EVALUATION OF BIOSTIMULANTS IN GROWBAG CULTURE OF ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)

SHERINLINCY A

(2018-12-032)

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2020

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by

SHERINLINCY A

(2018-12-032)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

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2020

DECLARATION

I, hereby declare that this thesis entitled **"EVALUATION OF EVALUATION OF BIOSTIMULANTS IN GROWBAG CULTURE OF ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani **SHERINLINCY A**

Date: 21-11-2020 (2018 -12-032)

CERTIFICATE

Certified that this thesis entitled **"EVALUATION OF BIOSTIMULANTS IN GROWBAG CULTURE OF ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)"** is a record of research work done independently by Ms. Sherinlincy A (2018-12-032) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place: Vellayani

Date: 21-11-2020

Dr. M. Rafeekher
(Chairman, Advisory Committee)
Assistant Professor and Head
Dept. of Fruit science
College of Agriculture, Vellayani
Thiruvananthapuram 695 522

,

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Sherinlincy A** (2018-12-032), a candidate for the degree of **Master of Science in Horticulture**, with major in Vegetable Science, agree that the thesis entitled **"EVALUATION OF BIOSTIMULANTS IN GROWBAG CULTURE OF ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)"** may be submitted by **Ms. Sherinlincy A** (2018-12-032), in partial fulfilment of the requirement for the degree.

Dr. M. Rafeekher
Assistant Professor and Head
Dept. of Fruit science
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Ms. Shruthy O. N.
Assistant Professor
Dept. of Vegetable Science
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Dr. S. Sarada
Assistant Professor and Head
Department of Vegetable Science
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Dr. Aparna B
Assistant Professor
Dept. of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Acknowledgement

First and fore most I bow my head before the almighty God, who blessed me with intellect, strength, good health, kind teachers and loving parents and these bounteous blessings enabled me to complete the research work successfully.

At this moment of accomplishment, I would like to express my deep sense of gratitude, indebtedness and respect to **Dr. Rafeekher M.**, *Professor and Head, Department of Fruit Science, College of Agriculture, Vellayani, the chairperson of my advisory committee, for his valuable guidance, practical suggestions, constant patience, friendly approach, inspiring advices, timely help and encouragement till the end of my research work. I am really grateful for the support and keen interest taken by him in the research work and in the preparation of manuscript.*

I would like to express my extreme gratitude and thankfulness to **Dr. Sarada S.**, *Professor and Head, Department of Vegetable Science, College of Agriculture, Vellayani, member of my advisory committee for her prudent support, constructive suggestions and advice extended to me throughout the research work.*

I take this opportunity to express my heartiest gratitude to **Dr. Aparna B**., *Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, member of my advisory committee for her meticulous help, timely support that has helped a lot for the improvement and preparation of the thesis.*

I wish to express my sincere thanks to **Mrs. Shruthy O. N**., *Assistant Professor, Department of Vegetable Science, College of Agriculture, Vellayani, member of my advisory committee for her timely guidance, technical and moral support, unwavering emcouragement rendered in the conduct of research work.*

I would like to express my extreme indebtedness and obligation to **Dr. Sreelathakumary I.,** *Rtd. Professor and Head, Department of Vegetable Science, College of Agriculture, Vellayani, for her dexterous supervision, inspiring and impetuous guidance and valuable suggestions right from the beginning.*

I also owe my deep sense of gratitude and sincere thanks to ***Dr. Ushakumari K****., Rtd. Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, for her meticulous help, valuable guidance and timely help by providing laboratory facilities during the period of research and analysis.*

I wish to express my sincere thanks to all the non-teaching staff members ***Udayan Chettan, Gopan Chettan, Anandhu Chettan, Lekha Chechi, Raji Chechi, Shaji Chettan, Soumya Chechi, Vijayakumar Chettan and Aneesh Chettan*** *for their support and help during the conduct of research work.*

My heartfelt thanks to my classmates ***Arya, Maneesha and Yoganand*** *for their immense co-operation, moral support and valuable suggestions during the course of research. Words cannot really express the help that I relished from my dear friends* ***Kavi, Anusha, Chippy, Lintu, Sree, Sreekutty, Nayana, Divya, Anit, Rakhi and Roshin****. They were always beside me during the happy and hard moments in my life to push and motivate me.*

I would also like to extend my huge warm thanks to my seniors ***Tasni Chechi, Aiswarya Chechi, Saranya Chechi, Merin Chechi, Pooja Chechi, Aruna Chechi, Jithettan, Amirtha Chechi and Shiva Chettan*** *for their constant encouragement and guidance imparted to me during the course of my research. I wish to express my gratefulness to all my juniors for their timely help and support.*

Words cannot really express the help that I relished from ***Vimala aunty, Vincent uncle, Sabu uncle, Lekha aunty, Shinto, Akshay, Chimmu and Chinnu*** *for their love and support.*

I express my deep obligation and gratitude to Kerala Agricultural University for the financial and technical support for persuasion of my study and research work, I

appreciate and acknowledge the facilities provided by the Library of College of Agriculture, Vellayani.

*I am in dearth of words to express my love and gratitude to my Pappa **Mr. Antony Raj,** Amma **Mrs. Alphonse Jothi**, beloved sister **Libi** and **kavinettan** for their boundless affection, moral support, eternal love, deep concern, personal sacrifices, prayers and encouragement which help me to stay hopeful.*

A word of apology to those I have not mentioned in person and a note of thanks to one and all who worked for the successful completion of this endeavour.

Sherinlincy A

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LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
@	:	at the rate of
µ	:	Micro
B	:	Boron
Ca	:	Calcium
CD (0.05)	:	Critical difference at 5 % level
cm	:	Centimetre
CRD	:	Completely Randomized Block Design
DAS	:	Days after sowing
DAT	:	Days after transplanting
e*t al.*	:	Co-workers/ Co-authors
Fe	:	Iron
Fig	:	Figure
g	:	Gram
ha^{-1}	:	Per hectare
HS	:	Humic substances
i.e	:	That is
K	:	Potassium
KAU	:	Kerala Agricultural University

LIST OF ABBREVIATIONS AND SYMBOLS

kg	:	Kilogram
m	:	Meter
Mg	:	Magnesium
MLE	:	Moringa Leaf Extract
mm	:	Millimeter
ºC	:	Degree Celsius
POP	:	Package of Practices
RH	:	Relative Humidity
SA	:	Salicylic Acid
SEm	:	Standard error of mean
t	:	Tonnes
viz.	:	Namely
Zn	:	Zinc

Introduction

1. INTRODUCTION

Amaranthus (*Amaranthus tricolor* L.) is an important leafy vegetable of Kerala. It is well known for its nutritive values like protein, vitamins and minerals, β – carotene, calcium and iron and also called as 'poor man's spinach'. Amaranthus is a C4 leafy vegetable plant belong to the family Amaranthaceae and an annual herb cultivated all over the world predominantly in tropical and temperate regions. The amaranthus can be cultivated for various purposes like leafy vegetable, grain amaranths and for ornamental purpose. It is grown throughout the year. Amaranthus is a cheap, high nutritive crop propagated by seeds.

The genus *Amaranthus* includes more than 50 species. Some of the species in Amaranthus are *A. tricolor, A. dubius, A. lividus, A. blitum, A. hypochondiacus, A. spinosus, and A. viridis*. It's easier cultivation practice, short duration, quick response to manures and fertilizers and adaptability to various agroclimatic conditions makes it commercially important crop. It is also drought tolerant and less susceptible to pest and disease able the farmer to prefer the crop for cultivation.

Amaranthus variety Arun is a mass selection from Palappoor local which has attractive maroon red leaves. It is a photo insensitive variety with good quality, suitable for multicut with a duration of 54 – 140 days. Its productivity is about 20.1 t/ha.

In Kerala, amaranthus is cultivated in an area of 2061 ha (DES, 2017) and growbag culture is a recent trend which paves a way to meet the nutritional requirement of 125g leafy vegetables per day/adult especially through urban farming but the major constraint associated with growbag culture is reduction in yield.

Organic cultivation play an essential role in ensuring soil fertility and plant nutrition. Addition of organic substances either to the soil or through foliar spray improves the efficiency of applied nutrients apart from promoting the conversion of unavailable form of nutrients to available forms. The organic compounds have chelating, plant growth stimulating effects and positive effect on the growth of various groups of microorganisms.

In vegetable production, plant biostimulants have been gaining interest due to improved yield, nutrient use efficiency, quality, and abiotic stress tolerance. Plant biostimulants contain substances and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality (Cavlo *et al.*, 2014). Biostimulants are widely used in many agricultural practices, particularly high value vegetable and fruit production systems.

Biostimulant like humic substances promote early growth, reduce mineral fertilizer application and hazardous effect of plant pathogens (Taha *et al.,* 2016). Humic acid helps to improve nutrient uptake. They can directly or indirectly influence the physiological activities in plant growth and yield. Humic acid is an organic biostimulant that significantly affects plant growth and development and increase crop yield and mitigate the drought effect.

Moringa (*Moringa oleifera*) leaf extract contains growth enhancing substances like zeatin, a source of cytokinin, which reduces the adverse effect of drought stress by delaying leaf senescence. Moringa leaf extract is a low cost and environment friendly biostimulant that can be used effectively for various crops due to its easy preparation, high nutritive and antioxidant effect (Abdalla, 2014). In Kerala, moringa leaves are abundant.

Salicylic acid can improve not only the yield but also bioactive compounds in leaf amaranth. Vermiwash can be used as foliar spray to increase yield and plant growth since nutrients are readily available for plants (Sundararasu, 2016). Cow urine is used for improving yield as well as quality. Significant differences in yield of capsicum were observed with application of cow urine (Boraiah *et al*., 2017).

However, different application methods influence the efficiency of biostimulants. Being a leafy vegetable, foliar spray of these biostimulants may have limitations with regards to visual appearance and other organoleptic characters. Wick irrigation have been widely promoted and adopted as an efficient irrigation system for urban agriculture. High water use efficiency, less need for manpower, increase in uniformity and quality of productive, temperature control of the root system are the major advantages of this system (Ferrarezi and Testezlaf, 2016).

In this background, the present study was undertaken with the following objectives

1. To evaluate the effect of biostimulants in growbag cultivation of organic amaranthus
2. To evaluate the different application methods of biostimulants in growbag cultivation of organic amaranthus

Review of Literature

2. REVIEW OF LITERATURE

Amaranthus is one of the important and popular leafy vegetables of India. The edible amaranth belongs to the family Amaranthaceae, subfamily Amaranthoideae, and genus *Amaranthus*. The genus *Amaranthus* includes 50-60 species, cultivated for leaf as well as for grains and few are wild species. The vegetable amaranth species (2n = 34) include *A. tricolor, A. dubius, A. lividus, A. blitum, A. hypochondiacus, A. spinosus, and A. viridis, while* (2n = 32) *includes A. cruentus and A. tristis, A. graecizans and A. caudatus*. Centres of diversity for amaranth are Central and South America, India and South East Asia with secondary centres of diversity in West and East Africa. Main vegetable type of leaf amaranth is *Amaranthus tricolor* originated in South East Asia particularly in India (Jangde *et al*., 2018).

Amaranthus produce high edible matter per unit area and time. It can be used as food, fodder and as medicine in various pharmaceutical and cosmetic products (Prakash and Pal, 1991; Shukla and Singh, 2003). Rai and Yadav (2005) reported that tender stems and leaves contains moisture (85.70 %), protein (4.0 g), fat (0.50 g), carbohydrates (6.30 g), calcium (397.0 mg), iron (25.5mg), phosphorus (83.0 mg), vitamin A (9200IU), and vitamin C (99 mg). It is also a good source of dietary fiber.

Organic farming is a holistic way of farming with the aim of conserving the natural resources (Boraiah *et al*., 2017). Organic foods are emerging as a global trend among health conscious consumers due to the perception that they have superior sensory attributes, contain lower levels of pesticides and synthetic fertilizers and higher levels of nutrients and protective phytochemicals (Aparna, 2011). Ruban *et al*. (2019) stated that organic biostimulants are such molecules useful in increasing productivity of crops. These biostimulants applied in small amounts, can promote plant development, increase yield and support plants to overcome from stress by acting directly or indirectly on plant physiology.

2.1. BIOSTIMULANTS

Plant biostimulants contain substances and/or microorganisms whose function when applied to plants or the rhizosphere, stimulates natural processes to reinforce or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress and crop quality (Cavlo *et al.,* 2014). Biostimulants are widely utilized in many agricultural practices, particularly high value vegetable and fruit production systems. These substances however differ from antitranspirants which reduce the water loss from plants by reducing transpiration which can also adversely affect the photosynthetic rate, growth and yield. Bulgari *et al*. (2015) stated that biostimulants are plant extracts and contain a wide range of bioactive compounds that are mostly still unknown. These products are usually able to improve the nutrient use efficiency of the plant and enhance tolerance to biotic and abiotic stresses. In vegetables, the application of biostimulants allowed a reduction in fertilizers without affecting yield and quality. In leafy vegetables susceptible to nitrate accumulation, biostimulants are able to improve the quality and keep the nitrates under the limits imposed by EU regulations. More over in leafy vegetables, biostimulants increased the leaf pigments (chlorophyll and carotenoids) and plant growth by stimulating root growth and enhancing the antioxidant potential of plants.

Akande (2006) reported that the use of organic biostimulant alone and in complement with fertilizer has proved to be effective because it stimulated profuse shoot growth and massive root development of amaranthus. Consequently, it increased nutrient composition of plant hence, increased in growth and yield was observed. Aroucha *et al*. (2018) stated that the pre-harvest application of biostimulant influenced quality characteristics of the yellow melon, depending on the cultivar and storage time. The utilization of biostimulant increased the length of the fruits of 'Iracema' melon. In the 'Goldex' melon, the application of biostimulant decreased the pulp firmness and increased the pH of fruits.

2.1.1. HUMIC SUBSTANCES

Humic substances (HS) are natural constituents of the soil organic matter, resulting from the decomposition of plant, animal and microbial residues, but also from the metabolic activity of soil microbes using these substrates. HS are collections of heterogeneous compounds, originally categorized corresponding with their molecular weights and solubility into humins, humic acids and fulvic acids. Humic substances such as soluble humic and fulvic acids fractions shows inconsistent positive results on plant growth. Humic substances are recognized for long as essential contributors to soil fertility acting on physical, physico-chemical, chemical and biological properties of the soil. Most biostimulant effects of humic substances refer to the amelioration of root nutrition via different mechanisms. One amongst them is the increased uptake of macro-and micronutrient due to the increased cation exchange capacity of the soil containing due polyanionic humic substances and to the increased availability of phosphorus by humic substances interfering with calcium phosphate precipitation. Another important contribution of HS to root nutrition is that the stimulation of plasma membrane H^+-ATP, which convert the free energy released by ATP hydrolysis into a transmembrane electrochemical potential used for the import of nitrate and other nutrients (Du Jardin, 2015).

Mac Carthy *et al*. (1990) stated that the mode of action of humic substance on plant growth can be divided into direct and indirect effects because it affects the membranes leading to improved transport of nutritional elements, enhanced protein synthesis, enhanced photosynthesis, solubilization of micronutrients, reduction of active levels of toxic elements, enhancement of microbial population, enhanced soil structure improvement and increased cation exchange capacity, moisture stress and water retention.

Humic acid promote plant growth and soil microorganisms like bacteria and fungi. It also provide carbon as a source for these organisms. Humic acid act as chelating agent and increase the availability of nutrients in soil such as phosphate, calcium and trace elements. Humic acid possess high capability in controlling soil pH against changes which could occur from the use of chemical fertilizer. Humus substances influenced plant physiological activities which reflected on plant growth and its chemical structure. Humic acid caused significant effect on all yield characteristics as compared to untreated plants (Sarhan, 2011).

2.1.1.1. Effect of humic substances on growth, quality and yield

Karakurt *et al*. (2009) reported that foliar spray of humic substances promote growth and increases yield and quality in a number of plant species. The highest yield was obtained from 20 ml L^{-1} of foliar spray (73.8 t ha^{-1}) over the control (57.0 t ha^{-1}).

Ugur *et al*. (2013) reported that humic acid applications in cress (*Lepidium sativum*), rocket (*Eruca sativa*) and sorrel (*Rumex acetosa*) have increased vegetable yield. The application of 0.8 % humic acid has increased the yield at the rate of 68 % in cress, 57 % in rocket and 78 % in sorrel. In terms of leaf length 0.4 % humic acid application has resulted in higher values. In terms of leaf width, humic acid application @ 0.2 % (rocket), 0.4% (sorrel) and 0.8 % (cress) doses were particularly remarkable. Highest doses of applications produced leaf with more saturated and darker colour. As a result, humic acid applications generally increased yield and quality.

Humic acid played a vital role in rooting and generally adding humic substances to soil increased nucleic acids and amino acids and improved cell multiplication in plant especially in roots. Humic acid significantly improved the plant height and ear size (Kholdi *et al*., 2015). Mohajerani *et al*. (2016) stated humic acid improved agricultural traits of red beans cultivars among the various tested cultivars, highest seed yield of red bean as 4253.7 kg per hectare was obtained using 1.5 litre per hectare of humic acid.

Humic acid, a decomposition product of organic matter, influences plant growth by modifying the physiology of plants and by improving the physical, chemical and biological properties of soil. The foliar spraying of humic acid @ 150 ml L^{-1} gave the best results of okra plant for growth, yield and quality parameters (Kumar *et al*., 2015). Taha *et al*. (2016) stated that the addition of humic substances (humic and fulvic acid) significantly increased the plant growth and mineral content of lettuce plant especially on higher dose but the positive effect of fulvic acid was greater than the positive effect of humic acid.

Effect of various concentrations of bio-regulators and humic acid on growth, yield and quality of french bean was observed by Sharma *et al*. (2017). Humic acid helped in improving the nutrient uptake and also favoured better seed germination in french bean and increased the synthesis of chlorophyll. Humic acid increased the yield and quality of beans. Application of humic acid 10 ml L^{-1} produced maximum number of nodules per plant (17.7) and fresh weight of nodule per plant (208.2 mg). Application of humic acid 30 ml L^{-1} recorded highest plant height (36.4 cm), leaf area (84.9 cm^2) and chlorophyll (0.06 mg g^{-1}). The concentration of humic acid @ 10 ml and 30 ml L^{-1} was the best suited for vegetative growth parameters.

Kumar *et al*. (2017) observed that different combinations of humic acid and nutrients mixture improved quality characteristics such as leaf nutrient content (Ca, Mg, B and Zn), fruit nutrient content (Ca, Mg, B and Zn), total soluble solids (TSS) and lycopene.

Fernandez-Escobar *et al*. (1996) stated that application of humic acid stimulated chlorophyll content and accumulation of K, B, Mg, Ca and Fe in leaves of vegetables. Ayas and Gulser (2005) reported that humic acid application was the main reason for enhanced nitrogen uptake in spinach.

2.1.1.2. Effect of fulvic acid on plant growth

Fulvic acid accelerated cell division and thereby stimulated vegetable growth. It influenced the development as well as increase of cellular energy and regulated plant metabolism thus it prevented nitrate compounds from accumulation in plants. It increased resistance to insects and diseases and encouraged tolerance to extreme temperatures like heat and coldness (Husein *et al*., 2015).

2.1.2. VERMIWASH

During the vermicomposting process, a liquid substance is produced which is called vermiwash. Vermiwash is the watery extract of vermicompost, extracted in the presence of rich population of earthworms. Vermiwash is a liquid that is collected after the passage of water through a column of worm action. It is a mixture of excretory products and mucus secretion of earthworms along with micronutrients from the soil organic molecules. It contains nitrogen as nitrogenous excretory product and growth promoting hormones and essential enzymes that infuses resistance in plants. It is applied as foliar spray. It contains various enzymes like protease, amylase, unease and phosphatase. These are beneficial for growth and development of plant and stimulate the yield and productivity of crops and also microbial study of vermiwash found that nitrogen fixing bacteria like *Azotobacter, Agrobacterium, Rhizobium* and some phosphate solublizing bacteria are also found in vermiwash (Kaur *et al*., 2015).

Sundararasu (2019) reported that vermiwash plays an important role in the plant growth and development, contribute to initiation of rooting, root growth and plant development. It promote growth rate and improvement in crop production. It also increased the soil organic matter and nutrient content which are readily available for the plants, leading to good crop yield.

2.1.2.1. Effect of vermiwash on growth and yield parameters

Siddappa and Hegde (2011) reported that the foliar spray of vermiwash produced vigorous growth with significantly higher fresh leaf yield (13.07 t ha^{-1}) compared to control (11.13 t ha^{-1}) in curry leaf. Elumalai *et al*. (2013) reported that vermiwash exhibited growth promoting effects on the morphological characters such as plant height, fruit length, number of leaves, leaf surface area, root length, wet and dry weight of the shoot and root in okra. Fathima and Sekar (2014) reported that vermiwash contains high amount of enzymes, vitamins and hormones like gibberellins together with macro and micronutrient and it can be used as foliar spray for improving the yield and quality of vegetables.

Vermiwash proves to be an effective fertilizer which contributed to the growth of plants when sprayed. The results revealed that vermiwash spray enhanced the growth (plant height and number of leaves) and yield (number of flowers and fruits per plant). Flowering and fruiting ratio was significantly increased in the production of brinjal (Kaur *et al*., 2015).

Ansari (2008) reported the effect of vermicompost and vermiwash on the productivity of spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*). The yield was significantly higher in plots treated with vermiwash. Vermiwash showed significant improvement in growth and yield of chilli, (*Capsicum annuum*) as reported by Sundararasu (2016).

2.1.3. SALICYLIC ACID

Salicylic acid (SA) is one of the most important phenolic compounds, found in several plants. It is considered as a hormonal substance which plays a significant role in regulating plant growth and development (Wang *et al*., 2006). Horvath *et al*. (2007) stated that it acts as bio-messenger or signalling agent in plants which promotes tolerance against several biotic and abiotic stresses. SA is also effective to regulate important physiological processes of plants like growth and development, membrane permeability, ion uptake and transport (Simaei *et al*., 2011).

2.1.3.1. Effect of salicylic acid on growth and yield parameters

Salicylic acid can also play a vital role in plant water relations, photosynthesis and growth (Arfan *et al*., 2007). Plants of cucumber and tomato when sprayed with lower concentrations of SA showed significant increase in fruit yield (Larque-Saavedra and Martin-Mex, 2007). Kazemi (2013) reported that low concentration of salicylic acid increased yield and quality of strawberry plants.

Salicylic acid, a naturally occurring plant hormone acting as an important signalling molecule adds to tolerance against abiotic stresses. It plays a significant role in plant growth, ion uptake and transport. It was reported that the foliar application of salicylic acid to soybean enhanced the flowering and pod formation (Vazirimehr *et al.*, 2014). Mahmood *et al*. (2017) reported that maximum plant height (44. 17 cm and 43. 55 cm) and total fruit weight was recorded in the plants sprayed with 3 mM salicylic acid. Maximum fruit diameter was also recorded in SA 3 mM treatment. Application of salicylic acid improved fruit physical and chemical characteristics such as fruit size, fruit weight, yield per hectare, fruit firmness, and ascorbic acid content.

SA used as foliar spray and MLE (Moringa Leaf Extract) used as seed soaking, was found to be highly effective at improving the growth and yield of bean plants by alleviating the inhibitory effects of soil salinity stress. Providing plants with SA induces plant tolerance against various biotic and abiotic stresses by altering the activities of enzymatic antioxidants and reducing the generation of reactive oxygen species. It has been found that SA positively affects growth and development, ion uptake and transport, and membrane permeability. The integrated treatment of seed soaking in SA and foliar spray with MLE was found to be the best, increasing shoot length, number of leaves per plant, leaf area per plant, plant dry weight, pod weight and seed weight (Rady *et al*., 2015).

Khandaker *et al*. (2011) reported that the growth parameters and yield of red amaranthus was significantly influenced by foliar SA applications. Salicylic acid could be expected to influence the growth and yield of red amaranth plants. Salicylic acid application also increased number of leaf per plant, leaf size, and fresh and dry matter yield of red amaranth. Thus foliar application of salicylic acid improved red amaranth yield and nutritionally valued bioactive compounds.

Javaheri *et al.* (2014) reported that salicylic acid improved the number of fruits per panicles, fruit number, fruit weight and fruit diameter in tomato. Amira and Qados (2015) reported that application of salicylic acid improved the growth of capsicum plants under stress.

2.1.3.2. Effect of salicylic acid on quality parameters

Yildirim *et al*. (2008) stated that foliar SA applications can ameliorate the deleterious effects of salt stress by increasing chlorophyll content, photosynthetic activity, relative water content, uptake of mineral nutrients, antioxidant enzyme activity, controlling hormonal balance or decreasing Na uptake, membrane injuries, oxidative stress effect of NaCl, thus inducing salt tolerance in cucumber plants.

Foliar application of SA can significantly regulate the plant growth parameters, yield as well as bioactive compounds in red amaranth. The highest yield, antioxidant activity, amount of betacyanins, chlorophyll and total polyphenol occurred in 10^{-5} M SA treatment. Applications of SA at the rate of 10^{-5} M enhanced yield and bioactive compounds in red amaranth (Khandaker *et al*., 2011).

2.1.4. MORINGA LEAF EXTRACT

Moringa leaf extract play as a plant hormone which reinforces seed germination, growth and yield of crops (Hala *et al*., 2017). Abdalla (2013) reported that possible reason for the acceleration of growth might be due to the enriched content crude proteins (43.5%) and growth promoting hormones like auxins and cytokinins in moringa leaf and twig extracts.

2.1.4.1. Effect of moringa leaf extract on growth and yield

MLE at concentration of 4% increased average fruit weight, length and diameter as well as fruit chemical contents such as carbohydrate, ascorbic acid and both K and Ca elements. Soaking of pepper seeds in moringa leaf extract solution at 4 % for 6h enhanced the germination percentage and seedling characteristics. 4% MLE spray on pepper plant seedlings obtained superior fruit yield with best quality (Hala *et al*., 2017).

Foliar spraying of MLE was done at the rate of 1%, 2%, 3% and 4% at 25, 35 and 45 days after planting. All treatments of MLE significantly increased fresh pod yield, shoot and seed dry weight, biological yield, 100 seed weight, yield efficiency, protein content and nutrient accumulation as compared to control. The highest values of photosynthetic pigments, growth parameters and nutrient accumulation of plants were obtained with 4% of MLE. Also, increased fresh pod yield (82.5%), protein (45%), plant height (49%) and pod length (85%) was seen in those plants applied with 4% MLE (Merwad, 2018).

Emongor (2015) reported that snap bean plants treated with moringa leaf extract at 11, 20, 33 and 50% exhibited significantly more plant height, pod length, leaf area and leaf number per plant than control plants. The highest leaf chlorophyll content was obtained on snap bean plants sprayed with 20% Moringa leaf extract, beyond which leaf chlorophyll content decreased.

MLE enhanced the plant growth and development in different crops. Improved seedling growth traits i.e. shoot length, number and area of leaves per plant and plant dry weight by MLE application might be due to the enhanced mobilization of germination related metabolites/inorganic solutes such as zeatin, ascorbic acid, Ca and K presented in MLE to the growing plumule and increase in amylase activity and reducing sugars, contributing to early vigor and increased plant growth (Rady *et al*., 2015). Elzaawely *et al*. (2017) stated that the MLE application not only enhanced yield of snap bean, but also enhanced quality as indicated by chemical composition of green pods.

2.1.5. COW URINE

Cow urine contains 95% water, 2.5% urea, and the remaining 2.5% is a mixture of salts, hormones, enzymes, and minerals. It has been considered that cow urine is very useful in agricultural operations as a biofertilizer and biopesticide as it can kill number of pesticide and herbicide resistant bacteria, viruses, and fungi (Jandaik *et al*., 2015). Cow urine has got anti-fungal properties and also good source of plant nutrients. It is being used in crop production since ages (Boraiah *et al*., 2017).

2.1.5.1. Effect of cow urine on yield parameters

Boraiah *et al*. (2017) reported significant differences in yield of capsicum with application of cow urine (30.76, 38.0, 48.52, 117.73, 97.15, 84.33, 48.44 q ha^{-1} at 60, 70, 80, 90, 100, 110 and 120 DAT, respectively).

The increase in cow urine concentrations increased the performance of all lettuce characteristics. Highest yield was obtained with the concentration of 1.25% (17.00 t ha^{-1}) applied to leaves and 1.01% (14.92 t ha^{-1}) applied to soil, corresponding to the increase of 28.1% and 47.3%, in compared to the control for lettuce crops (Oliveira *et al*., 2009).

Jandaik *et al*. (2015) reported that plant height of fenugreek improved with increase in concentration of cowurine. Maximum plant height of fenugreek was 14.30 ± 0.40cm with maximum concentration of 5% cow urine. Plant height of bhindi plants consistently increased to a maximum of 13.97±0.50 cm in the plants treated with 5% concentration of cowurine followed by the 12.03 ± 0.42 cm in 4% concentration of cowurine. Maximum inhibition in growth was at 15 % cowurine as compared to control.

2.2. METHODS OF APPLICATION OF BIOSTIMULANTS

2.2.1. WICK FERTIGATION

Raising vegetables in the grow bags on the terraces of buildings is gaining popularity. However, the main problem faced is with regard to timely application of water especially within the container grown plants. The limited rooting media of the containers demands frequent replenishment of water wherein wick fertigation can be a useful alternative. The main component of the irrigation system is the wick, which carries water from the water container to the rooting medium as per the requirement to keep it wet. Different kinds of materials were tried for the wick and a material similar to glass wool was found to be the best in terms of capillarity, durability and price (Joseph, 2016). Semananda *et al*. (2016) stated that water is delivered by capillarity action to the root zone in response to the water requirement of the plant by allowing individual plants to uptake water according to their demand.

Matric suction irrigation reduces the labour cost and suits for easy maintenance, as one-time installation of the set up provides year-round crop with low quantity water. Water is circulated in pipes at the bottom of pots all the time where growbag is placed. There is no drainage/leaching leading to prevention of water loss as well as nutrients. Always moisture is kept at optimum range in grow bag media. There is no drying cycle from sowing to harvest. Based on these advantages, it is concluded that crop production by matric suction irrigation using the growbag media identified may suit well for terrace garden as well as in levelled waste lands (Natarajan and Kothandaraman, 2018).

Kinoshita and Masuda (2012) reported high water use efficiency by controlled release fertilizers on capillary wick culture of tomato. Ferrarezi and Testezlaf (2016) reported that wick irrigation system operates in a closed cycle, without run off, permitting appropriate plant nutrition and creating alternatives to enhance production uniformity. These systems show major advantages such as independence of electricity for operation, high water and nutrient use efficiency, less need for man power, as the management is simplified compared with conventional cultivation, providing cost reduction as well as increase in the uniformity and quality of production, water savings and temperature control of the root system. Wick irrigation systems resulted in better lettuce plants, being an alternative for regions with high temperatures because of the substrate cooling effect, limited manpower and electrical power.

2.2.2. FOLIAR SPRAY

Karakurt *et al*. (2009) reported that pepper fruit yield was significantly influenced by soil and foliar application of humic acid. Mohajerani *et al*. (2016) stated that foliar application of humic acid on bean crops increased growth, number of pods per plant, pod weight, protein and chlorophyll of plants through increasing the rate and extent of nutrient absorption compared to soil application.

Foliar spray of vermiwash significantly improved the growth and yield of curry leaf (Siddappa and Hegde, 2011) and okra (Kaur *et al*., 2015). Ruban *et al*. (2019) stated that application of foliar sprays of humic substances and biostimulators can be safely used within the applied concentrations with a positive effect on yield parameters like number of fruits per plant, fruit length, fruit girth, fruit weight and yield.

Beneficial effect of spraying salicylic acid on tomato was reported by (Javaheri *et al.*, 2014). In a study on sugarbeet, Merwad (2015) observed that foliar spraying of salicylic acid increased the fresh shoot and root weight by 12 and 14 per cent respectively.

Abdalla (2013) reported that foliar spraying of moringa leaf extract at 2% was more effective than 4% and improved all measured growth parameters (plant height, number of leaves, leaf area, leaf area index, fresh and dry weight, number of pods, number of branches, dry leaf yield and dry pod yield) above control plants.

Foliar spray of cowurine increased the growth and yield of summer green gram (Patil and Dhonde, 2009).

Materials and Methods

3. MATERIALS AND METHODS

The study entitled 'Evaluation of biostimulants in growbag culture of organic Amaranthus (*Amaranthus tricolor)*' was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2018-2020.

3.1 EXPERIMENTAL SITE

The experimental site was located at 8.5^0 30' North latitude and 76.9^0 54' East longitude, at an altitude of 29 m above mean sea level.

3.2. MATERIALS

Amaranthus (*Amaranthus tricolor* L.) variety Arun was grown in growbag and biostimulants were applied through two different application methods. Biostimulants such as humic acid, humic fulvic acid mixture, moringa leaf extract, vermiwash, cow urine, salicylic acid were applied in weekly intervals. Humic fulvic acid mixture was extracted from a mixture of sand, soil and vermicompost. Two methods of applications viz., wick fertigation and foliar application were used to apply biostimulants. Growbag media included rock dust mixture, soil and FYM @ 1:1:1 ratio.

3.3 METHODS

Amaranthus variety Arun was sown in beds and transplanted to growbag after 24 days. The growbag media of rock dust mix, soil and FYM @ 1:1:1 ratio (KAU, 2018) was used and cultural practices were followed as per the recommendations in Package of Practices (Organic) Crops (KAU, 2017) for control and treatments. The Recommended Fertilizer Dose (RDF) of 100:50:50 Kg NPK per ha (KAU, 2017) was used for the treatment.

3.3.1. Extraction of humic fulvic acid mixture

Humic fulvic acid mixture was extracted from mixture of sand, soil and vermicompost. Extraction was carried out using classical procedure recommended by International Humic Substance Society, in which a mild alkali was used.

In the present study 0.5 N NaOH was used as extractant. 20 g of sand, soil and vermicompost mixture was added with 200ml 0f 0.5 N NaOH and was agitated for 12 hrs. The mixture was then filtered and dried.

3.3.2. Method of application

Two methods of applications *viz*., wick fertigation and foliar application were used to apply biostimulants. The quantity of biostimulants applied through both method of application was equal.

3.3.3. Application of biostimulants

Humic acid, humic fulvic acid mixture, moringa leaf extract, vermiwash were applied at 3 % concentration. Ten times diluted cow urine, salicylic acid @ 50 mgl^{-1} and RDF (0.22:0.11:0.11 g/plant) was used for the study. Application was done at seven days interval from transplanting through the entire cropping period (97 days).

3.3.4. Design and Layout

The field experiment was laid out in Completely Randomized Design (CRD) with three replication. The experiment was laid out as follows:

Design : CRD

Treatment : 16

Replication : 3

Number of plants/replication : 12

Season : Jan – April 2020

Treatment details

A. **Biostimulants(B)**

B_1- Distilled water (control)

B_2- RDF

B_3- Humic acid commercial

B_4- Humic acid - fulvic acid mixture

B_5- Moringa leaf extract

B_6- Vermiwash

B_7- Cow urine

B_8- Salicylic acid

B. **Application methods(M)**

M_1 - Wick fertigation

M_2 - Foliar application

Plate.1 General view of the experiment

Table 1. Details of treatment

S. No.	Treatment combinations	Treatment details
1.	$B_1 M_1$	Distilled water (control) through wick fertigation
2.	$B_2 M_1$	RDF through wick fertigation
3.	B_3M_1	Humic acid commercial through wick fertigation
4.	$B_4 M_1$	Humic acid - fulvic acid mixture through wick fertigation
5.	$B_5 M_1$	Moringa leaf extract through wick fertigation
6.	$B_6 M_1$	Vermiwash through wick fertigation
7.	B_7M_1	Cow urine through wick fertigation
8.	$B_8 M_1$	Salicylic acid through wick fertigation
9.	$B_1 M_2$	Distilled water (control) through foliar application
10.	$B_2 M_2$	RDF through foliar application
11.	B_3M_2	Humic acid commercial through foliar application
12.	$B_4 M_2$	Humic - fulvic acid mixture through foliar application
13.	$B_5 M_2$	Moringa leaf extract through foliar application
14.	$B_6 M_2$	Vermiwash through foliar application
15.	$B_7 M_2$	Cow urine through foliar application
16.	$B_8 M_2$	Salicylic acid through foliar application

3.4. OBSERVATIONS

3.4.1. Growth parameters

3.4.1.1. Plant height (cm)

The height of plant was measured from ground level to the topmost leaf bud, mean was worked out.

3.4.1.2. Leaves per plant

The total number of leaves of each observational plant was counted and the mean obtained.

3.4.1.3. Leaf length (cm)

The fifth leaf from top of the selected plant was used for making observation. The length was measured.

3.4.1.4. Leaf width (cm)

The width of same leaf, used for recording the length was taken at the region of maximum width.

3.4.1.5. Stem girth (cm)

The girth of main stem at the collar region was taken using a twine. The mean girth was worked out.

3.4.1.6. Branches / plant

The primary branches arising from the main stem were counted at the time of harvest and average obtained.

3.4.1.7. Root length (cm)

Length of root was measured using scale and twine after final harvest.

3.4.1.8. Days to flowering

Number of days from planting to the appearance of first flower was recorded.

3.4.2. Yield parameters

3.4.2.1. Leaf / stem ratio

Leaf /stem ratio was obtained by dividing the total weight of leaves by total weight of stem.

3.4.2.2. Fresh weight of leaves per plant

The weight of leaves per plant was recorded at harvest and expressed in gram.

3.4.2.3. Yield per cutting (g)

The vegetable yield per plant was recorded at each cutting (three). The mean yield was recorded in grams per cutting.

3.4.2.4. Yield per plant (g)

The vegetable yield from the observational plants was recorded at each cutting. The mean yield was recorded in grams per plant.

3.4.3. Quality parameters

3.4.3.1. Vitamin C (mg/100g)

Vitamin C content was estimated by volumetric method as suggested by A.O.A.C. (1975). The dried leaves were powdered and passed through 40 mesh sieve. The powdered sample (1g) was dissolved in 4 per cent oxalic acid, the volume made up to 100 ml.

Supernatant (5 ml) solution was taken and 10 ml of 4 per cent oxalic acid was added. Then titrated against the dye solution. (Dye solution was prepared by mixing 42 mg of sodium bicarbonate with small volume of distilled water and dissolved 52 mg of 2,6 – dichlorophenol indophenol in it. the final volume was made up to 200 ml with distilled water). The titre value was V2 (ml). Ascorbic acid (100 ml) was dissolved in 100 ml of 4 per cent oxalic acid and 10 ml of this solution was taken out and diluted to 100 ml with 4 per cent oxalic acid. From this solution, 5 ml was taken out and 10 ml of 4 per cent oxalic acid was added and titrated against the dye solution till the appearance of pink colour. This titre value was V1 (ml).

Amount of Vitamin C (mg/100g) in the sample was calculated using the following formula

$$\text{Vitamin C } (mg100^{-1}g) = \frac{0.5\ \text{mg}}{\text{V1ml}} \times \frac{\text{V2 ml}}{\text{5 ml}} \times \frac{\text{100 ml}}{\text{weight of the sample}} \times 100$$

3.4.3.2. Oxalate (mg)

One gram of dried powder was weighed into 100ml conical flask and 75ml 3M H_2SO_4 was added and stirred for 1hour with a magnetic stirrer A.O.A.C. (1975). This was filtered using a whatman no.1 filter paper. Twenty five ml of the filtrate was then taken and titrated against 0.05M $KMnO_4$ solution until pale pink colour persisted for at least 30sec. The oxalate content was calculated as 1ml of 0.05M $KMnO_4$ is equivalent to 2.2mg oxalate.

3.4.3.3. Carotenoid ($mg100^{-1}g$)

Five gram of fresh sample was crushed in 10-15 ml acetone after adding a few crystals of anhydrous sodium sulphate, with the help of pestle and mortar. The supernatant was decanted into a beaker. The process was repeated twice and the combined supernatant was transferred to a separatory funnel, 10-15 ml of petroleum ether was added and mixed thoroughly. The two layers were separated on standing. The lower layer was discarded and the upper layer was collected in a 100ml volumetric flask. The volume was made upto 100 ml with petroleum ether and the optical density recorded at 450 nm using petroleum ether as blank (Ranganna, 1997).

$$\text{Carotenoid } (mg100^{-1}g) = \frac{\text{Optical density x } 13.9 \text{ x } 10^4 \text{ x } 100}{\text{Weight of the sample x } 450 \text{ x } 1000}$$

3.4.3.4. Calcium content (mg100^{-1}g)

The calcium content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982). One gram of dried and powdered sample was predigested with 10 ml of 9:4 mixture of nitric acid and perchloric acid and made upto 100 ml. Ten ml of the solution was again diluted to 100 ml. This solution was read directly in atomic absorption spectrophotometer and calcium content was expressed in mg per 100 g of fresh sample.

3.4.3.5. Organoleptic test

Cooked leaves were used to evaluate organoleptic qualities. Five sensory attributes namely appearance, texture, flavor, taste and overall acceptability were recorded over a fivepoint hedonic scale (Amerine *et al*., 1965). Sensory attributes were evaluated by a panel of ten semi-trained judges. The score used for the evaluation of amaranthus was given in Appendix I. The score was statistically analysed using Kruskall-Wallis test (chi-square value) to find out whether treatments differed significantly (Shamrez *et al*., 2013).

3.4.4. Soil parameters

The soil samples were collected from growbag mixture before transplanting of the amaranthus seedlings to analyze the available N, P, K, soil pH, EC and organic C as per the standard procedures mentioned in the table 2.

Table 2. Initial status of soil parameters and methods followed for soil analysis

Parameter	Value	Method	Reference
pH	6.08	1: 2.5 soil water suspension – pH meter	Jackson (1958)
Electrical conductivity	0.21 dsm^{-1}	1: 2.5 soil water suspension- conductivity meter	Jackson (1958)
Oganic carbon	3.51%	Wet oxidation	Walkey and Black (1934)
Available nitrogen	677.376 kg/ha	Alkaline permanganometry	Subbiah and Asija (1956)
Available phosphorus	282.51 kg/ha	Bray extract	Bray and kurtz (1945)
Available potassium	414.4 kg/ha	Neutral normal ammonium acetate extraction followed by flame photometry	Jackson (1958)

3.4.5. Statistical Analysis

Statistical analysis of data was done in OPSTAT software and treatments were compared.

Results

4. RESULTS

The study titled "Evaluation of biostimulants in growbag culture of organic Amaranthus (*Amaranthus tricolor)*" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani, during 2019-2020. The observations were analyzed statistically using OPSTAT software and result obtained from the study are presented under the following headings.

A. Growth parameters
B. Yield Parameters
C. Quality parameters
D. Soil Parameters
E. Incidence of pest and diseases
F. B:C Ratio

4.1. Growth parameters

4.1.1. Plant height (cm)

Data pertaining the effect of biostimulants, method of application and their interaction on plant height is displayed in Table 3.

Significant difference was observed among biostimulants on height of the plant where the maximum height (72.25 cm) was recorded by B_4 which was at par with B_8 and B_3. There was no significant difference between the methods of application.

The interaction effect found to be significant with respect to plant height and B_4M_2 (humic-fulvic acid mixture @ 3% through foliar application) significantly increased the height of plant to 85.83 cm which was at par with B_2M_2 (74.66 cm) and B_3M_2 (71.26 cm). The least plant height of 43.96 cm was recorded in B_1M_2 (distilled water through foliar application).

Table 3. Effect of biostimulants, method of application and their interaction on plant height

Biostimulants	Plant height (cm)		
	Method		Mean
	M_1	M_2	
B_1	57.50	43.96	50.73
B_2	53.66	74.66	64.16
B_3	61.66	71.26	66.46
B_4	58.66	85.83	72.25
B_5	62.33	55.50	58.91
B_6	65.93	62.83	64.38
B_7	60.16	60.16	60.16
B_8	68.00	69.60	68.80
Mean	60.99	65.47	
	Biostimulants (B)	Method (M)	BXM
SE m±	3.844	1.922	5.436
CD (0.05)	11.123	NS	15.730

4.1.2. Leaves per plant

Effect of biostimulants, method of application and their interaction on number of leaves per plant is shown in Table 4.

There was significant difference among the biostimulants regarding leaves per plant. B_6 recorded the highest number leaves per plant of 117.83 and B_4 (113.07) was at par with it. There was also significant difference among the methods of application. M_2 recorded highest number of leaves per plant (106.10).

The interaction between biostimulants and methods also found to be significant. The treatment B_6M_1 where in vermiwash @ 3% through wick fertigation produced maximum number of leaves per plant of 118.83. It was on par with B_7M_2 (ten times diluted cowurine through foliar application) with 117.41 leaves per plant and B_6M_2 (vermiwash @ 3% through foliar application) with 116.83 leaves per plant. B_1M_2 (distilled water through foliar application) recorded the least (70.33) leaves per plant.

Table 4. Effect of biostimulants, method of application and their interaction on leaves per plant

Biostimulants	**Leaves per plant**		
	Method		**Mean**
	M_1	**M_2**	
B_1	82.00	70.33	76.16
B_2	93.33	105.66	99.50
B_3	100.66	112.53	106.60
B_4	110.00	116.15	113.07
B_5	91.16	115.56	103.36
B_6	118.83	116.83	117.83
B_7	94.56	117.41	105.98
B_8	96.33	94.33	95.33
Mean	98.36	106.10	
	Biostimulants (B)	Method (M)	BXM
SE m±	1.955	0.977	2.764
CD (0.05)	5.656	2.828	7.999

B_4M_2

B_3M_2

Plate.2 Effect of treatments on amaranthus leaf

B_4M_2

B_3M_2

Plate.3 Effect of treatments on plant height and branches per plant

4.1.3. Leaf length (cm)

Table 5. Effect of biostimulants, method of application and their interaction on leaf length

Biostimulants	**Leaf length (cm)**		
	Method		**Mean**
	M_1	**M_2**	
B_1	13.08	12.66	12.87
B_2	14.58	13.75	14.16
B_3	12.66	13.25	12.95
B_4	12.00	15.08	13.54
B_5	14.91	14.33	14.62
B_6	13.50	14.00	13.75
B_7	14.75	14.16	14.45
B_8	14.43	13.33	13.88
Mean	13.74	13.82	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.322	0.161	0.455
CD (0.05)	0.930	NS	1.316

Effect of biostimulants, method of application and their interaction on leaf length is presented in Table 5.

Significant difference was observed among biostimulants on leaf length where the maximum length (14.62 cm) was recorded by B_5 which was at par with B_2 and B_7. There was no significant difference between the methods of application.

The interaction effect found to be significant with respect to leaf length and the treatment B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) recorded the highest length of 15.08 cm which was on par with B_5M_1 (moringa leaf extract @ 3% through wick fertigation) and B_7M_1 (ten times diluted cowurine through wick fertigation) with the leaf length of 14.91 cm and 14.75 cm respectively. There was no significant difference in the method of application.

4.1.4. Leaf width (cm)

Effect of biostimulants, method of application and their interaction on leaf width is shown in Table 6.

Table 6. Effect of biostimulants, method of application and their interaction on leaf width

Biostimulants	**Leaf width (cm)**		
	Method		**Mean**
	M_1	**M_2**	
B_1	5.50	6.08	5.79
B_2	5.80	5.63	5.71
B_3	5.33	6.45	5.89
B_4	6.11	6.80	6.45
B_5	4.41	6.05	5.23
B_6	5.40	5.56	5.48
B_7	5.65	6.08	5.86
B_8	6.08	5.43	5.75
Mean	5.53	6.01	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.250	0.125	0.354
CD (0.05)	NS	0.362	NS

Perusal of the data revealed that leaf width did not differ significantly by the biostimulants, but there was significant difference in method of application. M_2 recorded highest leaf width of 6.01 cm. The interaction between biostimulants and methods was also found to be nonsignificant.

4.1.5. Stem girth (cm)

From the data, it could be inferred that biostimulants as well as method of application and also their interaction had no significant effect on stem girth. Effect of treatments on stem girth is given in Table 7.

Table 7. Effect of biostimulants, method of application and their interaction on stem girth

Biostimulants	**Stem girth (cm)**		
	Method		**Mean**
	M_1	**M_2**	
B_1	4.49	4.47	4.48
B_2	4.69	5.60	5.14
B_3	4.48	6.03	5.26
B_4	5.11	6.17	5.64
B_5	4.40	4.63	4.52
B_6	4.68	5.24	4.96
B_7	4.50	4.93	4.71
B_8	4.40	5.24	4.82
Mean	4.59	5.29	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.527	0.263	0.745
CD (0.05)	NS	NS	NS

4.1.6. Branches per plant

Effect of biostimulants, method of application and their interaction on branches per plant is presented in Table 8.

Table 8. Effect of biostimulants, method of application and their interaction on branches per plant

Biostimulants	Branches per plant		
	Method		Mean
	M_1	M_2	
B_1	4.66	5.66	5.16
B_2	8.33	10.33	9.33
B_3	6.00	10.66	8.33
B_4	7.33	11.66	9.50
B_5	7.33	6.66	7.00
B_6	5.33	8.66	7.00
B_7	5.66	9.33	7.50
B_8	8.66	8.00	8.33
Mean	6.66	8.87	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.643	0.321	0.909
CD (0.05)	1.860	0.930	2.631

There was significant difference among the biostimulants used for branches per plant. B_4 recorded the maximum branches per plant of 9.50 and B_2, B_3 and B_8 were on par with it. There was also significant difference among the methods of application. M_2 recorded highest number of leaves per plant (8.87).

The interaction between biostimulants and methods also found to be significant with respect to branches per plant. The treatment B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) showed more branches per plant (11.66). The result was on par with B_3M_2 (humic acid @ 3% through foliar application) with 10.66, B_2M_2 (RDF through foliar application) with 10.33, B_7M_2 (ten times diluted cowurine through foliar application) with 9.33 branches per plant. B_1M_1 (distilled water through wick fertigation) recorded the least (4.66) branches per plant.

4.1.7. Root length (cm)

Significant difference was observed among biostimulants on length of the root. B_8 recorded the longest root length of 28.50 cm which was at par with B_3 and B_4. There was also significant difference among the methods of application. M_2 recorded highest root length (29.04 cm).

The interaction between biostimulants and methods also found to be significant. Length of root was higher (34.16 cm) for the treatment B_3M_2 (humic acid @ 3% through foliar application) followed by B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) which exhibited the root length of 33.50 cm. The shorter length was observed in B_1M_1 (distilled water through wick fertigation) whose root length was recorded as 18.66 cm. The effect of treatments on root length is displayed in Table 9.

Table 9. Effect of biostimulants, method of application and their interaction on root length

Biostimulants	Root length (cm)		
	Method		Mean
	M_1	M_2	
B_1	18.66	26.26	22.46
B_2	25.10	26.60	25.85
B_3	22.78	34.16	28.47
B_4	23.00	33.50	28.25
B_5	25.03	29.83	27.43
B_6	25.20	25.16	25.18
B_7	22.45	25.16	23.81
B_8	25.33	31.66	28.50
Mean	23.44	29.04	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.904	0.452	1.278
CD (0.05)	2.616	1.308	3.699

4.1.8. Days to flowering

Effect of biostimulants, method of application and their interaction on days to flowering is shown in Table 10.

There was significant difference among the biostimulants used for days to flowering. B_3 recorded late bolting (59.41) and B_2 and B_6 were on par with it. There was also significant difference among the methods of application. M_1 recorded highest number of days to flowering (58.57).

There was significant influence of biostimulants, method and their interaction on days to flowering. B_6M_1 (vermiwash @ 3% through wick fertigation) recorded significantly more number of days to flowering (60.16) which was at par with B_8M_1 (60.00), B_3M_1 (59.50) and B_2M_1 (59.16). The treatment B_1M_1 (55.50) and B_8M_2 (55.92) recorded earlier bolting.

Table 10. Effect of biostimulants, method of application and their interaction on days to flowering

Biostimulants	**Days to flowering**		
	Method		**Mean**
	M_1	**M_2**	
B_1	55.50	56.83	56.16
B_2	59.16	59.00	59.08
B_3	59.50	59.33	59.41
B_4	58.50	57.91	58.20
B_5	57.58	58.83	58.20
B_6	60.16	57.16	58.66
B_7	58.16	56.16	57.16
B_8	60.00	55.92	57.96
Mean	58.57	57.64	
	Biostimulants(B)	Method (M)	BXM
SE m±	0.409	0.205	0.579
CD (0.05)	1.185	0.592	1.676

4.2. Yield Parameters

4.2.1. Leaf/stem ratio

Performance of biostimulants, method of application and their interaction on leaf/stem ratio is given in Table 11.

Table 11. Effect of biostimulants, method of application and their interaction on leaf/stem ratio

Biostimulants	**Leaf/stem ratio**		
	Method		**Mean**
	M_1	**M_2**	
B_1	0.38	0.39	0.38
B_2	0.37	0.26	0.31
B_3	0.31	0.35	0.33
B_4	0.33	0.36	0.35
B_5	0.30	0.38	0.34
B_6	0.45	0.36	0.41
B_7	0.28	0.27	0.28
B_8	0.50	0.30	0.40
Mean	0.37	0.33	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.016	0.008	0.023
CD (0.05)	0.047	0.024	0.067

There was significant difference among the biostimulants used for leaf/stem ratio. B_6 recorded the highest leaf/stem ratio of 0.41 which was at par with B_8 and B_1. There was also significant difference among the methods of application. M_1 recorded highest leaf/stem ratio (0.37).

The interaction between biostimulants and methods also found to be significant. Highest leaf/stem ratio was obtained in the treatment B_8M_1 (salicylic acid @ 50mg L^{-1} through wick fertigation) with the value of 0.50 which was at par with B_6M_1 (Vermiwash @ 3% through wick fertigation) with leaf/stem ratio of 0.45. Lowest leaf/stem ratio was recorded in B_2M_2 (RDF through foliar application) of 0.26.

4.2.2. Fresh weight of leaves per plant (g)

Data pertaining the effect of biostimulants, method of application and their interaction on fresh weight of leaves per plant is displayed in Table 12. There was a significant influence of biostimulants on fresh weight of leaves per plant. B_4 recorded the highest fresh weight of leaves per plant (167.14 g). There was also significant difference among the methods of application. M_2 recorded the highest fresh weight of leaves (134.24g).

The interaction between biostimulants and methods were also found to be significant. Fresh weight of leaves per plant was higher for B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) with a weight of 225.85g. The lowest fresh weight of leaves per plant was observed in B_1M_2 (distilled water through foliar application) of 77.31 g.

Table 12. Effect of biostimulants, method of application and their interaction on fresh weight of leaves per plant

Fresh weight of leaves per plant (g)			
Biostimulants	**Method**		**Mean**
	M_1	**M_2**	
B_1	86.76	77.31	82.03
B_2	83.63	161.27	122.45
B_3	75.81	152.42	114.12
B_4	108.44	225.85	167.14
B_5	88.46	110.02	99.24
B_6	113.22	110.30	111.76
B_7	91.83	137.97	114.90
B_8	103.96	98.77	101.36
Mean	94.01	134.24	
	Biostimulants (B)	Method (M)	BXM
SE m±	7.778	3.889	10.999
CD (0.05)	22.507	11.254	31.830

4.2.3. Yield per cutting (g)

Evaluation of biostimulants, method of application and their interaction on yield per cutting are presented in Table 13.

Perusal of data revealed that yield per cutting was significant within biostimulants at different harvests. B_7 (17.00 g) recorded the highest yield during first harvest which was at par with B_2 and B_4. B_2 (124.84 g) recorded highest yield during second harvest which was at par with B_4. During third harvest B_4 (137.56 g) recorded the highest yield. There was also significant difference among the methods of application. M_2 recorded highest yield in each harvest.

Table 13. Effect of biostimulants, method of application and their interaction on yield per cutting

Yield per cutting (g)									
Biostimulants	**1st harvest**			**2nd harvest**			**3rd harvest**		
	Method		**Mean**	**Method**		**Mean**	**Method**		**Mean**
	M_1	**M_2**		**M_2**	**M_1**		**M_1**	**M_2**	
B_1	4.60	8.81	6.71	47.99	67.07	57.53	57.29	53.18	55.23
B_2	12.38	18.19	15.28	78.06	171.62	124.84	95.99	112.61	104.30
B_3	3.45	13.80	8.63	58.81	115.65	87.23	81.97	126.65	104.31
B_4	3.49	15.06	9.28	73.25	160.88	117.07	104.38	170.73	137.56
B_5	2.21	15.76	8.99	61.51	70.27	65.89	76.75	125.18	100.97
B_6	3.46	14.27	8.87	79.02	89.94	84.48	98.11	109.88	103.99
B_7	3.36	30.64	17.00	74.70	92.78	83.74	85.10	152.81	118.96
B_8	4.64	12.46	8.55	83.17	81.82	82.49	107.35	103.67	105.51
Mean	4.70	16.12		69.56	106.26		88.37	119.34	
	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM
SE m±	0.391	0.195	0.552	2.555	1.277	3.613	4.813	2.406	6.806
CD (0.05)	1.130	0.565	1.598	7.392	3.696	10.454	13.927	6.963	19.695

The interaction between biostimulants and methods were also found to be significant. At first harvest, significantly higher yield was recorded in B_7M_2 (ten times diluted cowurine through foliar application) with 30.64g followed by B_2M_2 (RDF through foliar application) whose yield was 18.19 g. The lowest yield was recorded in B_5M_1 (moringa leaf extract @ 3% through wick fertigation) with 2.21g.

At second harvest, significantly higher yield was recorded in B_2M_2 (RDF through foliar application) with 171.62 g followed by B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) with a weight of 160.88 g and B_3M_2 (humic acid @ 3% through foliar application) with 115.65 g. The lower yield was observed in B_1M_1 (distilled water through wick fertigation) control with 47.99g.

Yield per cutting at third harvest was significantly higher for B_4M_2 (humic – fulvic acid mixture @ 3 % through foliar application) with 170.73g followed by B_7M_2 (ten times diluted cowurine through foliar application) and B_3M_2 (humic acid @ 3% through foliar application) with 152.81 g and 126.65g respectively.

The total yield was significantly higher for B_4M_2, B_2M_2 and B_3M_2. The treatment B_2M_1 and B_1M_1 have significantly low yield.

4.2.4. Yield per plant (g)

The results of biostimulants, method of application and their interaction on yield per plant is given in Table 14.

There was a significant influence of biostimulants on yield per plant. B_4 (471.60 g) recorded the highest yield per plant. There was also significant difference among the methods of application. M_2 (359.47g) recorded highest yield.

The interaction between biostimulants and methods were also found to be significant. Yield per plant was higher for B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) with weight of 646.01g. The lower yield was observed in B_1M_2 (distilled water through foliar application) with 180.72g.

Table 14. Effect of biostimulants, method of application and their interaction on yield per plant

Biostimulants	Yield per plant (g)		
	Method		Mean
	M_1	M_2	
B_1	228.71	180.72	204.71
B_2	236.06	452.77	344.42
B_3	208.23	392.03	300.13
B_4	297.19	646.01	471.60
B_5	255.19	253.20	254.20
B_6	298.32	323.83	311.07
B_7	246.21	388.02	317.11
B_8	264.25	239.22	251.74
Mean	254.27	359.47	
	Biostimulants (B)	Method (M)	BXM
SE m±	38.960	19.480	55.098
CD (0.05)	112.743	56.371	159.442

4.3. Quality parameters

4.3.1. Vitamin C (mg 100 $^{-1}$g)

Effect of biostimulants, method of application and their interaction on vitamin C content is depicted in Table15.

Perusal of the data revealed that there was significant difference among the biostimulants for vitamin C content. B_4 recorded the maximum content of vitamin C. There was also significant difference among the methods of application. M_2 recorded maximum vitamin C (93.14 mg 100 $^{-1}$g).

The interaction between biostimulants and methods also found to be significant. Vitamin C content was maximum (98.20 mg 100 $^{-1}$g) for the treatment B_3M_2 (humic acid @ 3% through foliar application) followed by B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) with 96.42 mg 100 $^{-1}$g. The lowest vitamin C content was recorded in B_7M_1 (ten times diluted cowurine through wick fertigation) with 57.14 mg 100 $^{-1}$g.

Table 15. Effect of biostimulants, method of application and their interaction on vitamin C

Biostimulants	**Vitamin C (mg100g^{-1})**		
	Method		**Mean**
	M_1	**M_2**	
B_1	71.38	92.85	82.11
B_2	74.89	91.16	83.02
B_3	78.56	98.20	88.38
B_4	85.44	96.42	90.93
B_5	64.38	94.53	79.45
B_6	82.13	91.61	86.87
B_7	57.14	88.48	72.81
B_8	83.92	91.86	87.89
Mean	74.73	93.14	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.076	0.038	0.107
CD (0.05)	0.220	0.110	0.310

4.3.2. Oxalate (mg)

Data pertaining the effect of biostimulants, method of application and their interaction on oxalate content was displayed in Table 16. There was significant difference among the biostimulants for oxalate content. B_2 (0.90 mg) recorded the maximum content of oxalate and lowest was recorded in B_5 (0.76 mg). There was also significant difference among the methods of application. M_2 (0.91 mg) recorded more oxalate content than M_1.

The interaction between biostimulants and methods also found to be significant. Highest oxalate content was recorded in B_7M_2 (ten times diluted cowurine through foliar application) and B_3M_2 (humic acid @ 3% through foliar application) with 0.97 mg. Oxalate content was low for treatment B_5M_1 (moringa leaf extract @ 3% through wick fertigation) with 0.69 mg.

Table 16. Effect of biostimulants, method of application and their interaction on oxalate

Biostimulants	**Oxalate (mg)**		
	Method		**Mean**
	M_1	**M_2**	
B_1	0.70	0.91	0.80
B_2	0.91	0.90	0.90
B_3	0.81	0.97	0.89
B_4	0.81	0.95	0.88
B_5	0.69	0.84	0.76
B_6	0.82	0.96	0.89
B_7	0.77	0.97	0.87
B_8	0.79	0.93	0.86
Mean	0.70	0.91	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.006	0.003	0.009
CD (0.05)	0.019	0.009	0.027

4.3.3. Carotenoid (mg 100 $^{-1}$g)

17. Effect of biostimulants, method of application and their interaction on carotenoid

Biostimulants	**Carotenoid (mg100g^{-1})**		
	Method		**Mean**
	M_1	**M_2**	
B_1	3.33	4.84	4.08
B_2	7.14	5.67	6.40
B_3	5.08	6.13	5.60
B_4	5.79	7.01	6.40
B_5	5.43	7.38	6.40
B_6	5.07	5.12	5.09
B_7	5.63	3.57	4.60
B_8	6.20	4.81	5.50
Mean	5.45	5.56	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.039	0.019	0.055
CD (0.05)	0.112	0.056	0.158

Effect of biostimulants, method of application and their interaction on carotenoid is shown in Table 17. Perusal of the data revealed that there was significant difference among the biostimulants for carotenoid content. B_5 (6.40 mg 100 $^{-1}$g) recorded the highest content of carotenoid. There was also significant difference among the methods of application. M_2 recorded highest carotenoid (5.56 mg 100 $^{-1}$g).

The interaction between biostimulants and methods also found to be significant. Carotenoid content was recorded highest for B_5M_2 (moringa leaf extract @ 3 % through foliar application) with 7.38 mg 100 $^{-1}$g followed by B_2M_1 (7.14 mg 100 $^{-1}$g) and lowest content was observed in B_1M_1 (distilled water through wick fertigation) with 3.33 mg 100 $^{-1}$g.

4.3.4. Calcium content (mg 100 $^{-1}$g)

Data pertaining the effect of biostimulants, method of application and their interaction on calcium was displayed in Table 18.

Table 18. Effect of biostimulants, method of application and their interaction on calcium

Biostimulants	Calcium (mg100g^{-1})		
	Method		Mean
	M_1	M_2	
B_1	1.80	2.90	2.35
B_2	1.50	2.70	2.10
B_3	1.46	3.20	2.33
B_4	1.40	2.40	1.90
B_5	2.40	1.40	1.90
B_6	2.20	3.40	2.80
B_7	2.20	3.70	2.95
B_8	2.70	2.60	2.65
Mean	1.95	2.78	
	Biostimulants (B)	Method (M)	BXM
SE m±	0.040	0.020	0.057
CD (0.05)	0.116	0.058	0.164

There was significant difference among the biostimulants for calcium content. B_7 (2.95 mg 100 $^{-1}$g) recorded the highest content of calcium. There was also significant difference among the methods of application. M_2 recorded maximum calcium content.

The interaction between biostimulants and methods also found to be significant. Highest calcium content was recorded in B_7M_2 (ten times diluted cow urine through foliar application) with 3.70 mg 100 $^{-1}$g and B_6M_2 (vermiwash @ 3% through foliar application) with 3.40 mg 100 $^{-1}$g. Calcium content was low for treatment B_4M_1 (humic – fulvic acid mixture @ 3% through wick fertigation) and B_5M_2 (moringa leaf extract @ 3% through foliar application) with 1.40 mg 100 $^{-1}$g.

4.3.5. Organoleptic properties

Effect of biostimulants, method of application and their interaction on organoleptic properties are depicted in Table 19.

Effect of different treatments on organoleptic properties was statistically analyzed using Kruskall-Wallis chi square test. Significant difference was found in appearance, flavor, taste, texture and overall acceptability among all treatments. Highest mean score was recorded in B_3M_2 (humic acid @ 3% through foliar application) and B_4M_2 (humic – fulvic acid mixture @ 3% through foliar application) for appearance (4.50) and flavour (4.66). B_3M_2 (humic acid @ 3 % through foliar application) recorded maximum mean score for texture (4.66) and overall acceptability (4.50). Maximum mean score for taste was recorded in B_5M_2 (moringa leaf extract @ 3% through foliar application) with (4.50). Lowest mean score for appearance (3.25), texture (3.16), taste (3.25) and overall acceptability (3.66) was recorded in B_1M_1 (distilled water through wick fertigation). The lowest score for flavour was recorded in B_1M_2 (distilled water through foliar application) control with 3.16.

4.4. Soil Parameters

From the data, it could be inferred that biostimulants as well as method of application had no significant effect on soil parameters such as soil pH, EC, organic carbon, available nitrogen, phosphorus and potassium (Table 20a and 20b).

Table 19. Organoleptic test for amaranthus

Treatments	Appearance	Texture	Flavour	Taste	Overall acceptability
	Mean score	Mean score	Mean score	Mean score	Mean score
B_1M_1	3.25	3.16	4.16	3.25	3.66
B_2M_1	4.50	3.25	3.66	3.50	4.16
B_3M_1	3.66	3.83	4.00	4.33	4.16
B_4M_1	4.16	3.66	3.85	3.66	3.66
B_5M_1	3.66	4.16	3.66	4.16	4.16
B_6M_1	3.33	3.16	3.50	3.60	3.66
B_7M_1	3.83	3.66	3.50	3.30	4.16
B_8M_1	3.66	3.33	3.33	3.83	4.33
B_1M_2	3.33	3.60	3.16	3.66	3.33
B_2M_2	4.16	4.00	3.50	3.33	4.16
B_3M_2	4.50	4.66	4.16	4.00	4.50
B_4M_2	4.50	4.30	4.16	4.33	4.00
B_5M_2	4.16	3.30	3.33	4.50	4.16
B_6M_2	3.50	3.50	4.16	4.16	4.16
B_7M_2	4.16	3.50	4.16	3.63	3.83
B_8M_2	4.16	4.16	4.00	4.16	3.66
KW value	333.00	243.33	256.81	305.77	265.75
χ^2**(0.05)**	24.99				

Table 20a. Effect of biostimulants, method of application and their interaction on soil parameters

Biostimulants	Ph			EC (dsm-1)			Organic carbon (%)		
	Method		Mean	Method		Mean	Method		Mean
	M_1	M_2		M_2	M_1		M_1	M_2	
B_1	6.05	6.09	6.07	0.22	0.24	0.23	3.50	3.54	3.52
B_2	6.05	6.06	6.05	0.23	0.24	0.23	3.52	3.49	3.51
B_3	6.06	6.06	6.06	0.23	0.24	0.24	3.52	3.46	3.49
B_4	6.07	6.05	6.06	0.24	0.23	0.23	3.46	3.50	3.48
B_5	6.04	6.03	6.03	0.25	0.23	0.24	3.47	3.49	3.48
B_6	6.09	6.07	6.08	0.25	0.22	0.24	3.50	3.50	3.50
B_7	6.08	6.05	6.06	0.25	0.24	0.24	3.50	3.50	3.50
B_8	6.02	6.07	6.05	0.25	0.23	0.24	3.50	3.52	3.51
Mean	6.06	6.06		0.24	0.23		3.50	3.50	
	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM
SE m±	0.016	0.008	0.023	0.012	0.006	0.017	0.013	0.007	0.019
CD (0.05)	NS								

Table 20b. Effect of biostimulants, method of application and their interaction on soil parameters

Biostimulants	N (%)			P (%)			K (%)		
	Method		Mean	Method		Mean	Method		Mean
	M_1	M_2		M_2	M_1		M_1	M_2	
B_1	0.027	0.026	0.027	0.009	0.008	0.008	0.016	0.017	0.016
B_2	0.028	0.025	0.026	0.009	0.011	0.010	0.016	0.014	0.015
B_3	0.027	0.027	0.027	0.010	0.010	0.010	0.015	0.016	0.015
B_4	0.025	0.027	0.026	0.009	0.010	0.010	0.017	0.014	0.016
B_5	0.026	0.028	0.027	0.010	0.011	0.011	0.017	0.015	0.016
B_6	0.025	0.027	0.026	0.011	0.010	0.011	0.014	0.017	0.015
B_7	0.026	0.027	0.027	0.010	0.012	0.011	0.015	0.015	0.015
B_8	0.025	0.025	0.025	0.011	0.011	0.011	0.016	0.013	0.014
Mean	0.026	0.027		0.010	0.010		0.016	0.015	
	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM	Biostimulants (B)	Method (M)	BXM
SE m±	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.002
CD (0.05)	NS								

4.5. Incidence of pest and diseases

Major pests observed were leaf webber and mites. Leaf spot and rust were the major diseases observed in the plot.

4.6. B:C Ratio

The B:C ratio of biostimulant application are depicted in Table 21. The B:C ratio for best treatment was B_4M_2 (humic – fulvic acid mixture @ 3 % through foliar application) with the value 1.35 and for control (B_1M_1 - distilled water through wick fertigation) with the value 0.22.

Table 21. B:C Ratio of biostimulant application

Treatments	Net returns	Cost of cultivation	BC Ratio
B_1M_1	297	1300	0.22
B_2M_1	504	1354.9	0.37
B_3M_1	378	1428.4	0.26
B_4M_1	486	1300	0.30
B_5M_1	378	1300	0.29
B_6M_1	486	1312.3	0.37
B_7M_1	495	1300	0.38
B_8M_1	531	1388.8	0.38
B_1M_2	351	700	0.50
B_2M_2	810	754.99	1.07
B_3M_2	666	828.5	0.80
B_4M_2	945	700	1.35
B_5M_2	576	700	0.82
B_6M_2	585	712.5	0.82
B_7M_2	747	700	1.06

Discussion

5. DISCUSSION

Amaranthus (*Amaranthus tricolor* L.) is an important leafy vegetable of Kerala. It is well known for its nutritive values hence referred as poor man's spinach because of its nutritional value like protein, vitamins and minerals, β – carotene, calcium and iron. In vegetable production, plant biostimulants have been gaining interest due to improved yield, nutrient use efficiency, quality, and abiotic stress tolerance. However, different application methods influence the efficiency of biostimulants. Being a leafy vegetable, foliar spray of these biostimulants may have limitations with regards to visual appearance and other organoleptic characters. Wick irrigation have been widely promoted and adopted as an efficient irrigation system for urban agriculture. In this context, the study entitled "'Evaluation of biostimulants in growbag culture of organic Amaranthus (*Amaranthus tricolor)*' was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2018-2020 in order to identify suitable biostimulant, method of application and evaluate growth and performance of amaranthus. The study was conducted using Arun variety of amaranthus in growbag.

5.1. EVALUATION OF BIOSTIMULANTS FOR GROWTH, YIELD AND QUALITY

5.1.1. Growth parameters

5.1.1.1. Plant height (cm)

Biostimulant, method of application and their interaction improved the plant height significantly. Spraying humic substances significantly increased the height of plant. Application of humic-fulvic acid mixture @ 3 % and humic acid @ 3 % through foliar application significantly increased the plant height in amaranthus. The positive effect of humic substances in improving plant height was also reported by Singeravel *et al.* (1993).

Sharma *et al*. (2017) confirmed that application of humic acid 30ml recorded highest plant height (36.4 cm) in french bean cv. Contender. The enhanced plant height caused by humic acid might be due to improved nutrient uptake which favours better growth. This result fall in line with the findings of O'donnell (1973), who observed increased plant height of sunflower due to humic acid application which is attributed to better rooting and adsorption of nutrients by plants and also due to the auxin type of activity of humic acid on plant growth.

5.1.1.2. Leaves per plant

Leaves per plant was increased by biostimulants, wick fertigation and their ineraction. Leaves per plant was highest for vermiwash when applied at 3% through wick fertigation. Ansari (2008) stated that growth parameters and yield of spinach and onion was significantly higher in plots treated with vermiwash, which might be due to presence of major micronutrients and soil organic molecules that are useful for plants.

5.1.1.3. Leaf length and leaf width

Leaf length and leaf width are important yield contributing trait in amaranthus. Leaf length was significantly improved by the application of biostimulant and interaction between biostimulant and method of application. Application of humic-fulvic acid mixture @ 3 % through foliar application significantly increased the leaf length as well as leaf width. This is in agreement with Ugur *et al.* (2013), who claimed that humic substances generally increases the growth and quality of green vegetables. 0.4% humic acid increased the leaf length and leaf width in rocket plants.

The findings of Kumar *et al.* (2015), supported this result. According to their study foliar application of humic substances increased the leaf length and width in okra. Jackson (1993) demonstrated that humic and fulvic acid accelerates cellular division thus stimulates vegetable growth and development as well as increase cellular energy and regulation of plant metabolism.

5.1.1.4. Stem girth

In the present study, statistically no significant differences were found in treatments as well as method of application on stem girth. Reddy (1999) also reported that stem girth of amaranthus did not differ significantly during harvest.

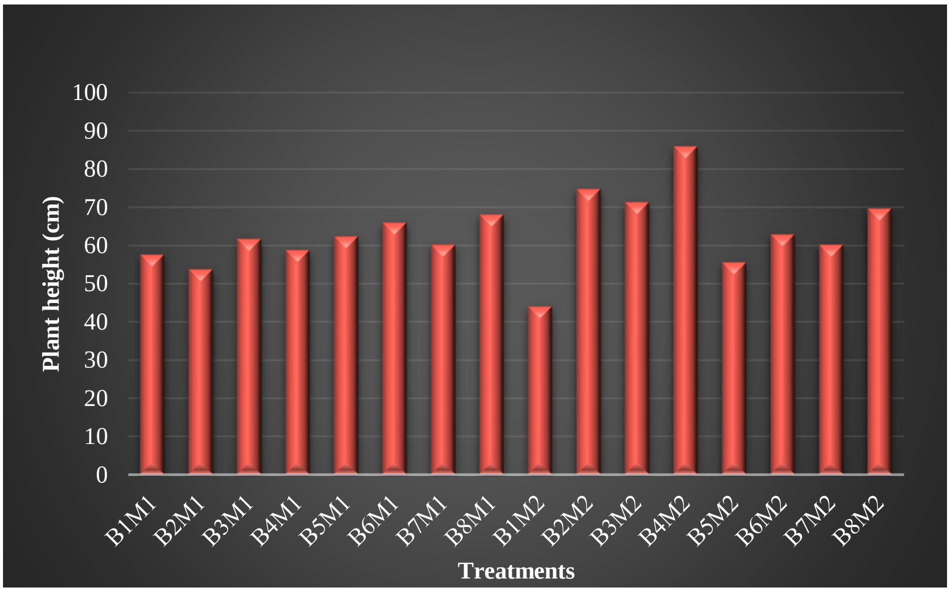

Fig. 1. Effect of biostimulants, method of application and their interaction on plant height of amaranthus

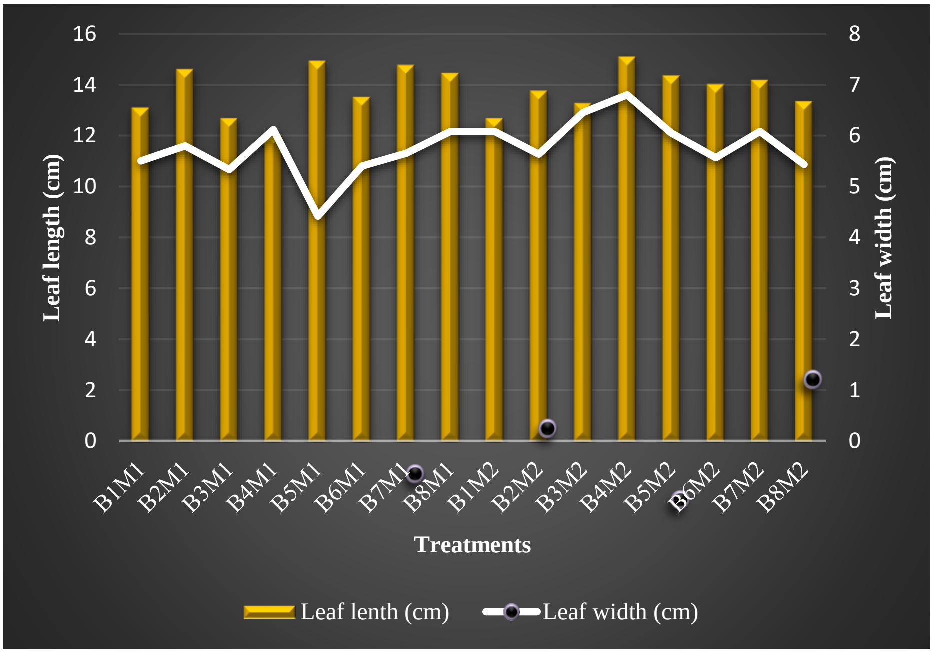

Fig. 2. Effect of biostimulants, method of application and their interaction on leaf length and leaf width of amaranthus

5.1.1.5. Branches per plant

The number of branches per plant is yet another yield contributing trait in amaranthus. It was increased due the application of biostimulant, method and their interaction. Application of humic-fulvic acid mixture @ 3 % and humic acid @ 3 % through foliar application significantly increased the number of branches per plant. The result was in agreement with Thakur (2013), who stated that humic substances showed higher plant growth characters.

5.1.1.6. Root length

Root length was increased due the application of biostimulant, method and their interaction. Length of root was higher for humic acid @ 3 % through foliar application followed by humic – fulvic acid mixture @ 3 % through foliar application. This result fall in line with Borcioni *et al.* (2016), who claimed that humic substances can promote plant growth, especially of the root system in lettuce.

Humic substances influence the absorption and transport of nutrients to alter the surface area of the roots. The effects caused by humic substances are attributed to its action as auxin, a plant hormone related to cell expansion and root initiation, among other physiological effects (Muscolo *et al.*, 2007; Trevisan *et al.*, 2010).

5.1.1.7. Days to flowering

Earlier bolting is an undesirable phenomenon in amaranthus. There was a significant influence of biostimulant, method and their interaction on days to flowering. Considering the days taken for flowering before all harvests, significantly earlier bolting was recorded in salicylic acid @ 50mg L^{-1} through wick fertigation and control. Late bolting was observed in humic acid @ 3 % and humic-fulvic acid mixture @ 3 % through foliar application.

This may be attributed by humic substances which reduce stress for moisture and higher nutrient contents of the component (Khaled and Fawy, 2011).

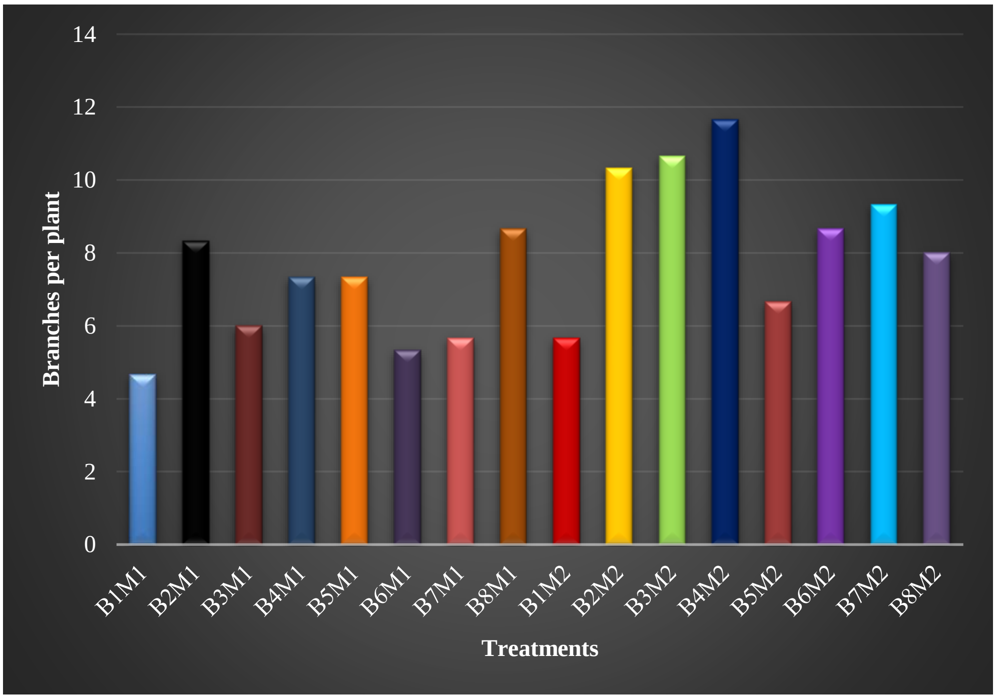

Fig. 3. Effect of biostimulants, method of application and their interaction on branches per plant of amaranthus

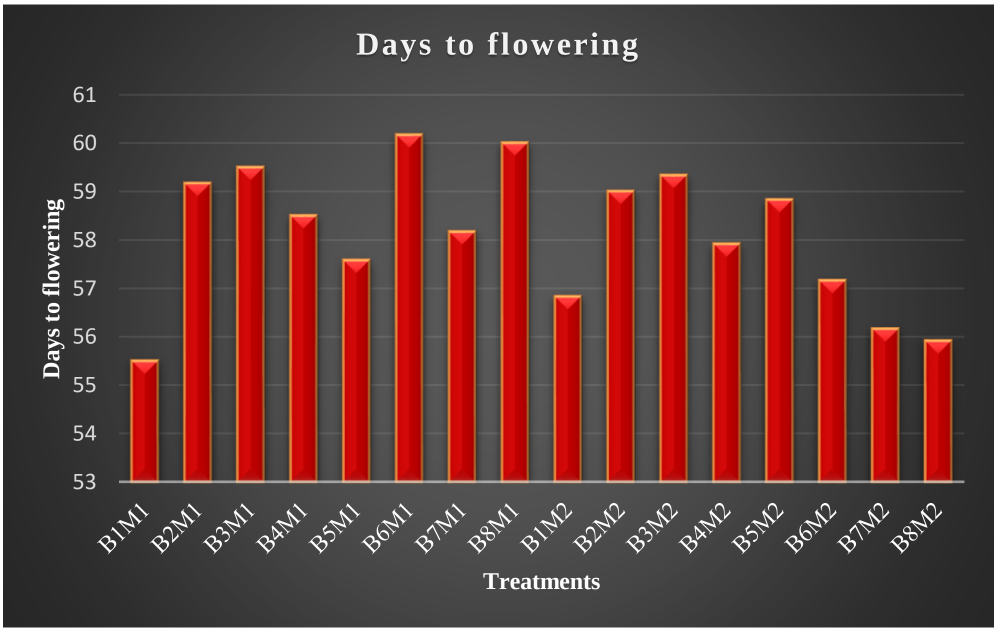

Fig. 4. Effect of biostimulants, method of application and their interaction on days to flowering of amaranthus

5.1.2. Yield Parameters

5.1.2.1. Leaf/stem ratio

Leaf/stem ratio was found to be increased due the application of biostimulant, method and their interaction. Among the biostimulants leaf/stem ratio was highest for salicylic acid @ 50mg L^{-1} through wick fertigation. Yıldırım and Dursun (2009) found highest yield of tomato at 0.5 mM salicylic acid treatment. Khandaker *et al.* (2011) also supported the result. According to their study low dose (10^{-5} M) foliar application of salicylic acid is effective than higher doses in improving growth parameters and yield of red amaranth.

5.1.2.2. Fresh weight of leaves per plant

Fresh weight of leaves per plant is a direct indicator of high yield in vegetable amaranth. Higher the weight of leaves will give high yield. It was increased due the application of biostimulant, method and their interaction. Fresh weight of leaves per plant was recorded higher in humic-fulvic acid mixture @ 3 % through foliar application. This increase in leaf weight can be correlated with increase in yield per plant. This result is in agreement with Taha *et al.* (2016), wherein the highest values of fresh and dry weight of leaves were at foliar addition of humic substances in lettuce.

5.1.2.3. Yield per plant

Yield per plant produced by any kind of vegetable is a direct indicator of total high yield. It was increased due the application of biostimulant, method and their interaction. Highest yield per plant was observed in humic-fulvic acid mixture @ 3 % through foliar application. This is in conformity with Khan *et al.* (2017), who reported that humic substances increase the bulb yield which could be due to its pivotal role in soil fertility and plant nutrition.

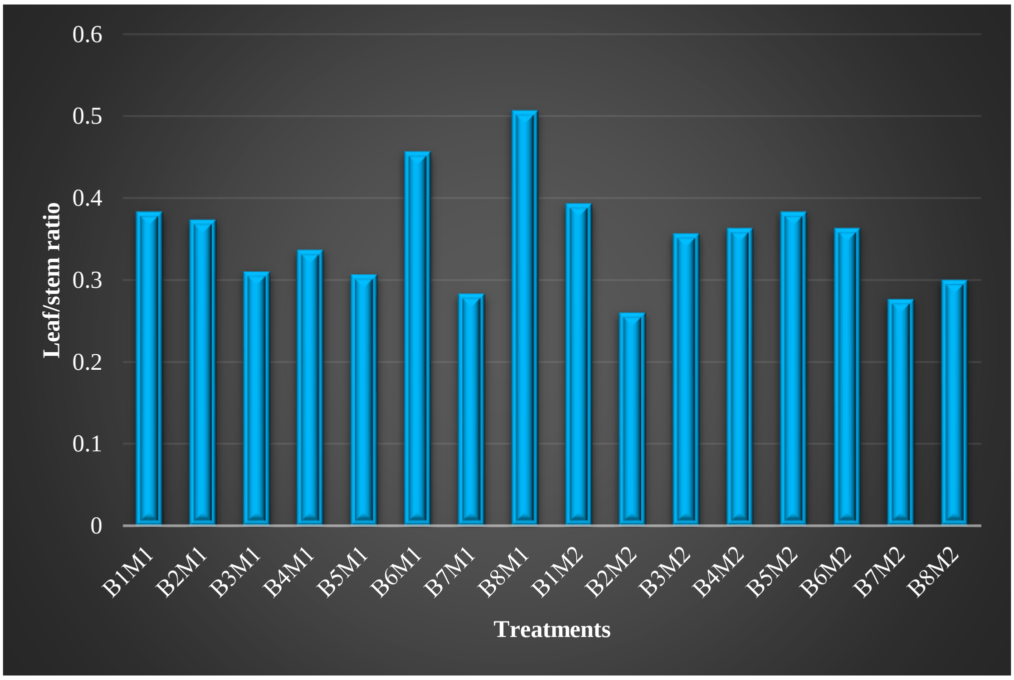

Fig. 5. Effect of biostimulants, method of application and their interaction on leaf/stem ratio of amaranthus

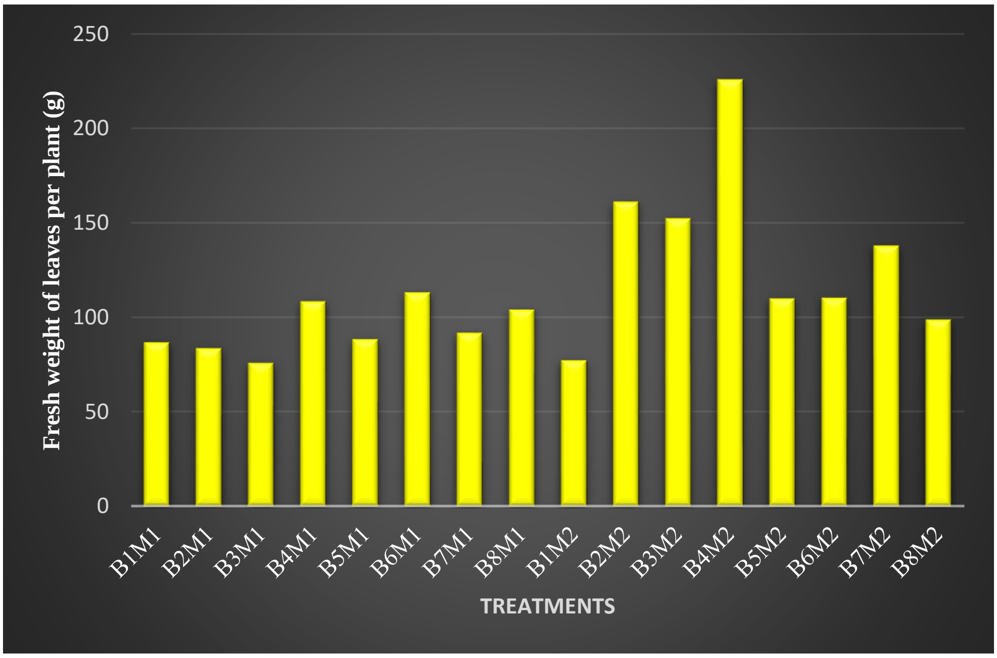

Fig. 6. Effect of biostimulants, method of application and their interaction on fresh weight of leaves per plant of amaranthus

5.1.2.4. Yield per cutting

The amount of the yield was decided in greater extent by fresh weight of leaves per plant as well as yield per plant. These results are in conformity with Khandaker *et al.* (2011) and Taha *et al.* (2016), where the yield increase was mainly due to the increase in weight of leaves and yield per plant in red amaranthus and lettuce respectively.

In the present study, yield was higher for humic-fulvic acid mixture @ 3 % through foliar application. This result is in agreement with Husein *et al.* (2015) and Kumar *et al.* (2015), in which higher yields were obtained by spraying plants with humic and fulvic substances in tomato and okra.

Humic acid caused significant effect on all yield characteristics of potato as compared to untreated plants. Humic acid is characterized by improving plant growth directly or indirectly, as it induce hormonal activity of plant releasing different auxin types which regulate plant growth, yield and environmental responses (Sarhan, 2011).

5.1.3. Quality parameters

5.1.3.1. Vitamin C

Vitamin C was influenced by biostimulants, methods and their interactions. Vitamin C content was observed maximum for humic-fulvic acid mixture @ 3 % through foliar application. This result fall in line with Kumar *et al.* (2017), who claimed that foliar application of humic acid increased the ascorbic acid content in tomato. Direct availability of nutrients from the humic substances improve the yield and quality of the product (Salman *et al.*, 2005).

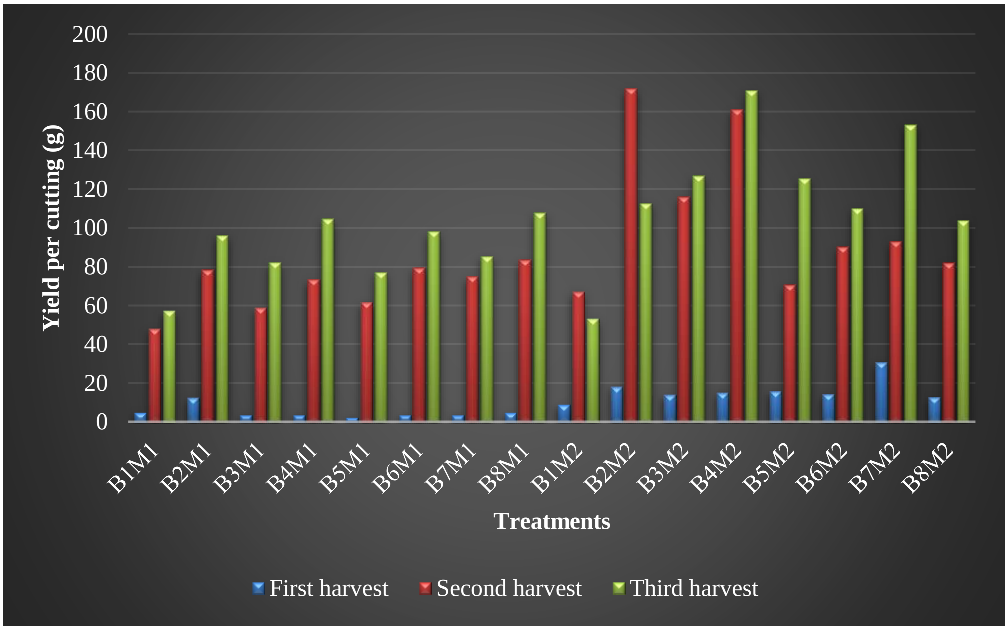

Fig. 7. Effect of biostimulants, method of application and their interaction on yield per cutting of amaranthus

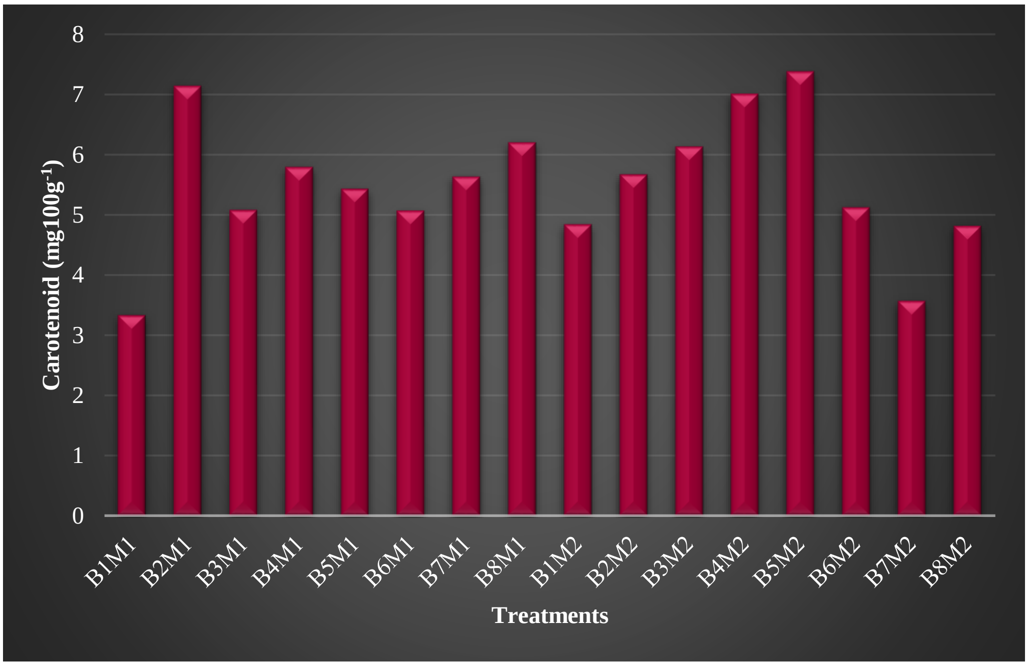

Fig. 8. Effect of biostimulants, method of application and their interaction on carotenoid content of amaranthus

5.1.3.2. Oxalate `

Despite of high level of nutrients, the main constraint to the nutritive value of green leafy vegetables is the presence of some antinutritional factors like oxalates and nitrates (Sadik, 1971; Singh and Saxena, 1972). Oxalate content was recorded high in ten times diluted cow urine applied through foliar application. The lowest oxalate range was observed in moringa leaf extract @ 3% through wick fertigation. The range of oxalate content was in line with observations of Aparna (2011), in Arun variety of amaranthus.

Comparing the methods of application oxalate content was found to be less in wick fertigation than foliar application. However, when compared to the content in present study Mziray *et al.* (2001), indicated a very high oxalate content in the range of 3.38 to 4.33 per cent in *Amaranthus hybridus*.

5.1.3.3. Carotenoid

Carotenoid content was improved by the application of biostimulants, methods and their interactions. Among the biostimulants maximum carotenoid content was recorded for moringa leaf extract @ 3% through foliar application. Merwad (2018) reported that the highest values of photosynthetic pigments, growth parameters and nutrient accumulation of plants were obtained with 4% of moringa leaf extract.

The use of moringa leaf extract as a possible plant growth enhancer can provide a relatively environmentally safe, easily accessible and affordable means for increasing crop quality and yield to meet the increasing demand of food (Emongor, 2015).

5.1.3.4. Calcium content

Calcium is an important quality attribute in leafy vegetables. It was increased by biostimulants, methods and their interactions. Application of ten times diluted cow urine through foliar application significantly increased the calcium content in amaranthus. It is in correlation with oxalate content as it might be present in the form of calcium oxalate (Vityakon and Standal, 1989).

Cow urine is very useful in agricultural operations as a fertilizer and biopesticide (Jandaik *et al*., 2015). Oliveira *et al*. (2009) reported that the quality and yield attributes were maximum when treated with cowurine in lettuce and methi.

5.1.3.5. Organoleptic properties

The organoleptic evaluation indicated high acceptability for all biostimulants in amaranthus. A mean score higher than 3 out of 5 was obtained for appearance, texture, flavour, taste and overall acceptability. However, among the different treatments, amaranthus cultivated using humic acid @ 3% through foliar application obtained maximum scores.

Effect of organic sources in improving the quality is well documented. Usually organic grown vegetables have better organoleptic properties than conventional grown. Agey and Suma (2012) stated that characteristics like taste, texture and flavour were superior in organic amaranth. Gennaro and Quaglia (2003) reported that organically grown okra produce more colour, taste, texture and flavour than conventional.

5.1.4. Soil Parameters

Soil parameters was found to be nonsignificant within the treatments. As the biostimulants were applied only through foliar and wick fertigation, which may not have influence on soil characters.

5.1.5. B:C Ratio

The B:C ratio was highest for humic – fulvic acid mixture @ 3 % through foliar application. The highest B:C ratio for humic – fulvic acid mixture might be due to the increased yield.

In conclusion, humic – fulvic acid mixture @ 3 % can be applied through foliar application gives better growth and yield characters. Among these biostimulants, humic – fulvic acid mixture produced highest growth characters like plant height, leaf length, leaf width, branches per plant, on par root length and yield parameters such as fresh weight of leaves, yield per plant and yield per cutting compared to control. In addition B:C ratio is also significantly higher for humic – fulvic acid mixture @ 3 % through foliar application.

Summary

6. SUMMARY

The study titled "Evaluation of biostimulants in growbag culture of organic Amaranthus (*Amaranthus tricolor)*" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2018-2020 in order to evaluate the effect of biostimulants under different application methods in growbag cultivation of organic amaranthus.

Amaranthus variety Arun was raised in seed bed and transplanted 21 days after sowing to growbags. Experiments were laid out in CRD with two factors replicated thrice for evaluation of biostimulants and method of application. Foliar application and wick fertigation were the two methods of application under the study for which wick fertigation were installed using pvc pipes and glass wool wicks were used. Biostimulants such as humic acid (3%), humic acid fulvic acid mixture (3%), moringa leaf extract (3%), vermiwash (3%), cow urine (ten times diluted), salicylic acid (50 mgL^{-1}) were compared with RDF (0.22:0.11:0.11 g/plant) and distilled water (control) at weekly intervals.

Biostimulant, humic - fulvic acid mixture was extracted from vermicompost. Extraction was carried out using a mild alkali (0.5 N NaOH).

Humic-fulvic acid mixture @ 3 % through foliar application significantly increased the height of plant (85.83 cm) and the least plant height was recorded in control which was distilled water through foliar application (43.96 cm). Vermiwash @ 3% through wick fertigation recorded highest number of leaves per plant of 118.83 which was at par with ten times diluted cow urine (117.41) and vermiwash @ 3% (116.83) through foliar application. Distilled water through foliar application recorded the least (70.33) number of leaves per plant.

Humic-fulvic acid mixture through foliar application @ 3% improved the leaf length (15.08 cm) which was at par with moringa leaf extract @ 3% and ten times diluted cow urine through wick fertigation of 14.91 cm and 14.75 cm respectively. Leaf width was also highest for humic-fulvic acid mixture through foliar application @ 3% (6.80 cm) and lowest leaf width was observed in moringa leaf extract @ 3% through

wick fertigation with 4.41 cm. Biostimulants and method of application did not differ significantly for stem girth.

Application of humic – fulvic acid mixture @ 3% through foliar application was effective in increasing the branches per plant of 11.66. The result was on par with humic acid @ 3% through foliar application (10.66), RDF through foliar application (10.33), ten times diluted cowurine through foliar application (9.33) branches per plant. Distilled water through wick fertigation reduced the branches per plant to 4.66.

Longest root length was recorded when humic acid @ 3% applied through foliar application (34.16 cm) followed by humic – fulvic acid mixture @ 3% through foliar application (33.50 cm). The shortest length was observed for distilled water through wick fertigation (18.66 cm).

Earlier bolting was recorded in salicylic acid @ 50mg L^{-1} through foliar application and control. Late bolting was recorded in vermiwash @ 3% (60.16), humic acid @ 3% (59.50) and RDF (59.16) through wick fertigation.

Application of salicylic acid @ 50mg L^{-1} through wick fertigation significantly increased the leaf/stem ratio (0.50) which was at par with vermiwash @ 3% through wick fertigation (0.45). Lowest leaf/stem ratio was recorded in RDF through foliar application of 0.26.

In the experiment, humic – fulvic acid mixture @ 3% through foliar application recorded highest fresh weight of leaves per plant (225.85g). The lowest fresh weight of leaves per plant was observed in distilled water through foliar application (77.31 g).

At first harvest, significantly higher yield per cutting was recorded in ten times diluted cowurine through foliar application (30.64g). The lowest yield was recorded in moringa leaf extract @ 3% through wick fertigation (2.21g). At second harvest, significantly higher yield was recorded in RDF through foliar application (171.62 g) followed by humic – fulvic acid mixture @ 3 % through foliar application (160.88 g).

Yield per cutting at third harvest was significantly higher for humic – fulvic acid mixture @ 3 % through foliar application (170.73g) compared to the control.

Yield per plant was higher for humic – fulvic acid mixture @ 3 % through foliar application with weight of 646.01g. The lower yield was observed in distilled water through foliar application with 180.72g.

Humic acid @ 3 % through foliar application enchanced the vitamin C (98.20 mg 100 $^{-1}$g) which was at par with humic – fulvic acid mixture @ 3 % through foliar application (96.42 mg 100 $^{-1}$g). The lowest vitamin C content was recorded in ten times diluted cowurine through wick fertigation (57.14 mg 100 $^{-1}$g).

Highest oxalate was recorded in ten times diluted cowurine and humic acid @ 3 % through foliar application with 0.97 mg. Oxalate content was observed low for moringa leaf extract @ 3% through wick fertigation with 0.69 mg. Moringa leaf extract @ 3 % through foliar application enchanced the carotenoid content (7.38 mg 100 $^{-1}$g) and lowest content was observed in distilled water through wick fertigation (3.30 mg 100^{-1}g).

Calcium content was recorded highest for ten times diluted cowurine through foliar application with 3.70 mg 100 $^{-1}$g and vermiwash @ 3 % through foliar application with 3.40 mg 100 $^{-1}$g. Calcium content was low for humic – fulvic acid mixture @ 3 % through wick fertigation and moringa leaf extract @ 3% through foliar application with 1.40 mg 100 $^{-1}$g.

The highest mean score was recorded for organoleptic properties in humic acid @ 3 % through foliar application and humic – fulvic acid mixture @ 3 % through foliar application for appearance (4.50) and flavour (4.66). Humic acid @ 3 % through foliar application recorded maximum mean score for texture (4.66) and overall acceptability (4.50). Maximum mean score for taste was recorded in moringa leaf extract @ 3% through foliar application with (4.50). Lowest mean score for appearance (3.25), texture (3.16), taste (3.25) and overall acceptability (3.66) was recorded in distilled water through wick fertigation. The lowest score for flavour was recorded in distilled water through foliar application control with 3.16.

As the biostimulants are applied through foliar and wick fertigation, treatments as well as method of application had no significant effect on soil parameters such as soil pH, EC, organic carbon, available nitrogen, phosphorus and potassium.

In conclusion, biostimulants and foliar method of application was found to be effective for improving growth, yield and quality of amaranthus in growbag organic cultivation. Among the biostimulants, humic – fulvic acid mixture @ 3% produced the highest plant height, leaf length, leaf width, branches per plant, fresh weight of leaves, yield and B:C ratio (1.35) compared to control (0.22).

FUTURE LINE OF WORK

Different concentration of commercially extracted humic fulvic acid mixture and effect of wick fertigation in different substrates can also be explored.

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Appendices

APPENDIX I

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE, VELLAYANI

DEPARTMENT OF VEGETABLE SCIENCE

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF AMARANTHUS

Name of student: Sherinlincy A (2018-12-032)

Title of thesis : Evaluation of biostimulants in growbag culture of organic amaranthus (*Amaranthus tricolor* L.)

CRITERIA	SAMPLES															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Appearance																
Texture																
Flavour																
Taste																
Overall Acceptability																

Scores

Highly Acceptable – 4.5-5

Acceptable – 3.50-4.49

Moderately Acceptable – 2.50-3.49

Slightly Acceptable – 1.50-2.49

Not Acceptable – 1-1.49

Name :

Signature :

EVALUATION OF BIOSTIMULANTS IN GROWBAG CULTURE OF ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)

by

SHERINLINCY A

(2018-12-032)

ABSTRACT

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2020

ABSTRACT

The study entitled "Evaluation of biostimulants in growbag culture of organic Amaranthus (*Amaranthus tricolor)"* was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani in order to evaluate the effect of biostimulants under different application methods in growbag cultivation of organic amaranthus.

Amaranthus variety Arun was raised in seed bed and transplanted 21 days after sowing to growbags. Experiments were laid out in CRD with two factors replicated thrice for evaluation of biostimulants and method of application. Foliar application and wick fertigation were the two methods of application under the study for which wick fertigation were installed using pvc pipes and glass wool wicks were used. Biostimulants such as humic acid (3%), humic acid fulvic acid mixture (3%), moringa leaf extract (3%), vermiwash (3%), cow urine (ten times diluted), salicylic acid (50 mgL^{-1}) were compared with RDF (0.22:0.11:0.11 g/plant) and distilled water (control) at weekly intervals.

Humic-fulvic acid mixture @ 3% through foliar application significantly increased the height of plant (85.83 cm), leaf length (15.08 cm) and leaf width (6.80 cm). Vermiwash @ 3% through wick fertigation exhibited the highest number of leaves per plant (118.83). Humic – fulvic acid mixture @ 3% through foliar application was also effective in increasing the branches per plant (11.66) while distilled water through wick fertigation recorded least number of branches per plant (4.66).

Longest root length (34.16 cm) was recorded when humic acid @ 3% were applied through foliar application compared to control (18.66 cm). Late bolting was recorded with humic acid @ 3%, humic-fulvic acid mixture @ 3% and RDF through foliar application. Earlier bolting was recorded in salicylic acid @ 50 mgL^{-1} through wick fertigation. Application of salicylic acid @ 50 mgL^{-1} through wick fertigation significantly increased the leaf/stem ratio (0.50) which was at par with vermiwash @ 3% through wick fertigation (0.45).

The total fresh weight of leaves per plant was significantly higher (225.85g) for humic – fulvic acid mixture @ 3% followed by RDF and humic acid @ 3%. At first, second and third harvest, significantly higher yield per cutting was recorded in ten times diluted cowurine (30.64g), RDF (171.62 g), humic – fulvic acid mixture @ 3 % (170.73g) through foliar application respectively while the lowest was recorded by distilled water through wick fertigation. Humic – fulvic acid mixture @ 3% through foliar application also recorded highest yield per plant (646.01 g) compared to distilled water through foliar application (180.72 g).

Humic acid @ 3% through foliar application enhanced vitamin C content (98.20 mg100g^{-1}) while ten times diluted cow urine through wick fertigation recorded the lowest vitamin C (57.14 mg100g^{-1}). Oxalate content was observed low for moringa leaf extract @ 3% through wick fertigation with 0.69 mg. Moringa leaf extract @ 3 % through foliar application enhanced the carotenoid content (7.38 mg100^{-1}g). Ten times diluted cow urine through foliar application produced highest calcium content (3.70 mg100^{-1}g). Biostimulants as well as method of application had no significant effect on stem girth and soil parameters such as soil pH, EC, organic carbon, available nitrogen, phosphorus and potassium.

In conclusion, biostimulants and foliar method of application was found to be effective for improving growth, yield and quality of amaranthus in growbag organic cultivation. Among the biostimulants, humic – fulvic acid mixture @ 3% produced the highest plant height, leaf length, leaf width, branches per plant, fresh weight of leaves, yield and B:C ratio (1.35) compared to control (0.22).

സംഗ്രഹം

“ജൈവ ഗ്രോബാഗ് ചീരകൃഷിയിൽ ബയോ സ്റ്റിമുലന്റ്റുകളുടെ പ്രയോഗഫലം വിലയിരുത്തൽ” എന്ന വിഷയത്തെ ആസ്പദമാക്കി വെള്ളായണി കാർഷിക കോളേജിലെ പച്ചക്കറി ശാസ്ത്രവിഭാഗത്തിൽ 2019 - 2020 കാലയളവിൽ ഒരു പഠനം നടത്തുകയുണ്ടായി.

ഹ്യൂമിക് ആസിഡ് (3%), വെർമിവാഷ് (3%), ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%), മുരിങ്ങ ഇല സത്ത് (3%), സാലിസിലിക് ആസിഡ് (50 മി. ഗ്രാം/ലി), ഗോമൂത്രം (10 മടങ്ങ് നേർപ്പിച്ചത്), ഡിസ്റ്റിൽഡ് വെള്ളം എന്നിവയാണ് പരീക്ഷണത്തിനായി ഉപയോഗിച്ചത്. പത്രപോഷണം, തിരിനന എന്നീ രണ്ടു പ്രയോഗ രീതികളും പഠനത്തിൽ ഉൾപ്പെടുത്തിയിരുന്നു.

പഠനത്തിൻറെ ഭാഗമായി അരുൺ എന്ന ഇനം ചീര, വിത്തു തടങ്ങളിൽ പാകുകയും 21 ദിവസങ്ങൾക്ക് ശേഷം ഗ്രോ ബാഗിലേക്ക് പറിച്ച് നടുകയും ചെയ്തു. ബയോസ്റ്റിമുലന്റ്റുകളുടെ മൂല്യനിർണയത്തിനും പ്രയോഗ രീതിക്കും മൂന്നുതവണ ആവർത്തിച്ചുള്ള പരീക്ഷണം നടത്തി.

ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%) പത്ര പോഷണത്തിലൂടെ നൽകുന്നത് ചെടിയുടെ ഉയരം ഗണ്യമായി (85.83 സെ. മീ) വർദ്ധിപ്പിക്കുന്നതായി കണ്ടെത്തി. വെർമി വാഷ് (3%) തിരിനനയിലൂടെ നൽകിയ ചെടികൾക്ക് കൂടുതൽ ഇലകൾ ഉള്ളതായി കണ്ടെത്തി (118.83). ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%) പത്ര പോഷണരീതിയിൽ നൽകുന്നത് ശാഖകളുടെ എണ്ണം (11.66) ഫലപ്രദമായി വർധിപ്പിക്കാൻ കാരണമായി.

ഹ്യൂമിക് ആസിഡ് 3% എന്ന തോതിൽ ചെടികളുടെ ഇലകളിൽ തളിക്കുന്നത് (പത്രപോഷണം) വേരിൻറെ നീളം (34.16 സെ.മി) വർദ്ധിപ്പിക്കാൻ സഹായിച്ചു. കൂടാതെ ഹ്യൂമിക് ആസിഡ്

(3%), ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%), ശുപാർശ പ്രകാരമുള്ള വളപ്രയോഗം എന്നിവ ചെടിയുടെ അകാല പുഷ്പിക്കൽ വൈകിപ്പിച്ചു.പക്ഷേ സാലിസിലിക് ആസിഡ് (50 മി. ഗ്രാം/ലി) തിരിനനയിലൂടെ നൽകുന്നത് ചീര വേഗത്തിൽ പുഷ്പിക്കാൻ ഇടയാക്കി.

തിരിനനയിലൂടെയുള്ള സാലിസിലിക് ആസിഡ് (50 മി. ഗ്രാം/ലി) പ്രയോഗം ഇല/തണ്ട് അനുപാതം ഫലപ്രദമായി വർദ്ധിപ്പിച്ചു. ഗോമൂത്രം (10 മടങ്ങ് നേർപ്പിച്ചത്), ശുപാർശ പ്രകാര മുള്ള വളപ്രയോഗം, ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%) എന്നിവ പത്രപോഷണ രീതിയിൽ ചെടികളിൽ തളിക്കുന്നത് ചീരയിൽ ഉയർന്ന വിളവ് നൽകി.

വിറ്റാമിൻ സി യുടെ അളവ് ഹ്യൂമിക് ആസിഡ് (3%) തളിച്ച ചെടികളിൽ ഉയർന്ന തോതിൽ കാണപ്പെട്ടു. ഓക്സലേറ്റിൻറെ തോത് മുരിങ്ങ ഇല സത്ത് (3%) തിരിനനയിലൂടെ നൽകിയ ചെടികളിൽ ഗണ്യമായി കുറഞ്ഞു, കൂടാതെ മുരിങ്ങ ഇല സത്ത് (3%) ചെടികളിൽ തളിക്കുന്നത് കരോട്ടിനോയ്ഡ് അളവും വർദ്ധിപ്പിച്ചു. പത്തു മടങ്ങ് നേർപ്പിച്ച ഗോമൂത്രം തളിച്ച ചെടികളിൽ ഉയർന്ന ഓക്സലേറ്റ്, കാൽസ്യം അളവുകൾ കാണപ്പെട്ടു.

ഹ്യൂമിക് ഫൾവിക്ക് ആസിഡ് മിശ്രിതം (3%) പത്ര പോഷണത്തിലൂടെ നൽകുന്നത് ചെടിയുടെ ഉയരം, ഇലയുടെ നീളം, ഇലയുടെ വീതി, ഇലകളുടെ എണ്ണം, ഇലകളുടെ ഭാരം, വിളവ്, വരുമാനം/ചിലവ് അനുപാതം (1.35) എന്നിവ വർദ്ധിപ്പിക്കുന്നതിനാൽ ഗ്രോബാഗിലുള്ള ജൈവ ചീരകൃഷിക്ക് അനുയോജ്യമാണെന്ന് കണ്ടെത്തി.