Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)

By

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(2015-11-063)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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Vishnu K. S.

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Abbreviations

DAS	Days after sowing
%	Per cent
CGR	Crop growth rate
RGR	Relative growth rate
NAR	Net assimilation rate
LAI	Leaf area index
IAA	Indole acetic acid
NAA	1-Naphthalene acetic acid
CCC	Cycocel
GA	Gibberellic acid
Kg ha^{-1}	Kilogram per hectare
t/ha	Tonnes per hectare
POP	Package of practices
NUE	Nutrient use efficiency

Introduction

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) commonly known as lady's finger, belongs to the family *Malvaceae*. It is one of the important summer vegetable crop grown widely in tropical regions of the world for its tender pods. It is cultivated for its green fibrous fruits. Okra fruits are a green capsule containing white seeds and the fruits are harvested at immature stage and eaten as a vegetable.

Okra plays an important role in human nutrition by supplying carbohydrates, protein, fat, minerals and vitamins that are generally deficient in basic foods. The vegetable is valued for many of its properties. The stems and roots are used for clarification of sugarcane juice from which 'Gur' or 'brown sugar' is prepared. Ripen seeds are roasted, ground and used as a substitute for coffee in some countries. The mature fruits and stems containing crude fibre are used in the paper industry. Extracts from okra seeds is an alternative source for edible oil. The greenish yellow edible oil has a pleasant taste and odour, and is rich in unsaturated amino acids such as oleic acid and linoleic acid (Chauhan, 1972). The tender fruits contain minerals especially calcium, magnesium, iron and phosphorus, protein, vitamin A and C including riboflavin as well as high mucilage. 100 g of edible portion of okra contains 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fiber. Okra has various health benefits and it can be used against genito-urinary disorders, spermatorrhoea and chronic dysentery. Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids (Chauhan, 1972).

The plant requires warm temperature and is unable to withstand low temperature for long or tolerate any threat of frost. Ideal temperature is in the range of 21-30^{0}C, with minimum of 18^{0}C and maximum of 35^{0}C respectively. Okra has good potential as a foreign exchanger crop and accounts for 65% export of fresh vegetables. In India it is cultivated in 0.35 mha area with a production of 3.5 mt and productivity of 9.6 mt/ha. The major okra producing states in India are

Uttar Pradesh, Bihar, Orissa, West Bengal, Andhra Pradesh and Karnataka. The largest area and production is in India followed by Nigeria. The highest productivity is reported from Saudi Arabia (13.3 tons' ha^{-1}) followed by Egypt (12.5 tons' ha^{-1}). (FAOSTAT, 2011).

In India okra production and productivity is significantly low due to the use of poor yielding local varieties, sub optimal plant density, inappropriate planting dates, soil fertility, attack of various insect pests and weeds etc. Ideal plant population and nitrogen fertilizer dose are the two essential key elements for enhancing the profitability in okra (Chadha, 2002). In the present scenario of agriculture, the extent to which farmers can depend on chemical fertilizers is constrained by its increasing cost and availability at right time. Moreover, fertilizer recommendation of crops based on soil test data is an important criterion to enhance the nutrient use efficiency. Balanced nutrition alone plays major role for higher efficiency and economy in fertilizer use. Balanced fertilization is achieved through soil testing. In many cases, farmers are applying very high doses of fertilizers, particularly N without adequate P and K than required. In this context, balanced nutrition management through soil testing will enhance the fertilizer use efficiency of crops and help in achieving sustainable economic farming.

Various growth stimulants containing amino acids, peptides, polyamines, humic acids and mixtures of nutrients were found to enhance the yield and quality of crops. The yield contributing characters and quality of plants could be improved by foliar application of growth stimulants. New approaches to sustainable agriculture emphasize on environment friendly safe products or formulations having growth stimulation activity. Majority of the growth stimulants are reported to have the capacity to enhance the nutrient use efficiency of plants which further stimulate photosynthesis and plant growth. Growth stimulants are often mixture of a variety of compounds and many are likely to have multiple functions in terms of improving nutrient availability, providing fungicidal, insecticidal and hormonal effects.

To attain sufficient and sustainable yield to meet the demand for food, different strategies to increase the efficiency of chemical fertilizers are envisaged. One approach to enhance productivity of crop is the development of environment friendly growth stimulants which have beneficial effects on plants. The soluble organic molecules in the growth stimulants has direct effect on metabolic and physiological process of plants due to their particular molecular structure. Growth stimulants influences the plant growth by modifying the physiology of plants and improving the physical, chemical and biological properties of the soil. Growth stimulants, an elixir to plants, have been recognized by the scientists for its influence on the growth and development of crops (Ertani *et al.*, 2015).

Hence the present study was undertaken to find out the influence of growth stimulants on morpho-physiological changes, yield and quality of Okra (*Abelmoschus esculentus* L.) with respect to soil fertility management.

Review of Literature

2. REVIEW OF LITERATURE

2.1. Nutrient management

The concept of soil health deals with the integration of the physical, chemical and biological components of the soil. To assess the soil health attributes, soil testing is the only tool used to measure the physical, chemical and biological health of the soil. Soil testing provides sound information about the fertility and productivity of the soils. Though chemical fertilizer is an indispensable factor in modern agriculture, an excessive use of the same not only affects soil and plant health and quality but also economical holdings of farmers as the cost of chemical fertilizers are escalating day by day. Excessive use of fertilizers especially nitrogenous and phosphate fertilizers leads to environmental pollution such as eutrophication and nitrate toxicity of ground water. Soil testing helps to recommend chemical fertilizers for more judicious use in combination with organic manures and bio fertilizers and hence balanced nutrition to crop (Doran and Parkin, 1994).

2.2 Growth stimulants

Growth stimulants are materials that promote plant growth and hormonal activity in plants. Plant hormones are chemical communicators, or agents, which help regulate a plant's development and its response to its surrounding environment. Growth stimulants also promote antioxidant production in plants which, in turn, reduces "free radicals". Free radical molecules result from stress such as drought, heat, ultraviolet light and herbicide use. Free radicals are damaging because they are strong oxidizing agents which damage lipids, proteins and DNA within plant cells. Antioxidants are metabolites and enzymes which seek out free radical molecules and protect plants from damage. They include lipid soluble substances like vitamin E and beta-carotene and water soluble materials such as vitamin C and various enzymes. Plant growth stimulants provide a key hormone or organic element that influences growth in a particular way.

They were different from fertilizers to provide a supplemental meal for plants, although some stimulants may also contain plant nutrients. Growth stimulants can be applied to any kind of plant and have no toxic properties (Azcona *et al.*, 2011).

2.3. Origin and Geographic Distribution of okra

Okra is an annual crop, requiring warm growing condition and found in almost every parts all over India. There are two main hypotheses when it comes to explaining geographical origin of *A. esculentus*. Some authors stated that one putative ancestor (*A. tuberculatus*) is native to Uttar Pradesh in northern India, suggesting that the species originated from this geographic area. Others, on the basis of ancient cultivation in East Africa and the presence of the other putative ancestor (*A. ficulneus*), suggest that the area of domestication is north Egypt or Ethiopia, but no precise proof is available today. Southeast Asia is considered as the center of diversity of okra plant (Qhureshi, 2007).

2.4. Soil and Climatic Requirements

Okra requires a long, warm and humid growing period. It is sensitive to frost and extremely low temperatures. For normal growth and development of the plants, a temperature between 24°C and 28°C is preferred. (Rice *et al.*, 1987).

Warm soil is one of the most important requirement for okra seed germination. Seeds will germinate in relatively warm soils and no germination occurs below 16^0C. It can be grown on sandy to clay soils due to its well-developed tap root system. Relatively light, well-drained, nutrients rich soils are ideal for the crop growth. The pH ranges of about 6.0 to 6.8 is recommended for okra production (Kochlar, 1986).

2.5. Humic acid

Humic acid is a naturally occurring polymeric organic compound. It is produced by the decaying of organic materials and is found in soil, peat and lignites. It also forms chelates by forming complexes with micronutrients such as

sodium (Na), potassium (K), magnesium (Mg), zinc (Zn), calcium (Ca), iron (Fe), copper (Cu), and with various other elements (Aiken *et al.*, 1985), (Sharif *et al.*, 2002). It enhances water retention, increases seed germination rates, improves water, air and roots penetration. Humic acids are materials that promote plant growth and improve yield. It is particularly used to ameliorate or reduce the negative effect of stress. It promotes both hormonal activity and antioxidant production in plants which, in turn, reduces free radicals. Humic acid reduces the amount of fertilizer consumption, and makes plant tolerant against stress, drought stress. In addition, foliar spray of humic acid improved plant growth and development, yield and quality in various plant species (Padem *et al.*, 1997)

The foliar spraying of humic acid substances into the plant tissue bringing about different biochemical effects through elevate uptake and maintaining vitamins and amino acids level in plant tissues (David *et al.*, 1994).

2.5.1. Effect on growth parameters and physiological parameters

A couple of theories have been proposed to understand the effect of humic acid. This deals with the impact of humic acid on respiration and photosynthesis, and stimulation of nucleic acid absorption and hormone action of humic acid (Serenella *et al.*, 2002). Sharif *et al.* (2002) reported that humic acid could maintain more photosynthetic tissues and which will improve the dry weight of the plants. A study on wheat demonstrated that the impact of various concentrations of humic acid at three foliar sprayings improve the leaf area of the plants (Sabzevari and Khazaei, 2009).

Complex formation properties of humic acid with Fe and Zn imparts the stimulatory impacts of humic acid in plant growth and development (Clapp *et al.*, 2001). In this specific circumstance, humic acid have been generally viewed as an agent of fixing Fe concentration in plants (Chen and Aviad, 1990). This impact has been basically ascribed to the complexing properties of humic acid, which improves the accessibility of micronutrients from sparingly solvent hydroxides (Stevenson, 1991). Their effects appear to be mainly exerted on plant

development and advancement by acting as hormone-like substances (Nardi *et al.*, 1996).

Humic acid act as a hormone like substances which enhances plant growth, development and nutrient utilization as well as enhances stress tolerance (Serenella *et al.*, 2002). Also the humic acid act as a repository of mineral plants nutrients (Yildirim, 2007).

Liu *et al.* (1998) revealed that 400 mgL^{-1} humic acid increased photosynthetic rates of plants when compared with control. Chlorophyll substance was unaffected whereas roots dehydrogenase activity and root growth were altogether expanded by humic acid application. It additionally increased tissue concentrations of Mg, Mn and S. Foliar spraying of humic acid increases vegetative development of plant and improves photosynthates movement and leaf area index (Ghorbani *et al.*, 2010).

Anuja *et al.* (2011) have conducted experiment on foliar use of growth stimulants and inorganic fertilizers. The treatments include foliar supply of growth stimulants namely, vermiwash (1:3 and 1:5) humic acid (0.1 and 0.2%), water spray (control) and 100% and 75% prescribed dose of fertilizers. Study revealed that the humic acid 0.2 % +100 per cent NPK application increased the plant height and finally the yield of palak var. OOTY-1. The treatment with 2000 mgl^{-1} humic acid, had the maximum plant height, leaf and flower number in marigold (Mohammadipour *et al.*, 2012).

Alphonse and Saad (2000) recorded higher plant growth and leaf growth in green house cucumber with the use of humic acid and poultry fertilizer. Karuppaiah *et al.* (2008) conducted a study with organic manures of FYM (25t ha^{-1}), inorganic fertilizers of NPK (60:50:40) in combination with Vermiwash (1:5) dilution, *panchagavya* (3%) and humic acid (0.2%). The results revealed that the treatment 25 t ha^{-1} of FYM with recommended dose of inorganic fertilizers (60:50:40) by foliar application of humic acid (0.2%) was found the best with a total yield of 19.21 t ha^{-1} and a cost benefit ratio of 3:76 which was *at par* with the

treatment combination. Ayyobi *et al.* (2013) observed that the application of humic acid and other growth stimulants have the tallest plants, number of pods per plant, the longest pods and number of lateral branches as compare to control in peppermint.

Mallikarjuna *et al.* (1987) found that humic acid as exceptionally effective in increasing the dry matter yields of root and shoot of sorghum. The dry matter yield of sorghum increased with an increase in the level of humic acid up to 30kg ha^{-1} and afterwards it declined. Chen and Aviad, (1990) observed that the utilization of humic acid and growth stimulants as media alterations or foliar spray can advance more root and shoot development, root expanding, leaf chlorophyll content, rates of nutrient uptake, photosynthesis and respiration.

Foliar application of humic acid improves the photosynthetic assimilates translocation into different growing regions of the plant (Cooper, 1998). Also the incorporation of humic acids into soils stimulated root development and also the multiplication and initiation of root hairs which in turn enhances the nutrient uptake by the plants (Atiyeh, 2002).

Nardi *et al.* (1996) observed that foliar application of humic acid resulted in enhancement of shoot growth and development which is more evident than the root development. Humic substances impact the development of plant roots. Pettit (2004) also reported that spraying of humic acid and fulvic acid improves the shoot growth in common millet.

Albairak and Camas, (2005) reported that foliar spraying of humic acid improves the growth and development, production, and quality changes of agricultural products. They stated that this improvement of plant growth and development is mainly due to the chelating capacity of humic acid with different microelements which will improve the availability of nutrients to plants.

Ghorbani *et al.,* 2010 stated that in legumes, humic acid foliar spray resulted in a remarkable effect on vegetative growth of plant. Haghigh *et al.*

(2011) investigated the effect of humic acid on growth parameters of cowpea and found that humic acid increased leaf area index.

2.5.2. Effect on yield and yield attributes

Nikbakht *et al.* (2008) reported that 500 mgL^{-1} humic acid caused a 52 % yield increase gerbera flowers. Shahmaleki *et al.* (2010) found that treatment with 20 & 50 mgL^{-1} humic acid in lettuce increased yield characteristics significantly. Vijayakumari *et al.* (2012) reported the micro herbal fertilizers and humic acid are found to stimulate plant growth and yield of soya bean (*Glycine max* L.).

David and Samule (2002) reported that the foliar application of humic acid alone and/or in combination with other foliar fertilizers had significant beneficial effect on the growth and yield of mustard. Albayrak and Camas (2005) reported that humic acid significantly affected most of the yield components of *Brassica rapa.*

Khan and Mir (2002) observed that spraying of humic acid increased the permeability of plant membranes and which enhanced the uptake of nutrients. Baskar and Sankaran (2005) evaluated that the application of 100 % NPK with humic acid applied to soil @ 10 kg/ha significantly enhanced the growth and yield attributes, fresh and cured rhizome yields of turmeric.

Chris *et al.* (2005) found that both the foliar and soil application of humic acid significantly improved seed yield in mustard. Ulukan (2008) reported that humic acid treated plants showed more plant height, spike number, grain number and 100 grain weight compared to untreated plants. Balakumbahan and Rajamani (2010) reported that foliar application of humic acid gave better yield in senna (*Cassia angustifolia*).

2.5.3. Effect on quality

Yaofu (2005) found that the foliar application of humic acid increased the leaf quality of tobacco plant. He observed that humic acid increases plant yield, leaf area and the nicotine content of leaves in tobacco plants.

Foliar applications of humic acid resulted in a significant improvement of fruit quality in table grapes. Spraying with humic acid at 20 mg/L with respect to the control treatment caused an increase in total soluble solids (°Brix) in table grapes (Ferrara and Brunetti, 2010).

Mohsen (2014) reported that foliar application of humic acid combined with microelements at different rates increased fruit quality (Total soluble solids, protein, pH, vitamin C, fruit firmness and fruit lycopene content) of tomato fruits. The maximum fruit firmness of 3.91 kg cm^{-2} was recorded at 30 ppm humic acid +15 mM Ca application.

2.6. Potassium silicate

Potassium silicate is helps to build the plants defense from attacks by insects and fungi. Potassium silicate helps the plant growth by depositing on epidermal cell walls and enhancing the plant's capacity to keep the leaves pointed towards the light source. It also boosts the stem strength, making it easier to hold up more weight. As the plant builds itself up with potassium silicate, it also assisted in balancing nutrient uptake and distribution, and increased concentration of chlorophyll and RUBP carboxylase in leaves. (Yorinori *et al.*, 2005).

Potassium silicate is impregnated in the epidermal cell layer acting as a barrier against penetration of fungal attacks like powdery mildew, black spots, pythium and phytophthora and many more fungal pathogens. Silicate additionally increases the mechanical strength of the plant to withstand extreme heat and cold swings and increased total dissolved salts in water. It also reduced the rate of transpiration of plants (Nolla *et al.*, 2006).

Potassium silicate plays a dynamic role in fighting against fungal growth by the production of polyphenolic compounds, thereby increasing the natural defense of the plant against fugal and insect attacks. Spraying of potassium silicate will help to lowering the rate of disease attack and helps to protect the plant's newly developing leaves from spider mites, aphids, and many other sucking type insects (Bowen *et al.*, 1992).

Mathai *et al.* (1978) claimed that potassium silicate imparts disease resistance in both monocot and dicot plants. And they observed that the negative relationship between the potassium silicate and disease intensity for blast *(Pyriculuria oryzae)* and sheath blight *(Corticium sasakii)* in rice. A reduction of the frequency of a wilt pathogen of cucumber requires the use of 2250 to 4500 kg potassium silicate/ ha. Foliar application of potassium silicate to crop plants is possibly a reasonable option to root-zone application (Miyake and Takahashi, 1983). 1% solution of potassium silicate was important to control powdery mildew of wheat (Leusch and Buchenauer, 1989).

2.6.1. Effect on growth parameters and physiological parameters

According to Muthuvel (2002) spraying growth stimulants like moringa leaf extract spray @ 25 ml/plant and potassium silicate @ 0.5 per cent spray resulted in higher plant height, number of branches per plant in mustard. Ali *et al.* (2011) reported higher plant height, primary branches, secondary branches per plant due to the foliar application of potassium silicate, which in turn improved the yield of green gram (*Vigna radiata*), chilli (*Capsicum frutescens*) and mustard (*Brassica campestris*).

Cheng (1982) reported that potassium silicate decreases the toxicity effects of other foliar application of fertilizers and micronutrients and it also improves the plant growth and development. Potassium silicate application enhances flowering of strawberry plants. The plants sprayed with potassium silicate developed longer petioles and appreciably higher dry matter than the control (Wang and Galletta,

1998). Gadimor *et al.* (2007) reported that potassium silicate improves the product quality of the produce and plant tolerance against biotic stresses in soybean.

Ahmad *et al.* (1992) declared that the "addition of potassium silicate resulted in significant restoration from salt stress" in wheat. Gong *et al.* (2003) reported that application of 1% of potassium silicate increases the leaf area (8.3 $cm^{2)}$ and dry mass (45.3 mg per plant) in wheat plants. Kaya *et al.* (2006) found that application of 0.5% potassium silicate increased shoot dry mass by 0.02 g for each plant, and entire plant dry mass by 0.74 g for each plant in drought-stressed corn grown in a blend of peat, perlite, and sand for 45 days.

Aranda *et al.* (2006) showed that the both soil and foliar application of potassium silicate resulted in an increase of leaf area in tomato plants. Gunes *et al.* (2008) reported that potassium silicate applied sunflower cultivars showed an increase in plant dry weight and plant height than the untreated plants.

2.6.2. Effect on yield and yield attributes

Okuda and Takahashi (1961) found that potassium silicate was essential to advance the development of rice (*Oryza sativa*) and enhance the grain yield. They tried different concentrations of potassium silicate (0, 5, 20, 60, and 100 ppm) as foliar spray. The use of K_2SiO_3 at 60 and 100 ppm resulted in maximum plant height, stem number, dry weight and grain yield of the rice. Patel *et al.* (2009) reported that earlier flowering (33.83 days) in okra cv Parbani kranti with 100% of recommended dose (100:50:50 NPK kg/ha) + 2 % K_2SiO_3 foliar application.

Anderson (1991) reported that foliar application of potassium silicate increased the sugarcane yield by 39 %. Pereira *et al.* (2004) reported that at 15 days' interval application of potassium silicate enhanced the number of productive tillers and total number of tillers/m^2 in rice. Silicon @ 1.0% solution produced maximum grain diameter and grain protein while potassium silicate (1% solution) resulted in maximum number of productive tillers, straw yield, spike per panicle, 1000 grain weight, paddy yield and grain starch in rice (Ahmad *et al.*, 2013).

2.6.3. Effect on quality

Adatia and Besford (1986) reported that the action of RuBP carboxylase, in leaves of high potassium silicate treated cucumber plants was 50 % higher on an area basis and 31 % higher on a fresh weight basis than that of control plants. Also the soluble protein content was high in potassium silicate treated cucumber plants. Nishizawa (1995) found that the amount of total soluble carbohydrates in leaves on a per plant basis were greater for potassium silicate treated plants than for the controls.

Foliar application of Potssium silicate at 0.5% resulted in better visual scores for quality, color, and density of seashore paspalum (*Paspatum vaginata*) (Trenholm *et al.*, 2001). Savvas *et al.* (2002) found that potassium silicate application in gerbera (*Gerbera jamesonii*) cultured in hydroponic system had effects on both crop quality and the nutrient uptake. They reported that application of potassium silicate increased the flower quality and stem thickness during the hydroponic gerbera production.

2.7. Cytozyme

Cytozyme is a heterogenous protein hydrolase comprising of different types of plant growth promoting substances, such as auxins, cytokinins, gibberellins (gibberellic acid 0.001%), sea weed extracts, enzymes, and chelated micronutrients. Cytozyme in plant is mainly absorbed through stomatal pores, lenticles and cuticular openings. It synergistically acts with the plant metabolism and also helps to improves cell functions. Cytozyme enhances hormonal and enzymatic activities of plants and physiological efficiency of crops. It increased vegetative growth of plants, better flower setting, fruit initiation and higher yield. Cytozyme adds quality to produce in terms of uniformity in size, shape, colour and thereby enhanced the market value of the produce (Khurana and Pandita, 1986).

2.7.1. Effect on growth parameters and physiological parameters

Cytozyme controls stomatal opening and also increases leaf area, amount of chlorophyll and carotenoids contents (Khurana and Pandita,1986). Nawalgatti *et al.* (1991) reported that there was increase in the LAI, DM production, NAR and CGR in groundnut cv. DH-3-30 with the foliar application of 500 and 1000 ppm cytozyme, CCC, Vipul or Paras, 50-60 ppm TIBA or 10 ppm NAA at 45 days after sowing. CCC was the most effective followed by cytozyme and NAA (20 ppm).

According to Malawadi (2003) the plant height, number of branches, leaf area, LAI and total dry matter production in various plant parts of chilli recorded significantly higher values with combined application of NPK + FYM+ cytozyme as compared to NPK alone. Cytozyme is known to have the activity of cytokinins and auxins which retard abscission (Taiz and Zeiger, 2006). Cytokinins and auxins are also known to stimulate flower bud initiation (Wetzstein *et al.*, 2011)

Cytozyme increased photosynthetic efficiency on account of stabilization of chlorophyll and higher production of photosynthates resulting in increased secondary branches simultaneously. Cytozyme increases CO_2 fixation, chlorophyll and carotenoid contents of leaves and increases leaf area. It also controls stomatal opening and reduces photo-respiration losses, thereby improving the rate of photosynthesis, Rana and Vashistha (1988). Application of cytozyme and urea resulted in an increase of mean plant height of 47.95 cm in potatoes, compared to without cytozyme treatments (Khan *et al.*, 2014).

2.7.2. Effect on yield and yield attributes

Bucker *et al.* (1999) observed that the radish yield increased by 7.3 % by weekly applications of cytozyme. Foliar spray of cytozyme (450 ml/ha) was relatively more beneficial in improving the biological yield, harvest index, 100 seed weight and seed yield in soybean (Raut *et al.*, 1995). Chougale (1997) reported that cytozyme spray increased the yield potential of sesamum. Jirali

(2001) revealed that application of cytozyme @ 2000 ppm and miraculan @ 2000 ppm was found very effective and has improved yield and yield attributes in turmeric.

Chaudhary *et al.* (2006) reported that the increase in fruit size, weight and volume with the application of cytozyme could be due to nature of auxins (NAA) to stimulate cell division and cell enlargement and increased sink strength of the fruits.

2.7.3. Effect on quality

Application of foliar spray of 25 and 50 ppm NAA, 40 and 60 ml cytozyme and 500 and 1000 ppm CCC (chlormequat) on peas increased the N and P contents in leaves, stems and seeds (Shende *et al.*, 1987). Abd El-Rhman (2010) reported that the cytozyme significantly improved fruit quality and reduced fruit cracking in pomegranate. The highest fruit length, diameter, weight, volume and minimum fruit cracking were recorded in trees treated with cytozyme 4 ml/L.

Hoang (2003) reported that the maximum fruit length (91.16 mm), diameter (88.68 mm), weight (316.30 g) and volume (293.57 cc) was observed with cytozyme (4ml/l) application in pomegranate. This increase in fruit size, weight and volume with the application of cytozyme could be due to nature of auxins (NAA). Clayton *et al.* (2006) reported that foliar application of cytozyme at the rate of 5 ml/L improves fruit quality in sweet cherries.

Khan *et al.* (2014) demonstrated that a significant improvement in potato productivity and quality by applying urea with cytozyme. Cytozyme appears to improve the availability of the applied urea and thus resulted in better improvement in potato yield and quality at the lower rate (200 kg N ha^{-1}). Cytozyme improved tuber yield and quality when it was applied with standard urea and Agrotain-treated urea resulted in a yield depression at the higher rate (300 kg N ha^{-1}).

2.8. Putrescine

Polyamines are low molecular weight polycations found in every single living creature (Cohen, 1998). They are known to be basic for development and advancement in prokaryotes and eukaryotes (Tabor and Tabor, 1984)

Major polyamines present in plants are diamine putrescine (Put), triamine spermidine (Spd) and tetramine spermine (Spm). They occur in the free form or as conjugated forms which are bound to phenolic acids and macromolecules like proteins and nucleic acids. Polyamines stimulate DNA replication, transcription and translation. Polyamines play an important role in wide range of biological process in plant development, including senescence and environmental stress. Their biological activity is ascribed to their cationic nature (Bais and Ravishankar, 2002).

Putrescines are small nitrogenous compounds seen in plants. Increased putrescine levels in stressed plants are of adaptive significance due to their association in the control of cell ionic condition, maintenance of membrane integrity, prevention of chlorophyll loss and improvement in synthesis of protein, nucleic acids and protective alkaloids (Kusano *et al.*, 2008).

Putrescine was considered to act as a free radical scavenger to protect the plant from oxidative and chilling stress (Shen *et al.*, 2000). Membrane stabilization and minimization of water stress of different sorts of cells are few of the known physiological impacts of putrescine in the plant system (Goyal and Asthir, 2010).

2.8.1. Effect on growth parameters and physiological parameters

Putrescine is known to improve plant growth and development due its effects on cell division and differentiation in bean plants (Altman *et al.*, 1982). Youssef *et al.* (2004) reported that foliar spraying of putrescine at the rate of 250

ppm to *Matthiola incana* plants significantly improved plant height, number of leaves per plant, fresh and dry weights of leaves per plants.

Talaat *et al.* (2005) sprayed putrescine at the rate of 3-10 mM in periwinkle (*Vinca minor*) plants which gave the best results in plant height, number of branches, fresh and dry weights of leaves as compared with the untreated plants. Mahgoub *et al.* (2006) studied the impact of putrescine on carnation plants at the rate of 200 and 400 ppm. They found that, spraying of putrescine at the concentration of 200 ppm improves plant height, number of branches per plant, dry weights of the plants, contrasted with control plants.

El-Quesni *et al.* (2007) found that foliar application of putrescine @ 200 ppm on *Bougainvillea glabra* gave the highest values of plant height, number of branches and leaves per plant, stem diameter, fresh and dry weights of leaves as compared with untreated plants. Youssef (2007) found that, spraying gladiolus seedlings with 10 and 20 ppm putrescine particularly increased dry weight of shoots per plant.

Abd El-Aziz *et al.* (2009) found that foliar use of putrescine @ 200 ppm improved plant height, number of leaves per plant, fresh and dry weights of leaves per plant as compared with untreated gladiolus plants. El-Sayed (2009) on *Chrysanthemum indicum* found that, foliar use of putrescine improves plant height, number of branches per plant, number of leaves per plant, fresh and dry weights of plant. The best results were found when plants treated with 200 ppm putrescine.

Ayad *et al.* (2010) studied the impact of foliar spray of putrescine at the concentrations of (0, 10, 20 and 40 mg/l) on *Pelargonium graveolens*. The results revealed that, all criteria of vegetative growth expressed as plant height, fresh and dry weights of plants were significantly influenced by spraying of putrescine particularly at 20 mg/l putrescine.

El-Quesni *et al.* (2007) reported the effect of putrescine at different concentrations of (0, 100 and 200 ppm) on *Syngonium podophyllum*. The study indicated that, foliar spraying of putrescine increased growth characters at the concentrations of 100 and 200 ppm. The maximum plant height, stem diameter, number of leaves, fresh and dry weights of leaves per plant were obtained at 100 ppm putrescine as compared to untreated control plants.

El-Lethy *et al.* (2010) revealed that, the foliar spraying of putrescine at the dose of (40, 80 and 120 mg/l) to flax (*Linum usitatissimum*) plants significantly improve the plant height, fresh and dry weights per plant, particularly in plants treated with 120 mg/l putrescine.

Mahgoub *et al.* (2006) reported that, spraying *Dahlia pinnata* plants with putrescine at the concentrations of (50, 100 and 150 ppm) increased plant height, stem diameter, number of branches, fresh and dry weights of leaves and stems per plant. The highest values were obtained when plants treated with 150 ppm putrescine compared to untreated control plants.

2.8.2. Effect on yield and yield attributes

Putrescine (as one of the polyamine group) has a regulatory role in promoting productivity of tomato (Cohen *et al.*, 1982).

Postharvest application of putrescine has also been reported to delay colour changes in lemon (Valero *et al.*, 1998). Singh *et al.* (2008) found that the use of putrescine 50 ppm improved yield and yield-related indices in marigold (*Calendula officinalis* L.).

Mahgoub *et al.* (2006) concluded that, spraying of putrescine on carnation at the concentration of 200 ppm led to significant improvement in number of flowers/plant, fresh and dry weights of flowers compared to untreated control plants. El-Quesni *et al.* (2007) claimed that, foliar application of putrescine at the concentrations of (100 and 200 ppm) on *Bougainvillea glabra* significantly

improved the number of flowers per plant, as well as fresh and dry weights of the flowers compared to control plants.

Abd El-Aziz *et al.* (2009) reported that, spraying of putrescine at the concentration of 200 ppm had a promotive effect on cormlets and florets caracters of gladiolus plants. They found that putrescine application improves the number of cormlets, fresh and dry weights of cormlets, spike length and number of florets in gladiolus plants.

2.8.3. Effect on quality

Mitra and Sanyal (1990) reported that pre harvest treatment of putrescine in mango results in higher TSS and lower fruit acidity, compared with control.

Putrescine (50 ppm) has been reported to prolong storage of tomato (Law *et al.,* 1991), maintain higher fruit firmness and delay colour changes (Valero *et al.,* 1998) in lemons. Higher TSS was reported in apple with exogenous application of putrescine (Costa and Bagni, 1983).

Talaat *et al.* (2005) claimed that, application of putrescine at the rate of 10^{-3}M, 10^{-4} M and 10^{-5} M significantly increased the contents of chlorophyll a, b and total carotenoids in flowering and fruiting stages in periwinkle plants. Abd El-Aziz *et al.* (2009) reported that, spraying of putrescine at the concentration of (0.05 and 0.15 mM) led to significant increase in total carotenoid content in maize.

Materials and Methods

3. MATERIALS AND METHODS

Investigations on " Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)" was conducted in Central Nursery, College of Horticulture, Vellanikkara. The details of materials used and methods adopted are presented in this chapter.

3.1General details

3.1.2 Location

The experiment was conducted in Central Nursery, College of Horticulture, Vellanikkara.

3.1.3 Variety used

The okra variety Arka Anamika, a popular variety of 100-120 days duration was used for the experiment. The variety is an interspecific hybrid between *Abelmoschus esculentus* (IIHR20-31) x *A.manihot* spp. It is a tall well branched variety with fruits lush green, tender and long, fruits born in two flushes. Purple pigment is present on both sides of the petal base. Stem is green with purple shade. Fruits are free from spines having 5-6 ridges with delicate aroma, good keeping and cooking qualities. It is resistant to Yellow vein mosaic virus and capable of yielding over 12 t/ha under favorable conditions and gives moderate yields even under adverse situation.

3.1.4 Season

The crop grown during September 2016 to December 2016.

3.2 Treatment details

The experiment was laid out in a randomized block design (RBD) with 15 treatments in 3 replications. The plot size was 3 m x 2.4 m (7.2 m^2). The crop was raised as per standard POP recommendations of KAU (KAU, 2016) and also

under soil test based nutrient management system, incorporating the following treatments.

T_1	Standard POP (KAU)
T_2	Soil test based modified nutrient management
T_3	T_1 + Humic acid spray @ 0.2 %.
T_4	T_1 + Potassium silicate spray @ 0.3%
T_5	T_1 + Cytozyme spray @ 0.2%
T_6	T_1 + Putrescine spray @ 50 ppm
T_7	T_2 + Humic acid spray @ 0.2 %.
T_8	T_2 + Potassium silicate spray @ 0.3%
T_9	T_2 + Cytozyme spray @ 0.2%
T_{10}	T_2+ Putrescine spray @ 50 ppm
T_{11}	50% T_1 + Humic acid spray @ 0.2 %.
T_{12}	50% T_1+ Potassium silicate spray @ 0.3%
T_{13}	50% T_1+ Cytozyme spray @ 0.2%
T_{14}	50% T_1+ Putrescine spray @ 50 ppm
T_{15}	T_1+ Water spray

Lay out of the experiment

Season	September-December, 2016
Variety	Arka Anamika
Spacing	60 cm x 60 cm
Design	RBD
Treatments	15
Replications	3
No of plants per replication	20

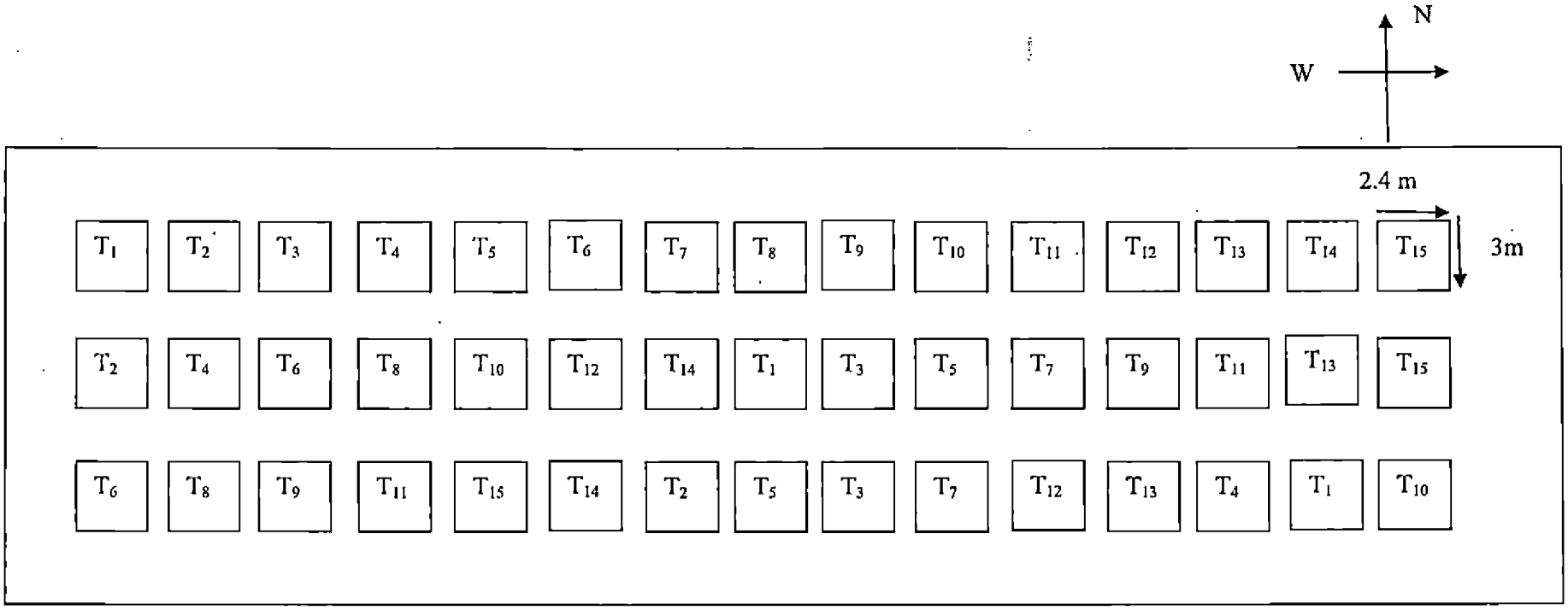

Fig. 1. Layout of experiment

T_1- Standard POP (KAU)

T_2- Soil test based modified nutrient management

T_3- T_1 + Humic acid spray @ 0.2 %.

T_4- T_1 + Potassium silicate spray @ 0.3%

T_5- T_1 + Cytozyme spray @ 0.2%

T_6- T_1 + Putrescine spray @ 50 ppm

T_7- T_2 + Humic acid spray @ 0.2 %

T_8- T_2 + Potassium silicate spray @ 0.3%

T_9 - T_2 + Cytozyme spray @ 0.2%

T_{10}- T_2+ Putrescine spray @ 50 ppm

T_{11}- 50% T_1 + Humic acid spray @ 0.2 %

T_{12} -50% T_1+ Potassium silicate spray @ 0.3%

T_{13} -50% T_1+ Cytozyme spray @ 0.2%

T_{14} -50% T_1+ Putrescine spray @ 50 ppm

T_{15}- T_1+ Water spray

Growth stimulants

Humic acid	: SUPER HUME
	57% Humic acid (44% Fulvic & 13% Humic)
	Manufactured by AGRI INFOTECH, Coimbatore.
Cytozyme	: SPIC CYTOZYME
	Gibberellic Acid- 0.001% w/w, Protein
(hydrolised)-	2.500% w/w
	Manufactured by FOLIAGE CROP SOLUTION,
	Chennai.
Potassium silicate	: SIL- GUARD
	7% Potassium silicate & 2% Phosphite
Putrescine	: 1,4-Diaminobutane, 99%
	$C_4H_{12}N_2$

3.3 Field operations

The details of various field operations from land preparation to harvesting are given below.

3.3.1 Land preparation, sowing and fertilizer application

To ascertain physio-chemical characteristics of the soil during the season of study, soil samples from 0-15 cm depth were collected from different locations of the experimental field before application of fertilizers. A representative composite sample was prepared by processing and mixing them together and then analysed for physical and chemical properties. The experimental field was thoroughly ploughed with the help of mould board plough and cross harrowing was done with tractor. Planking was followed after this and the soil was brought to a good tilth.

The area was ploughed and levelled. The plot size adopted was 7.2 m^2 (3 m x 2.4 m). Plots of 3 m x 2.4 m were made by taking bunds of 25 cm width and height. Secondary and micronutrients were applied as per soil test data except in treatments T_1, T_3, T_4, T_5, T_6, T_{11}, T_{12}, T_{13} and T_{14}. Soil test data showed that, soil was acidic in nature and elements like magnesium, boron and sulphur were deficient. $CaCO_3$ @ 350 Kg ha^{-1}, $MgSO_4$ @ 80 Kg ha^{-1} and Borax @ 10 kg ha^{-1} was applied to soil for correcting the soil nutrient status. At the time of sowing N, P_2O_5 and K_2O @ 55, 35 and 70 kg ha^{-1} was applied. Another 55 kg N ha^{-1} applied one month after sowing. After basal fertilizer application, the seeds were dibbled at a spacing of 60×60 cm at the rate of 7 kg ha^{-1}. Foliar spraying of growth stimulants was done at 15, 30 and 45 DAS. The methods used for soil and plant analysis are given in Table 1 and Table 2.

Table 1: Methods used for soil analysis

Parameters	Methods		References
	Extraction	Estimation	
pH	Soil water suspension of 1:2.5 ratio	Potentiometric method using pH meter	Jackson (1958)
Electrical conductivity	Soil water suspension of 1:2.5 ratio	Conductivity meter	Jackson (1958)
Organic carbon	Wet digestion method		Walkley and Black (1934)
Available nitrogen	Alkaline permanganate method		Subbiah and Asija (1956)
Available phosphorous	Bray-1 extract	Spectrophotometer (Model: Lambda 25)	Bray and Kurtz (1945)
Available potassium	Neutral normal ammonium acetate	Flame photometer (Model: CL 308)	Jackson (1958)

Available calcium and magnesium	Neutral normal ammonium acetate	Atomic Absorption Spectrophotometer	Jackson (1958)
Available sulphur	.0.15% $CaCl_2$	Turbidimetrically by $BaCl_2$ using spectrophotometer	Williams and Steinbergs (1959)
Available Iron, Manganese, Zinc and Copper	Extraction using 0.1M HCl	Atomic Absorption Spectrophotometer	Sims and Johnson, (1991)
Available Boron	Hot water extraction	Colorimetrically by Azomethane-H using spectrophotometer	Berger and Truog (1939)

Table 2: Methods used for plant nutrient analysis

Parameters	Method	Reference
Nitrogen	Micro-Kjeldahl method	Jackson, 1973
Phosphorus	Vanado-molybdo phosphoric yellow colour method	Jackson, 1973
Potassium	Diacid extract method using flame photometer	Jackson, 1973
Calcium, Magnesium	Diacid extract method using atomic absorption spectrophotometer	Jackson, 1973

3.3.2 Plant protection

Timely plant protection measures were taken up as per the package of practices recommendations of KAU (KAU, 2016). Thrips and jassids attack was

Plate 1. Land preparation

Plate 2. Bund preparation

Plate 3. Layout of the experimental plot

Plate 4. Field view of sowing of okra

Plate 5. Irrigation of the experimental plot

Plate 6. Foliar spray of growth stimulants

Plate 7. Measurement of gas exchange parameters by portable photosynthesis system

Plate 8. Harvest of okra

Plate 9. View of experimental plot

noticed during the seedling stage of the crop and neem oil-garlic mixture (2 %) was sprayed.

3.3.3 Plucking of fruits

The fruits were plucked manually when they were green, tender and of marketable size. The picked fruits were weighed and subjected to other observations immediately, after each plucking.

3.4 Sample collection

Five plants were randomly selected from each plot and tagged permanently. The following observations were recorded from tagged plants during entire study period. Morphological, physiological and biochemical observations were recorded at 25^{th} and 50^{th} DAS.

3.5 Morphological Observations

3.5.1 Plant height

The plant height was measured from the base of plant to tip of main shoot by meter scale and the average height of five plants were recorded as mean plant height (cm).

3.5.2 Number of leaves per plant

Total number of leaves per plant of five selected plants were recorded and the average number of leaves per plant was calculated.

3.5.3 Leaf area per plant

The five tagged plants were also used for leaf area measurement. The leaf area was measured with the help of leaf area meter. The average leaf area ($cm^{2)}$ was recorded to calculate total leaf area (cm^2) per plant.

3.5.4 Number of branches per plant

Total number of branches per plant was counted in each of the five tagged plants and the average number of branches per plant was calculated.

3.6 Physiological studies

The physiological and biochemical parameters were estimated at 25 DAS and 50 DAS.

3.6.1 Leaf gas exchange parameters

Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$), transpiration rate ($\mu mol\ H_2O\ m^{-2}s^{-1}$), and stomatal conductance (mol $H_2O\ m^{-2}s^{-1}$) were recorded using portable photosynthesis system (Model – LI-6400 of Licor Inc. Lincoln, Nebraska, USA) during 25th and 50th days after sowing. The measurements were made on upper most fully expanded leaf (3rd leaf from top) and totally 3 measurements were taken from the same leaf. Five plants from each treatment was selected for measurement of photosynthetic characters. Observations were recorded between 8.30am to 10.30 am.

3.7 Biochemical characters

3.7.1 Chlorophyll content

The total chlorophyll, chlorophyll a and chlorophyll b were estimated in a fully expanded young leaf by the method suggested by Hiscox and Israelstam (1979) using DMSO as extraction reagent. Chlorophyll extracted in DMSO was estimated in UV- VIS Spectrophotometer (Spectroquant, Pharo 300, Merck KGaA, Germany) at two wavelengths 645 and 663 nm. The formulae used for the chlorophyll calculation is given below and the results were expressed in mg g^{-1} fr. wt.

Chlorophyll a = [(12.7xA 663) - (2.69xA 645)] x V/1000xW

Chlorophyll b = [(22.9xA 645) - (4.68xA 663)] x V/1000xW

Total chlorophyll = [(20.2xA 645) + (8.02xA 663)] x V/1000xW

Where, A - Absorption at given wavelength

V - Volume of supernatant solution made

W- Weight of the sample

3.7.2 IAA content

IAA (Indole acetic acid) was estimated by the method suggested by Parthasarathy *et al.* (1970) with little modification using Garden Weber reagent. The IAA was expressed in mg g^{-1} of unoxidised auxin g^{-1} hr^{-1}

3.8 Yield and yield attributes

3.8.1 Days to 50 % flowering

Days to 50 % flowering and days to flowering was recorded.

3.8.2. Number of fruits per plant

Total number of okra fruits harvested in all the plucking from randomly selected five plants were recorded and average number of fruits per plant were calculated.

3.8.3 Fruit length and diameter

The length of randomly selected five okra fruits were measured from the base of the fruit to the tip of the fruit in centimeters. A thin wire was rolled around each selected fruit at the broadest point and length of wire was measured. Five fruits for each treatment were taken for diameter measurement.

3.8.4 Fruit weight

The same fruits after recording length and diameter were weighed with the help of electronic balance and average fruit weight (g) was taken. The fruit weight per plant was also calculated.

3.8.5 Yield per plant

Total number of okra fruits harvested from each plant and fruit weight was recorded and average fruit weight per plant was calculated.

3.9 Quality attributes

3.9.1 Crude fibre content in fruits

Crude fibre content was determined by the method suggested by A.O.A.C., 1960. Representative ground fruit sample of 2 g was refluxed with 1.25 per cent H_2SO_4, washed and again refluxed with 1.25 per cent NaOH for 30 minutes, respectively. The sample was dried out, weighed and ignited in muffle furnace. Loss in weight was considered as crude fibre content and expressed.

$$\text{Crude fibre (\%)} = \frac{W2 - W3}{W1} \times 100$$

Where,

W1 = Initial weight of sample

W2 = Weight of refluxed sample

W3 = Weight of ignited sample

3.9.2 Ascorbic acid content of fruit

One gram of sample was blended with 3 per cent meta phosphoric acid and then made up to 100 ml and filtered. From the filterate, 10 ml sample was pipetted into conical flask and titrated with the standard dye to a pink end point (Ranganna, 1986).

Dye factor = 0.5/ Titre value

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken} \times \text{Wt or Vol. of sample}}$$

3.9.3 Mucilage content of fruit

Harvestable maturity okra fruits were cut into small pieces and soaked in water (1:10, v/v) for 6 hours. Then it was filterd through double layer muslin cloth for the residue. The residue was then treated with ethanol in 50:50 v/v. It was washed with acetone (100 %) and air dried to get a powder of the mucilage. The percentage yield of extracted mucilage was calculated based on the amount of fresh okra fruits used for the extraction process and the amount of dry mucilage obtained individually depending upon solvent and expressed as mucilage percentage (%). The percentage yield was calculated from the ratio between weight of dried mucilage obtained and weight of fresh material (Malviya, 2011).

3.9.4 Protein content in fruit

The protein content of the fruit was calculated by multiplying nitrogen per cent in fruit by the factor 6.25 as suggested by Gupta *et al.* (1978).

3.9.5 Nitrogen content in fruit

Nitrogen content was estimated by digesting fruit samples with sulphuric acid using hydrogen peroxide for removing black colour. Estimation of nitrogen was done by colorimetric method using Spectronic-20 after development of colour with Nesseler's reagent.

3.10 Data analysis

The data were subjected to statistical analysis using the statistical package WASP. Multiple comparison among treatment means, where the F test was significant (at 5 % level) were done with Duncan's Multiple Range Test.

Results

4. RESULTS

The present study aims to understand the influence of growth stimulants on morpho-physiological changes, yield and quality in okra (*Abelmoschus esculentus* L.) with respect to soil fertility management. The results of the study are detailed below.

Table 3: Soil characters before the experiment

Parameters	Quantity	Remarks
pH	5.3	Strongly Acidic
Electrical Conductivity (dS/m)	0.04	Normal
Organic Carbon (%)	0.86	Medium
Available Nitrogen (Kg/ha)	80.23	Medium
Available Phosphorus (Kg/ha)	67.23	High
Available Potassium (Kg/ha)	308.00	High
Available Calcium (mg/kg)	785.00	Sufficient
Available Magnesium (mg/kg)	65.30	Deficient
Available Sulphur (mg/kg)	3.91	Deficient
Micronutrients		
Copper (mg/kg)	5.92	Sufficient
Iron (mg/kg)	116.90	Sufficient
Zinc (mg/kg)	2.9	Sufficient
Manganese (mg/kg)	34.03	Sufficient
Boron (mg/kg)	0.04	Deficient

Soil was acidic in nature and the elements like magnesium, sulphur and boron were deficient in the experimental field. These deficient nutrients and lime were applied in treatments T_2, T_7, T_8, T_9, and T_{10}.

4.2 Morphological and phenological observations:

4.2.1 Plant height

The data regarding the plant height (cm) at 25 DAS and 50 DAS are presented in Table 4. It shows that plant height influenced significantly with application of foliar spraying of growth stimulants.

Table 4: Effect of various growth stimulants on plant height

Treatments	Plant height (cm)	
	25 DAS	50 DAS
T_1: Standard POP (KAU)	13.50^{e}	75.56^{g}
T_2: Soil test based modified nutrient management	20.85^{abcd}	75.66^{g}
T_3: T_1 + Humic acid spray @ 0.2 %.	21.69^{abcd}	79.20^{e}
T_4: T_1 + Potassium silicate spray @ 0.3%	21.47^{abcd}	77.83^{ef}
T_5: T_1 + Cytozyme spray @ 0.2%	21.56^{abcd}	77.76^{ef}
T_6: T_1 + Putrescine spray @ 50 ppm	20.76^{abcd}	76.96^{fg}
T_7: T_2 + Humic acid spray @ 0.2 %.	24.14^{ab}	90.75^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	25.46^{a}	85.79^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	24.41^{ab}	88.36^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	23.29^{abc}	81.56^{d}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	20.36^{abcd}	73.83^{hi}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	18.84^{bcde}	69.00^{j}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	20.18^{abcd}	73.33^{i}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	18.14^{cde}	65.00^{k}
T_{15}: T_1 + Water spray	16.70^{de}	75.46^{gh}
CD (0.05)	5.88	1.73

The plant height at 25 DAS was analyzed statistically to observe pairwise difference among the treatments. The post hoc test using CD revealed that treatment T_8 had contributed to the maximum plant height (25.46 cm). Plant height under the treatments T_9 (24.41 cm), T_7 (24.14 cm), T_{10} (23.29 cm), T_3 (21.69 cm), T_5 (21.56 cm), T_4 (21.47 cm), T_2 (20.85 cm), T_6 (20.76 cm), T_{11} (20.36 cm) and T_{13} (20.18 cm) were on par with that of T_8 (25.46 cm). The lowest plant height was recorded with the treatment T_1 (13.50 cm).

At 50 DAS, maximum height was observed in the treatment T_7 (90.75 cm) followed by T_9 (88.36 cm) and T_8 (85.79 cm). Treatment T_{15} (75.46 cm) and T_1 (75.56 cm) were on par with that of T_2 (75.66 cm) and the treatments T_5 (77.76 cm) and T_4 (77.83 cm) were on par with that of treatment T_3 (79.20 cm. The lowest plant height was recorded for treatment T_{14} (65.00 cm).

4.2.2 Leaf area per plant

Table 5: Effect of various growth stimulants on leaf area per plant

Treatments	Leaf area per plant (cm^2)	
	25 DAS	50 DAS
T_1: Standard POP (KAU)	294.81^{i}	615.00^{h}
T_2: Soil test based modified nutrient management	306.03^{h}	659.68^{g}
T_3: T_1 + Humic acid spray @ 0.2 %.	356.05^{d}	735.35^{e}
T_4: T_1 + Potassium silicate spray @ 0.3%	332.01^{f}	697.15^{f}
T_5: T_1 + Cytozyme spray @ 0.2%	345.76^{e}	720.28^{e}
T_6: T_1 + Putrescine spray @ 50 ppm	320.45^{g}	685.51^{f}
T_7: T_2 + Humic acid spray @ 0.2 %.	398.83^{a}	979.11^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	380.40^{bc}	775.86^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	386.71^{b}	793.02^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	373.63^{c}	756.76^{d}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	279.50^{j}	583.80^{i}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	256.65^{l}	492.75^{k}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	270.90^{k}	543.67^{j}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	236.25^{m}	432.91^{l}
T_{15}: T_1 + Water spray	295.52^{i}	618.33^{h}
CD (0.05)	7.77	16.14

A perusal of data (Table 5) showed that leaf area differed significantly with application of different growth stimulants. The leaf area per plant at 25 DAS was analyzed statistically to observe pairwise difference among the treatments. The application of humic acid spray along with soil test based modified nutrient management resulted in significantly higher value of leaf area (398.83 cm^2)

followed by T_9 (386.71 cm^2) and T_8 (380.40 cm^2). Treatment T_8 (380.40 cm^2) was on par with that of treatment T_9 (386.71 cm^2) and the treatment T_1 (294.81 cm^2) was on par with that of T_{15} (295.52 cm^2). Treatment T_{14} was recorded the lowest leaf area (236.25 cm^2).

On the 50th day the maximum leaf area was observed in treatment T_7 (979.11 cm^2) followed by the treatment T_9 (793.02 cm^2), this was significantly higher than that of the treatments T_8 (775.86 cm^2), T_{10} (756.76 cm^2) and T_3 (735.35 cm^2). The treatment T_1 (615.00 cm^2) on par with treatment T_{15} (618.33 cm^2). Treatment T_6 (685.51 cm^2) was on par with that of T_4 (697.15 cm^2) and T_5 (720.28 cm^2) was on par with that of T_3 (735.35 cm^2). The lowest value was observed in treatment T_{14} (432.91 cm^2).

4.2.3 Number of leaves per plant

Table 6: Effect of various growth stimulants on number of leaves per plant

Treatments	Number of leaves per plant	
	25 DAS	50 DAS
T_1: Standard POP (KAU)	5.70^{hi}	13.40^{ef}
T_2: Soil test based modified nutrient management	5.86^{gh}	13.50^{e}
T_3: T_1 + Humic acid spray @ 0.2 %.	6.00^{fg}	16.00^{d}
T_4: T_1 + Potassium silicate spray @ 0.3%	6.26^{ef}	15.80^{d}
T_5: T_1 + Cytozyme spray @ 0.2%	6.40^{e}	17.26^{cd}
T_6: T_1 + Putrescine spray @ 50 ppm	6.73^{d}	19.03^{bc}
T_7: T_2 + Humic acid spray @ 0.2 %.	8.40^{a}	25.20^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	7.13^{c}	20.20^{b}
T_9: T_2 + Cytozyme spray @ 0.2%	7.43^{b}	23.66^{a}
T_{10}: T_2 + Putrescine spray @ 50 ppm	6.03^{fg}	14.00^{e}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	5.43^{ij}	13.00^{ef}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	5.36^{jk}	12.73^{ef}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	5.33^{jk}	11.70^{fg}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	5.10^{k}	10.63^{g}
T_{15}: T_1 + Water spray	5.76^{gh}	13.40^{ef}
CD (0.05)	0.28	1.77

The number of leaves per plant at 25 DAS was analyzed statistically to observe pairwise difference among the treatments (Table 6). The post hoc test using CD revealed that treatment T_7 had contributed to the maximum number of leaves per plant (8.40) followed by T_9 (7.43) and T_8 (7.13). Treatment T_5 (6.40) was on par with that of T_4 (6.26) and T_{10} (6.03) was on par with T_3 (6.00). Treatment T_{13} (5.33) was on par with that of T_{12} (5.36). The minimum number of leaves per plant was obtained in the T_{14} (5.10) treatment.

On the 50th day the maximum number of leaves per plant was observed in treatment T_7 (25.20) followed by the treatment T_9 (23.66), this was significantly higher than that of the treatments T_8 (20.20), T_6 (19.03) and T_5 (17.26). In treatments T_{15} (13.40), and T_1 (13.40) similar values of number of leaves was recorded. The number of leaves per plant under the treatments T_{15} (13.40), T_1 (13.40) and T_{11} (13.00) was on par with that of T_{12} (12.73). The lowest number of leaves per plant was observed in treatment of T_{14} (10.63).

4.2.4 Number of branches per plant

Table 7: Effect of various growth stimulants on number of branches per plant

Treatments	Number of branches per plant	
	25 DAS	50 DAS
T_1: Standard POP (KAU)	1.06	2.66^{ghi}
T_2: Soil test based modified nutrient management	1.06	2.86^{fghi}
T_3: T_1 + Humic acid spray @ 0.2 %.	1.06	3.10^{efg}
T_4: T_1 + Potassium silicate spray @ 0.3%	1.13	3.46^{de}
T_5: T_1 + Cytozyme spray @ 0.2%	1.06	3.76^{cd}
T_6: T_1 + Putrescine spray @ 50 ppm	1.00	4.06^{bc}
T_7: T_2 + Humic acid spray @ 0.2 %.	1.46	4.56^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	1.26	4.20^{abc}
T_9: T_2 + Cytozyme spray @ 0.2%	1.33	4.33^{ab}
T_{10}: T_2 + Putrescine spray @ 50 ppm	1.13	2.93^{fgh}
T_{11}: 50 % T_1 + Humic acid spray @ 0.2 %.	1.13	3.26^{ef}
T_{12}: 50 % T_1 + Potassium silicate spray @ 0.3%	1.13	2.50^{hi}
T_{13}: 50 % T_1 + Cytozyme spray @ 0.2%	1.13	2.40^{ij}
T_{14}: 50 % T_1 + Putrescine spray @ 50 ppm	1.00	2.00^{j}
T_{15}: T_1 + Water spray	1.00	2.70^{ghi}
CD (0.05)	NS	0.48

A critical examination of the data in Table 7 reveals that the application of different growth stimulants significantly influenced the number of branches. On 25 DAS, the maximum number of branches (1.46) per plant was recorded with treatment T_7 and the minimum number of branches of per plant was obtained from the treatments T_{14} (1.00) and T_{15} (1.00). On 50 DAS, the maximum number of branches per plant was observed in treatment T_7 (4.56) and T_9 (4.33) followed by the treatment T_8 (4.20) this was significantly higher than that of the treatments T_6 (4.06) and T_5 (3.76). The treatment T_{11} (3.26) was on par with that of T_3 (3.10) and T_1 (2.66) was on par with that of T_{15} (2.70). Minimum number of branches per plant was observed in treatment T_{14} (2.00).

4.2.5 Days to 50 % flowering

Table 8: Effect of various growth stimulants on days to 50 % flowering

Treatments	Days
T_1: Standard POP (KAU)	35.66^{c}
T_2: Soil test based modified nutrient management	34.00^{de}
T_3: T_1 + Humic acid spray @ 0.2 %.	33.66^{ef}
T_4: T_1 + Potassium silicate spray @ 0.3%	35.66^{c}
T_5: T_1 + Cytozyme spray @ 0.2%	36.00^{bc}
T_6: T_1 + Putrescine spray @ 50 ppm	37.00^{ab}
T_7: T_2 + Humic acid spray @ 0.2 %.	30.33^{g}
T_8: T_2 + Potassium silicate spray @ 0.3%	32.66^{f}
T_9: T_2 + Cytozyme spray @ 0.2%	33.66^{ef}
T_{10}: T_2 + Putrescine spray @ 50 ppm	35.00^{cd}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	33.66^{ef}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	35.33^{c}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	36.00^{bc}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	35.00^{cd}
T_{15}: T_1 + Water spray	37.66^{a}
CD (0.05)	1.08

A critical examination of data (Table 8) reveals that days to 50% flowering was affected significantly by different growth stimulants application. Treatment T_{15} (37.66) took more days to complete 50% flowering and this was on par with the treatments T_6 (37.00). Treatments T_4 (35.66), T_{12} (35.33), T_{10} (35.00), T_{14} (35.00) were statistically on par with that of treatment T_1 (35.66). Treatments T_9 (33.66) and T_{11} (33.66) were on par with that of T_3 (33.66). Treatment T_7 (30.33) took minimum days to complete 50% flowering.

4.2.6 Days to first harvest

Table 9: Effect of various growth stimulants on days to first harvest

Treatments	Days
T_1: Standard POP (KAU)	41.66^{c}
T_2: Soil test based modified nutrient management	40.00^{de}
T_3: T_1 + Humic acid spray @ 0.2 %.	39.66^{ef}
T_4: T_1 + Potassium silicate spray @ 0.3%	41.66^{c}
T_5: T_1 + Cytozyme spray @ 0.2%	42.00^{bc}
T_6: T_1 + Putrescine spray @ 50 ppm	43.00^{ab}
T_7: T_2 + Humic acid spray @ 0.2 %.	36.33^{g}
T_8: T_2 + Potassium silicate spray @ 0.3%	38.66^{f}
T_9: T_2 + Cytozyme spray @ 0.2%	39.66^{ef}
T_{10}: T_2 + Putrescine spray @ 50 ppm	41.00^{cd}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	39.66^{ef}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	41.33^{c}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	42.00^{bc}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	41.00^{cd}
T_{15}: T_1 + Water spray	43.66^{a}
CD (0.05)	1.08

The highest numbers of days to first harvest was recorded with treatment T_{15} (43.66) which was on par with T_6 (43.00). In treatments T_3, T_{11} and T_9 similar values (39.66) of number of days for first harvest was recorded. Treatments T_4 (41.66), T_{12} (41.333), T_{10} (41.00), T_{14} (41.00) were statistically on par with that of treatment T_1 (41.66). Treatment T_{13} (42.00) was on par with that of T_5 (42.00). The least numbers of days to first harvest was recorded with treatment T_7 (36.33).

4.2.7 Duration of crop

Table 10: Effect of various growth stimulants on duration of crop

Treatments	Days
T_1: Standard POP (KAU)	94.00^{defg}
T_2: Soil test based modified nutrient management	96.33^{bc}
T_3: T_1 + Humic acid spray @ 0.2 %.	97.00^{b}
T_4: T_1 + Potassium silicate spray @ 0.3%	93.33^{efg}
T_5: T_1 + Cytozyme spray @ 0.2%	99.00^{a}
T_6: T_1 + Putrescine spray @ 50 ppm	100.00^{a}
T_7: T_2 + Humic acid spray @ 0.2 %.	96.66^{bc}
T_8: T_2 + Potassium silicate spray @ 0.3%	95.33^{bcd}
T_9: T_2 + Cytozyme spray @ 0.2%	95.00^{cde}
T_{10}: T_2 + Putrescine spray @ 50 ppm	99.33^{a}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	94.33^{def}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	95.66^{bcd}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	94.33^{def}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	92.33^{g}
T_{15}: T_1 + Water spray	93.00^{fg}
CD (0.05)	1.95

The duration of crop was highest with treatment T_6 (100.00) which was on par with T_{10} (99.33) and T_5 (99.00). In treatments T_{11} and T_{13} (94.33) similar crop duration was recorded. Treatments T_8 (95.33), T_{12} (95.66), T_2 (96.33) and T_7 (96.66) were on par with that of T_3 (97.00). The minimum duration was recorded with treatment T_{14} (92.33).

4.2.8 Fruit length

Table 11: Effect of various growth stimulants on fruit length

Treatments	Fruit length (cm)
T_1: Standard POP (KAU)	11.16^{hi}
T_2: Soil test based modified nutrient management	11.63^{gh}
T_3: T_1 + Humic acid spray @ 0.2 %.	13.23^{e}
T_4: T_1 + Potassium silicate spray @ 0.3%	12.30^{fg}
T_5: T_1 + Cytozyme spray @ 0.2%	12.80^{ef}
T_6: T_1 + Putrescine spray @ 50 ppm	12.10^{g}
T_7: T_2 + Humic acid spray @ 0.2 %.	17.76^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	15.43^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	16.23^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	14.03^{d}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	10.80^{ij}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	10.23^{jk}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	10.26^{jk}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	9.96^{k}
T_{15}: T_1 + Water spray	11.20^{hi}
CD (0.05)	0.69

Table 11 revealed that application of growth stimulants produced significant improvement in fruit length. The maximum fruit length was recorded with the treatment T_7 (17.76 cm) followed by T_9 (16.23 cm). Treatments T_3 (13.23 cm), was statistically on par with that of treatment T_5 (12.80 cm) and treatment T_1 (11.16 cm) was on par with T_{15} (11.20 cm). The minimum fruit length was recorded with the treatment T_{14} (9.96 cm).

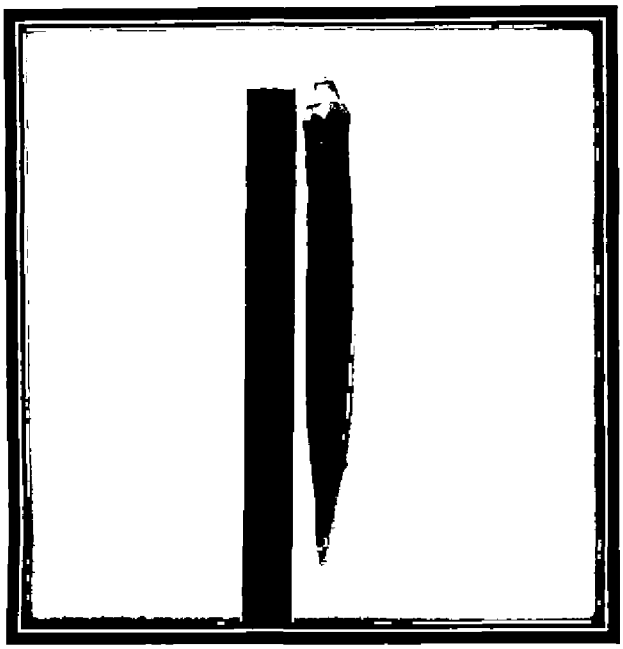

Plate 10. Okra fruit length under treatment T_7

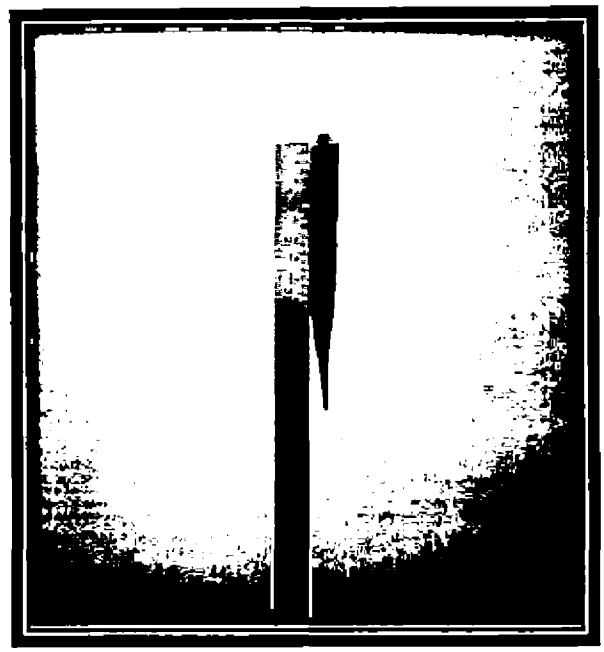

Plate 11. Okra fruit length under control

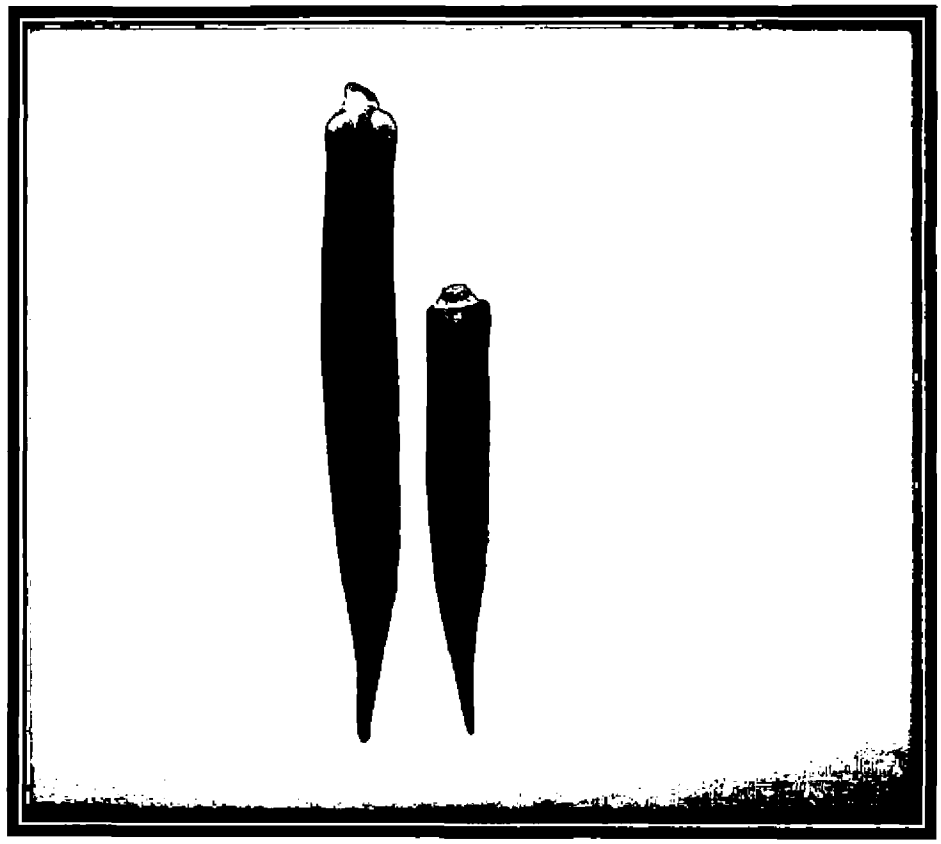

Plate 12. Okra fruit length under treatment T_7 and Control

4.2.9 Fruit diameter

Table 12: Effect of various growth stimulants on fruit diameter

Treatments	Fruit diameter (cm)
T_1: Standard POP (KAU)	5.43^{gh}
T_2: Soil test based modified nutrient management	5.86^{f}
T_3: T_1 + Humic acid spray @ 0.2 %.	6.36^{d}
T_4: T_1 + Potassium silicate spray @ 0.3%	5.96^{ef}
T_5: T_1 + Cytozyme spray @ 0.2%	6.20^{de}
T_6: T_1 + Putrescine spray @ 50 ppm	5.96^{ef}
T_7: T_2 + Humic acid spray @ 0.2 %.	7.86^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	6.86^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	7.23^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	6.66^{c}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	5.23^{h}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	4.90^{i}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	4.63^{j}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	4.70^{ij}
T_{15}: T_1 + Water spray	5.53^{g}
CD (0.05)	0.26

Table 12 revealed that application of growth stimulants produced significant improvement in fruit diameter. The maximum fruit diameter was recorded with the treatment T_7 (7.86 cm) followed by T_9 (7.23 cm). Treatments T_6 (5.96 cm) was on par with that of T_4 (5.96 cm) and T_1 (5.43 cm) was on par with T_{15} (5.53 cm). The minimum fruit diameter was recorded with the treatment T_{13} (4.63 cm).

4.2.10 Mean fresh fruit weight at marketable stage

Table 13: Effect of various growth stimulants on mean fresh fruit weight at marketable stage

Treatments	Mean fresh fruit weight at marketable stage (g)
T_1: Standard POP (KAU)	13.00^{hi}
T_2: Soil test based modified nutrient management	13.70^{g}
T_3: T_1 + Humic acid spray @ 0.2 %.	14.90^{e}
T_4: T_1 + Potassium silicate spray @ 0.3%	14.36^{ef}
T_5: T_1 + Cytozyme spray @ 0.2%	14.53^{ef}
T_6: T_1 + Putrescine spray @ 50 ppm	14.23^{fg}
T_7: T_2 + Humic acid spray @ 0.2 %.	20.56^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	16.23^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	17.53^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	15.60^{d}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	12.80^{hi}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	12.50^{i}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	12.50^{i}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	11.60^{j}
T_{15}: T_1 + Water spray	13.06^{h}
CD (0.05)	0.55

A critical examination of the data in Table 13 revealed that the application of different growth stimulants significantly influenced the mean fresh weight of fruits. The highest mean fresh weight was recorded with the treatment T_7 (20.56 g) and the minimum was recorded with the treatment T_{14} (11.60 g). Treatments T_5 (14.53 g) and T_4 (14.36 g) were on par with that of treatment T_3 (14.90 g). Treatments T_1 (13.00 g) and T_{11} (12.80 g) were on par with that of T_{15} (13.06 g).

4.2.11 Number of fruits per plant

Table 14: Effect of various growth stimulants on number of fruits per plant

Treatments	Number of fruits per plant
T_1: Standard POP (KAU)	12.34^{fg}
T_2: Soil test based modified nutrient management	12.66^{f}
T_3: T_1 + Humic acid spray @ 0.2 %.	14.67^{d}
T_4: T_1 + Potassium silicate spray @ 0.3%	13.32^{ef}
T_5: T_1 + Cytozyme spray @ 0.2%	14.34^{de}
T_6: T_1 + Putrescine spray @ 50 ppm	12.66^{f}
T_7: T_2 + Humic acid spray @ 0.2 %.	21.66^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	17.33^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	18.65^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	16.33^{c}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	12.66^{f}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	13.00^{f}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	12.34^{fg}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	11.34^{g}
T_{15}: T_1 + Water spray	12.32^{fg}
CD (0.05)	1.00

A critical examination of the data in Table 14 revealed that the application of various growth stimulants significantly influenced the number of fruits per plant. Maximum number of fruits per plant was recorded with the treatment T_7 (21.66) followed by the treatment T_9 (18.65) and the minimum number of fruits per plant was recorded with the treatment T_{14} (11.34). Treatments T_1 (12.34), T_{13} (12.34), T_{15} (12.32), T_6 (12.66), T_2 (12.66) and T_{11} (12.66) were par with that of T_{12} (13.00).

4.2.12 Marketed fruit yield per plant

Table 15: Effect of various growth stimulants on marketed fruit yield per plant

Treatments	Marketed fruit yield per plant (g)
T_1: Standard POP (KAU)	129.66^{g}
T_2: Soil test based modified nutrient management	132.16^{g}
T_3: T_1 + Humic acid spray @ 0.2 %.	147.50^{e}
T_4: T_1 + Potassium silicate spray @ 0.3%	145.53^{ef}
T_5: T_1 + Cytozyme spray @ 0.2%	145.46^{ef}
T_6: T_1 + Putrescine spray @ 50 ppm	142.46^{f}
T_7: T_2 + Humic acid spray @ 0.2 %.	191.50^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	166.00^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	173.00^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	159.66^{d}
T_{11}: 50 % T_1 + Humic acid spray @ 0.2 %.	122.80^{h}
T_{12}: 50 % T_1 + Potassium silicate spray @ 0.3%	116.933^{i}
T_{13}: 50 % T_1 + Cytozyme spray @ 0.2%	119.50^{hi}
T_{14}: 50 % T_1 + Putrescine spray @ 50 ppm	110.63^{j}
T_{15}: T_1 + Water spray	130.23^{g}
CD (0.05)	3.77

The highest marketed fruit yield per plant was recorded with treatment T_7 (191.50 g) followed by T_9 (173.00 g). Treatments T_3 (147.50 g) and T_4 (145.53 g) were statistically on par with that of treatment T_5 (145.46 g). Treatments T_1 (129.66 g) and T_{15} (130.23 g) were on par with that of T_2 (132.16 g). The lowest marketed fruit yield per plant was recorded with treatment T_{14} (110.63 g).

4.2.13 Mean fruit yield per plant, per plot and per ha

Table 16: Effect of various growth stimulants on mean fruit yield per plant, per plot and per ha

Treatments	Mean fruit yield per plant (g)	Fruit yield per plot (Kg)	Fruit yield per ha (t/ha)
T_1: Standard POP (KAU)	240.00^{g}	4.80^{g}	6.71^{k}
T_2: Soil test based modified nutrient management	243.25^{f}	4.86^{f}	6.86^{i}
T_3: T_1 + Humic acid spray @ 0.2 %.	262.30^{d}	5.24^{d}	7.26^{f}
T_4: T_1 + Potassium silicate spray @ 0.3%	254.12^{e}	5.08^{e}	7.12^{g}
T_5: T_1 + Cytozyme spray @ 0.2%	261.44^{d}	5.22^{d}	7.29^{e}
T_6: T_1 + Putrescine spray @ 50 ppm	252.33^{e}	5.04^{e}	7.04^{h}
T_7: T_2 + Humic acid spray @ 0.2 %.	297.32^{a}	5.94^{a}	8.28^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	278.50^{b}	5.57^{b}	7.68^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	280.55^{b}	5.61^{b}	7.77^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	269.72^{c}	5.39^{c}	7.52^{d}
T_{11}: 50 % T_1 + Humic acid spray @ 0.2 %.	232.05^{h}	4.64^{h}	6.54^{l}
T_{12}: 50 % T_1 + Potassium silicate spray @ 0.3%	224.87^{j}	4.49^{j}	6.28^{n}
T_{13}: 50 % T_1 + Cytozyme spray @ 0.2%	228.84^{i}	4.57^{i}	6.37^{m}
T_{14}: 50 % T_1 + Putrescine spray @ 50 ppm	224.32^{j}	4.48^{j}	6.25^{o}
T_{15}: T_1 + Water spray	241.57^{fg}	4.83^{fg}	6.73^{j}
CD (0.05)	2.79	0.05	12.60

The highest mean fruit yield per plant was recorded with treatment T_7 (297.32 g) followed by T_9 (280.55 g) and T_8 (278.50 g). Treatment T_5 (261.44 g) was on par with that of T_3 (262.30 g) and treatment T_6 (252.33 g) was on par with T_4 (254.12 g). The lowest mean fruit yield per plant was recorded with the treatment T_{14} (224.32 g).

4.2.14 Occurrence of pest and diseases

Thrips and jassids attack was noticed during the seedling stage of the crop.

4.3 Physiological observations:

4.3.1 Photosynthetic rate

Table 17: Effect of various growth stimulants on photosynthetic rate

Treatments	Photosynthetic Rate (μ mol CO_2 m^{-2} s^{-1}) at 25 DAS	Photosynthetic Rate (μ mol CO_2 m^{-2} s^{-1}) at 50 DAS
T_1: Standard POP (KAU)	15.33^{fg}	28.35^{ef}
T_2: Soil test based modified nutrient management	16.00^{ef}	30.20^{cde}
T_3: T_1 + Humic acid spray @ 0.2 %.	17.33^{cd}	30.57^{bcd}
T_4: T_1 + Potassium silicate spray @ 0.3%	18.62^{c}	27.63^{f}
T_5: T_1 + Cytozyme spray @ 0.2%	20.72^{b}	28.78^{def}
T_6: T_1 + Putrescine spray @ 50 ppm	21.66^{b}	31.00^{bc}
T_7: T_2 + Humic acid spray @ 0.2 %.	24.33^{a}	33.63^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	23.53^{a}	32.53^{ab}
T_9: T_2 + Cytozyme spray @ 0.2%	24.30^{a}	33.16^{a}
T_{10}: T_2 + Putrescine spray @ 50 ppm	17.00^{de}	30.73^{bcd}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	14.70^{fgh}	29.53^{cdef}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	14.33^{ghi}	28.30^{ef}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	13.53^{hi}	30.20^{cde}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	13.03^{i}	28.70^{def}
T_{15}: T_1 + Water spray	15.50^{fg}	20.90^{g}
CD (0.05)	1.30	2.05

The mean value of photosynthetic rate at two different stages of growth are given in Table 17. Photosynthetic rate was recorded at 25th DAS and 50th DAS. At 25th DAS significantly higher photosynthetic rate was recorded with the treatments T_7 (24.33 μmol CO_2 m^{-2} s^{-1}), T_9 (24.30 μmol CO_2 m^{-2} s^{-1}) and T_8 (23.53 μmol CO_2 m^{-2} s^{-1}) when compared to all other treatments. The lowest


Plate 13. Aphids

Plate 14. Leaf roller

Plate 15. Fruit borer

photosynthetic rate was recorded by T_{14} (13.03 µmol CO_2 m^{-2} s^{-1}). The treatments T_1 (15.33 µmol CO_2 m^{-2} s^{-1}) and T_{11} (14.70 µmol CO_2 m^{-2} s^{-1}) were on par with T_{15} (15.50 µmol CO_2 m^{-2} s^{-1}).

At 50 DAS significantly higher photosynthetic rate was recorded with the treatments T_7 (33.63 µmol CO_2 m^{-2} s^{-1}), T_9 (33.16 µmol CO_2 m^{-2} s^{-1}) and T_8 (32.53 µmol CO_2 m^{-2} s^{-1}) when compared to all other treatments. The lowest photosynthetic rate was recorded by T_{15} (20.90 µmol CO_2 m^{-2} s^{-1}). The treatments T_{10} (30.73 µmol CO_2 m^{-2} s^{-1}), and T_3 (30.57 µmol CO_2 m^{-2} s^{-1}), were on par with T_6 (31.00 µmol CO_2 m^{-2} s^{-1}). In treatments T_{13} and T_2 similar values (30.20 µmol CO_2 m^{-2} s^{-1}) of mean photosynthetic rate was recorded.

4.3.2 Transpiration rate

Table 18: Effect of various growth stimulants on transpiration rate

Treatments	Transpiration rate (mmol H_2O m^{-2} s^{-1}) 25 DAS	Transpiration rate (mmol H_2O m^{-2} s^{-1}) 50 DAS
T_1: Standard POP (KAU)	2.31	3.18^{h}
T_2: Soil test based modified nutrient management	2.83	3.53^{g}
T_3: T_1 + Humic acid spray @ 0.2 %.	2.42	3.96^{ef}
T_4: T_1 + Potassium silicate spray @ 0.3%	2.17	4.10^{d}
T_5: T_1 + Cytozyme spray @ 0.2%	3.10	4.31^{d}
T_6: T_1 + Putrescine spray @ 50 ppm	3.70	4.41^{d}
T_7: T_2 + Humic acid spray @ 0.2 %.	3.00	5.19^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	2.63	4.66^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	3.70	4.96^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	2.56	3.83^{f}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	3.16	3.00^{i}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	3.50	2.84^{i}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	3.53	2.55^{j}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	3.16	2.45^{j}
T_{15}: T_1 + Water spray	2.93	3.30^{h}
CD (0.05)	NS	0.15

The mean value of transpiration rate at two different stages of growth are given in Table 18.

Transpiration rate recorded at 25th DAS was non-significant but there was a significant difference at 50th DAS. At 25th DAS, the highest value for transpiration rate was recorded with the treatments T_6 and T_9 (3.70 mmol H_2O m^{-2} s^{-1}). And the lowest transpiration rate was recorded with T_1 (2.31 mmol H_2O m^{-2} s^{-1}). At 50th DAS significantly higher transpiration rate was recorded with the treatment T_7 (5.19 mmol H_2O m^{-2} s^{-1}) followed by T_9 (4.96 mmol H_2O m^{-2} s^{-1}) and T_8 (4.66 mmol H_2O m^{-2} s^{-1}). Treatment T_3 (3.96 mmol H_2O m^{-2} s^{-1}) was on par with that of treatment T_4 (4.10 mmol H_2O m^{-2} s^{-1}). The lowest value for transpiration rate was recorded with the treatment T_{14} (2.45 mmol H_2O m^{-2} s^{-1}) which was on par with that of T_{13} (2.55 mmol H_2O m^{-2} s^{-1}).

4.3.3 Stomatal conductance

Table 19: Effect of various growth stimulants on stomatal conductance

Treatments	Stomatal conductance (mol H_2O m^{-2} s^{-1}) 25 DAS	Stomatal conductance (mol H_2O m^{-2} s^{-1}) 50 DAS
T_1: Standard POP (KAU)	0.18^{ef}	0.20^{hij}
T_2: Soil test based modified nutrient management	0.17^{fg}	0.21^{gh}
T_3: T_1 + Humic acid spray @ 0.2 %.	0.20^{cdef}	0.22^{fg}
T_4: T_1 + Potassium silicate spray @ 0.3%	0.27^{ab}	0.34^{b}
T_5: T_1 + Cytozymc spray @ 0.2%	0.23^{bcde}	0.24^{ef}
T_6: T_1 + Putrescine spray @ 50 ppm	0.22^{bcde}	0.25^{e}
T_7: T_2 + Humic acid spray @ 0.2 %.	0.24^{abc}	0.29^{c}
T_8: T_2 + Potassium silicate spray @ 0.3%	0.28^{a}	0.38^{a}
T_9: T_2 + Cytozyme spray @ 0.2%	0.23^{bcd}	0.27^{d}
T_{10}: T_2 + Putrescine spray @ 50 ppm	0.19^{def}	0.21^{gh}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	0.12^{gh}	0.20^{hij}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	0.11^{h}	0.19^{ijk}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	0.12^{gh}	0.18^{k}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	0.10^{h}	0.19^{ijk}
T_{15}: T_1 + Water spray	0.18^{ef}	0.21^{ghi}
CD (0.05)	0.05	0.01

The mean value of stomatal conductance at two different stages of growth are given in Table 19

At 25 DAS, the highest value for stomatal conductance was recorded with the treatment T_8 (0.28 mol H_2O m^{-2} s^{-1}). Treatments T_4 (0.27 mol H_2O m^{-2} s^{-1} and T_7 (0.24 mol H_2O m^{-2} s^{-1}) were on par with that of treatment T_8 (0.28 mol H_2O m^{-2} s^{-1}). The lowest value for stomatal conductance was recorded with the treatment T_{14} (0.10 mol H_2O m^{-2} s^{-1}) which was on par with that of T_{12} (0.11 mol H_2O m^{-2} s^{-1}).

At 50 DAS, significantly higher transpiration rate was recorded with the treatments T_8 (0.38 mol H_2O m^{-2} s^{-1}), T_4 (0.34 mol H_2O m^{-2} s^{-1}), T_7 (0.29 mol H_2O m^{-2} s^{-1}) and T_9 (0.27 mol H_2O m^{-2} s^{-1}) when compared to all other treatments. Treatments T_2 (0.21 mol H_2O m^{-2} s^{-1}), and T_{15} (0.21 mol H_2O m^{-2} s^{-1}) were on par with that of treatment T_{10} (0.21 mol H_2O m^{-2} s^{-1}). The lowest value for transpiration rate was recorded with the treatment T_{13} (0.18 mol H_2O m^{-2} s^{-1}).

4.3.4 Nutrient content in leaves

Table 20: Effect of various growth stimulants on leaf nutrient content of okra at 25 DAS.

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_1: Standard POP (KAU)	2.47^{fg}	0.17^{h}	1.97^{h}	1.00^{def}	0.26^{cdefg}
T_2: Soil test based modified nutrient management	2.04^{h}	0.23^{g}	2.42^{e}	1.20^{cd}	0.28^{abcdef}
T_3: T_1 + Humic acid spray @ 0.2 %.	2.29^{g}	0.27^{f}	2.39^{ef}	1.25^{c}	0.25^{defg}
T_4: T_1 + Potassium silicate spray @ 0.3%	2.64^{ef}	0.21^{g}	3.06^{b}	1.12^{def}	0.33^{abcd}
T_5: T_1 + Cytozyme spray @ 0.2%	3.05^{c}	0.28^{f}	2.92^{c}	1.58^{a}	0.29^{abcdef}
T_6: T_1 + Putrescine spray @ 50 ppm	2.73^{de}	0.31^{de}	2.78^{cd}	1.32^{bc}	0.16^{h}
T_7: T_2 + Humic acid spray @ 0.2 %.	3.88^{a}	0.50^{a}	3.29^{a}	0.97^{ef}	0.34^{abc}
T_8: T_2 + Potassium silicate spray @ 0.3%	3.55^{b}	0.42^{b}	2.90^{c}	1.00^{def}	0.33^{abcd}
T_9: T_2 + Cytozyme spray @ 0.2%	3.69^{ab}	0.40^{b}	3.18^{ab}	1.14^{cdef}	0.37^{a}
T_{10}: T_2 + Putrescine spray @ 50 ppm	2.77^{de}	0.34^{cd}	2.65^{d}	1.32^{bc}	0.28^{bcdefg}
T_{11}: 50 % T_1 + Humic acid spray @ 0.2 %.	2.41^{g}	0.36^{c}	2.28^{fg}	1.50^{ab}	0.22^{fgh}
T_{12}: 50 % T_1 + Potassium silicate spray @ 0.3%	2.62^{ef}	0.27^{f}	2.36^{ef}	1.31^{bc}	0.36^{ab}
T_{13}: 50 % T_1 + Cytozyme spray @ 0.2%	2.85^{d}	0.28^{ef}	2.20^{g}	0.98^{ef}	0.32^{abcde}
T_{14}: 50 % T_1 + Putrescine spray @ 50 ppm	2.00^{h}	0.29^{ef}	1.92^{h}	0.93^{f}	0.24^{efgh}
T_{15}: T_1 + Water spray	1.45^{i}	0.24^{g}	1.74^{i}	1.16^{cde}	0.19^{gh}
CD (0.05)	0.18	0.02	0.13	0.20	0.08

Table 21: Effect of various growth stimulants on leaf nutrient content of okra at 50 DAS.

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_1: Standard POP (KAU)	3.45^{d}	0.32^{gh}	2.06^{gh}	1.04	0.51^{abcd}
T_2: Soil test based modified nutrient management	3.02^{f}	0.38^{de}	2.51^{ef}	1.24	0.53^{abc}
T_3: T_1 + Humic acid spray @ 0.2 %.	3.27^{e}	0.42^{c}	2.48^{ef}	1.29	0.50^{abcd}
T_4: T_1 + Potassium silicate spray @ 0.3%	3.44^{d}	0.36^{ef}	3.15^{b}	1.01	0.58^{a}
T_5: T_1 + Cytozyme spray @ 0.2%	3.76^{c}	0.43^{c}	3.05^{bc}	1.62	0.54^{abc}
T_6: T_1 + Putrescine spray @ 50 ppm	3.44^{d}	0.41^{c}	2.93^{cd}	1.36	0.41^{e}
T_7: T_2 + Humic acid spray @ 0.2 %.	4.59^{a}	0.57^{a}	3.44^{a}	1.01	0.58^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	4.25^{b}	0.49^{b}	3.05^{bc}	1.02	0.54^{ab}
T_9: T_2 + Cytozyme spray @ 0.2%	4.38^{b}	0.47^{b}	3.33^{a}	1.16	0.58^{a}
T_{10}: T_2 + Putrescine spray @ 50 ppm	3.46^{d}	0.41^{cd}	2.80^{d}	1.38	0.49^{bcde}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	3.10^{f}	0.43^{c}	2.48^{ef}	1.65	0.43^{de}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	3.38^{de}	0.34^{fg}	2.56^{e}	1.46	0.57^{ab}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	3.65^{c}	0.35^{ef}	2.40^{f}	1.13	0.53^{abc}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	2.80^{g}	0.36^{ef}	2.15^{g}	1.08	0.45^{cde}
T_{15}: T_1 + Water spray	2.25^{h}	0.30^{h}	1.99^{h}	1.31	0.40^{e}
CD (0.05)	0.16	0.03	0.13	NS	0.08

Plant nutrient analysis was done at 25 days after sowing and 50 days after sowing. The percentage of nitrogen, phosphorus, potassium, calcium, magnesium content in the plants at 25 DAS and 50 DAS are given in Table 20 and Table 21 respectively.

At 25 DAS, the highest nitrogen content was observed in treatment T_7 (3.880) which was par with treatment T_9 (3.69). The least nitrogen content was observed in the treatment T_{15} (1.45). The treatments T_{10} (2.77) and T_6 (2.73) were on par with that of T_{13} (2.85). Phosphorus content was higher for the treatment T_7 (0.50) followed by T_8 (0.42), T_9 (0.400) and T_{11} (0.36). The least value for phosphorus was recorded for the treatment T_1 (0.17). Potassium content was

higher for the treatment T_7 (3.29) followed by T_9 (3.18), T_4 (3.06), and T_5 (2.92). The least value for potassium was recorded for the treatment T_{15} (1.74). The treatments T_3 (2.39) and T_{12} (2.36) were on par with that of T_2 (2.42). Calcium content was higher for the treatment T_5 (1.58) followed by T_{11} (1.50), T_{10} (1.32), and T_6 (1.32). The least value for calcium was recorded for the treatment T_{14} (0.93). The treatments T_2 (1.20), T_{15} (1.16), T_9 (1.14) and T_4 (1.12) were on par with that of T_3 (1.25). Magnesium content was higher for the treatment T_9 (0.37). The treatments T_{12} (0.36), T_7 (0.34), T_8 (0.33), T_4 (0.33), T_{13} (0.32), T_5 (0.29), and T_2 (0.28) were on par with that of T_9 (0.37). The least value for magnesium was recorded for the treatment T_6 (0.16).

At 50 DAS, the higher nitrogen content was observed in treatment T_7 (4.590) followed by T_9 (4.38) and T_8 (4.25). The least nitrogen content was observed in the treatment T_{15} (2.25). The treatments T_1 (3.45), T_6 (3.44), T_4 (3.44) and T_{12} (3.38) were on par with that of T_{10} (3.46). Phosphorus content was higher for the treatment T_7 (0.57) followed by T_8 (0.49) T_9 (0.47) and T_{11} (0.43). The lowest value for phosphorus was recorded for the treatment T_{15} (0.30). Potassium content was higher for the treatment T_7 (3.44) followed by T_9 (3.33), T_4 (3.150), and T_5 (3.05). The least value for potassium was recorded for the treatment T_{15} (1.99). The treatments T_5 (3.05) and T_8 (3.05) were on par with that of T_4 (3.15). There was no significant difference between treatments in calcium content. Magnesium content was higher for the treatment T_4 (0.58). The treatments T_9 (0.58), T_7 (0.58), T_{12} (0.57), T_8 (0.54), T_5 (0.54), T_2 (0.53), T_{13} (0.53), T_1 (0.51) and T_3 (0.50) were on par with that of T_4 (0.58). The least value for magnesium was recorded for the treatment T_{15} (0.40).

4.4 Biochemical observations:

4.4.1 Chlorophyll content

Table 22: Effect of various growth stimulants on Chlorophyll content

Treatments	25th DAS			50th DAS		
	Chl a (mg g^{-1} fr. wt.)	Chl b (mg g^{-1} fr. wt.)	Total Chl (mg g^{-1} fr. wt.)	Chl a (mg g^{-1} fr. wt.)	Chl b (mg g^{-1} fr. wt.)	Total Chl (mg g^{-1} fr. wt.)
T_1: Standard POP (KAU)	1.85^{e}	0.51^{bc}	2.36^{de}	1.58	0.37	1.95
T_2: Soil test based modified nutrient management	2.09^{cde}	0.53^{bc}	2.63^{bc}	1.61	0.45	2.06
T_3: T_1 + Humic acid spray @ 0.2 %.	2.27^{bc}	0.50^{bc}	2.77^{b}	1.96	0.32	2.28
T_4: T_1 + Potassium silicate spray @ 0.3%	2.61^{a}	0.58^{b}	3.19^{a}	1.83	0.39	2.23
T_5: T_1 + Cytozyme spray @ 0.2%	2.51^{ab}	0.54^{bc}	3.05^{a}	1.79	0.44	2.23
T_6: T_1 + Putrescine spray @ 50 ppm	2.50^{ab}	0.51^{bc}	3.01^{a}	1.53	0.50	2.03
T_7: T_2 + Humic acid spray @ 0.2 %.	2.48^{ab}	0.63^{ab}	3.11^{a}	1.38	0.40	1.79
T_8: T_2 + Potassium silicate spray @ 0.3%	2.54^{a}	0.58^{b}	3.13^{a}	1.48	0.30	1.78
T_9: T_2 + Cytozyme spray @ 0.2%	1.95^{de}	0.76^{a}	2.71^{bc}	1.68	0.46	2.14
T_{10}: T_2 + Putrescine spray @ 50 ppm	2.52^{ab}	0.63^{ab}	3.15^{a}	1.68	0.45	2.13
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	2.50^{ab}	0.58^{b}	3.08^{a}	1.50	0.46	1.96
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	2.08^{cde}	0.57^{b}	2.66^{bc}	1.38	0.39	1.78
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	1.97^{de}	0.53^{bc}	2.50^{cd}	1.75	0.42	2.17
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	2.14^{cd}	0.59^{b}	2.73^{b}	1.69	0.38	2.07
T_{15}: T_1 + Water spray	1.87^{e}	0.40^{c}	2.27^{e}	1.51	0.31	1.83
CD (0.05)	0.26	0.14	0.21	NS	NS	NS

The mean values of chlorophyll content at two different stages of growth are given in Table 22 Chlorophyll a, chlorophyll b and total chlorophyll were found significantly different at 25th DAS and those were insignificant at 50th DAS.

At 25th DAS, higher value for chlorophyll a content was recorded under the treatment of T_4 (2.61mg g^{-1} fr. wt) and the least value was recorded under the treatment of T_1 (1.85 mg g^{-1} fr. wt). The treatments T_8 (2.54 mg g^{-1} fr. wt), T_{10} (2.52 mg g^{-1} fr. wt), T_5 (2.51 mg g^{-1} fr. wt), T_{11} (2.50 mg g^{-1} fr. wt), T_6 (2.50 mg g^{-1} fr. wt), and T_7 (2.48 mg g^{-1} fr. wt) were on par with that of T_4 (2.61 mg g^{-1} fr. wt). The maximum value for chlorophyll b was recorded with the treatment T_9 (0.76 mg g^{-1} fr. wt) which was on par with T_7 (0.63 mg g^{-1} fr. wt) and T_{10} (0.63 mg g^{-1} fr. wt). The least value for chlorophyll b was recorded with the treatment T_{15} (0.40 mg g^{-1} fr. wt). Remaining all other treatment values are par with that of treatment T_{14} (0.59 mg g^{-1} fr. wt). The highest total chlorophyll content was obtained from the treatment T_4 (3.19 mg g^{-1} fr. wt) which was on par with the treatments T_{10} (3.15 mg g^{-1} fr. wt), T_8 (3.13 mg g^{-1} fr. wt), T_7 (3.11 mg g^{-1} fr. wt), T_{11} (3.08 mg g^{-1} fr. wt), T_5 (3.05 mg g^{-1} fr. wt) and T_6 (3.01 mg g^{-1} fr. wt). Lowest value was recorded with the treatment T_{15} (2.27 mg g^{-1} fr. wt).

4.4.2 IAA Content

Table 23: Effect of various growth stimulants on IAA Content at 25 DAS and 50 DAS.

Treatments	IAA Content ($mg.g^{-1}$) 25 DAS	IAA Content ($mg.g^{-1}$) 50 DAS
T_1: Standard POP (KAU)	0.36^{abcd}	0.39^{ghi}
T_2: Soil test based modified nutrient management	0.38^{abc}	0.40^{gh}
T_3: T_1 + Humic acid spray @ 0.2 %.	0.35^{abcd}	0.47^{d}
T_4: T_1 + Potassium silicate spray @ 0.3%	0.43^{a}	0.42^{f}
T_5: T_1 + Cytozyme spray @ 0.2%	0.39^{abc}	0.45^{e}
T_6: T_1 + Putrescine spray @ 50 ppm	0.26^{e}	0.40^{g}
T_7: T_2 + Humic acid spray @ 0.2 %.	0.43^{a}	0.57^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	0.39^{ab}	0.52^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	0.43^{a}	0.54^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	0.34^{bcde}	0.51^{c}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	0.28^{de}	0.38^{hij}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	0.36^{ab}	0.37^{j}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	0.36^{abc}	0.37^{ij}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	0.30^{cde}	0.35^{k}
T_{15}: T_1 + Water spray	0.25^{e}	0.39^{gh}
CD (0.05)	0.08	0.01

Effect of different growth stimulants on IAA content is showed in Table 23. At 25th DAS among the treatments T_4 (0.43 mg. g^{-1}) recorded maximum value of IAA content which was on par with that of T_9 (0.43 mg. g^{-1}), T_7 (0.43 mg. g^{-1}), T_{12} (0.36 mg. g^{-1}), T_8 (0.39 mg. g^{-1}), T_5 (0.39 mg. g^{-1}), T_2 (0.38 mg. g^{-1}), T_{13} (0.36 mg. g^{-1}), T_1 (0.36 mg. g^{-1}) and T_3 (0.35 mg. g^{-1}). The lowest value of IAA content was recorded with the treatment T_{15} (0.25 mg. g^{-1}) which was on par with that of T_6 (0.26 mg. g^{-1}). At 50th DAS maximum value of IAA content was recorded with the treatment T_7 (0.57 mg. g^{-1}) followed by T_9 (0.54 mg. g^{-1}), T_8 (0.52 mg. g^{-1}), T_{10} (0.51 mg. g^{-1}), T_3 (0.47 mg. g^{-1}), T_5 (0.45 mg. g^{-1}), T_4 (0.42 mg. g^{-1}), T_6 (0.40

mg. g^{-1}) and T_2 (0.40 mg. g^{-1}). The least value of IAA content was recorded with the treatment T_{12} (0.37 mg. g^{-1}) and T_{14} (0.35 mg. g^{-1}).

4.5 Fruit quality

4.5.1 Crude fibre content of fruit

Table 24: Effect of various growth stimulants on crude fibre content of fruit

Treatments	Crude fibre content of fruit (%)
T_1: Standard POP (KAU)	8.20^{e}
T_2: Soil test based modified nutrient management	8.30^{e}
T_3: T_1 + Humic acid spray @ 0.2 %.	9.16^{d}
T_4: T_1 + Potassium silicate spray @ 0.3%	9.13^{d}
T_5: T_1 + Cytozyme spray @ 0.2%	9.10^{d}
T_6: T_1 + Putrescine spray @ 50 ppm	8.56^{e}
T_7: T_2 + Humic acid spray @ 0.2 %.	12.48^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	10.23^{c}
T_9: T_2 + Cytozyme spray @ 0.2%	11.13^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	9.50^{d}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	7.33^{f}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	7.03^{f}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	7.03^{f}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	7.06^{f}
T_{15}: T_1 + Water spray	8.26^{e}
CD (0.05)	0.40

The data recorded on crude fibre content was influenced by the growth stimulants are presented in Table 24.

Data collected on crude fibre content ranged between 12.48 % (T_7) to 7.03 % (T_{13}). Among the treatments the lowest crude fibre content (7.03 %) was recorded with T_{13} treatment. Significantly highest crude fibre content was recorded with T_7 (12.48 %) treatment followed by T_9 (11.13 %) and T_8 (10.23 %).

Treatments T_2 (8.30 %), T_{15} (8.26 %), and T_1 (8.20 %) were on par with that of T_6 (8.56 %).

4.5.2 Ascorbic acid content of fruit

Table 25: Effect of various growth stimulants on ascorbic acid content of fruit

Treatments	Ascorbic acid content of fruit (mg/100g)
T_1: Standard POP (KAU)	11.89^{bc}
T_2: Soil test based modified nutrient management	10.52^{cd}
T_3: T_1 + Humic acid spray @ 0.2 %.	10.29^{cd}
T_4: T_1 + Potassium silicate spray @ 0.3%	9.52^{d}
T_5: T_1 + Cytozyme spray @ 0.2%	11.63^{bcd}
T_6: T_1 + Putrescine spray @ 50 ppm	10.70^{cd}
T_7: T_2 + Humic acid spray @ 0.2 %.	14.37^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	12.93^{ab}
T_9: T_2 + Cytozyme spray @ 0.2%	13.48^{ab}
T_{10}: T_2 + Putrescine spray @ 50 ppm	9.76^{cd}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	10.20^{cd}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	9.65^{d}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	10.37^{cd}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	9.82^{cd}
T_{15}: T_1 + Water spray	6.99^{e}
CD (0.05)	2.22

The data recorded on ascorbic acid content in fruit (mg/100g) influenced by the growth stimulants are presented in Table 25. Significant differences were observed among the treatments for ascorbic acid content in fruits (mg/100g).

Ascorbic acid content ranged between 14.37 mg/100g to 6.99 mg/100g. Among the treatments studied, T_7 (14.37 mg/100g), T_9 (13.48 mg/100g) and T_8 (12.99 mg/100g) were recorded maximum ascorbic acid content which differed significantly over the other treatments, followed by T_1 (11.89 mg/100g) and T_5 (11.63 mg/100g). The lowest ascorbic acid content (6.99 mg/100g) was recorded

T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	0.40^{g}
T_{15}: T_1 + Water spray	0.34^{g}
CD (0.05)	0.15

Treatments T_2 (8.30 %), T_{15} (8.26 %), and T_1 (8.20 %) were on par with that of T_6 (8.56 %).

4.5.2 Ascorbic acid content of fruit

Table 25: Effect of various growth stimulants on ascorbic acid content of fruit

Treatments	Ascorbic acid content of fruit (mg/100g)
T_1: Standard POP (KAU)	11.89^{bc}
T_2: Soil test based modified nutrient management	10.52^{cd}
T_3: T_1 + Humic acid spray @ 0.2 %.	10.29^{cd}
T_4: T_1 + Potassium silicate spray @ 0.3%	9.52^{d}
T_5: T_1 + Cytozyme spray @ 0.2%	11.63^{bcd}
T_6: T_1 + Putrescine spray @ 50 ppm	10.70^{cd}
T_7: T_2 + Humic acid spray @ 0.2 %.	14.37^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	12.93^{ab}
T_9: T_2 + Cytozyme spray @ 0.2%	13.48^{ab}
T_{10}: T_2 + Putrescine spray @ 50 ppm	9.76^{cd}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	10.20^{cd}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	9.65^{d}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	10.37^{cd}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	9.82^{cd}
T_{15}: T_1 + Water spray	6.99^{e}
CD (0.05)	2.22

The data recorded on ascorbic acid content in fruit (mg/100g) influenced by the growth stimulants are presented in Table 25. Significant differences were observed among the treatments for ascorbic acid content in fruits (mg/100g).

Ascorbic acid content ranged between 14.37 mg/100g to 6.99 mg/100g. Among the treatments studied, T_7 (14.37 mg/100g), T_9 (13.48 mg/100g) and T_8 (12.99 mg/100g) were recorded maximum ascorbic acid content which differed significantly over the other treatments, followed by T_1 (11.89 mg/100g) and T_5 (11.63 mg/100g). The lowest ascorbic acid content (6.99 mg/100g) was recorded

in T_{15} treatment (water spray). Treatments T_2 (10.52 mg/100g), T_{13} (10.37 mg/100g), T_3 (10.29 mg/100g), T_{11} (10.20 mg/100g), T_{14} (9.82 mg/100g) and T_{10} (9.76 mg/100g) were on par with that of T_6 (10.70 mg/100g).

4.5.3 Mucilage content of fruit

Table 26: Effect of various growth stimulants on mucilage content of fruit

Treatments	Mucilage content of fruit (%)
T_1: Standard POP (KAU)	0.91^{cd}
T_2: Soil test based modified nutrient management	0.84^{cde}
T_3: T_1 + Humic acid spray @ 0.2 %.	0.84^{cde}
T_4: T_1 + Potassium silicate spray @ 0.3%	0.97^{bc}
T_5: T_1 + Cytozyme spray @ 0.2%	0.74^{e}
T_6: T_1 + Putrescine spray @ 50 ppm	0.74^{e}
T_7: T_2 + Humic acid spray @ 0.2 %.	1.11^{ab}
T_8: T_2 + Potassium silicate spray @ 0.3%	1.14^{a}
T_9: T_2 + Cytozyme spray @ 0.2%	1.26^{a}
T_{10}: T_2 + Putrescine spray @ 50 ppm	0.83^{cde}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	0.77^{de}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	0.84^{cde}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	0.58^{f}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	0.40^{g}
T_{15}: T_1 + Water spray	0.34^{g}
CD (0.05)	0.15

The data recorded on mucilage content of fruit (%) as influenced by the growth stimulants are presented in Table 26. Maximum mucilage percentage was recorded with the treatment T_9 (1.26 %) followed by T_8 (1.14 %) and T_7 (1.117 %). Treatments T_{12} (0.84 %), T_3 (0.84 %), T_2 (0.84 %) and T_{10} (0.83 %) were on par with that of treatment T_1 (0.97 %). The lowest mucilage percentage was recorded with the treatments T_{14} (0.40 %) and T_{15} (0.34 %).

4.5.4 Total protein content of fruit

Table 27: Effect of various growth stimulants on total protein content of fruit

Treatments	Total protein content of fruit (mg.g^{-1})
T_1: Standard POP (KAU)	0.91^{g}
T_2: Soil test based modified nutrient management	1.17^{fg}
T_3: T_1 + Humic acid spray @ 0.2 %.	1.17^{fg}
T_4: T_1 + Potassium silicate spray @ 0.3%	2.53^{cd}
T_5: T_1 + Cytozyme spray @ 0.2%	2.16^{de}
T_6: T_1 + Putrescine spray @ 50 ppm	2.23^{de}
T_7: T_2 + Humic acid spray @ 0.2 %.	4.51^{a}
T_8: T_2 + Potassium silicate spray @ 0.3%	2.91^{bc}
T_9: T_2 + Cytozyme spray @ 0.2%	3.56^{b}
T_{10}: T_2 + Putrescine spray @ 50 ppm	2.23^{de}
T_{11}: 50 %T_1 + Humic acid spray @ 0.2 %.	1.18^{fg}
T_{12}: 50 %T_1 + Potassium silicate spray @ 0.3%	1.86^{e}
T_{13}: 50 %T_1 + Cytozyme spray @ 0.2%	1.82^{ef}
T_{14}: 50 %T_1 + Putrescine spray @ 50 ppm	0.88^{g}
T_{15}: T_1 + Water spray	0.72^{g}
CD (0.05)	0.66

The data recorded on total protein content of fruit (mg. g^{-1}) as influenced by the growth stimulants are presented in Table 27. Maximum total protein was recorded with the treatment T_7 (4.51 mg. g^{-1}) followed by T_9 (3.56 mg. g^{-1}) and T_8 (2.91 mg. g^{-1}). Treatments T_{10} (2.22 mg. g^{-1}) and T_5 (2.16 mg. g^{-1}) were on par with that of treatment T_6 (2.23 mg. g^{-1}). The lowest total protein content in fruit was recorded with the treatments T_{14} (0.88 mg. g^{-1}) and T_{15} (0.72 mg. g^{-1}).

Discussion

5. DISCUSSION

The results of the present study entitled " Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)" was presented in the previous chapter. It is endeavored to discuss the significant events or those assuming a definite pattern in respect of different parameters studied so as to established cause and effect relationship in the light of existing evidences and conceivable in view of accessible literature. The results obtained from the experiment are discussed here under various sub heads.

5.1 Morphological parameters as influenced by growth stimulants

In the present experiment, besides recommended dose of fertilizers (110:35:70 NPK kg ha^{-1}), application of growth stimulants exerted a significant influence on morphological characters such as plant height, leaf area per plant, number of leaves, branches per plant, days to 50 per cent flowering and days to first picking.

Growth stimulants were applied at fortnightly intervals from 15 DAS. Morphological attributes such as plant height, number of branches per plant, leaf area and number of leaves per plant were compared with that control T_1 (standard package of practices). Morphological parameters of control (T_1) plots were recorded on par with that of water sprayed (T_{15}) plots. An increase in 20.10 per cent plant height was recorded in treatment T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by 16.94 per cent in T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %) and 13.53 per cent in T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3 %) compared to control. The plants which received 50 per cent standard POP along with growth stimulants recorded minimum plant height. Among different sets of treatments, soil test based nutrient management with growth stimulants application resulted higher plant height than treatments receiving standard POP with growth stimulants followed by 50 per cent standard

POP with growth stimulants (Figure 2). Among the growth stimulants, humic acid performed better followed by cytozyme, potassium silicate and putrescine. A similar pattern of effectiveness of growth stimulants was observed in the case of number of branches per plant, leaf area (Figure 3) and number of leaves per plant. This implicated that soil test based nutrient management practices with growth stimulants gave a significant improvement in plant morphological characters which influenced the yield parameters also.

Foliar application of humic acid, cytozyme and potassium silicate and putrescine significantly increased the plant height, leaf area and number of leaves per plant. These findings clearly indicated that growth stimulants like humic acid, cytozyme, potassium silicate and putrescine played a significantly role in enhancing the growth of okra. The beneficial effect of humic acid on plant growth might be due the better uptake of micronutrients from soil to plant. Effects of humic acid appear to be mainly on cell membrane properties and it act as hormone-like substances. These results are in conformity with the findings of Padem *et al.* (1997), Clapp *et al.* (2001), Nardi *et al.* (1996), and Ghorbani *et al.* (2010).

Potassium silicate improves the vegetative growth characters, nutrient uptake and distribution. The results are in agreement with the findings of Ali *et al.* (2011) and Cheng, (1982). Foliar application of cytozyme and putrescine also enhanced the morphological characters of okra. Cytozyme increased photosynthetic efficiency on account of stabilization of chlorophyll and higher production of photosynthates resulting in increased secondary branches simultaneously. Cytozyme increase CO_2 fixation and chlorophyll contents of leaves and improved leaf area. These results are in accordance with findings of Rana and Vashistha (1988). Putrescine application in plants improve the cell ionic condition, maintenance of membrane integrity, prevention of chlorophyll loss and improvement in synthesis of protein, nucleic acids and protective alkaloids (Kusano *et al.*, 2008).

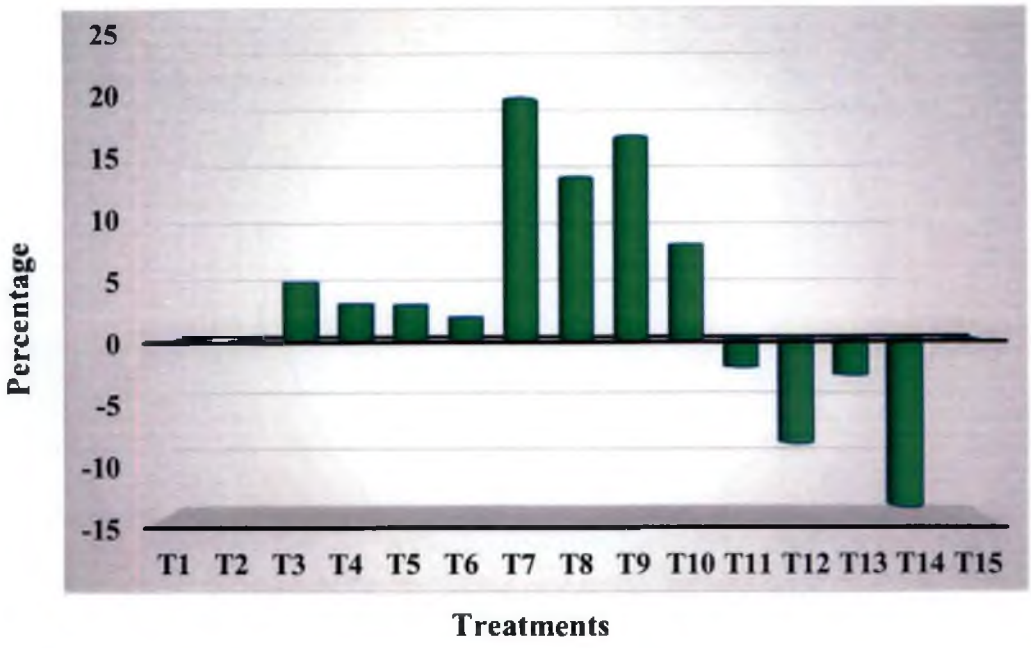

Figure 2: Percentage variation of plant height (cm) from control

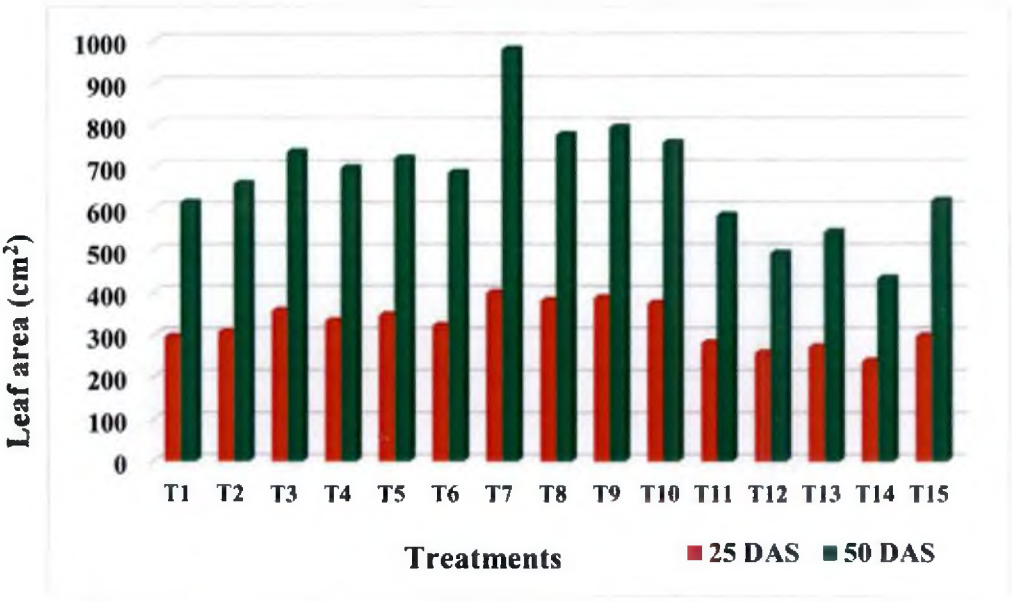

Figure 3: Effect of treatments on leaf area (cm^2) of okra

5.2 Gas exchange parameters as influenced by growth stimulants

Photosynthesis is one of the most important gas exchange parameter that influences total growth and development of plants. Comparison of the photosynthetic rate of crop at two different growth stages (25 DAS and 50 DAS) revealed that growth stimulants produced a significant improvement in photosynthetic rate when compared to control treatment (Figure 4). This effect was prominent in both vegetative stage and reproductive stages of crop. Among the 15 treatments, T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) recorded the highest photosynthetic rate followed by T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %) and T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3 %).

Transpiration is another important gas exchange parameter that influences growth and development of plants. Comparison of the transpiration rate of crop at two different stages revealed that treatments at vegetative growth phase (25 DAS), did not show a significant difference. However, at reproductive phase (50^{th} DAS) the transpiration rate varied significantly among the treatments and maximum transpiration rate was recorded with soil test based modified nutrient management with humic acid spray @ 0.2 % followed by soil test based modified nutrient management with cytozyme spray @ 0.2 % and T_8 soil test based modified nutrient management with potassium silicate spray @ 0.3 % (Figure 5). Foliar spray of humic acid and cytozyme spray improved the photosynthetic rate movement and leaf area index. It decreased photorespiration losses accordingly enhancing the photosynthesis rate and transpiration rate. These results are supported by Khurana and Pandita, (1986) and (Ghorbani *et al.*, 2010).

Among the different treatments, soil test based nutrient management with growth stimulants application resulted in higher photosynthetic rate than the treatments which receiving standard POP with growth stimulants and 50 per cent

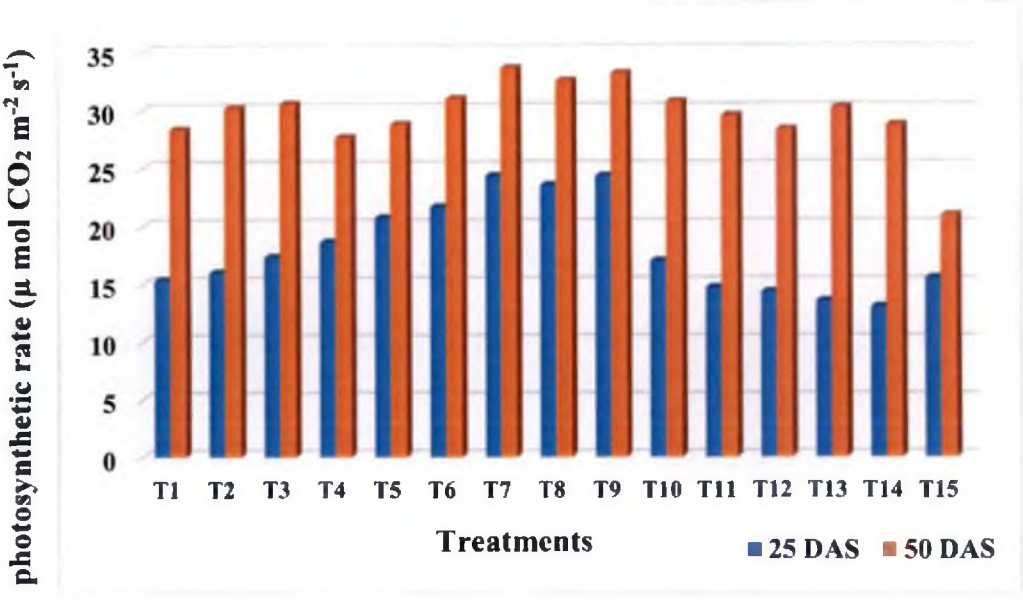

Figure 4: Effect of treatments on photosynthetic rate (μ mol CO_2 m^{-2} s^{-1}) of okra

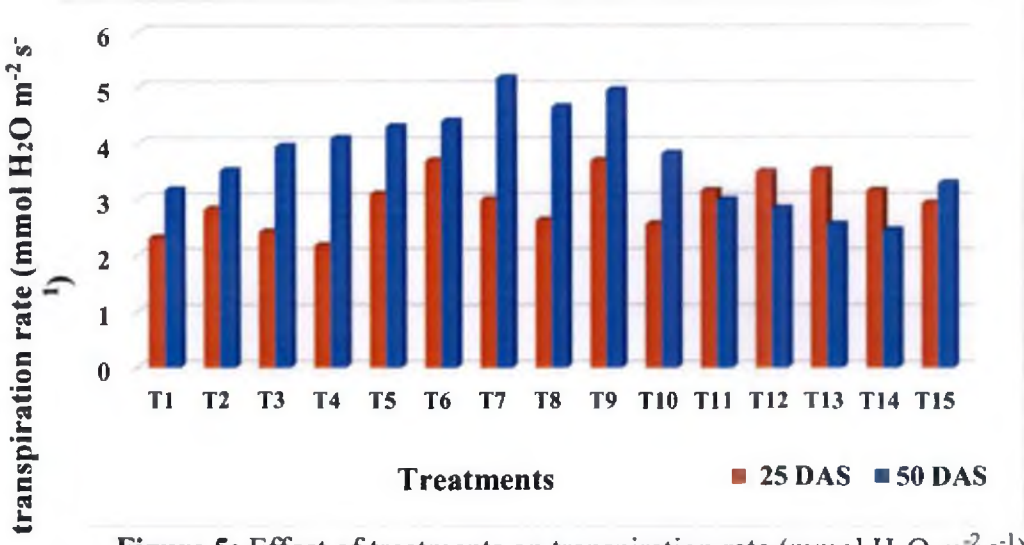

Figure 5: Effect of treatments on transpiration rate (mmol H_2O m^{-2} s^{-1}) of okra

standard POP with growth stimulants. A similar pattern was observed in the case of transpiration rate also.

In the present study, application of growth stimulants sprays significantly influenced the stomatal conductance on both 25 and 50 days after sowing. Among the different growth stimulants applied, potassium silicate spray contributed higher stomatal conductance (Figure 6). Potassium element present in the potassium silicate contributed higher value of stomatal conductance. The present study also revealed that stomatal conductance is correlated with transpiration rate which leads to CO_2 influx for assimilatory metabolism. Photosynthesis can be influenced by stomatal conductance or by chlorophyll content (chlorophyll a, chlorophyll b and total chlorophyll). Potassium silicate increases the mechanical strength of the plant and controls the rate of transpiration and stomatal conductance of plants (Nolla *et al.*, 2006).

5.3 Biochemical parameters as influenced by growth stimulants

In the present investigation, among the 15 treatments, the treatments which received potassium silicate spray recorded higher total chlorophyll content followed by putrescine and humic acid spray. The higher total chlorophyll content was recorded in T_4 (standard package of practice with potassium silicate spray @ 0.3 %), which was on par with T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) and T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %). Nitrogen was one of the major component of these growth stimulants. Nitrogen is a very important constituent of protoplasm and its favorable effect on chlorophyll content of leaves might have increased the synthesis of carbohydrates, amino acids etc., from which the phytohormones such as auxins, gibberellins, cytokines and ethylene might have been synthesized. Putrescines are small nitrogenous compounds present in the plants and increased putrescine levels in plants reduces chlorophyll loss. These results are also supported by the findings of Kusano *et al.* (2008).

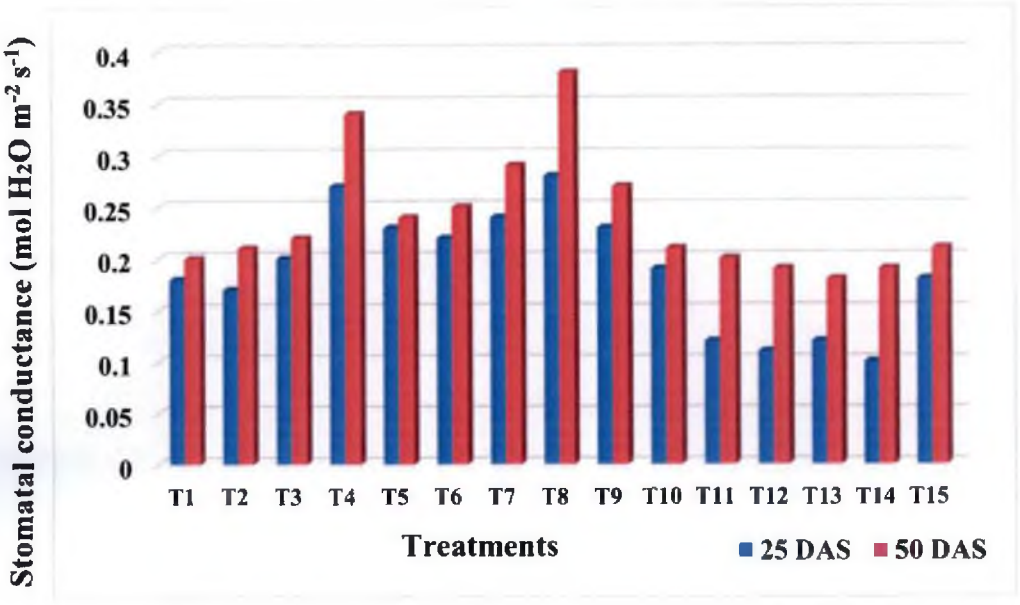

Figure 6: Effect of treatments on stomatal conductance (mol H_2O m^{-2} s^{-1}) of okra

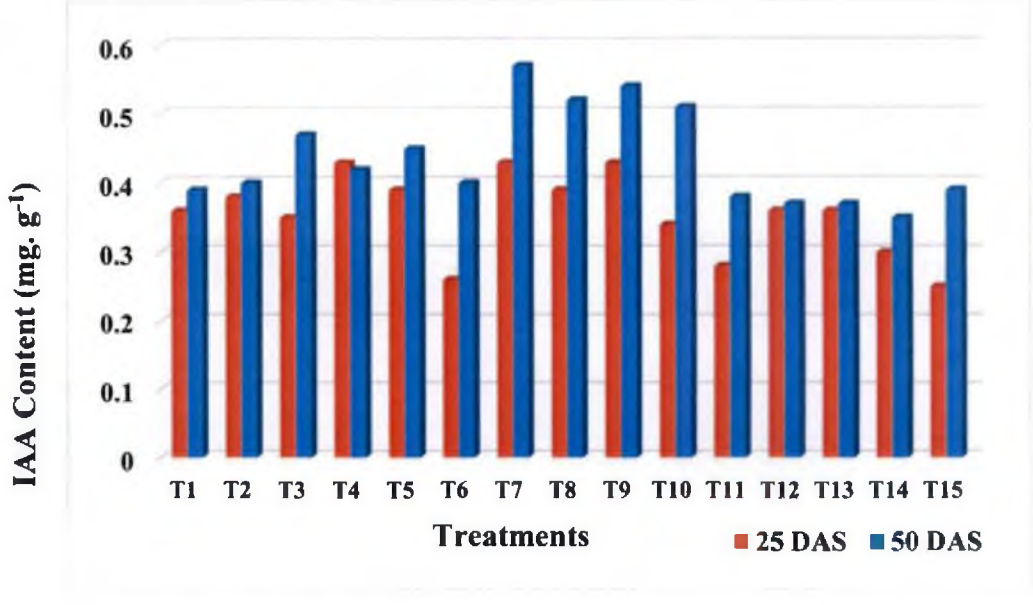

Figure 7: Effect of treatments on IAA Content (mg. g^{-1}) of okra

Potassium Silicate assists with balancing nutrient uptake and distribution, and increased concentration of chlorophyll in leaves (Yorinori *et al.*, 2005). Chen and Aviad, (1990) observed that the utilization of humic acid and growth stimulants as foliar spray can increase root and shoot development, leaf chlorophyll content and nutrient uptake.

Growth stimulants (potassium silicate, cytozyme and humic acid) significantly improved the IAA content in both pre flowering and post flowering periods. An increase in 46.15 per cent IAA content was recorded in treatment T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by 38.46 per cent in T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %) and 33.33 per cent in T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3 %) compared to control. Among different sets of treatments, soil test based nutrient management with growth stimulants application resulted higher IAA content than the treatments received standard POP with growth stimulants and 50 per cent standard POP with growth stimulants (Figure 7). The application of these growth stimulants favoured the metabolic and auxin activities in plant and ultimately resulted in increased fruit size, number of fruits per plant, fruit weight and yield per hectare. Application of humic acid and cytozyme increased the IAA content which stimulated cell division and cell enlargement and increased the sink strength of fruits. These results are supported by the findings of Chaudhary *et al.*, (2006).

5.4 Yield and yield parameters as influenced by growth stimulants

Among the 15 treatments, T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) recorded the least number of days to 50 per cent flowering followed by T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3%). A similar pattern was also observed in the case of number of days to first harvest. Significant superiority over control might be due to increased photosynthetic activity and uptake of nutrients resulting in early flowering as reported by Patel *et al.* (2009) in bhendi.

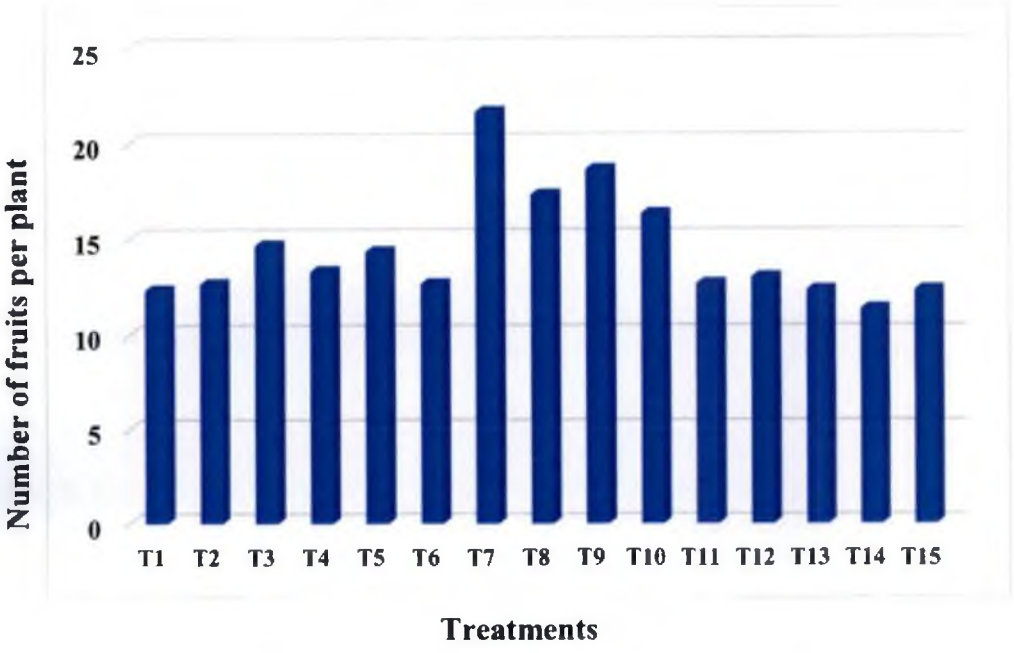

Figure 8: Effect of treatments on number of fruits of okra

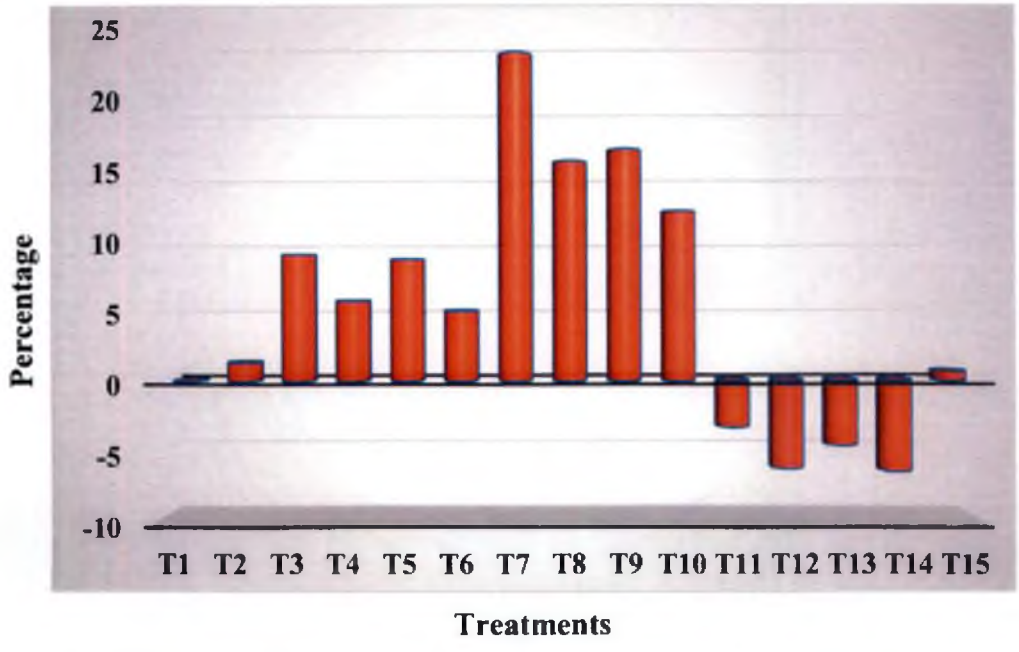

Figure 9: Percentage variation of okra fruit yield (g) from control

The present investigation showed significant differences due to growth stimulants spray and soil test based nutrient management on fruit characters like fruit length, fruit diameter, fruit weight and number of fruits per plant. An increase in 59.13 per cent fruit length (cm) was recorded in treatment T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by 45.30 per cent in T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %) and 38.26 per cent in T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3 %) compared to control. A similar pattern of effectiveness of growth stimulants was observed in the case of fruit diameter, fruit weight and number of fruits per plant (Figure 8). This implicated that soil test based nutrient management practices with growth stimulants gave a significant contribution for improving the fruit yield and yield characters. Soil test based nutrient management with growth stimulants application resulted higher fruit length, fruit diameter, fruit weight and number of fruits per plant than treatments which received standard POP with growth stimulants followed by 50 per cent standard POP with growth stimulants.

Maximum number of fruits per plant was obtained in T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2%). These results are in conformity with the findings of David and Samule (2002) in mustard, who reported significant superiority in growth parameters with the application of humic acid like growth stimulants over control and attributed it to increased photosynthetic activity and uptake of nutrients, resulting in significantly longer and wider pods and more number of pods per plant. Vijayakumari *et al.* (2012) reported that micro herbal fertilizers and humic acid are found to stimulate the growth and yield of Soybean (*Glycine max* L.).

Foliar application of growth stimulants along with soil test based nutrient management resulted in higher mean fruit yield per plant (Figure 9). Higher mean fruit yield per plant was obtained in humic acid (T_7), cytozyme (T_9), and potassium silicate (T_8) 23.88 %, 16.89 % and 16.04 % respectively whereas small

increase in fruit yield was recorded with putrescine (T_{10}) 12.38 % over control (T_1). Foliar application of cytozyme along with soil test based nutrient management, full NPK dose and 50 % NPK had increased fruit yield by 16.89 % (T_9), 8.93 % (T_5) and -4.68 % (T_{13}) respectively over control (T_1). Foliar application of potassium silicate along with soil test based nutrient management, full NPK dose and 50 % NPK had increased fruit yield 16.04 % (T_8), 5.88 % (T_4) and -6.31 % (T_{12}) respectively over control (T_1). Foliar application of putrescine along with soil test based nutrient management, full NPK dose and 50 % NPK had increased fruit yield 12.38 % (T_{10}), 5.13 % (T_6) and -6.54 % (T_{14}) over control (T_1). Foliar application of growth stimulants namely humic acid, cytozyme, potassium silicate and putrescine along with standard POP recorded 9.29 %, 8.93 %, 5.88 % and 5.13 % increase respectively over control (T_1). Foliar application of growth stimulants namely humic acid, cytozyme, potassium silicate and putrescine along with 50 % NPK recorded -3.32 %, -15.30 %, -6.31 % and -6.54 % respectively over control (T_1). Here yield was reduced than control plot because of the less availability of fertilizer to those plots. Yield and yield parameters of control (T_1) plots were recorded significantly on par with that of water sprayed (T_{15}) plots.

The improvement in yield and yield attributes with growth stimulant treated plots may be ascribed to the fact that they improved the nutrient uptake and these nutrients being important constituents of nucleotides, proteins, chlorophyll and enzymes, involving in various metabolic processes which have direct impact on vegetative and reproductive phases of plants

5.5 Quality parameters as influenced by growth stimulants

An increase in 52.19 per cent crude fiber content was recorded in treatment T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by 35.73 per cent in T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2 %) and 24.75 per cent in T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3 %)

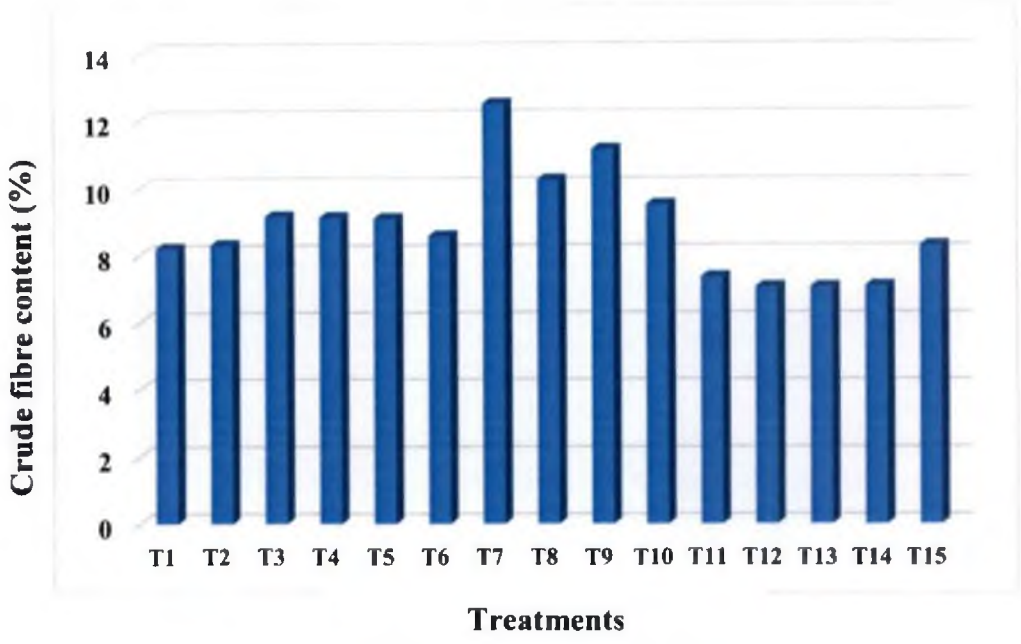

Figure 10: Effect of treatments on crude fibre content of okra fruit (%)

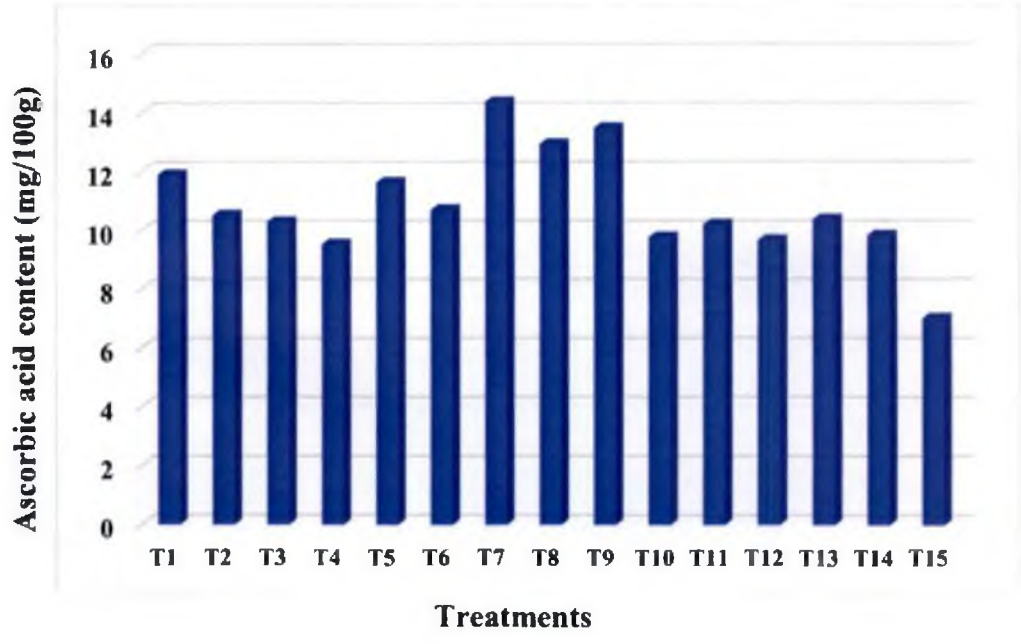

Figure 11: Effect of treatments on ascorbic acid content of okra fruit (mg/100g)

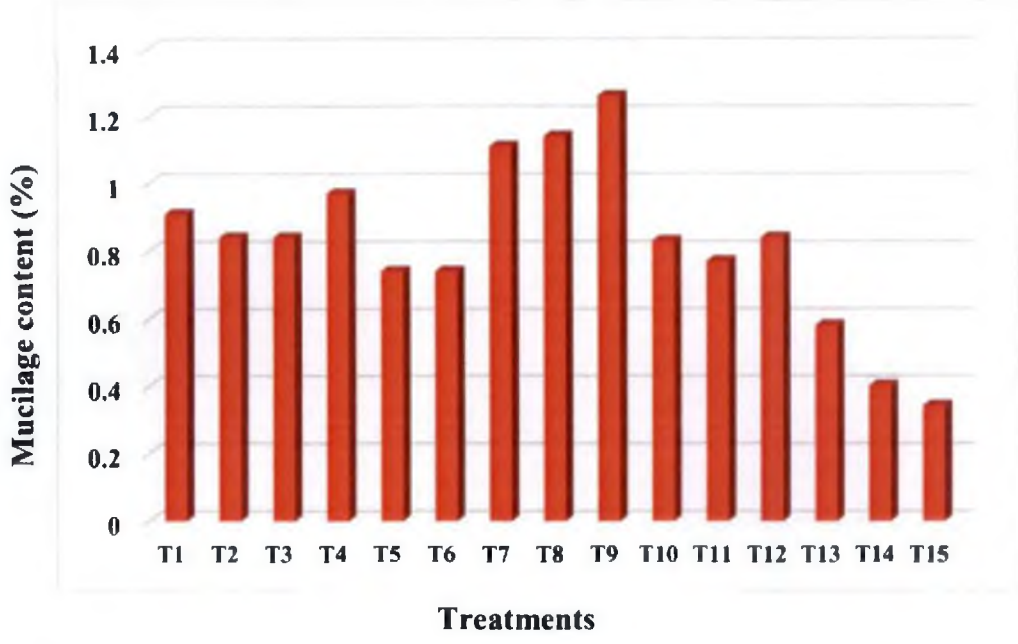

Figure 12: Effect of treatments on mucilage content of okra fruit (%)

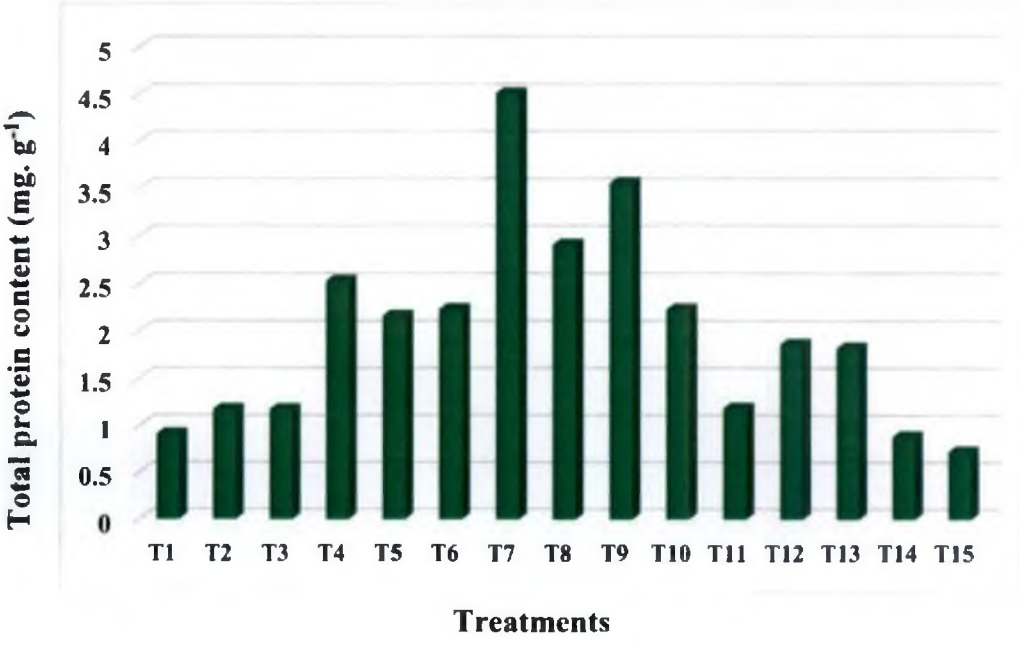

Figure 13: Effect of treatments on total protein content of okra fruit (mg. g^{-1})

compared to control. Soil test based nutrient management with the application of growth stimulants resulted higher crude fiber content than treatments which received standard POP with growth stimulants and 50 per cent standard POP with growth stimulants (Figure 10). This might be due to the easy availability of nitrogen by growth stimulants leading to balanced C: N ratio, enhancing the vegetative growth resulting in high photosynthetic activity as reported by Patel *et al.* (2009).

A similar pattern of effectiveness of growth stimulants was observed in the case of ascorbic acid content of fruit also (Figure 11). This implicated that the soil test based nutrient management practices with growth stimulants gave a significant factor for improving the fruit quality characters.

Among the treatments studied, maximum mucilage content was recorded with treatment T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2%) followed by T_8 (Soil test based modified nutrient management with potassium silicate spray @ 0.3%) and T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %). Minimum mucilage content was recorded with T_{15} (T_1+ water spray) (Figure 12). Maximum protein content was recorded in T_7 (Soil test based modified nutrient management with humic acid spray @ 0.2 %) followed by T_9 (Soil test based modified nutrient management with cytozyme spray @ 0.2%), while minimum value was recorded with T_{15} (T_1 + water spray) (Figure 13). The increase in protein content was pronounced with humic acid application and it favored protein synthesis and its efficient storage in the presence of abundant supply of available nitrogen. Mohsen (2014) reported that humic acid sprayed treatments increased fruit quality (total soluble solids, protein, pH, vitamin C, fruit firmness and fruit lycopene content) of tomato fruits.

5.4.4 Plant nutrient analysis

Nutrient analysis done after foliar spray indicated that among the nutrients, nitrogen and potassium content varied significantly between the treatments. Foliar

application of humic acid, cytozyme and potassium silicate might have contributed to improved availability of nutrients for the growing plants. Growth stimulants like humic acid might have been complexed with sodium (Na), potassium (K), magnesium (Mg), zinc (Zn), calcium (Ca), iron (Fe), copper (Cu), and with various other elements. This might have increase the nutrient content in plant as reported by Aiken *et al.* (1985).

Summary

6. SUMMARY

Various growth stimulants containing amino acids, peptides, polyamines, humic acids and mixtures of nutrients were found to enhance the yield and quality of crops. The yield contributing characters and quality of plants could be improved by foliar application of growth stimulants. New approaches to sustainable agriculture tend to use environment friendly and safe products or formulations having growth stimulation activity. Many of the growth stimulants are reported to have the capacity to enhance nutrient use efficiency of the plants which further stimulate photosynthesis and plant growth. In the present scenario of agriculture, the extent to which farmers can depend on chemical fertilizers is constrained by its increasing cost and availability at right time. Moreover, fertilizer recommendation of crops based on soil test data is an important criterion to enhance nutrient use efficiency. As the growth stimulants are often mixtures of a variety of compounds many are likely to have multiple functions in terms of improving nutrient availability, providing fungicidal and insecticidal effect and hormonal effect. Growth stimulants are supposed to act on physiology of plants enhancing the vigor, yield and quality. But the mechanism behind the physiological and biochemical effects of the growth stimulants on crops is still unknown.

Hence, the present study was carried out at College of Horticulture, Vellanikkara to understand the influence of growth stimulants on physiology, growth, yield and quality attributes of okra variety Arka Anamika under standard POP recommended by KAU and also soil test based nutrient management system.

The main objective of the present study was:

- The study aims to understand the influence of growth stimulants on morpho-physiological changes, yield and quality in Okra (*Abelmoschus esculentus* L.) with respect to soil fertility management.

The salient findings of the study are as follows

- A comparison of the morphological attributes such as plant height, number of branches per plant, leaf area and number of leaves per plant were indicated that as compared to the control plot (standard package of practice) there was significant improvement in morphological parameters when estimated on the 25th DAS and 50th DAS.
- The improvement in morphological parameters like plant height, leaf area, leaves per plant etc. was more for the growth stimulants like humic acid, cytozyme and potassium silicate with soil test based nutrient management plots than standard fertilizer applied plots followed by 50 % NPK applied plots.
- Plants which received potassium silicate spray, putrescine spray and humic acid sprays were recorded higher total chlorophyll content.
- Growth stimulants (potassium silicate, cytozyme and humic acid) significantly improved the IAA content in both pre flowering and post flowering periods.
- Comparison of the photosynthetic rate of crop at two different growth stages revealed that growth stimulants such as humic acid, cytozyme and potassium silicate along with soil test based nutrient management resulted a significant improvement in photosynthetic rate when compared to control treatments.
- There was no significant variation in transpiration rate at 25th DAS. However, at reproductive phase (50 DAS) the transpiration rate varied significantly among treatments and maximum rate was recorded with humic acid spray with soil test based nutrient management.
- At 25 DAS and 50 DAS, potassium silicate as foliar spray along with soil test based nutrient management showed a significantly higher stomatal conductance.
- Among the treatments, humic acid spray along with soil test based nutrient management recorded the least number of days to 50 per cent flowering

and days to first harvest followed by potassium silicate spray with soil test based nutrient management.

- Soil test based nutrient management with growth stimulants application resulted higher fruit length, fruit diameter, fruit weight and number of fruits per plant than treatments which receiving standard POP with growth stimulants followed by 50 per cent standard POP with growth stimulants.
- Regarding the quality parameters like crude fibre, ascorbic acid, mucilage, and total protein content of fruit was higher in plants receiving growth stimulants like humic acid, cytozyme and potassium silicate along with soil test based nutrient management system followed by standard POP with growth stimulants and 50 per cent standard POP with growth stimulants.

Conclusion

Application of growth stimulants along with soil test based nutrient management system enhances the growth, yield and quality of okra. There was a significant increase in plant growth, development and yield in soil test based nutrient management with humic acid, cytozyme and potassium silicate applied plots followed by standard POP with growth stimulants and 50 per cent standard POP with growth stimulants applied plots. Growth stimulants with soil test based nutrient management applied plots recorded 12.38 to 23.88 per cent more fruit yield over control followed by standard POP with growth stimulants recorded 5.13 to 9.29 per cent over control and 50 per cent standard POP with growth stimulants applied plots recorded 3.32 to 6.54 per cent lesser yield than control. These growth stimulants increased the nutrient use efficiency of plants which further stimulated the photosynthesis, plant growth and development. Hence the present study concluded that the application of growth stimulants along with soil test based nutrient management can be recommended as a booster for enhancing crop growth, fruit quality and fruit yield in okra.

References

REFERENCES

Abd El-Aziz, N. G., Lobna, S. T., and Soad, M. L. 2009. Some studies on the effect of putrescine, ascorbic acid and thiamine of gladiolus plant. *J. Appl. Sci.* 2(2): 169-179.

Abd El-Rhman, I. E. 2010. Physiological studies on cracking phenomena of Pomegranates. *J. Appl. Sci. Res.* 6(6): 696-703.

Adatia, M. H. and Besford, R. T. 1986. The effects of silicon on cucumber plants grown in recirculating nutrient solution. *Ann. Bot.* 58:343-351.

Ahmad, R., Hussain, S., Farooq, M., and Rehman, A. U. 2013. Improving the performance of direct seeded system of rice intensification by seed priming. *Int. J. Agric. Biol.* 15(4): 791-794.

Ahmad, R., Zaheer, S., and Ismail, S. 1992. Role of silicon in salt tolerance of wheat (*Triticum aestivum* L.). *Plant Sci.* 85: 43–50.

Aiken, G. R., Edwards, D. M., and McKnight, D. 1985. Humic substances in soil, sediment, and water, geochemistry, isolation, and characterization. *J. Plant Biotechnol.* 69: 1-34.

Albayrak, S. and Camas, N. 2005. Effects of different levels and application times of humic acid on root and leaf yield and yield components of forage turnip (*Brassica rapa* L.). *J. Agron.* 4(2): 130-133.

Ali, A., Tahir, M., Amin, M., Basra, S. M. A., Maqbool, M., and Lee, D. J. 2011. Silicon induced stress tolerance in wheat hydroponically grown under water deficit conditions. *J. Agric. Sci.* 19(5): 951-957.

Alphonse, M. and Saad, E. M. 2000. Growing greenhouse cucumber in FYM and chicken manure media in combination with foliar application of zinc, boron and manganese. *Egyptian J. Hortic.* 27(3): 315-316.

Altman, A. R., Friedman, D., Amir, N., and Levin, N. 1982. Polyamine effects and metabolism in plants under stress conditions. In: Wareing, P. F. (ed.), *Plant Growth Substances* (4th Ed.). Academic Press, London, pp. 483-494.

Anderson, J. M. 1991. Jasmonic acid-dependent increase in the level of specific polypeptides in soybean suspension cultures and seedlings. *J. Plant Growth Reg.* 7: 203–211.

Anuja, S., Jayalaksmi, L., and Joshi, P. K. 2011. Effect of foliar application of organic nutrients and inorganic fertilizers on NPK uptake, post-harvest soil available nutrients and yield performance of palak (*Beta vulgaris* L.). *Asian J. Hortic.* 6(2): 423-426.

Aranda, M. R., Romero, R., and Jurado, O. 2006. Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *J. Plant Physiol.* 163(8): 847-855.

Atiyeh, R. M., Lee, S., Edwards, C. A., Arancon, N. Q., and Metzger, J. D. 2002. The influence of humic acids derived from earthworm processed organic wastes on plant growth. *Soil Ecol.* 18: 105-112.

Ayad, H. S., Reda, F., and Abdalla, M. S. A. 2010. Effect of putrescine and zinc on vegetative growth, photosynthetic pigments, lipid peroxidation and essential oil content of geranium (*Pelargonium graveolens* L.). *World J. Agric. Sci.* 6(2): 601-608.

Ayyobi, H., Peyvast, G., and Olfati, J. A. 2013. Effect of vermicompost and vermicompost extract on oil yield and quality of peppermint (*Mentha piperita* L.). *J. Agric. Sci.* 58(1): 51–60.

Azcona, I., Pascual, I., Aguirreolea, J., Fuentes, M., García-Mina, J. M., and Sánchez-Díaz, M. 2011. Growth and development of pepper are affected by humic

substances derived from composted sludge. *J. Plant Nutr. Soil Sci.* 174(5): 916–924.

Bais, H. P. and Ravishankar, G. A. 2002. Role of polyamines in the ontogeny of plants and their biotechnological applications. *J. Plant Biotechnol.* 69: 1-34.

Balakumbahan, R. and Rajamani, K. 2010. Effect of bio stimulants on growth and yield of senna (*Calsia angustifolia* var KKm.1). *J. Hortic. Sci. Ornamental Plants* 2(1): 16-18.

Baskar, K. and Sankaran, K. 2005. Effect of humic acid (potassium humate) on growth and yield of turmeric (*Curcuma longa* L.) in an *alfisol*. *J. Spices Aromat. Crops* 14(1): 34-38.

Berger, K. C., and Truog, E. 1939. Boron determination in soils and plants. *Indian Eng. Chem. Anal.* 11: 540-542.

Bowen, P., Menzies, J., and Ehret, D. 1992. Soluble silicon sprays inhibit powdery mildew development on grape leaves. *J. Am. Soc. Hortic. Sci.* 117: 906–912.

Bray, R. H. and Kurtz, L. T. 1945. Determining total organic and available forms of phosphate in soils. *Soil Sci.* 59: 39-45.

Buckerfield, J. C., Flavel, T. C., Lee, K. E., Webster, K. A., Diazcozin, D. J., Jesus, J. B., Trigo, D., and Garvin, M. H. 1999. Vermicompost in solid and liquid forms as a plant growth promoter. *J. Plant Nutr.* 43(5): 1345-1353.

Chadha, K. L. 2002. *Hand Book of Horticulture.* Indian Council of Agricultural Research, New Delhi, 427p.

Chaudhary, B. R., Sharma, M. D., Shakya, S. M., and Gautam, D. M. 2006. Effect of plant growth regulators on growth, yield and quality of chilly (*Capsicum annuum* L.). *J. Inst. Agric. Anim. Sci.* 27: 65-68.

Chauhan, V. S. 1972. *Vegetable Production in India*, (3rd Ed.). Ram Prasad and sons, Agra, 185p.

Chen, Y. and Aviad, T. 1990. Effects of humic substances on plant growth. In: MacCarthy, P., Clapp, C.E., Malcom, R. L., and Bloom, P. R. (ed.), *Humic Substances in Soils and Crop Science: Selected Readings* (10th Ed.). Soil Science Society of America, Madison, pp. 161–186.

Cheng, B.T. 1982. Some significant functions of silicon to higher plants. *J. Plant Nutr.* 5:1345-1353.

Chougale, D. Y. 1997. Influence of growth regulators on productivity potential in sesamum genotypes. M.Sc. (Ag) thesis, University of Agricultural Science, Dharwad, 90p.

Chris, W., Anderson, N., and Stewart, R. B. 2005. Soil and foliar application of humic acid for mustard production. *Environ. Pollut.* 35: 254-257.

Clapp, C. E., Chen, Y., Hayes, M. H. B., and Cheng, H. H., 2001. Plant growth promoting activity of humic substances. In: Swift, R. S. and Sparks, K. M. (ed), *Understanding and Managing Organic Matter in Soils, Sediments, and Waters* (11th Ed.). International Humic Science Society, Madison, pp. 243–255.

Clayton, M., Biasi, W. V., Agar, I. T., Southwick, S. M., and Mitcham, E. J .2006. Sensory quality of 'Bing' sweet cherries following preharvest treatment with hydrogen cyanamide, calcium ammonium nitrate and gibberellic acid. *Hortic. Sci.* 41: 745-748.

Cohen, E., Heimer, Y. M., and Mizrahi, Y. 1982. Ornithine decarboxylase and arginine decarboxylase activities in meristematic tissues of tomato and potato plants. *Plant Physiol.* 70(2): 544-550.

Cohen, S. S. 1998. *A Guide to the Polyamines*. Oxford University Press. New York, 428p.

Cooper, R. I., Liu, C. and Fisher, D. S. 1998. Influence of humic substances on rooting and nutrient content of creeping bent grass. *Crop Sci.* 38: 163-169.

Costa, G. and Bagni, N. 1983. Effect of polyamines on fruit set of apple. *Hortic. Sci.* 18: 59-61.

David, P. P., Nelson, P. V., and Sandres, D. C. 1994. Humic acid improves growth of tomato seedling in solution culture. *J. Plant Nutr.* 17: 173- 184.

David, R. A. and Samuel, M. 2002. Effect of lignite derived ammonium humate on mustard (*Brassica juncea* L.) using different levels of phosphate fertilizer. *Pakist. J. Sci.* 45 (4): 273-276.

Doran, J. W. and Parkin, T. B. 1994. Defining and assessing soil quality. In: Coleman, D.(ed.), *Defining Soil Quality for a Sustainable Environment* (11th Ed.). SSSA, Madison, Wisconsin, USA, pp. 31-65.

EL-Lethy, M. E., Reymond, M., Stich, B., Koornneef, M., and Vreugdenhil, D. 2010. Relation among plant growth, carbohydrates and flowering time in the *Arabidopsis* recombinant inbred line population. *Plant Cell Environ.* 33: 1369–1382.

El-Quesni, F. E. M., Taha, L. S., Ibrahim, S. M. M., and Farahat, M. M. 2007. Growth and chemical constituents of *Cupresus sempervirens* L. plant as influence by kinetin and iron treatments at Nubaria. *J. Agric. Environ. Sci.* 2(2): 282-288.

El-Sayed, G. 2009. Sodicity and boron tolerance evaluation for chrysanthemum and carnation flower plants. *J. Agric. Environ. Sci.* 8(2): 144-150.

Ertani, A., Smbo, P., Nicoletto, C., Santagata, S., Sachiavon, S., and Nardi, S. 2015. The use of organic biostimulants in hot pepper plants to help low input sustainable agriculture. *Chem. Biol. Technol. Agric.* 11(2): 252-256.

FAOSTAT [Food and Agricultural Organization of the United Nations production statistics]. 2011. [online] Available: http://fao.org). [17 May 2011].

Ferrara, G. and Brunetti, G. 2010. Effects of the times of application of a soil humic acid on berry quality of table grape (*Vitis vinifera* L.) cv Italia. *Spanish J. Agric. Res.* 8: 817-822.

Gadimor, A., Ahmadove, N., and Alivea, R. C. 2007. Symbiosis nodules Bacteria Rhizobium legominosae with peas (*Pisum sativum*) nitrate reductes, salinification and potassium humate. *Azerbaijan J. Natl. Acad. Sci.* 25(3): 156-162.

Ghorbani, S., Khazaei, H. R., Kafi, M., and Banayanl, M. 2010. The effect of adding humic acid to irrigation water on yield and yield components of corn. *J. Agric. Ecol.* 2: 123-131.

Gong, H. K., Chen, G., Chen, S., Wang, S., and Zhang, C. 2003. Effects of silicon on growth of wheat under drought. *J. Plant Nutr.* 26: 1055–1063.

Goyal, M. and Asthir, B. 2010. Polyamine catabolism influences antioxidative defense mechanism in shoots and roots of five wheat genotypes under high temperature stress. *Plant Growth Reg.* 60: 13–25.

Gunes, A., Pilbeam, D. J., Inal, A., and Coban, S. 2008. Influence of silicon on sunflower cultivars under drought stress, I: growth, antioxidant mechanisms, and lipid peroxidation. *Soil Sci. Plant Anal.* 39: 1885–1903.

Gupta, O. P., Anand, K. K., Ghatak, B. J. and Atal, C. K. 1978. Vasicine, Alkaloid of *Adhatoda vasica*. *Indian J. Exp. Biol.* 16: 1075-1082.

Haghighi, S., Sakinejad, T., and Lack, S.H. 2011. Evalution of changes the qualitation and quantitative yield of horse been (*Vicia faba*) plant in the levels of humic acid fertilizer. *J. Life Sci.* 8: 112-119.

Hiscox, J. D. and Israelstam, G. F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian J. Bot.* 57: 1332-1334.

Hoang, N. H. 2003. Effect of plant growth regulators and other chemicals on fruit thinning, fruit drop, yield and quality in pomegranate cv. G-137. M.Sc. (Ag) thesis, Dr. Y S Parmar University of Horticulture and Forestry, Solan, HP, 90p.

Jackson, M. L. 1958. *Soil Chemical Analysis* (Indian Reprint, 1967). Prentice Hall of India, New Delhi, 498p.

Jirali, D. I. 2001. Physiological investigation in turmeric (*Curcuma longa* L.). Ph. D. thesis, University of Agricultural Science, Dharwad, 120p.

Karuppaiah, P., Manivonnar, K., Sriramach, M. V., and Kuppusamy, K. 2008. Response of cucumber to foliar application of nutrients on light mine spoil. *J. Indian Soc. Soil Sci.* 49(1): 150-153.

Kaya, C., Tuna, L., and Higgs, D. 2006. Effect of silicon on plant growth and mineral nutrition of maize grown under water-stress conditions. *J. Plant Nutr.* 29: 1469-1480.

Khan, A. R. and Mir, S. 2002. Effect of lignite derived ammonium humate on wheat (*Triticum aestivum*) crop using different levels of phosphate fertilizer. *Pakist. J. Sci.* 45 (4): 251-257.

Khan, M., Zaman, M., and Khan, M. J. 2014. How to improve yield and quality of potatoes: effects of two rates of urea N, urease inhibitor and cytozyme nutritional program. *J. Soil Sci. Plant Nutr.* 14(2): 145-150.

Khurana, S. C. and Pandita, M. L. 1986. Shoot emergence studies in four commercial potato cultivars in relation to cytozyme. *Haryana Agric. Univ. J. Res.* 16(4): 367-370.

Kochar, S. L. 1986. *Tropical Crops-A Text Book of Economic Botany*. Macmillan Indian Ltd, 264p.

Kusano, T., Berberich, T., Tateda, C., and Takahashi, Y. 2008. Polyamines: essential factors for growth and survival. *Biol. Plant.* 228: 367–381.

Law, D. M., Davies, P. J., and Mutscheler, M. A. 1991. Polyamine induced prolongation of storage in tomato fruits. *Plant Growth Reg.* 10: 283-290.

Leusch, H. J. and Buchenauer, H. 1989. Effect of soil treatments with silica; rich lime fertilizers and sodium trisilicate on the incidence of wheat by *Erysiphe graminis* and *Septoria nodorum* depending on the form of N-fertilizer. *Am. J. Sustain. Agric.* 96(4): 154-172.

Liu, V. L., Kant, L., and Joshi, A. 1998. Study of nodulation, Leghemoglobin contents and nitrate reductase activity in black gram (*Vigna mungo* L.). *J. Legume Res.* 21: 221-224.

Mahgoub, H. M., Rawia, A. E., and Leila, B. H. A. 2006. Response of Iris bulbs grown in sandy soil to nitrogen and potassium fertilization. *J. Appl. Sci. Res.* 2: 899–903.

Malawadi, M. N. 2003. Effect of secondary and micronutrients on yield and quality of chilli (*Capsicum annum* L.). M.Sc.(Ag.) thesis, University of Agricultural Sciences, Dharwad, 90p.

Mallikarjuna, R. M., Govindasamy, R., and Chandrasekaran, S. 1987. Effect of humic acid on *Sorghum vulgare* var. CSH-9. *Curr. Sci.* 56(4): 1273-1276.

Malviya, R. 2011. Extraction and characterization of selected mucilage as a pharmaceutical excipient. *Polym. Med.* 41(3): 39-44.

Mathai, G., Paily, P. V., and Menon, M. R. 1978. Effect of fungicides and silica in the control of sheath blight disease of rice caused by *Corticum sasakii* (Shiriai). *Agr. Res. J. Kerala* 19(1): 79-83.

Mitra, S. K. and Sanyal, D. 1990. Effect of putrescine on fruit set and fruit quality of Litchi. *J. Appl. Bot.* 55: 83-84.

Miyake, Y. and Takahashi, E. 1983. Effect of silicon on the growth of cucumber plant in soil culture. *Soil Sci. Plant Nutr.* 29: 463-471.

Mohammadipour, E., Golchin, A., Mohammadi, J., Negahdar, N., and Zarchini, M. 2012. Effect of Humic Acid on Yield and Quality of Marigold (*Calendula officinalis* L.). *An. Biol. Res.* 3(11): 5095-5098.

Mohsen, K. 2014. Effect of foliar application of humic acid and calcium chloride on tomato growth. *Environ. Pharmacol. Life Sci.* 3: 41-46.

Muthuvel, M. 2002. Effect of organics on growth and yield of bhendi var. Varsh Uphar. *Plant Physiol.* 12: 41- 44.

Nardi, S., Pizzeghello, D., Gessa, C., Ferrarese, L., Trainotti, L., and Casadoro, G. 1996. A low molecular weight humic fraction on nitrate uptake and protein synthesis in maize seedlings. *Soil Biol. Biochem.* 32: 415–419.

Nawalgatti, C. M., Panchal, Y. C., Manjunath, S., and Channappagoudar, B. B. 1991. Effect of different level of plant growth regulators on growth and yield of groundnut. *J. Maharashtra Agric. Univ.* 16(1): 122-123.

Nikbakht, A., Kafi, M., Babalar, M., Xia, Y., Luo, A., and Etemadi, N. 2008. Effect of humic acid on plant growth, nutrient uptake, and postharvest life of Gerbera *J. Plant. Nutr.* 31(4): 2155-2167.

Nishizawa, T. 1995. Effect of defoliation on fruit development and carbohydrate levels in vegetative organs of strawberry plants. *J. Jpn. Soc. Hortic. Sci.* 64: 55-61.

Nolla, A., Korndorfer, G. H., and Coelho, L. 2006. Efficiency of calcium silicate and carbonate in soybean disease control. *J. Plant Nutr.* 29: 2049–2061.

Okuda, A. and Takahashi, E. 1961. Effect of the period of silicon deficiency on the growth of rice plant and nutrients uptake. *J. Sci. Soil Manure Jpn.* 32(2): 481-488.

Padem, H., Ocal, A., and Alan, R. 1997. Effect of humic acid added foliar fertilizer on seedling quality and nutrient content of eggplant and pepper. *Acta Hortic.* 491: 241-246.

Parthasarathy, K., Balu, D. R. C., and Rao, P. S. 1970. Studies on sandal spur. VII. Polyphenol oxidase activity and metabolism of sandal (*Santalam album* L.) in healthy and diseased. *Proc. Indian. Acad. Sci.* 72: 277-284.

Patel, A. P., Tandel, Y. N., Patel, C. R., Patel, M. A., and Patel, P. B. 2009. Effect on combined application of organic manures with inorganic fertilizers on growth and yield of okra cv. parbhani kranti. *Asian J. Hortic.* 4(1) :78-81.

Pereira, H. S., Korndörfer, G. H., Vidal, A. A., and Camargo, M. S. 2004. Silicon sources for rice crop. *Sci. Agric.* 61(5): 522-528.

Pettit, R. E. 2004. Organic matter, humus, humic acid, fulvic acid and humin: Their importance in soil fertility and plant health. *Soil Ecol.* 38: 115-122.

Qhureshi, Z. 2007. Breeding investigation in bhendi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag) thesis, University of Agriculture Sciences, GKVK, Bangalore,79p.

Rana, B. S. and Vashistha, R. N. 1998. Effect of various chemical on growth and yield characteristics of radish (*Raphanus Sativus* L.). *Haryana J. Hort. Sci.* 14(2): 97-101.

Ranganna, S. 1986. *Hand book of Analysis and Quality Control for Fruits and Vegetable Products.* Tata MC Graw Hill Publishing Company Limited, New Delhi, 345p.

Raut, V. M., Hauankar, G. B., Taware, S. P., and Patil, V. P. 1995. Performance of commercial spray formulation on soybean seed yield and yield components. *J. Maharashtra Agric. Univ.* 20(3): 476-477.

Rice, R., Rice, L. W., and Tindal, H. D. 1987. *Fruit and Vegetable Production in Africa*. MacMillan, London, 198p.

Sabzevari, S. H. and Khazaei, R. 2009. The effect of foliar spray of different levels of humic acid on growth characteristics and yield of wheat, Pishtaz cultivar. *J. Agric. Ecol.* 1:53-63.

Sankaran, M., Thangaraj, T., and Veeraragavathatham, D. 2005. Quality and shelf life of fresh Okra (*Abelmoschus esculentus* L.) pods as influenced by prepackaging and storage temperatures. *South Indian Hortic.* 53: 97-101.

Savas, D., Manos, G., Kotsiras, A., and Soulaliotis, S. 2002. Effects of silicon and nutient-induced salinity on yield, flower quality and nutrient uptake of gerbera grown in a closed hydroponic system. *J. Appl. Bot.* 76: 153-158.

Savvas, D. and Gizas, G. 2002. Response of hydroponically grown gerbera to nutrient solution recycling and different nutrient cation ratios. *Indian J. Hortic.* 96: 267–280.

Serenella, N., Pizzeghelloa, D., Muscolob, A., and Vianello, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biol. Biochem.* 34: 1527-1536.

Shahmaleki, K., Peyvast, S., and Olfati, J. 2010. Effect of humic acid on growth and yield of tomato cv. Isabela. *J. Hortic. Sci.* 24(2): 149-153.

Sharifi, M., Khattak, R. A., and Sarir, M. S. 2002. Effect of different levels of lignitic coal derived humic acid on growth of surface-irrigated wheat. *Agric. Sci.* 52: 207-210.

Shen, W., Nada, K., and Tachibana, S. 2000. Involvement of polyamines in the chilling tolerance of cucumber cultivars. *Plant Physiol.* 124: 431- 440.

Shende, V. P., Deore, B. P., and Patil, R. C. 1987. Effect of Plant growth substances on nutrient uptake by pea. *J. Maharashtra Agric. Univ.* 12(3): 381 – 382.

Sims, J. R. and Johnson, G. V. 1991. Micronutrient soil tests. In: Mortvedt, J. J., Cox, Shuman, L. M., and Welch, R. M. (eds), *Micronutrient in Agriculture* (2nd ed.). SSSA, Madison, USA, pp. 427-476.

Singh, Y. P., Dwivedi, R., and Dwivedi, S. V. 2008. Effect of bio fertilizer and graded dose of nitrogen on growth and flower yield of Calendula (*Calendula officinalis* L.). *Plant Arch.* 8(2): 957-958.

Stevenson, F. J. 1991. Organic matter-micronutrient reactions in soil. In: Mortvedt, J. J., Cox, F. R., Shuman, L. M., Welch, R. M. (ed.), *Micronutrients in Agriculture* (4th Ed.). Soil Science Society of America, Madison, pp. 145–186.

Subbiah, B. V. and Asija, G. L., 1956. Alkaline permanganate method. *Current Sci.* 25: 255-260.

Tabor, C. W. and Tabor, H. 1984. Polyamines. *Annu. Rev. Biochem.* 5: 749-790.

Taiz, L. and Zeiger, E. 2006. *Plant Physiology* (3rd Ed.). Sinauer Associates Inc., Publishers, Sunderland, 782p.

Talaat, I. M., Bekheta. M. A., and Mahgoub. M. M. H. 2005. Physiological response of Periwinkle plants (*Cataranthus roseus* L.) to tryptophan and putrescine. *Int. J. Agric. Biol.* 7(2): 210- 213.

Talaat, M. I. 2005. Physiological effect of salicylic acid and tryptophan on *Pelargonium graveolens*. *Egyptian J. Appl. Sci.* 20(2): 751-760.

Trenholm, L. E., Duncan, R. R., Carrow, R. N., and Snyder, G. H. 2001. Influence of silica on growth, quality, and wear tolerance of seashore paspalum. *J. Plant Nutr.* 24(2): 245-259.

Ulukan, 2008. Effect of soil applied humic acid at different sowing time on some yield component in wheat hybrids. *Int. J. Bot.* 2: 164-175.

Valero, D., Martinezromero, D., Serrano, M., and Riquelme, F. 1998. Influence of postharvest treatment with putrescine and calcium on endogenous polyamines and abscisic acid in Lemon (*Citrus lemon* L.). *J. Agri. Food Chem.* 46: 2102-2109.

Vijayakumari, B., Yadav, R., Hiranmai, R., Gowri, P., and Kandari, L. S. 2012. Effect of panchagavya, humic acid and micro herbal fertilizer on the yield and post-harvest soil of soybean (*Glycine max.* L.). *Asian J. Plant Sci.* 11: 83-86.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.* 31: 29-38.

Wang, S. Y. and Galletta, G. L. 1998. Foliar Application of Potassium Silicate Induces Metabolic Changes in Strawberry Plants. *J. Plant Nutr.* 21(1): 371-375.

Wetzstein, H. Y., Ravid, N., and Wilkins, E. 2011. A morphological and histological characterization of bisexual and male flower types in pomegranate. *Am. J. Sustain. Agric.*136(2): 83–92.

Williams, C. H. and Steinbergs, A. 1959. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Aust. J. Agric. Res.* 10(3): 340-352.

Yaofu, W. 2005. Effect of irrigation and rate of humic acid on concentration of nutrients and yield and quality of flue-cured tobacco. *J. Anhui Agric. Sci.* 33(1): 96-97..

Yildirim, E. 2007. Foliar and soil fertilization of humic acid affect productivity and quality of tomato. *Soil Plant Sci.* 57: 182-186.

Yorinori, J. T., Paiva, W. M., Frederick, R. D., Costamilan, L. M., Bertagnolli, P. F., Hartman, G. E., Godoy, C. V., and Nunes, J. 2005. Epidemics of soybean rust in Brazil and Paraguay from 2001 to 2003. *Plant Dis.* 89: 675-677.

Youssef, A. A., Mahgoub, M. H., and Talaat, I. M. 2004. Physiological and biochemical aspects of *Matthiola incana* L. plants under the effect of putrescine and kinetin treatments. *Egyptian J. Appl. Sci.* 19(4): 492– 510.

Youssef, E. A. E. 2007. Increasing drought tolerance of gladiolus plants through application of some growth regulators. *Asian J. Hortic.* 4(1): 299- 306.

Abstract

Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)

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ABSTRACT OF THE THESIS

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Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)

Abstract

Okra or Bhindi (*Abelmoschus esculentus* L.) is one of the most popular summer vegetable crop grown widely in Kerala. It accounts for 65 % of the fresh vegetables exported from the country. However, the productivity of the crop is low in the state. The low fertility status of the soil due to heavy rains may be a major reason. Currently, for sustainable increase in productivity soil test based nutrient management practices are recommended. Another approach is the use of environment friendly growth stimulants, which have beneficial effects on plants. Hence, the present study was carried out to understand the influence of growth stimulants on growth, yield and quality attributes of okra variety Arka Anamika under standard package of practices (POP) recommended by KAU and also soil test based nutrient management system.

The experiment was laid out in Randomized block design with 15 treatments and three replications at Central nursery, College of Horticulture, Vellanikkara. The crop was raised as per standard POP recommendations of KAU and also under soil test based nutrient management system. Experiments consisted of 15 treatments *viz.*, standard POP, KAU (T_1) as control, soil test based modified nutrient management (T_2), T_1 + humic acid spray @ 0.2 % (T_3), T_1 + potassium silicate spray @ 0.3 % (T_4), T_1 + cytozyme spray @ 0.2 % (T_5), T_1 + putrescine spray @ 50 ppm (T_6), T_2 + humic acid spray @ 0.2 % (T_7), T_2 + potassium silicate spray @ 0.3 % (T_8), T_2 + cytozyme spray @ 0.2 % (T_9), T_2 + putrescine spray @50 ppm (T_{10}), 50 % T_1 + humic acid spray @ 0.2 % (T_{11}), 50 % T_1 + potassium silicate spray @ 0.3 % (T_{12}), 50 % T_1 + cytozyme spray @ 0.2 % (T_{13}), 50 % T_1 + putrescine spray @ 50 ppm (T_{14}) and T_1 + water spray (T_{15}). Foliar application of growth stimulants was given at 15, 30 and 45 DAS. Morphological, physiological and biochemical parameters were recorded at 25 and 50 DAS and the yield and fruit quality characters were recorded at the time of harvest.

The use of growth stimulants such as humic acid, cytozyme and potassium silicate with soil test based nutrient management system improved the morphological parameters like plant height, leaf area, the number of leaves per plant etc. than control. Plants which received potassium silicate, putrescine and humic acid as foliar spray recorded higher total chlorophyll content and IAA content. Comparison of photosynthetic rate, transpiration rate and stomatal conductance of crop at two different growth stages revealed that growth stimulants such as humic acid, cytozyme and potassium silicate along with soil test based nutrient management showed a significant improvement over control. A similar pattern of the effectiveness of growth stimulants was observed in the case of fruit yield and quality characters such as crude fiber content, ascorbic acid content, mucilage content and total protein content.

Comparison of POP, soil test based application of fertilizers and 50 per cent POP showed that soil test based nutrient management gave significantly higher yield as compared to the other treatments including control. The response of the stimulants was also higher for soil test based nutrient management treatments.

Growth stimulants with soil test based nutrient management applied plots recorded 12 to 23 per cent higher fruit yield over control followed by standard POP with growth stimulants which recorded an improvement of 5 to 9 per cent over control. Reduction in fruit yield of 3 to 6 per cent was recorded with 50 per cent standard POP over control.

Among the four growth stimulants used, humic acid performed better followed by cytozyme and potassium silicate. These growth stimulants may have enhanced the nutrient use efficiency of the plants which further improved the photosynthesis, plant growth and development. The result of the present study indicated that growth stimulants can be recommended along with soil test based nutrient management for enhancing crop growth, fruit quality and yield of okra.