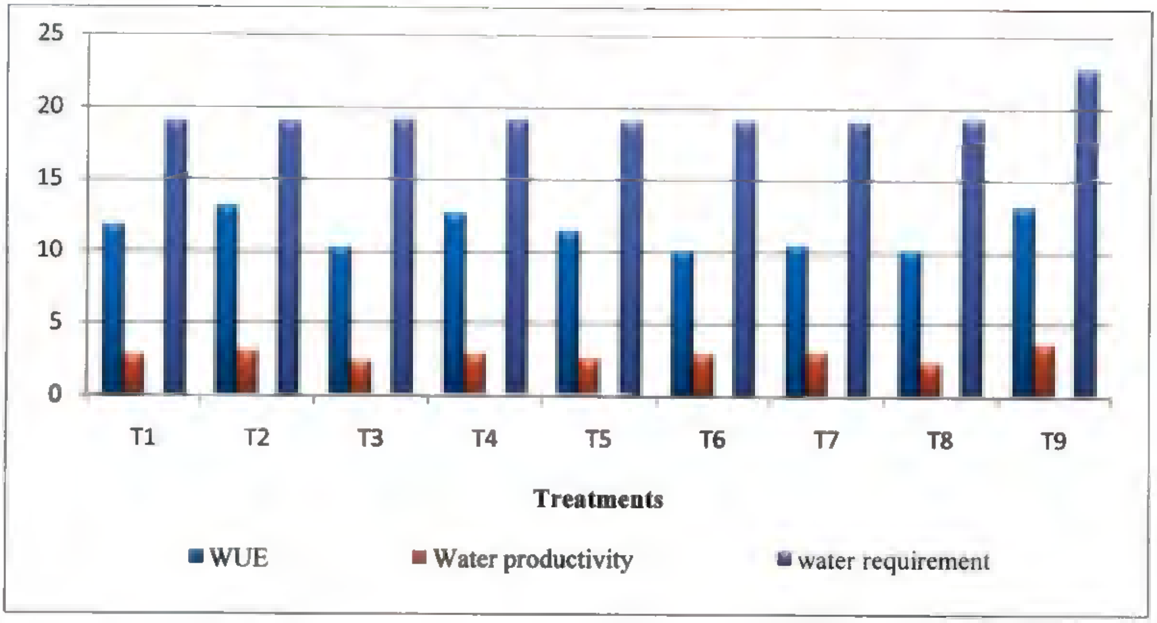

Fig 11. Effect of organic preparations and biostimulants on water use efficiency, water productivity and irrigation requirement of okra

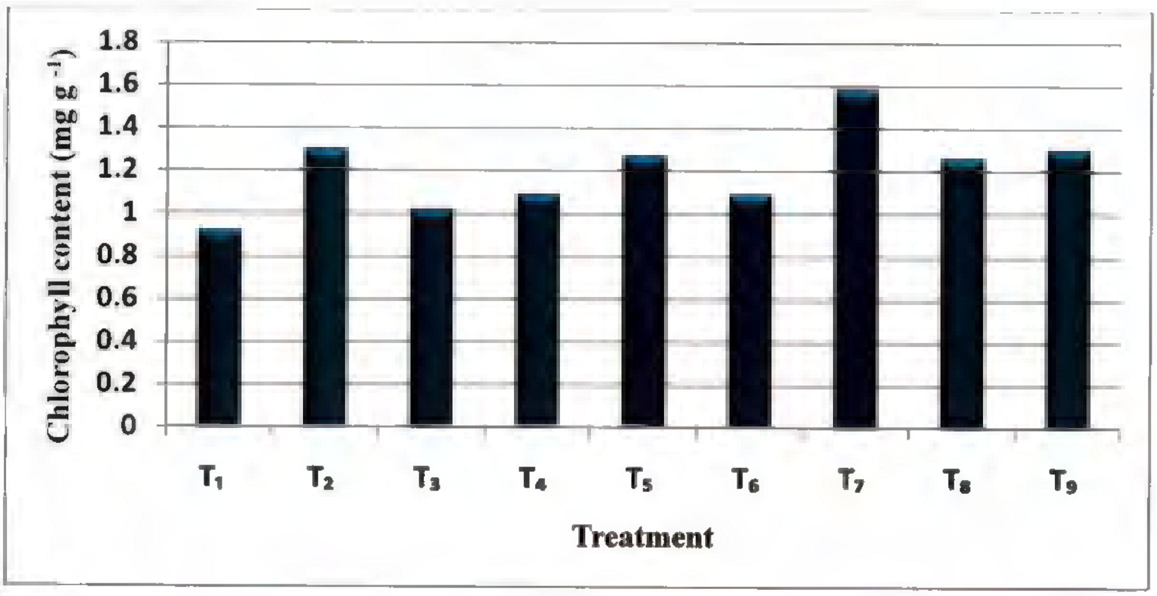

Fig. 12. Effect of organic preparations and biostimulants on chlorophyll content of okra, mg g^{-1}

5.5 PHYSIOLOGICAL STUDIES

Chlorophyll is the major chloroplast components for photosynthesis and the chlorophyll content has a positive relationship with photosynthetic rate. As shown in Fig 12, spraying of salicylic acid-100 ppm (T_7) recorded significantly higher chlorophyll content compared to other biostimulants and it was on a par with the no stress treatment which produced the same chlorophyll content (1.30 mg g^{-1}). Salicylic acid is a common signal molecule in plant which is responsible for inducing tolerance to a number of biotic and abiotic stresses. According to Singh and Usha (2003), high photosynthetic activity coupled with high rubisco activity and chlorophyll content associated with salicylic acid application was responsible for higher dry matter accumulation in drought stressed maize plants. Salicylic acid spraying in improving the chlorophyll content was reported by workers like Khodary (2004) in maize and Yildirim *et al.* (2008) in cucumber.

The stomatal count and proline content at 45 DAP were not significantly influenced by the application of organic preparations and biostimulants. Accumulation of proline in the leaves as an osmolyte is only one of the several physiological and biochemical mechanisms of drought tolerance in vegetables and interaction effect of different parameters of drought tolerance depend on the growth strategy of the species (Bahadur *et al.*, 2011). Furthermore, the application of biostimulants are likely to modify the moisture stress tolerance mechanisms in plants by virtue of the bio chemical components associated with them and in this study proline accumulation might not have been the prominent mechanism of moisture stress tolerance in okra under the influence of biostimulants.

Relative water content is important characteristic that affect plant water relations. The relative leaf water content 1 week after Ist spraying (at 20 DAP) was significantly influenced by the treatments (Table 12). Spraying of sorghum water extract- 5 per cent (T_3) recorded the highest relative leaf water content at this stage

(93.46 per cent) which was significantly higher than the value recorded with spraying of water and yeast extract-2 per cent and was also on a par with no stress treatment. The relative leaf water content 1 week after 2nd spraying (at 40 DAP) and 3rd spraying (at 60 DAP) were not significantly influenced by the treatments. According to Maqbool and Sadiq (2017), the total free amino acids were found to be increasing in drought stressed plants with the application of sorghum water extract or *sorgaab* and this increase in free amino acids could contribute to the tolerance of plant to water deficit through an increase in osmotic potential and better water relations. The positive influence of sorghum water extract on relative leaf water content of okra plants during the early growth stage might be due to its synergetic effect on osmotic potential through the production of free amino acids.

The treatments however significantly influenced the relative leaf water content recorded at 1 week after 4th spraying (80 DAP) and highest value (89.33 per cent) was recorded with T_6 (spraying of moringa leaf extract-3 per cent) which was significantly higher than that with spraying of water and yeast extract and on a par with no stress treatment. Hanafy (2017) suggested that moringa leaf extract could trigger the activation of physiological compounds persist in plants to alleviate the oxidative damage causing by drought, leading to improvements in physiological and biochemical aspects for the plant growth under drought conditions. The higher leaf water content with the spraying of moringa leaf extract at later growth stage indicated its stress mitigating effect even on older plants. In line with the above findings, favourable influence of moringa leaf extract on relative leaf water content was reported earlier by Bakhtavar *et al.* (2015) in maize.

5.6 POTTING MIXTURE ANALYSIS

From the post- experiment analysis of the potting mixture, it was found that different treatments did not significantly influence the pH and electrical conductivity of the potting mixture. There was a general decline in pH compared to

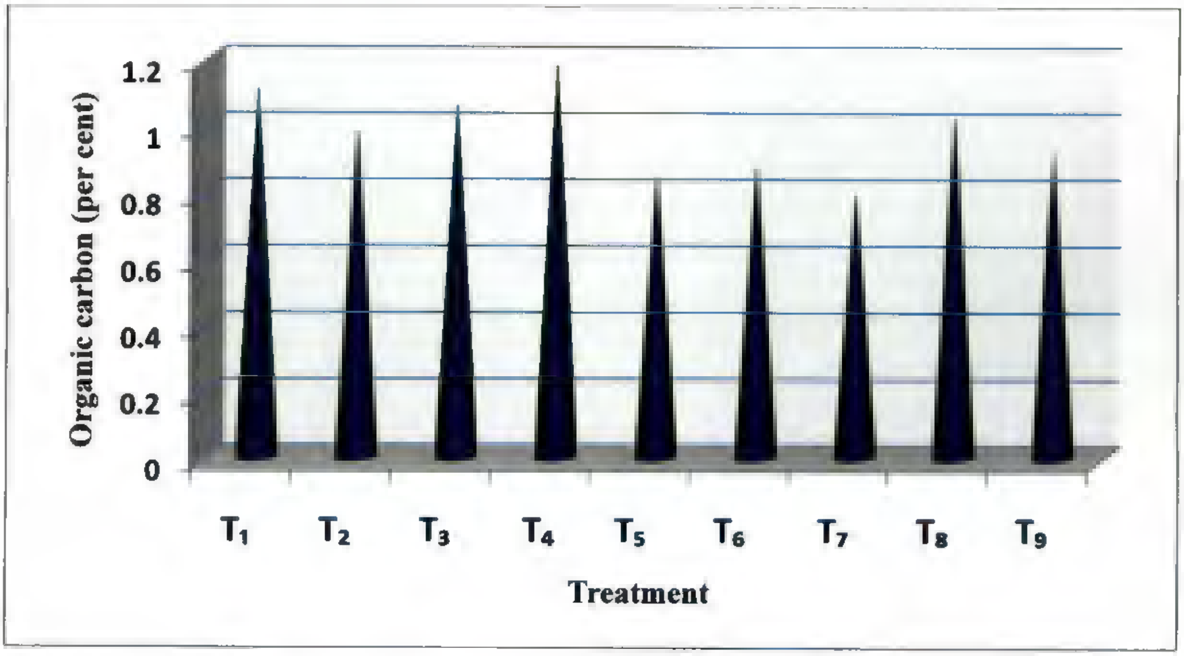

Fig. 13. Effect of organic preparations and biostimulants on organic carbon content of potting mixture after the experiment, per cent

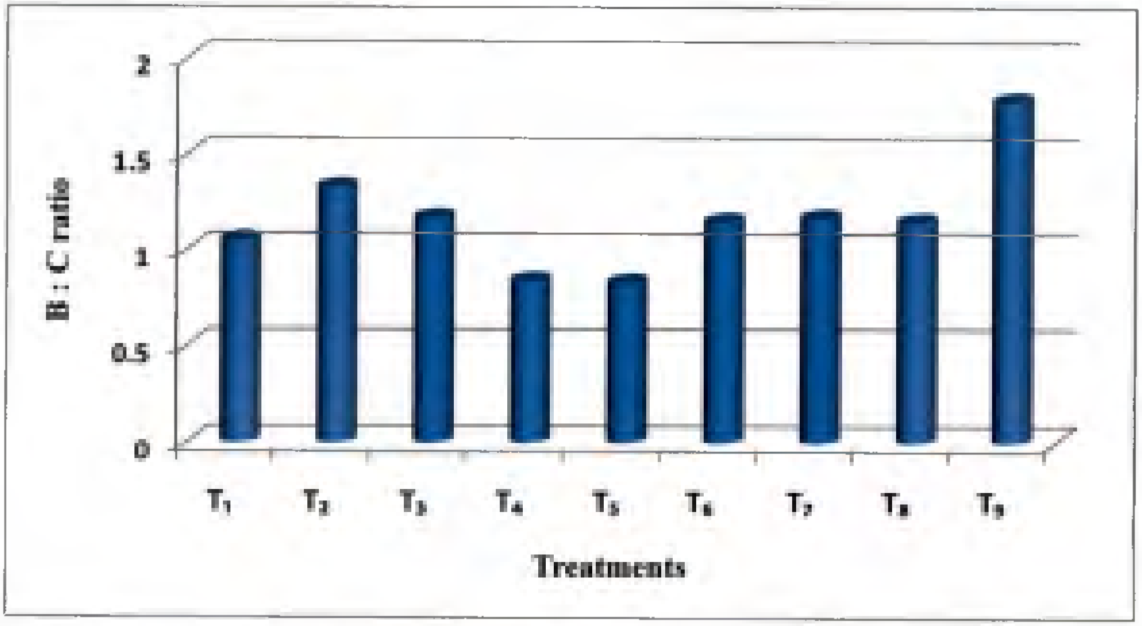

Fig 14. Effect of organic preparations and biostimulants on benefit : cost ratio of container grown okra

the initial value which might be due to the fact that the organic preparations and biostimulants used in the study were fermented products or week organic acids or contained organic constituents having acidic property. The result of the study showed that spraying of 1 percent humic acid (T_4) recorded the highest organic carbon content (1.18 per cent) in the potting mixture after the experiment (Fig 13). Humic acid is a rich source of organic carbon and in the present study humic acid was applied at a higher concentration of 1 per cent. Though the humic acid was applied as foliar spray, it might have enhanced the organic carbon content of potting mixture due to dripping of spray solution to the potting medium combined with leaf fall of older leaves.

Analysis potting mixture after the experiment indicated that spraying of organic preparations and biostimulants had no significant influence on the available N, P and K content (Table 14). However compared to the initial nutrient status, the available N and P content after the experimentation showed an increase. As explained in the case of organic carbon, the nutrient addition from leaf fall as well as the foliar spray of biostimulants rich in nutrients might have supplemented the nutrients indirectly to the potting mixture.

5.7 ECONOMICS OF CULTIVATION

The economics of cultivation was worked out as net income and benefit : cost ratio. It can be observed from the Table 15 that the spraying of organic preparation and biostimulants could significantly influence the net income and benefit : cost ratio.

Spraying of citric acid - 0.2 per cent (T_2) registered the highest net return and benefit : cost ratio (Fig 14) which were significantly higher than all other treatments among the organic preparations and biostimulants. The improvement in net income could be attributed to the enhanced yield realised in the above treatment. However the no stress treatment (T_9) resulted in highest benefit : cost ratio when compared to application of organic preparation and biostimulants. The economics of cultivation is surpassed by other considerations like safe to eat food production and water economy in urban homesteads and therefore the use of organic preparations and biostimulants which could produce moderate yield with less quantity of water are having a prominence in such situation.

The discussion of the results obtained in this investigation indicated the usefulness of organic preparations and biostimulants in mitigating moisture stress in container grown okra. Among different treatments, spraying of citric acid (0.2 per cent) was found to be the best treatment for inducing stress tolerance, through reduction in irrigation requirement, increasing water use efficiency, water productivity and irrigation interval and it also produced higher yield, net returns and benefit: cost ratio.

Summary

6. SUMMARY

The field experiment entitled "Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench)" was conducted during July to October 2016 at Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram to evaluate the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance and to assess their impact on growth, yield and irrigation requirement of okra in urban homesteads.

The experiment was laid out as Completely Randomised Design with nine treatments replicated thrice. Uniform sized plastic sacks were selected as containers and they were housed in a rain shelter. The treatments comprised of application of organic preparations and biostimulants, which included T_1 - spraying of fermented cow dung water mixture (10 per cent), T_2 - spraying of citric acid (0.2 per cent), T_3- spraying of sorghum water extract (5 per cent), T_4 - spraying of humic acid (1 per cent), T_5 - spraying of yeast extract (2 per cent), T_6- spraying of moringa leaf extract (3 per cent), T_7 - spraying of salicylic acid (100 ppm), T_8 - spraying of water and T_9 - no stress treatment (daily irrigation to field capacity and no spraying). For T_1 to T_8, irrigation was withheld after 20 days of planting and resumed only when plant showed temporary wilting symptoms. Spraying as per treatments was given to the plants at 20, 40, 60 and 80 DAP (Days After Planting).

The result revealed that spraying of organic preparations and biostimulants significantly influenced the growth, yield, physiological aspects, biochemical characters and economics of cultivation. The salient results of the study are summarised in this chapter.

The growth parameters viz., plant height and root volume indicated varying responses under spraying of different organic preparations and biostimulants.

Organic preparations and biostimulants did not influence the plant height of okra at 1 MAP and 2 MAP. However it was significantly affected by the treatments at 3 MAP. Spraying of moringa leaf extract-3 per cent (T_6) produced taller plants (72.33 cm) compared to other organic preparations and biostimulants which was significantly higher than the plant height produced with spraying of 5 per cent sorghum water extract (T_3) and 1 per cent humic acid (T_4). The no stress treatment (T_{10}) however produced the tallest plants (77.23 cm) compared to the application of organic preparations and biostimulants which was also on a par with T6.

Among the organic preparations and biostimulants, spraying of moringa leaf extract- 3 per cent (T_6) recorded the highest root volume (76.53 cm^3). The T_6 however did not vary from spraying of humic acid-1 per cent (T_4), yeast extract-2 per cent (T_5) or citric acid-0.2 per cent (T_2). The no stress treatment resulted in significantly higher root volume at final harvest compared to the application of organic preparations and biostimulants.

Spraying of organic preparations and biostimulants did not have any significant influence on major yield attributes such as number of fruits $plant^{-1}$, length of fruit and number of pickings. Organic preparations and biostimulants behaved differently in terms of fruit weight and yield $plant^{-1}$. Spraying of sorghum water extract-5 per cent (T_3) recorded the highest fruit weight (19.20 g $fruit^{-1}$) which did not vary much from all other treatments except no stress treatment (T_9). Considering the fruit yield $plant^{-1}$, spraying of citric acid- 0.2 per cent (T_2) or humic acid- 1 per cent (T_4) recorded superior fruit yield (0.25 kg $plant^{-1}$) than with spraying of sorghum water extract- 5 per cent (T_3), moringa leaf extract- 3 per cent (T_6), salicylic acid-100 ppm (T_7) or water (T_8).

Among the quality characters, only the crude fibre and ascorbic acid contents were significantly influenced by the treatments. Spraying of sorghum water extract- 5 per cent (T_3) recorded the highest crude fibre content (7.22 per cent) and the treatment was however on a par with spraying of 0.2 per cent citric acid (T_2), 1 per cent humic acid (T_4), 2 per cent yeast extract (T_5) and water (T_8). The crude fibre content was the lowest with spraying of 10 per cent fermented cow dung water mixture which did not differ from no stress treatment (T_9). The highest ascorbic acid content (20.44 mg 100 g^{-1}) was recorded with spraying of 2 per cent yeast extract (T_5) which was significantly higher than the content recorded with spraying of water (T_8), 1 per cent humic acid (T_4) and 5 per cent sorghum water extract (T_3). Ascorbic acid content in fruit was the lowest with spraying of 5 per cent sorghum water extract (T_3) which did not differ from T_4 and T_8.

Nitrogen content in plant was the highest (3.39 per cent) with the spraying of salicylic acid-100 ppm (T_7) which was significantly higher than the content recorded with spraying of 10 per cent fermented cow dung water mixture (T_1), 5 per cent sorghum water extract (T_3), water spraying (T_8), 1 per cent humic acid (T_4) or 3 per cent moringa leaf extract (T_6). Different treatments could not significantly influence the nitrogen content in fruit and the phosphorus content in both plant and fruit. The highest potassium content (2.36 per cent) in plant was produced by spraying of fermented cow dung water mixture-10 per cent (T_1) which was significantly superior to spraying of 1 per cent humic acid, 100 ppm salicylic acid, water, 3 per cent moringa leaf extract and 2 per cent yeast extract. The highest potassium content (2.63 per cent) in fruit was recorded by spraying of fermented cow dung water mixture - 10 per cent (T_1) which was significantly higher than potassium content recorded with no stress treatment, spraying of 3 per cent moringa leaf extract, spraying of 0.2 per cent citric acid and spraying of 2 per cent yeast extract.

Dry matter production was the highest (58.85 g $plant^{-1}$) with spraying of citric acid-0.2 per cent compared to other organic preparations and biostimulants though the no stress treatment resulted in significantly higher total dry matter production (85.71 g $plant^{-1}$) compared to biostimulant application in stressed condition.

On comparing the efficacy of organic preparations and biostimulants, it was found that nitrogen uptake was the highest (2.59 g plant^{-1}) with spraying of moringa leaf extract- 3 per cent (T_6) which was significantly higher than the uptake recorded with spraying water, sorghum water extract- 5 per cent and fermented cow dung water mixture-10 per cent. Uptake of phosphorus was the highest (0.14 g plant^{-1}) with spraying of citric acid-0.2 per cent (T_2), humic acid - 1 per cent (T_4), moringa leaf extract- 3 per cent (T_6) or salicylic acid-100 ppm (T_7) which were on a par. The potassium uptake was the highest (1.05 g plant^{-1}) with the spraying of cow dung water mixture - 10 per cent (T_1) and the lowest with spraying of water (T_8) which was on a par with other treatments. The uptake N, P and K were however significantly higher with no stress treatment (T_9) compared to the spraying of organic preparations and biostimulants.

From this study it was found that the total irrigation requirement of container grown okra was the lowest (19.04 L plant^{-1}) with spraying of 0.2 per cent citric acid (T_2) which was significantly lower than the irrigation requirement resulted from spraying of 1 per cent humic acid, 5 per cent sorghum water extract and spraying of water. The highest irrigation requirement was recorded with no stress treatment (22.78 L plant^{-1}). Water use efficiency was another parameter influenced by the treatments. Among different organic preparations and biostimulants, the water use efficiency was the highest (13.17 g L^{-1}) with spraying of 0.2 per cent citric acid (T_2) which was significantly higher than the water use efficiency recorded with spraying of 3 per cent moringa leaf extract, water, sorghum water extract (5 per cent) and salicylic acid (100 ppm). Similar to water use efficiency, water productivity was also the highest with spraying of 0.2 per cent citric acid (3.08 g L^{-1}) which was significantly higher than the water productivity produced by spraying of sorghum water extract-5 per cent and water. Irrigation interval was more (5.5 days) with spraying of 0.2 per cent citric acid which was followed by spraying of fermented cow dung water mixture-10 per cent, salicylic acid-100 ppm, moringa leaf extract-3 per cent, humic acid- 1 per cent, yeast extract-2 per cent and sorghum water extract- 5 per cent. Irrigation interval was the lowest (3.2 days) with spraying of water (T_8).

Regarding the physiological characters, it was found that stomatal count and proline content were not significantly influenced by the treatments. The chlorophyll content was the highest (1.58 mg g^{-1}) with spraying of salicylic acid-100 ppm (T_7) which was on a par with spraying of citric acid-0.2 per cent (T_2) and no stress treatment (T_9), each recording a chlorophyll content of 1.30 mg g^{-1}

The relative leaf water content 1 week after I^{st} spraying (at 20 DAP) was significantly influenced by the treatments. Spraying of sorghum water extract- 5 per cent (T_3) recorded the highest relative leaf water content (93.46 per cent) which was significantly higher than spraying of water and yeast extract-2 per cent. Relative leaf water content 1 week after 2^{nd} spraying (at 40 DAP) and 3^{rd} spraying (at 60 DAP) were not significantly influenced by the treatments. The treatments however significantly influenced the relative leaf water content recorded at 1 week after 4^{th} spraying (at 80 DAP) and the highest value (89.33 per cent) was recorded with T_6 (spraying of moringa leaf extract-3 per cent) which did not vary much from all other treatments except T_8 and T_5.

The post-experiment analysis indicated that different treatments did not significantly influence the pH and electrical conductivity of the potting mixture. There was however a general decline in pH compared to the initial value. Organic carbon content of the potting mixture after the experiment was the highest (1.18 per cent) with the spraying of 1 per cent humic acid (T_4). The available nitrogen, phosphorus or potassium content of the potting mixture after the experiment was not significantly influenced by the treatments.

Among different organic preparations and biostimulants, the cost of cultivation was the lowest for spraying of sorghum water extract, spraying of moringa leaf extract and spraying of water while the highest net returns (₹ 3.15 $sack^{-1}$) was obtained by spraying of citric acid-0.2 per cent (T_2) which was also on a par with spraying of moringa leaf extract-3 per cent (T_6), water (T_8), sorghum water extract-5 per cent (T_3) and salicylic acid-100 ppm (T_7). Highest benefit: cost ratio of 1.33 was recorded with the spraying of citric acid-0.2 per cent (T_2) which was significantly higher than the ratio recorded with all other treatments among the organic preparations and biostimulants. The no stress treatment (T_9) however resulted in the highest net returns and benefit: cost ratio when compared to the application of organic preparations and biostimulants.

From the results of the study it could be concluded that spraying of citric acid (0.2 per cent) at 20, 40, 60 and 80 DAP to container grown okra was found to be the ideal treatment for inducing stress tolerance, reducing the irrigation requirement, increasing water use efficiency, water productivity and irrigation interval and for producing higher yield, net returns and benefit: cost ratio.

FUTURE LINE OF WORK

- There is a need to investigate the efficacy of biostimulants on moisture stress mitigation under open field conditions and such studies can benefit the commercial vegetable farmers also.
- Basic studies for identification of chemical constituents in the biostimulants which induce the moisture stress tolerance are another future line of research.
- Production of chemical analogues in biostimulants which can be safely used for inducing stress tolerance without deleterious effects on growth and yield is another future area of research.

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Abstract

ORGANIC PREPARATIONS AND BIOSTIMULANTS FOR MOISTURE STRESS MITIGATION IN CONTAINER GROWN OKRA (*Abelmoschus esculentus* (L.) Moench).

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ABSTRACT

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ABSTRACT

The study entitled "Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L.) Moench)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during 2016 to 2017. The objective of the study was to evaluate the efficacy of organic preparations and biostimulants on inducing moisture stress tolerance and to assess their impact on growth, yield and irrigation requirement of okra in urban homesteads.

The field experiment was laid out at the Instructional Farm during July to October 2016 as Completely Randomised Design with nine treatments replicated thrice. Uniform sized plastic sacks were selected as containers and they were housed in a rain shelter. The treatments comprised of application of organic preparations and biostimulants, which included T_1- spraying of fermented cow dung water mixture (10 per cent), T_2- spraying of citric acid (0.2 per cent), T_3- spraying of sorghum water extract (5 per cent), T_4- spraying of humic acid (1 per cent), T_5- spraying of yeast extract (2 per cent), T_6- spraying of moringa leaf extract (3 per cent), T_7- spraying of salicylic acid (100 ppm), T_8- spraying of water and T_9- no stress treatment (daily irrigation to field capacity and no spraying). For T_1 to T_8, irrigation was withheld after 20 days of planting and resumed only when plant showed temporary wilting symptoms. Spraying as per treatment was given to the plants at 20, 40, 60 and 80 DAP (Days After Planting).

Results of the study indicated that among the organic preparations and biostimulants, moringa leaf extract spraying (T_6) resulted in significantly higher plant height (72.33 cm) at 3 MAP (Months After Planting) and root volume (76.53 cm^3) at harvest. With respect to yield attributes, sorghum water extract produced the highest fruit weight (19.2 g $fruit^{-1}$) which was on a par with other treatments. Fruit yield $plant^{-1}$ was significantly higher (0.25 kg) on spraying citric acid (T_2) or humic acid (T_4). The no stress treatment however recorded

significantly higher growth attributes, yield attributes and yield compared to the application of organic preparations and biostimulants.

Fruit quality aspects like crude fibre and ascorbic acid content were influenced by the spraying of biostimulants. Significantly higher crude fibre content was recorded with spraying of sorghum water extract and ascorbic acid content was significantly higher with yeast extract spraying. Spraying of salicylic acid recorded significantly higher plant N content while plant K content was the highest in no stress treatment. Fruit K content was significantly higher with spraying fermented cow dung water mixture. The highest N uptake was recorded by spraying moringa leaf extract, the highest P uptake with spraying citric acid, humic acid, moringa leaf extract and salicylic acid while the highest K uptake was recorded with fermented cow dung water mixture which was on a par with other treatments. However the no stress treatment recorded significantly higher N, P and K uptake (2.59, 0.22, 1.55 g $plant^{-1}$) compared to biostimulant application.

Irrigation requirement was the lowest with spraying of citric acid (19.04 L $plant^{-1}$) which did not differ from spraying of other biostimulants and was significantly lower than no stress treatment (22.78 L $plant^{-1}$). Spraying citric acid or humic acid, cow dung water mixture or yeast extract produced higher water use efficiency which did not vary from no stress treatment. Spraying of citric acid also produced significantly higher water productivity among biostimulants which was on a par with no stress treatment. The irrigation interval was the highest for citric acid spraying (5.5 days) and lowest for spraying of water (3.2 days).

Chlorophyll content was the highest with salicylic acid (1.58 mg g^{-1}) spraying and was on par with citric acid spraying and no stress treatment. Relative Leaf Water Content (RLWC) one week after 1st spraying was significantly higher with sorghum water extract and one week after 4th spraying was significantly higher with spraying of moringa leaf extract or citric acid or no stress treatment compared to yeast extract or water spraying. The highest organic carbon content of potting mixture after the experiment was recorded with spraying of humic acid (1.18 per cent) which was significantly higher than no stress treatment. Among the biostimulants, citric acid recorded higher net returns (₹ 3.15 $sack^{-1}$) and benefit: cost ratio (1.33).

The results of the study indicated that spraying of citric acid (0.2 per cent) to the container grown okra was found to be the ideal treatment for inducing stress tolerance, reducing the irrigation requirement and increasing water use efficiency, water productivity and irrigation interval. It was also found to produce higher yield, net returns and benefit: cost ratio.

സംഗ്രഹം

"കണ്ടെയ്നറിലെ / പ്ലാസ്റ്റിക് ചാക്കുകളിലെ വെണ്ടകൃഷിയ്ക്ക് വരൾച്ചാ പ്രതിരോധത്തിനായി ജൈവക്കൂട്ടുകളുടെ ഉപയോഗം" എന്ന വിഷയത്തെ സംബന്ധിച്ച ഒരു പഠനം 2016-2017 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിൽ വച്ച് നടത്തുകയുണ്ടായി. വരൾച്ചാ പ്രതിരോധ ശക്തി വർധിപ്പിക്കുന്നതിൽ വിവിധ ജൈവ കൂട്ടുകളുടെ കര്യക്ഷമതയും സസ്യ വളർച്ചയിലുള്ള സ്വാധീനവും മനസിലാക്കുക, ഒപ്പം നഗര കൃഷിയിടങ്ങളിലെ വെണ്ടകൃഷിയ്ക്കുള്ള ജല ആവശ്യകത മനസിലാക്കുക എന്നിവയായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യങ്ങള്.

മഴമറയ്ക്കുള്ളിൽ സ്ഥാപിച്ച ചെടികളിൽ എട്ടു വ്യത്യസ്ത ജൈവകൂട്ടുകളാണ് പഠന വിധേയമാക്കിയത്. പുളിപ്പിച്ച ചാണകവെള്ളം (10 ശതമാനം വീര്യം), സിട്രിക് ആസിഡ് (0.2 ശതമാനം വീര്യം), മണിച്ചോളത്തിന്റെ ഇലയുടെ നീര് (5 ശതമാനം വീര്യം), ഹ്യുമിക് ആസിഡ് (1 ശതമാനം വീര്യം), യീസ്റ്റ് എക്സ്ട്രാക്റ്റ് (2 ശതമാനം വീര്യം), മുരിങ്ങ ഇലയുടെ സത്ത്(3 ശതമാനം വീര്യം), സാലിസിലിക് ആസിഡ് (100 മി.ഗ്രാം /ലി.), വെള്ളം എന്നീ 8 ട്രീറ്റ്മെന്റ്കൾക്ക് , റമേ വരൾച്ചാ സമ്മർദം ഇല്ലാതെ ദിവസവും നനച്ചു വളർത്തുന്ന ഒരു ട്രീറ്റ്മെ റും കൂടി പഠന വിധേയമാക്കി. നട്ടിട്ട് 20, 40, 60, 80 ദിവസങ്ങളിലായി ജൈവക്കൂട്ടുകൾ തളിച്ച് കൊടുത്തു.

പഠനത്തിന്റെ പ്രധാന കണ്ടെത്തലുകൾ ഇവയാണ്. വിവിധ ജൈവക്കൂട്ടുകൾ പരീക്ഷിച്ചതിൽ, മുരിങ്ങയില സത്ത് തളിച്ച ചെടികൾ ഉയരത്തിലും വേരുകളുടെ വ്യാപനത്തിലും മുന്നിട്ടു നിന്നു. കായുടെ ാരം കൂടുതൽ രേഖപ്പെടുത്തിയത് മണിച്ചോളത്തിന്റെ ഇലയുടെ നീര് തളിച്ച ചെടികളായിരുന്നു. എന്നാൽ മെച്ചപ്പെട്ട കായ്ഫലം തന്നത് സിട്രിക് ആസിഡ്, ഹ്യുമിക് ആസിഡ് എന്നിവ തളിച്ച ചെടികളായിരുന്നു. എന്നിരുന്നാലും, വരൾച്ചാ സമ്മർദം ഇല്ലാത്ത ചെടികൾ ജൈവകൂട്ടുകളെ

അപേക്ഷിച്ച് വളർച്ചയിലും വിളവിലും മുന്നിട്ട് നിന്നു. കായുടെ ഗുണമേന്മയിലും ജൈവക്കൂട്ടുകൾക്ക് വ്യക്തമായ സ്വാധീനം ഉള്ളതായി കണ്ടെത്തി.

ജൈവക്കൂട്ടുകളുടെ ഉപയോഗം ജലത്തിന്റെ ആവശ്യകതയിൽ ഗണ്യമായ കുറവു വരുത്തുന്നതായും ജല ഉപയോഗ ക്ഷമത കൂട്ടുന്നതായും പഠനം തെളിയിച്ചു. സിട്രിക് ആസിഡ് തളിച്ച ചെടികൾ കൂടതൽ ദിവസം വാടാതെ നിൽക്കുകയും കൂടിയ ജല ഉപയോഗ ക്ഷമതയും ജലസേചന ഇടവേളയും രേഖപ്പെടുത്തുകയും ചെയ്തു. ഹ്യൂമിക് ആസിഡിന്റെ ഉപയോഗം മണ്ണിലെ ജൈവാംശം ഉയർത്തുന്നതായും കണ്ടെത്തി.

വിവിധ ജൈവക്കൂട്ടുകൾ പരീക്ഷിച്ചതിൽ സിട്രിക് ആസിഡ് തളിച്ച ചെടികൾ വിളവിലും അറ്റാദായത്തിലും വരവ് : ചെലവു അനുപാതത്തിലും മുന്നിട്ടു നിന്നു. കൂടാതെ ഇവ മെച്ചപ്പെട്ട വരൾച്ചാ പ്രതിരോധ ശേഷിയും ജല ഉപയോഗ ക്ഷമതയും രേഖപ്പെടുത്തി.

Appendices

APPENDIX-I

Weather parameters during the crop period (July to Oct. 2016) – Open condition

Standard Week	Temperature		Relative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Bright Sunshine hours
	Max.	Min.	Max.	Min.			
29	31.8	24.7	91.4	79.9	0	4.0	9.6
30	31.1	24.6	95	79.3	7.8	3.3	8.7
31	31.2	24.9	91.9	76.7	6	4.4	9.3
32	32.3	25.2	88.7	75.3	1	4.4	9.7
33	31.8	24.5	92.1	77.4	3.2	4.2	9.4
34	31.8	25	91.0	76.0	10.4	4.2	9.7
35	31.7	24.5	91.0	77.4	2	4.4	9.2
36	31.5	24.4	92.3	76.6	0.2	4.6	9.4
37	31.9	24.5	91.3	74.9	0	4.2	9.6
38	32.0	24.7	92.2	76.8	2.6	3.8	9.1
39	31.9	24.7	91.1	74.3	0	4.2	9.1
40	31.7	24.3	90.9	74.1	0	4.3	9.6
41	31.6	24.3	90.3	76.3	0	4.2	9.6
42	32.1	24.3	88.0	74.0	12	4.3	9.0
43	31.5	24.1	91.4	75.7	0	4.4	8.5
44	31.9	24.4	92.4	80.4	6.0	3.8	7.7
45	32.0	24.2	91.7	76.7	0	3.5	7.6

APPENDIX - II

Weather parameters during the crop period (July to Oct 2016) – Rain shelter

Standard Week	Temperature (°C)		Relative Humidity (%)		Evaporation (mm)
	Max.	Min.	Max.	Min.	
29	31.8	27.7	82.28	70.56	3
30	31.1	26.8	85.50	71.45	4
31	31.2	27.2	82.67	68.23	4
32	32.3	27.4	79.84	67.00	3.8
33	31.8	26.7	82.9	68.90	3.8
34	31.8	27.3	81.9	67.64	4
35	31.7	26.7	81.9	68.92	4.2
36	31.5	26.5	83.05	68.14	3.8
37	31.9	26.7	82.15	66.62	3.4
38	32.0	26.9	82.95	68.38	3.8
39	31.9	26.9	82.02	66.11	3.9
40	31.7	26.5	81.77	65.98	3.8
41	31.6	26.4	81.25	67.89	3.9
42	32.1	26.5	79.20	65.86	4
43	31.5	26.2	82.28	67.38	3.4
44	31.9	26.6	83.18	71.58	3.2
45	32.0	26.4	82.64	66.70	3.6

APPENDIX III

Irrigation schedule of the treatments

APPENDIX III a

Quantity of water applied per irrigation (L)

Treatment	Stress treatment (No. of irrigation)																					
	1st20 Days	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st
T_1	3.17	0.82	0.88	0.92	0.79	0.82	0.98	0.90	0.95	0.82	0.98	0.95	0.92	0.89	0.77	0.80	0.93	0.88	-	-	-	-
T_2	3.17	0.90	0.92	0.93	0.94	0.96	0.88	0.98	0.95	0.89	0.93	0.94	0.88	0.95	0.98	0.93	0.95	0.96	-	-	-	-
T_3	3.17	0.78	0.80	0.75	0.81	0.83	0.78	0.82	0.77	0.81	0.80	0.85	0.75	0.80	0.81	0.79	0.89	0.81	0.95	0.88	0.75	-
T_4	3.17	0.75	0.88	0.85	0.81	0.79	0.77	0.81	0.80	0.75	0.85	0.80	0.81	0.77	0.82	0.78	0.83	0.81	0.75	0.80	0.78	-
T_5	3.17	0.89	0.88	0.93	0.80	0.77	0.89	0.82	0.85	0.82	0.78	0.92	0.79	0.82	0.81	0.81	0.75	0.85	0.78	0.85	-	-
T_6	3.17	0.85	0.88	0.81	0.79	0.82	0.85	0.92	0.79	0.83	0.85	0.89	0.88	0.83	0.81	0.77	0.88	0.85	0.78	0.78	-	-
T_7	3.17	0.89	0.93	0.80	0.85	0.89	0.95	0.90	0.85	0.89	0.93	0.84	0.86	0.92	0.88	0.86	0.92	0.80	0.96	-	-	-
T_8	3.17	0.81	0.76	0.73	0.78	0.80	0,73	0.76	0.75	0.81	0.75	0.77	0.81	0.72	0.74	0.81	0.75	0.76	0.83	0.75	0.75	0.72

APPENDIX III a (continuation)

Treatment	1st 20 days	No stress treatment																			
T9	3.17	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
		0.18	0,18	0.20	0.20	0.21	0.19	0.20	0.22	0.22	0.19	0.22	0.20	0.20	0.198	0.184	0.20	0.18	0.21	0.21	0.20
		21st	22nd	23rd	24th	25th	26th	27th	28th	29th	30th	31th	32th	33th	34th	35th	36th	37th	38th	39th	40th
		0.19	0.22	0.22	0.20	0.24	0.20	0.20	0.19	0.20	0.20	0.20	0.23	0.21	0.19	0.22	0.22	0.23	0.23	0.19	0.21
		41st	42nd	43rd	44th	45th	46th	47th	48th	49th	50th	51th	52th	53th	54th	55th	56th	57th	58th	59th	60th
		0.20	0.21	0.19	0.19	0.18	0.20	0.22	0.20	0.21	0.21	0.19	0.25	0.20	0.24	0.23	0.29	0.21	0.19	0.19	0.21
		61st	62nd	63rd	64th	65th	66th	67th	68th	69th	70th	71th	72th	73th	74th	75th	76th	77th	78th	79th	80th
		0.21	0.21	0.19	0.24	0.18	0.22	0.21	0.18	0.20	0.19	0.19	0.20	0.20	0.22	0.18	0.19	0.19	0.23	0.20	0.20
		81st	82nd	83rd	84th	85th	86th	87th	88th	89th	90th										
		0.21	0.18	0.19	0.19	0.20	0.21	0.21	0.23	0.18	0.21										

APPENDIX III b

Irrigation interval (days)

Treatment	Stress treatments (No. of irrigation)																					
	1st20 Days	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**	**13th**	**14th**	**15th**	**16th**	**17th**	**18th**	**19th**	**20th**	**21st**
T_1	1	4.9	5.2	5.4	4.8	4.9	5.7	5.3	5.5	4.9	5.6	5.5	5.3	5.1	4.7	4.8	5.4	5.5	5.3	-	-	-
T_2	1	5.4	5.8	5.8	5.5	5.7	5.8	5.2	5.4	5.8	5.6	5.3	5.5	5.7	5.2	5.1	5.8	4.9	-	-	-	-
T_3	1	3.8	4	3.5	4.1	4.4	3.8	4.2	5.7	4.1	4.1	4.8	3.9	4.1	4.2	4.5	3.6	4.6	4.9	3.4	4.0	-
T_4	1	4.3	4.6	4.2	4.9	5	5.1	4.9	4.8	4.5	4.3	4.1	4.6	4.9	5.2	4.5	4.3	4.5	4.1	5.5	4.2	-
T_5	1	4.1	4.6	4.2	3.9	4.5	4.8	4	4.4	4.4	4.7	4.8	4.2	4.5	3.8	4	4.5	4.8	4.7	4.7	-	-
T_6	1	5.1	4.9	4.5	4.7	4.9	5.3	5.2	4.2	4.2	5.5	5	5.1	4.5	4.1	4.9	5.5	4.3	4.8	4.8	-	-
T_7	1	4.8	5.1	4.9	5.5	5.4	4.9	5	5.7	5.7	5.6	5.4	5.2	5.4	5.5	5.8	4.8	5.6	4.2	4.2	-	-
T_8	1	4.1	3.8	3.0	3.5	2.9	2.8	3.0	3.1	3.7	3.4	3.7	3.2	2.9	3.4	3.2	3.0	2.5	3.8	3.8	3.5	3.0
T_9	1	No stress treatment- 1 day interval (Daily irrigation)																				

APPENDIX IV

Average input cost and market price of produce

Items	Cost (Rs)
Inputs	
Seed	1200 kg^{-1}
Sack	2 $sack^{-1}$ $season^{-1}$
Farm yard manure	2.5 kg^{-1}
Urea	9 kg^{-1}
Rock phosphate	10 kg^{-1}
Muriate of potash	17 kg^{-1}
Citric acid	540 kg^{-1}
Humic acid	650 kg^{-1}
Yeast	1300 kg^{-1}
Sugar	35 kg^{-1}
Salicylic acid	1632 kg^{-1}
Jaggerry	52 kg^{-1}
Produce	
Market price of okra	50 kg^{-1}