OKRA PRODUCTION IN THE FISH POND THROUGH THE APPLICATION OF GIBBERELLIC ACID AND VERMICOMPOST

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CERTIFICATE

This is to certify that the thesis entitled **"OKRA PRODUCTION IN THE FISH POND THROUGH THE APPLICATION OF GIBBERELLIC ACID AND VERMICOMPOST"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **MD. MAMUNUR RASHID**, Registration No. **18-09234** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

June, 2020

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Dedicated to
My
Beloved Parents

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OKRA PRODUCTION IN THE FISH POND THROUGH THE APPLICATION OF GIBBERELLIC ACID AND VERMICOMPOST

ABSTRACT

The experiment was conducted in the fish pond through determine the effect of gibberellic acid and vermicompost on okra production during July to October 2019 at the fish pond near Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment was consisted of two factors; Factor A: GA_3 *viz.* (i) G_0; 0 ppm GA_3 (control) and (ii) G_1; 100 ppm GA_3 and Factor B: Vermicompost *viz.* (i) V_0; 0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water (control), (ii) V_1; 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water and (iii) V_2; 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water. The experiment was laid out in Completely Randomized Design (CRD). In terms of GA_3 application, the highest fruit yield (405.66 g plant^{-1}) was found from G_1 whereas the lowest fruit yield (336.03 g plant^{-1}) was found from G_0. Regarding vermicompost, V_2 showed higher growth and yield attributes which resulted the highest fruit yield (421.00 g plant^{-1}) whereas the lowest fruit yield (303.80 g plant^{-1}) was found from V_0. Considering interaction effect, G_1V_2 showed highest fruit yield (470.10 g plant^{-1}) whereas the lowest fruit yield (290.60 g plant^{-1}) was found from G_0V_0. So, the treatment combination of G_1V_2 can be treated as the best among all the treatment combinations.

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ABBREVIATIONS AND ELABORATIONS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
FAO	=	Food and Agriculture Organization of The United Nations
i.e.	=	id est (L), that is
LSD	=	Least Significant Difference
M.S.	=	Master of Science
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Agricultural land of our country is rapidly declining as a result of rapid population growth, increased food requirements and urbanization, to meet future demands for food, there is a need for innovative, space-saving, and ecological food production technologies.

Aquaponics is a polyculture (integrated multi-trophic production system) consisting of two technologies: aquaculture (a fish farm) and hydroponic (soillesscultivation of vegetables on surface water). Combined of aquaculture and hydroponic can be termed as aquaponics. The primary goal of aquaponics is to reuse the nutrients contained in fish feed and fish faeces in order to grow crops (Graber and Junge 2009; Lennard and Leonard 2004; Lennard and Leonard 2006; Rakocy *et al.* 2003).

Growing of crops in fish pond is an amazingly productive way to grow vegetables, herbs and fruit while providing added benefits of fresh fish as a safe, healthy source of protein. Due to soilless, clean water and regulated condition in aquaponics system, it is believed that the flavor and quality of herbs and vegetables would be much higher than those grown in the field (Estim and Mustafa, 2010).

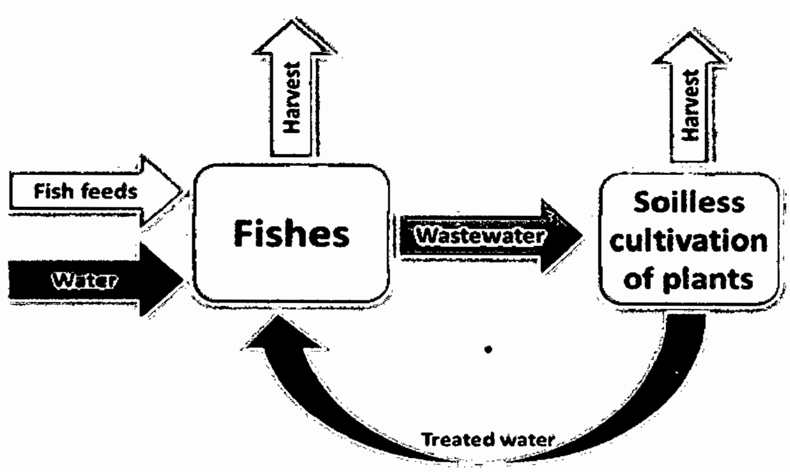

Figure 1: Basic material flows to plants in fish pond

Fish excrement can be used by plants either directly or after bacteria have converted the ammonia to nitrite and nitrate. The fish feed adds a continuous supply of nutrients to the plants, thereby solving the need for any discharge and replacement of depleted nutrient solutions or, in the case of extensively operated systems, the adjustment of the solutions are vegetables cultivation in fish pond (aquaponics) (Junge and Antenen, 2020). As the need to buy additional fertilizer for the plant crop is reduced, the profit potential of the system increases.

Aquaculture plays an important role in the fish production compared to the area of capture fisheries in our country. The sector contributes about 4.43% to GDP, 2.73% to the total export earnings (DoF, 2012). Farmers used various chemicals and fertilizers in food production which make the food toxic and dangerous for human health. In such situation crop production like vegetables in fish ponds (aquaponics) may be an excellent way to become sustainable food production. This system provides organic food with no health hazards. Aquaponics is the combination of 'aquaculture' and 'hydroponics'. Aquaculture is termed as fish farming and hydroponics is termed as crop production in soilless substrate. The aquaponics has control on farming systems which can protect the crops from diseases, heavy rains, floods, drought etc. which is also an environmental friendly and sustainable food production system (Salam *et al.*, 2014). It is the symbiotic relation between the fish and vegetables where fish provides fertilizer to the plants, in return plants help to purify the wastewater as they use the nutrients where the fish live in (Roe and Midmore, 2008). Some reimbursements like (i) Conservation of water resources, (ii) Efficient use of nutrient source (fish feed), (iii) Recycling of non-renewable resources (like phosphorus, potassium) and also of renewable, but scarce, ones (like water), (iv) No use of chemical herbicides or pesticides, as the recycling of water within the system hinders their use due to their adverse effects either on the fish or on the plants, (v) Very restricted use of pesticides of biological origin Higher level of biosecurity and fewer contaminants, (vi) Reduced operating costs (compared to aquaculture or hydroponics separately), (vii) Can be used on non-arable land, (viii) Construction materials and information are widely available, (ix) Can be operated in different climates and in both rural and urban locations, thereby enabling the production of family food or cash crops, (x) Can increase the productivity of the available space, because two crops can be harvested from the same surface area etc. are found in aquaponics system (vegetable cultivation in fish ponds) reported by Junge and Antenen (2020) which tends to be an eco-friendly method for producing nutritious food and, at the same time, for meeting consumer demand for a sustainable and healthy lifestyle.

Okra (*Abelmoschus esculentus* L.) belongs to the family Malvaceae, is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. It is generally an annual plant. It is also known as lady's finger or bhindi, originated in tropical Africa which is rich in nutrition, good taste, medicinal and industrial (Smriti and Ram, 2018). Vegetable cultivation in fish pond (aquaponics) is a bio-integrated system. The waste produced by fish serves as perfect manure for plants and water cleaned in this way is made available to fish through recirculation (Racoky *et al.*, 2004). With the right choice of fish and plant species, aquaponics serves as a model of environmentally compatible and sustainable food production system (Chand *et al.*, 2006). Because aquaponics is energy-efficient, prevents discharge of waste into the environment, provides organic fertilizer to plants (rather than synthetic chemicals), reuses the waste water through biofiltration and ensures higher production of food per unit area through multiple cropping. It deserves to be treated as a working model of green technology (Mustafa *et al.*, 2010). Okra can be considered as plant material to grow with fish in fish pond due to its excellent combining ability. Right choice of growing media may also increase the growth and yield of okra.

Okra is the most popular vegetables in all section of people. Okra is mainly propagated by seeds and has duration of 90-100 days. It can be grown in both the seasons i.e., Rabi and Kharif which requires a long, warm and humid growing period. It is a good source of vitamins, minerals, calories, and amino acid found in seeds and compares favourably with those in poultry, eggs and soybean, (Schipper, 2000). All parts of okra likes fresh leaves, buds, flowers, pods, stems and seeds can be used for different purpose and hence it is a multipurpose crop in term of its use (Gemede *et al.*, 2015). The mucilage found in okra may be used for plasma replacement or blood expender (Maramag, 2013).

Growth and yield of okra depends upon many factors including seed quality, nutrition, climatic conditions and cultural practices (Kusvuran, 2012). Organic manures improve the quality of green pods. Therefore, the applications of plant nutrients through organic sources like vermicompost, farm yard manure and biofertilizers remains the alternative choice of the growers for maintaining its sustainable production. Okra produces fruit for a long time and needs balanced and sufficient supply of nutrients for higher yield and better quality. Vermicompost is a safe and non polluting conversion of organic wastage into organic manures which is cost effective and contains plant nutrients in available form as reported by Narkhede *et al.* (2011). Vermicompost is a source of micro and macro nutrients and acts as a chelating agent. Vermicompost is greatly humified through the fragmentation of parent organic materials by earthworms and colonization by micro-organisms (Edwards and Burrows, 1988).

The application of plant growth regulators is known as one of the most effective treatments used now a day in agriculture, productivity of horticulture crop productions were increased by application of different growth regulators (Jafarullah *et al.,* 2007). These can improve physiological efficiency of plants including photosynthetic capacity and effective partitioning of assimilates.

Exogenous application of plant growth regulators improved the yield production and fruit quality of horticulture crops. It also can bring changes in the phenotypes of plants and affect growth either by enhancing or by stimulating the natural growth regulatory systems from seed germination to senescence (Das and Das, 1995). The plant growth regulators have multifarious uses on fruit vegetable i.e. seed germination, sex modification, fruit set, size manipulation of fruits, earliness of crop and enhanced production. GA_3 is a natural growth hormone and is a part of a type of plant hormones called gibberellins. The most widely available compound is a gibberellic acid (GA_3) which induces stem and internode elongation, seed germination, enzyme production during germination, and fruit setting and growth (Karssen *et al.*, 1989; Dijkstra and Kuiper, 1989; Ross *et al.*, 1990; Davies, 1995). GA_3 promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava, 2007). Foliar application of gibberellic acid (GA_3) modified also plant growth and pod characteristics (Asghar *et al.*, 1997).

The present study was under taken for quality okra production in the fish pond using soillesssubstrate (aquaponics) system through utilization of fish waste. Considering this fact, production of okra might be increased and also be profitable through the use of vermicompost and GA_3 in addition. From this point of view, the experiment was carried out with the following objectives:

1. To find out the effect of vermicompost on growth, yield and quality of okra in the water surface of fish pond.
2. To determine the effect of GA_3 on growth, yield and quality okra production in the fish pond.
3. To find out the combined effect of vermicompost and GA_3 on okra production in the fish pond.
4. To utilize the water surface and dissolved nutrients in the fish pond for quality okra production.

CHAPTER II

REVIEW OF LITERATURE

Production of vegetables in fish ponds (aquaponics), also known as the integration of hydroponics with aquaculture, is gaining increased attention as a bio-integrated food production system. There are some published reports on aquaponics, its study and related activities. A short description on the available literature relevant to the present investigation is presented here. Some of the important and informative works conducted home and abroad in this aspect, have been reviewed below:

2.1 Role of vegetable cultivation in fish ponds (aquaponics)

Thi-Da *et al.* (2020) reported that the increasing intensification of aquaculture systems requires the development of strategies to reduce their environmental impacts such as pollution caused by the discharge of nutrient rich sediments into local water bodies. Recycling of fish pond sediments (FPS) as fertilizer has been proposed as a possible solution that may also reduce the reliance on synthetic fertilizers. They carried out a case study and determined suitable mixtures of striped catfish (*Pangasianodon hypophthalmus*) pond sediment (PPS) and locally sourced organic amendments of rice straw (RS), or common water hyacinth (WH) to fertilize cucumber plants (*Cucumis sativus* L.) in an integrated cucumber–giant gourami fish (*Osphronemus goramy*) farming system. Highest nutrient concentrations were found when mixing 30% PPS with 70% RS or WH. When used in combination with chemical fertilizer, it was found that a 25% to 75% reduction in chemical fertilizer application could be achieved, while also increasing cucumber yields, with the highest yields found when RS was used in organic amendments. In combination with the additional income from fish production, integrated farming systems such as that demonstrated in this study, may increase both farm income and production diversity.

Danner and Mankasingh (2019) carried out the present study to develop and design aquaponic production systems towards integration into small greenhouse farming strengthening economic viability and sustainability. The effects of water flow on plant growth and on nutrient utilization in culture water were measured and evaluated. Four aquaponics test systems were designed, built and operated, and results were used to develop a pilot commercial aquaponics system implemented for greenhouse farming in Iceland. One of the test systems was a media filled flood and drain system and the other three were deep water culture systems. Tilapia (*Oreochromis niloticus*), one of the most popular fish in aquaculture, was reared in all systems, while different leafy greens and fruiting vegetables were grown in the hydroponics. The production of the leafy green plants (e.g., pak-choi) was approximately four times, by weight, that of the production of fish, a similar yield as shown in other researches in the field. The continuous rise of nitrate and phosphate concentrations in the aquaponic system indicated the potential to support even higher crop yield. Long day length in the summer in Iceland is clearly beneficial for crop production in aquaponics. Based on the results, it is concluded that aquaponics can be a feasible opportunity for greenhouse farming at least to diversify the current business model. Not only can the fish provide an extra income but also the effluent from the aquaculture is easily used as fertilizer for the plants, thus the circular production system offers new innovative ideas for diversifying and value-adding the business.

Konig and Janker (2018) carried out an institutional case study and reported that vegetable cultivation in fish ponds (aquaponics) is an approach of coupling two technologies: recirculation aquaculture (fish-farms) and hydroponics (soillesscultivation of crops). A framework was proposed to analyze aquaponics as an emerging technological innovation system at the interface between existing fish and plant production systems. The approach is explorative based on a literature review and interviews with experts. The main findings are that stakeholders have different views regarding the future development pathways, knowledge to manage complex systems in the long term is needed and it is still unclear how to design institutional conditions to deliver sustainable outcomes.

Mamat *et al.* (2016) reported that aquaponic is a system that mutually integrates aquaculture and plant cultivation (by means of hydroponic). Both crops are combined in a recirculating system that utilizes less water than the traditional farming. Nutrients contained in fish tanks are recycled into plant biomass with the presence of nitrifying bacteria that convert the excreted ammonia to nitrite and then to nitrate. In this study, fifteen sets of aquaponic system were developed to study the growth of African catfish (*Clarias gariepinus*) and three types of plants; the red and green-red amaranth (*Amaranthus spp.*) and water spinach (Ipomoea aquatica). The combination of aquaculture and hydroponic gives a new insight into increasing the efficiency of food production which respects principles of sustainable agriculture.

Love *et al.* (2015) found in a survey of vegetable cultivation in fish ponds in the United States, that Tilapia was the fish species that was commonly raised in the pond while the commonly grown crops were high-value vegetables and herbs such as basil, lettuce, tomatoes, salad greens, kale, chard, bok choy, peppers and cucumbers. The study showed that many vegetables cultivation in fish ponds operations were not profitable. Out of the 257 farms studied, only 31 percent reported profitability of their business within the last 12 months of the study.

Tokunaga *et al.* (2015) investigated the economics of vegetable production in fish ponds in the state of Hawaii using a case study of three farms. They reported that some constraints to vegetable cultivation in fish ponds include high initial investment costs, labor-intensity of the operations, high use of electricity, and sensitivity of profits to output prices. Other risks include plant losses due to plant diseases and pests. Overall, the study found that small-scale farms were profitable, indicating that vegetable cultivation in fish ponds may be a viable option to produce vegetables and fish to local markets.

Petrea *et al.* (2014) conducted a study aims to reveal the performances parameters, both in terms of quantity and quality, for spinach (*Spinacia oleracea*)-Matador variety, growth in a fish pond integrated system, along with stellate sturgeons (*A. stellatus*) under three crops densities (V_1-59 crops/m^2, V_2–48 crops/m^2 and V_3–39 crops/m^2), by using hydroton as growing substrate, under a continuous flow hydraulic regime. The experiment was run in triplicate for each one of the three variants. The water quality was monitored and a series of growth parameters were determined, as follows: leaf area index (LAI), relative growth rate (RGR), average net assimilation rate (NAR), mean leaf area ratio (LAR) and crop growth rate (CGR). Also the concentration of chlorophyll a, b, carotenoids, ash and dry matter for spinach leaf, from each of the three experimental variants was determined and compared with the one of marketable spinach, growth conventional, in soil. It can be concluded that statistical significant differences ($p<0.05$) were recorded in terms of growth performance and crops quality, between the experimental variants. Also the quality of spinach grown in fish pond conditions, by using effluent derived from stellate sturgeon intensive aquaculture is similar to that of the marketable spinach, growth conventional.

Salam *et al.* (2014) conduct an experiment on nutrient recovery from fish farming wastewater for plant and fish integration and found that mean weight gain (%) of tilapia was 926.18 % using spinach *(Ipomoea aquatica)* for 115 days and survival rate was 91.90 %.

Ingrid (2013) conducted a study on how water quality changes over time in a small scale re-circulating system where waste water from smolt production was used to grow lettuce for commercial use. The treatment effect of lettuce on different solutions was tested and corresponding lettuce yield was evaluated. Phosphorus, potassium, manganese, zinc and copper decreased significantly in most of the waste water solutions, these elements are all nutrients for plants, hence they are most likely taken up by the lettuce. Despite the uptake of essential nutrients, the lettuce did not grow optimally and had several signs of distress symptoms both during and at the end of the experiment. Magnesium and chloride increased significantly due to evaporation from the reservoirs. Together with the high concentration found for sodium in all the wastewater solutions it was believed that the lettuce was exposed to toxic levels of salt. This was a possible explanation to why the lettuce did not grow sufficiently. Considering optimal conditions for lettuce growth the pH of the waste water solutions was too high, and the electrical conductivity was higher than recommended. One of the challenges with integrated production of salmon smolt and plants is the high content of salt in the waste water. The salt is necessary in most cases for production of salmon smolt but inhibits plant growth. If the plant is able to treat the water for nutrients and other waste products, without being depressed by the salt, re-use of the water is possible in addition to getting a marketable product.

Jason and Austin (2013) conducted an experiment to compare and contrast the growth of tomatoes, beans, and pea plants a pond with fish and no fish by monitoring the changes in ammonia, pH, nitrate, phosphate, temperature, and salinity of water overtime. Results showed that there were no significant growth differences by height of peas, tomatoes, and beans when growing in pond vs. traditional soil. However, there were significant differences between growing plants in fish pond vs. the control hydroponic with water only. Data confirmed at day 7 that nitrates at its peak and as ammonia decreased, caused the plants in fish pond to grow rapidly. Thus, the experiment confirmed a correlation between nitrate and plant growth.

Roosta and Hamidpour (2013) reported that, effects of foliar applications of some micro- and macro-nutrients on mineral nutrient content of tomato leaves and fruits were investigated in an aquaponic system in comparison with a hydroponic system. Fourteen days old tomatoes seedlings were transplanted on to growth bed of aquaponic and hydroponic systems. Foliar nutrients application began 30 days after transplantation. Eight treatments were used, untreated control and foliar application at the rate of 250 mL plant^{-1} with 0.5 g L^{-1} potassium sulfate (K_2SO_4), magnesium sulfate ($MgSO_4.7H_2O$), ferrous (Fe)- ethylenediamine-N,N'-bis (EDDHA), manganese sulfate ($MnSO_4.H_2O$), boric acid (H_3BO_3), zinc chloride ($ZnCl_2$), and copper sulfate ($CuSO_4.5H_2O$). Foliar application of potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) increased their corresponding concentrations in the leaves of aquaponic-treated plants. On the other hand, foliar spray of K, Fe, Mn, Zn, and Cu caused a significant increment of applied element concentrations in the fruits of hydroponic-grown plants. These findings indicated that foliar application of some elements can effectively alleviate nutrient deficiencies in the leaves of tomatoes grown on aquaponics.

Sace *et al.* (2013) installed two recirculating vegetables cultivation in ponds in a controlled environment greenhouse to study the growth and yield of lettuce (*Lactuca sativa*), Chinese cabbage (*Brassica rapa pekinensis*) and pac choi (*Brassica rapa*) using Nile tilapia (*Oreochromis niloticus*) culture with and without freshwater prawn (*Macrobrachium rosenbergii*). Culture water was lifted by a 40 W submersible pump from a 220 L bio-filtration tank to a 250 L fish tank, and allowed to flow by gravity to a 2.44 × 4.88 m raceway in a closed loop. Water was maintained at 20 cm depth permitting rafts to float. Hydroponically germinated seedlings in rockwool blocks were planted on the rafts at 15 cm spacing 30 days after stocking 22 kg of mixed-sex Nile tilapia in the fish tanks while 295 prawns were added in one of the raceways. Environmental conditions were maintained and water quality parameters were monitored in a compromise between the ideal requirements of fish, prawn and vegetables including the beneficial bacteria throughout the108-day culture period. Two sets of data for the three vegetables and one for tilapia and prawn were gathered after the two 35 day growing seasons of vegetables. Results showed that average dissolved oxygen of 5.6 ppm at 98% saturation and 21°C temperature, and a pH of 7.1–7.7 were established by the systems that provided a favorable environment for tilapia, prawn and nitrifying bacteria. However, the pH was disadvantageous to vegetables. With a low concentration of total dissolved solids of less than 330 ppm which was far below the requirement, the high pH retarded the normal growth of the vegetables resulting in chlorotic and necrotic leaves. Results also revealed that the vegetables demonstrated significantly better growth in the system with prawns. Among the three vegetables, pac choi had the highest growth, yield, and productivity followed by Chinese cabbage and lettuce. It was determined that integrating prawn culture helped stabilize and diversify the system which aided in improving the harvest.

Jessica (2012) stated that in a system of vegetable cultivation in fish pond water containing fish waste is pumped to the plants, where nutrient water is absorbed and utilized for plant growth. Alternatively, plants provide filtering of the water of excess nutrients that can be toxic to the fish. This experiment tested two food crops (lettuce and radish) grown in three different medias (soil, coconut fiber, gravel) in two separate aquaponics systems Nutrient Film Technique (NFT) and Floating Raft (FR) to determine which media maximized plant growth in both systems. Each plant was planted and replicated in each pot (3X) and differing media (3X) as seed and grown for 8 weeks (NFT) and 5 weeks (FR). Growth rates were measured by recording heights weekly and biomass (mg) at the end of the experiment. Both lettuce and radishes had the greatest growth in soil in both systems.

Tyson *et al.* (2012) reviewed existing aquaponic systems with emphasis on opportunities and challenges to systems sustainability. Aquaponics combines hydroponic plant and aquaculture fish production into a sustainable agriculture system that uses natural biological cycles (nitrification) to supply nitrogen and reduces the use of non-renewable fertilizer and water inputs. Preliminary data from a startup aquaponic greenhouse research/demonstration project at UF/ IFAS Extension-Orange County's Exploration Gardens show the potential for growing two vegetable crops concurrently to facilitate the recirculation and re-use of aquaponic waste water. In addition, microbial water quality testing of the aquaponic system water was conducted across three sampling dates. No Escherichia coli was detected in either re-circulating irrigation or filter-return water samples or from a single sampling of flake and pellet fish feed.

Dunn (2012) stated that modern vegetable cultivation system in fish ponds is a viable resource to sustainability that combines (i) growing fish and plants in a controlled environment and (ii) growing plants without soil. The system relies on fish waste to provide organic food and nutrients to help the plants grown; in turn, the plants clean, filter, and recycle the water back to the fish creating a symbiotic relationship.

Michael (2012) investigated an innovative approach to recapture nutrients from post-consumer food waste by converting it into a pelletized fish food for a bench- scale vegetable cultivation system in fish ponds. Two treatments, each with three replicated, were constructed to determine the effect of using food waste for fish and lettuce production. Food waste pellets had significantly more fat, less mineral content, and similar protein and fiber content compared with commercial fish feed. Nile tilapia *(Oreochromis niloticus)* had significantly greater specific growth rate (SGR) and food consumption rates on the commercial diet than those on the food waste diet. The feed conversion ratio (FCR) between treatments was similar. Lettuce biomass production was significantly reduced in food waste systems. Palatability of post-consumer food waste seemed to be the most significant factor to overcome.

Rana *et al.* (2011) studied on searching of low-cost eco-tech for the reclamation of municipal domestic wastewater, tomato plants *(Lycopersicum esculentum)* were cultivated on the floating bed of pulp-free coconut fiber over four different concentrations of wastewater (25%, 50%, 75% and 100%) and groundwater as control, in 10 L plastic bucket for two months. The study revealed that PO_4-P was removed by 58.14-74.83% with maximum removal at 50% wastewater. More than 75% removal of NO_3-N was observed in all treatments. Both COD and BOD were reclaimed highest at 100% wastewater by 61.38% and 72.03%, respectively. Ammonium-N concentration was subsided below the toxic level in all the treatments. The population of coliform bacteria *(Escherichia coli)* was reduced to 91.10-92.18% with maximum efficiency at 100% wastewater. Growth performance was observed relatively better at 100% wastewater. Crop production as the value addition of this technology was also recorded maximum at 100% wastewater.

Steve and Rinehart (2010) stated that fish raised in re-circulating tank require good water quality. Water quality testing kits from aquaculture (growing fish) supply companies are fundamental. Critical water quality parameters include dissolved oxygen, carbon dioxide, ammonia, nitrate, nitrite, pH, chlorine and other characteristics. The stocking density of fish, growth rate of fish, feeding rate and volume and related environmental fluctuations can elicit rapid changes in water quality; hence, constant and vigilant water quality monitoring is essential.

Baker (2010) also analyzed an integrated tilapia and lettuce production system in Hawaii and found it to be technically feasible and profitable. However, the study reported that there are no additional economic benefits in integrated production compared with only lettuce production.

Philippe (2010) conducted a study is to investigate the techno-economic feasibility of operating a farm of vegetable cultivation system in fish ponds in South Africa. The study finds that currently system in South Africa is hindered by a number of constraints that result in it being a high-risk venture with meager returns on investment. However, the study shows that if vegetable cultivation system in fish ponds were designed, built and managed correctly, it could theoretically be an economically viable venture.

Normala *et al.* (2010) noted that fish culture could be carried out in vegetable production system in fish ponds over extended periods, mint stocks had to be harvested at shorter intervals, preferably every fortnight, and replaced by fresh stocks. Keeping the same plant in the system led to fall in biomass and would impair the water quality since nutrient uptake in unhealthy plants was slower and might even cease if the culture would continue. In fact, shortage of certain nutrients such as iron, calcium and potassium in soilless culture might be occurred. While most of the nitrogen and phosphate requirements were met from the fish waste, there could be deficiency of potassium and some micronutrients, including iron and magnesium.

Rupasinghe and Kennedy (2010) in Australia, conducted a study over a 10-year planning horizon for barramundi and lettuce production as stand-alone units, and alternatively as integrated. They observed an increase in benefits equal to the reduction in barramundi effluent disposal costs.

Jason (2009) found in aquaponics system under the specified environmental conditions 5 kg m˙ of Nile tilapia *(O. niloticus)* fed 2% of their body weight daily yields on average 4.7 kg m-2 of lettuce *(L. sativa* cv. Rex) in 35 days. There was no significant difference ($p<0.05$) in biomass or chlorophyll concentration index in lettuce *(L. sativa* cv. Rex) grown with aquaponics water. The aquaponics solution generated equal biomass and chlorophyll concentration indexes compared to the hydroponic solution. Aquaponics water plus supplementation can yield *L. sativa* cv. Rex with equal biomass accumulation and chlorophyll concentration indexes compared to hydroponics lettuce. Nutrients added to the aquaponics system consisted of iron, manganese, and zinc. These nutrient concentrations became depleted in the aquaponics water over time and were not 12 replenished via the fish feed. Dolomite was added to the aquaponics system every two weeks to increase the buffering capacity of the water and maintain optimal pH levels. Aquaponics lettuce had similar nutrient composition to hydroponic lettuce. One head of L. sativa cv.

Rex (176.75 g) will assimilate approximately 5.96 grams of nitrogen (3.38% per dry gram lettuce). One kilogram of fish will yield 6.4 lettuce heads (1,128 grams) and fixate 38.13 grams of nitrogen.

Graber *et al.* (2008) recommended that there were several benefits to the owner of a backyard vegetable cultivation system in fish ponds. Firstly, the waste produced by the fish was recovered by the plant instead of being expelled to the environment. Water exchange is minimized since the growing medium and plants act as bio-filters, cleaning and returning the clean water to the fish tank. The surface area of the grow bed provided the area for bacterial growth and was related to the treatment capacity of the system. The treatment capacity had a unit of mass removal per unit time.

Al-Hafedh *et al.* (2008) stated that fish waste and accumulated feed builds up in the system. Nitrogen, phosphorous, and organic matter accumulate in high quantities in aquaculture (growing fish) systems. Nitrogenous wastes are produced when nitrogen in the form of ammonia is excreted by the fish. Ammonia is the byproduct of protein synthesis by the fish. Nutrient levels from aquaculture (growing fish) are suitable for plant growth and can be manipulated by increasing fish biomass and feed rate or by increasing the protein levels in the feed.

Chaves *et al.* (2008) studied incorporating tomatoes grown hydroponically into a recirculation system for channel catfish production in Scotland. They estimated an internal rate of return of 27.32%, but found little difference in financial results compared with producing catfish alone. The authors point out that reduction in effluent in aquaponics would add further benefit in social cost terms.

Andreas and Junge (2008) conducted an experiment where Aubergine, tomato and cucumber cultures were established in the LECA filter and nutrient removal rates calculated during 42-105 days. The highest nutrient removal rates by fruit harvest were achieved during tomato culture: over a period of greater than 3 months, fruit production removed 0.52, 0.11 and 0.8 gm-2d-l for N, P and K in hydroponic and 0.43, 0.07 and 0.4 gm-2d-l for N, P and K in aquaponics system. In aquaponics system, 69% of nitrogen removal by the overall system could thus be converted into edible fruits.

Li *et al.* (2007) conducted a research to investigate the use of water spinach *(Ipomoea aquatica* Forsk.) with N ion-beam implantation for removal of nutrient species from eutrophic water. The mutated water spinach was grown on floating beds, and growth chambers were used to examine the growth of three cultivars of water spinach with ion implantation for 14 days in simulated eutrophic water at both high and low nitrogen levels. The specific weight growth rates of three cultivars of water spinach with ion implantation were significantly higher than the control, and their NO -N and NH -N removal efficiencies were also greater than those of the control.

Saleh (2006) studied on bell pepper *(Capsicum annuum* L.) production system in fish ponds of Nile tilapia *(Oreochromis niloticus)* in re-circulating water. In this experiment nile tilapia *(Oreochromis niloticus)* and bell pepper *(Capsicum annuum* L. 'Godeon') were cultured for 180 days in a closed system containing 1160 L of water for each unit. Six units were used with three treatments (all three treatments were in duplicated) to determine the effect of the integration 2-3 between plant number /m to fish density (100 fish /m) on fish performance. 2 Each unit consists of 500 L fish rearing tank, hydroponic tank (2 m), filter and 2 sumps. Treatments were T (fish culture with 10 plant/m), T_2 (fish culture with 215 plant/m) and T3 fish culture without plant (control). Water quality suitable for fish production was maintained by aeration, mechanical and biological filtration, hydroponics vegetable production unit and the addition of make-up water. Fish metabolites and wasted feed served as nutrient sources for pepper 2 productions. The results showed that T1 (fish culture with 10 plants /m) gave the best significant ($P<0.05$) fish production 20.1 kg / m, followed by T_2 (fish 2 culture with 15 plants /m) 17.95 kg / m and the lowest ($P<0.05$) was

T_3 fish 3 culture without plant (control) 16.3 kg / m. Also, Ti (fish culture with 10 plants 2 2 /m) was higher in average yield of marketable bell pepper 11.34 kg fai 2 (P>0.05) than T2 (fish culture with 15 plants /m).

Diver (2006) stated that the fish species was an important consideration when setting up an aquaponics system (growing plants in fish pond). Trout, perch, Arctic char, tilapia and bass were just a few of the warm and cold-water fish suitable for re-circulating aquaculture systems. However, most commercial aquaponics systems in North America were based on tilapia.

Rakocy *et al.* (2006) reported that, when choosing a crop to cultivate, the grower's objective should be taken into account first and foremost. If the objective of the venture is to turn a profit, as it is with commercial scale systems, then crops that have a high market value and short harvesting time will be more appropriate. These include herbs such as basil, chives, cilantro, and parsley whose harvest times are between 25 and 40 days. Other leafy green vegetable of this nature are Swiss chard, Pak Choi, Chinese cabbage, collard and watercress, which in addition to the aforementioned advantages, also experience less pest problems than fruiting plants. Lettuce is the most grown crop in aquaponics due to both its short harvesting time (3-4 weeks) and high demand in western diets. Annual projected yield of basil for the aquaponic system is 5.34 mt for batch production and 5.01 mt for staggered production whereas on field production was 7.7 mt. Fruiting vegetables have a longer growing cycle and often have more pest and disease problems associated with them, but typically receive higher prices at markets.

Wilson and Brian (2006) studied on comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponics test system. Murray Cod, Maccullochella peelii (Mitchell), and Green Oak lettuce, *(Lactuca sativa)*, were used to test for differences between three hydroponic subsystems, Gravel Bed, Floating Raft and Nutrient Film Technique (NFT), in a freshwater Aquaponics test system, where plant nutrients were supplied from fish wastes while plants stripped nutrients from the waste water before it was returned to the fish. The Murray Cod had FCR's and biomass gains that were statistically identical in all systems. Lettuce yields were good, and in terms of biomass gain and yield, followed the relationship Gravel bed > Floating > NFT, with significant differences seen between all treatments. The NFT treatment was significantly less efficient than the other two treatments in terms of nitrate removal (20% less efficient), whilst no significant difference was seen between any test treatments in terms of phosphate removal. In terms of dissolved oxygen, water replacement and conductivity, no significant differences were observed between any test treatments. Overall, results suggest that NFT hydroponic sub-systems are less efficient at both removing nutrients from fish culture water and producing plant biomass or yield than Gravel bed or Floating hydroponic sub-systems in an Aquaponics context.

Savidov (2005) stated that here are also several varieties of plant species that can be grown in soillessmedia integrated with fish pond systems. These fall into three main categories based on the solution conductivity factor (CF) in which the plants perform best. Group 1 comprises plants with high CF and includes tomato and eggplant. Group 2 plants have medium CF and include lettuce, basil, and cucumber. Group 3 consists of plants with low CF and includes watercress.

Lin *et al.* (2005) stated that since the concept of vegetable cultivation in fish ponds (aquaponics) implied use of fish waste as a major source of nutrient for the plant production, the nutrient balance in the fish feed is crucial for the plant. The requirements for potassium were different for plants and for fish. Fish meal, the major component of the fish feeding formulations is not always rich in potassium. The measured level of potassium in the fish effluent was 10 folds less than that of calcium and 5 folds less than sodium in the beginning of the experiment. The recommended Ca: K (calcium: potassium) ratio for hydroponic production of most crops was between 2:1 and 1:1. Ca (calcium) and Na (sodium) interfere with K (potassium) uptake. The increased level of these elements can cause severe K starvation. Thus, the preliminary observations in this system revealed an intrinsic nutrient unbalance in the system based on fish feeding feeds prepared with plant nutrients.

Ghaly *et al.* (2004) stated that high-value vegetable crops, such as tomato, lettuce, cucumber and sweet basil, had cultured in hydroponic media. It was more desirable to grow high priced produce such as herbs to get the best profit per unit area of aquaponics bed.

Rakocy *et al.* (2004) stated that vegetable cultivation in fish ponds is the most efficient food production system in terms of amount of product produced per volume of water. It takes approximately 500 liters of water to produce $100 of product (fish and lettuce), whereas producing cattle take more than 100 times as much water to produce a $100 of product.

Rakocy *et al.* (2004) developed a commercial scale vegetable production system in fish ponds (aquaponics) at the University of Virgin Islands in St. Croix. No major changes in the system had been implemented since 2000, 2002 and 2003, where trials were conducted to evaluate the production of basil and okra. Batch and staggered production of basil in the aquaponics system was compared to field production of basil using staggered production technique. There were four harvests of the basil in batch production with an average yield of 2.0 kg/m. Initially there were savoir of nutrients; however, by the fourth harvest evidence of nutrient deficiency was obvious. The cropping system was therefore changed to a staggered production to moderate nutrient uptake. In the staggered production trial, the plants were cut 2 2 once (1.2 Kg/m) and allowed to re-grow for a final second harvest (2.4 Kg/m).

Wilson (2004) suggested that in terms of plant yield and nutrient stripping, Nutrient Film Technique (NFT) might be as much as 20% less efficient than gravel beds and floating rafts because in gravel bed and raft systems the plant roots were 100% in contact with the water column whereas, in NFT, only up to 50% of the root mass was in contact with the water. It stood to reason that with up to 50% less contact area, plans grown in NFT would grow a bit slower and, therefore, remove a bit less nutrient.

Britto *et al.* (2002) stated nitrate is taken up by the plant at better rates than ammonia which can be toxic to plants. Ammonia concentrations at elevated levels can inhibit nutrient uptake in plants by altering the ionic capacity of the water medium. Depending on plant species sensitivity symptoms of ammonia toxicity appear with external ammonia concentrations above 0.1 - 0.5 Smol/L.

Timmons *et al.* (2002) stated that re-circulating aquaculture (growing fish) was an environmentally responsible alternative to fishing and virtually eliminates bycatch waste which occurs in wild fisheries. Water discharge/replacement requirements was 5% to 10 % of re-circulating water volume per day makes these systems subject to discharge restrictions due to concerns with environmental waste management. RAS can produce more fish per liter of water than other types of aquaculture systems therefore reducing water used.

Randall and Tsui (2002) reported that the success of recirculating aquaponic systems relies on a healthy environment for both fish and plants, by securing good aeration, a suitable pH in the system, efficient biological conversion of harmful ammonia to beneficial nitrate and the plant uptake of dissolved nutrients. Plants utilize nitrogen mostly as nitrate (NO_3^-) or ammonium (NH_4^+), but the total ammonium nitrogen (TAN) in the fish waste consists of two forms, i.e., ammonia (NH_3) and ammonium (NH_4+). Generally, biological membranes are highly permeable to NH_3 but impermeable to NH_4^+, consequently causing NH_3 toxicity to fish at high concentrations. The NH_3/NH_4^+ balance, and thereby the level of toxicity of TAN, is related to the pH within the system, with NH_3 predominating at higher p^H.

Popma and Masser (1999) stated that Continuous supply of adequate amounts of aeration to fish and the bacteria bio-filter in a re-circulating system is essential to its proper operation. Tilapia needs at least 5 mg/L of dissolved oxygen for optimal growth, and if concentrations fall below 2.5 mg/L they have significant growth retardation.

Bailey *et al.* (1997) also found that aquaponic farms can be profitable in the U.S. Virgin Islands. The authors analyzed data from three sizes of farms producing tilapia and lettuce. Each farm size had positive returns but the smallest farm presented the lowest return and could not be an acceptable investment given the risks associated with aquaponic farming. The lettuce revenue was important to cover the costs of both products. These published results may not be transferrable to farms in the Midwest region because the tropical climate of the study locations might keep some cost factors such as heating low compared to operations in colder climates. Furthermore, prices of many inputs and outputs in these tropical locations could differ considerably from prices in the Midwest so that estimations of costs and revenues may not be comparable between the two locations.

2.2 Role of GA_3 for vegetable production

Tahir *et al.* (2019) conducted a field study to evaluate the effect of different plant growth regulators (PGRs) applied through seed priming and foliar spray on growth and yield of three okra cultivars grown under calcareous soils. The cultivars of Punjab Selection and Sabzpari produced significantly higher number of branches and leaves per plant, pod length and diameter and pod yield as compared to cv. Green ferry, while, cv. Punjab selection produced significantly greater number of flowers and pods per plant as compared to other two cultivars. Seed germination (%), plant height, and fruit set (%) were not affected by the cultivars. Among the PGR treatments, seed primed with GA_3 resulted in significantly higher germination percentage and greater plant height at flowering. Seed priming and foliar spray with NAA and GA_3 were effective in increasing the final plant height, number of branches, number of leaves, number of flowers and number of pods per plant and fruit set (%), fresh weight per pod and pod yield. However, pod diameter, pod moisture content and dry weight per pod were not influenced by the PGR treatments applied. These results suggested that the PGRs have great potential to improve seed germination, enhance growth and increase yield of okra cultivars under calcareous soils.

Miceli and Moncada (2019) carried out an experiment to study the efficacy of supplementation of low levels of gibberellic acid (0, 10^{-8}, 10^{-6}, and 10^{-4} M GA_3) through the mineral nutrient solution of a floating system on yield and quality of leaf lettuce and rocket plants was tested. The marketability of plants was lost when 10^{-4} M GA_3 was added to the mineral nutrient solution. This study demonstrated that the addition of 10^{-4} M GA_3 exceeded the acceptable threshold for use in hydroponics production systems. Below the concentration of 10^{-4} M, the presence of GA_3 in the mineral nutrient solutions (MNS), especially at 10^{-6} M GA_3, stimulated plant growth and enhanced the yield. Various morphological and physiological traits were enhanced by GA_3 treatments (biomass accumulation, leaf expansion, stomatal conductance, water use efficiency (WUE), Nitrogen use efficiency (NUE), etc.), with superimposable trends in both lettuce and rocket. The addition of 10^{-6} M GA_3 to the nutrient solution of a hydroponic floating system can promote growth and quality of lettuce and rocket plants.

Verma *et al.* (2019) conducted a field experiment during Kharif season of 2012-13. Combination of gibberellic acid and maleic hydrazide, treatment T_9 (100 ppm MH + 60 ppm GA_3) was found significantly superior as compared to other treatments. Highest morphological characters (*viz.*, plant height, number of leaves per plant, number of branches per plant, stem girth per plant and leaf area index) and yield attributes (*viz.*, no of fruits per plant, fruit yield/plant and fruit yield/ha) were recorded in T_9 (100 ppm MH + 60 ppm GA_3). Maximum fruit yield of 125.29 q/ha obtained in treatment T_9 but maximum net return of

Rs 88698 /ha and cost benefit ratio of 1:3.52 was observed in treatment T_8 (100ppm MH+ 40 ppm GA_3).

Chormule and Patel (2017) conducted an investigation entitled "Effect of spacing and plant growth regulators on plant growth parameters, seed yield and its attributes of okra [*Abelmoschus esculentus* (L.) Moench]" with two consecutive seasons (kharif 2015 and kharif 2016). Seeds of okra variety GJO-3 were treated with aqueous solution of growth regulators *viz.*, GA_3, IBA and NAA, each at 50, 100 and 150 ppm concentrations and without growth regulators (water soaking) and with three plant spacing (S_1 : 45 cm × 30 cm, S_2 : 60 cm × 30 cm and S_3 : 60 cm × 45 cm). All plant growth parameters, seed yield and its attributes studied were significantly influenced by different plant spacing and application of different plant growth regulators. Interactions effects of spacing and seed treatments (S × T) with growth regulators were found significant for field emergence, number of branches per plant, fruit length and fruit thickness during kharif 2015; for fruit length and fruit thickness during kharif 2016; and for field emergence in pooled over years. A combination of wider plant spacing 60 cm × 45 cm and GA_3 @ 150 ppm was found best suited combination, as it has good field emergence and produced significantly and/or comparatively the maximum plant height, stem diameter, number of branches per plant, number of fruits per plant, fruit length, fruit thickness, number of seeds per fruit and seed yield per plant.

Meena *et al.* (2017) conducted a field experiment with eight treatments consisting of three levels of GA_3 (10, 20, 30 ppm), three levels of naphthalene acetic acid (10, 20, 30 ppm), were tested in randomized block design with three replications. Results showed that spray of naphthalene acetic acid, gibberellic acid significantly influenced the performance of growth attributes *viz.*, plant height, fruit length, fruit diameter, number of fruits per plant, average weight of fruits per plant, yield per plot as well as per hectare. The best treatment for growth parameter and yield attributes was found at 20-ppm naphthalene acetic acid (T_6) 40 days after sowing. The maximum net profit of Rs. 152344.3 per hectare was obtained when the crop was treated with 20-ppm naphthalene acetic acid with benefit: cost ratio 2.68:1.

Singh *et al.* (2017) conducted a field experiment during the kharif season to study the effect of GA_3 and NAA on yield and quality of Okra. Yield parameters like number of fingers harvested per plant, average weight of finger, yield per plant, yield per plot and yield per hectare and quality parameters like total number of pickings, thickness of finger and length of finger were analyzed. The experiment consisted of 16 treatments combination involving two growth regulators with four levels each (0, 25, 50 and 75 ppm). GA_3 and NAA (75 ppm) was found to be the most effective in increasing more number of fingers harvested per plant (15.10), total number of pickings (9.33) and thickness of finger (1.54 cm). Treatment combinations of (GA_3 75 and NAA 50 ppm) increased average weight of finger (16.28 g) and yield per plant (0.232 g). Maximum length of finger (15.82 cm) was found treatment combinations of (GA_3 and NAA 50 ppm each).

Dev *et al.* (2017) conducted a field experiment to ascertain the influence of foliar application of plant growth regulators (PGRs) and nutrients with different concentrations on yield and its contributing characters. The experiment consisted of two growth regulators and four nutrients in different concentrations. The different treatment concentration tested were NAA (25, 50 and 75ppm), GA_3 (25, 50 and 75ppm), $MnSO_4$ (2000 and 4000 ppm), $FeSO_4$ (2000 and 4000 ppm), $MgSO_4$ (2500 and 5000 ppm), $CuSO_4$ (1000 and 2000 ppm) and Control (water spray). All variables parameters regarding yield attributes were significantly influenced by different concentrations of the growth regulators and nutrients. Results revealed that among all the treatments, the foliar application of GA_3 (75 ppm) registered significantly higher reproductive aspects viz., number of flower per plant (22.88), number of pod per plant (20.68), fruit setting (90.34 %), pod length (20.63 cm), pod diameter (1.77 cm) and green pod yield (15.23 t/ha) over NAA and other treatments.

Tomar *et al.* (2016) showed that the combinatorial use of GA_3, NAA and 2, 4-D at specific concentration (GA_3 at 30 ppm, NAA at 30 ppm and 2, 4-D at 5 ppm) considerably increase the weight of fruit and significantly increases total yield up to 523 q/h in tomato.

Maity *et al.* (2016) carried out a field experiment to evaluate the effects of GA_3 and IBA on growth and yield attributes of okra (*Abelmoschus esculentus* L. Moench) cv. Arka Abhay. Four treatments each of GA_3 @ T_3-25, T_4- 50, T_5-100 and T_6-150 (ppm) and IBA @ T_7-25, T_8-50, T_9-100 and T_{10}-150 (ppm) were used besides controls i.e. T_1- without spray and T_2-with water spray. Both growth regulators were found to enhance early flowering. Other parameters of growth and yield were also found to be increased by treatments with growth regulators in okra. The results revealed that highest yield was recorded from T_6 (324.87 g/plant) followed by T_7 (314.17 g/plant). All the growth and yield parameters of okra were more positively influenced by GA_3 as compared to IBA under respective treatment.

Jyoti *et al.* (2016) carried out an experiment to study the influence of different growth regulators on seed yield and seed quality parameters in ridge gourd [*Luffa acutangula* (Roxb) L.]. The results indicated that significantly the highest average fruit weight (32.76 g), matured fruit yield per plant (65.84 g), 100 seed weight (13.41 g) and seed yield per plant (12.79 g) was recorded with spraying of 500 ppm ethereal, whereas significantly the maximum fruit length (20.89 cm) and fruit diameter (5.15 cm) with 25 ppm GA_3. Significantly the highest seed germination (69.22 %) was recorded with spraying of 250 ppm ethereal, while application of NAA at 50 ppm recorded significantly the highest vigour index I (2737.85) and vigour index II (5029.33). Spraying of PGR at two to four leaf stage recorded the higher fruit length (20.19 cm), fruit yield per plant (47.49 g), 100 seed weight (13.18 g) and seed yield per plant (11.98 g) as well as highest germination (60.90%), vigour index I (2460.80) and vigour index II (4377.66).

Chandiniraj *et al.* (2016) reported that maximum plant height (75.60 cm), plant spread in north-south direction (46.53 cm), number of days to flowering (47.56) and maximum fruit diameter (1.24 cm) were recorded in GA_3 60 ppm treated plants in chilli.

Thomson *et al.* (2015) examined the effect of plant growth substances on growth, flowering, yield and economics of garden pea, *(Pisum sativum)* L cv. Bonneville. Plants were sprayed with treatments *viz* control, NAA at (25 and 50 ppm), GA_3 at (50 and 100 ppm), the results revealed that the plant growth substance GA_3 at (100 ppm) showed highest growth parameters. Days to first flowering ranged between 48.97 and 52.75. The minimum days (48.97) to first flowering were taken by the treatment GA_3 at (100 ppm) and all other treatments were *statistically at par* for the days taken to first flowering.

Rathod *et al.* (2015) reported that the maximum plant height (34.53 cm), plant spread (31.46 cm), number of leaves per plant (15.73) and number of branches per plant (7.66) in treatment where GA_3 at 200 ppm was applied, while minimum plant height (25.93 cm), plant spread (24.70 cm), number of leaves per plant (11.66) and number of branches per plant (5.20) respectively observed in the treatment in Cycocel 200 ppm, in French bean.

Ravat and Makani (2015) reported that among the different treatments GA_3 @ 100 ppm was the best for growth characters *viz.*, plant height (cm), number of leaves, number of internodes per plant, days to flower initiation and days to 50 (%) flowering. While the start sprayed with thiourea @ 500 ppm yielded the best for growth characters *viz.* leaf area (cm^2), leaf area index and total dry weight of the plant. Ravat and Makani (2015) also reported that among the different treatments GA_3 @ 50 ppm was the best for seed quality traits *viz.*, average pod weight, 100 seed weight, while the plants sprayed with thiourea @ 500 ppm best for fruit yield traits viz., number of pods per plant, length of pod, number of seeds per pod, seed yield per plant and seed yield per hectare.

Mehraj *et al.* (2015) found that the tallest plant (89.0 cm), longest petiole (29.0 cm), number of leaves (49.0 per plant), leaf area (29.7 cm^2), number of branches (5.5 per plant), fresh weight (84.5 g/plant) and dry weight (10.9 g/plant) was from G_1 (GA_3 50 ppm) which was statistically identical with G_2 (NAA 50 ppm) while minimum from G_0 (control fresh water). The maximum number of pods (33.4/plant), pod length (17.5 cm), pod diameter (1.7 cm) and fruit yield (338.1 g/plant, 2.9 kg/plot and 16.4 t/ha) were also recorded from G_1 (50 ppm GA_3) which was statistically identical with G_2 (50 ppm NAA) while minimum from control. GA_3 and NAA have the potentiality to increase the yield of okra but GA_3 was found to be most effective in the present study.

Samapika *et al.* (2015) reported that the treatment of GA_3 20 ppm + NAA 100 ppm was significantly superior in terms of growth parameters ***i.e.*** vine length (cm), number of primary branches per plant and number of leaves per plant as compared to control and other applied treatments in cucumber. Treatment GA_3 20 + NAA 100 ppm was also produced highest fruit yield of cucumber as compared to control.

Chowdhury *et al.* (2014) conducted a study during April to September, 2012 to determine the suitability of selected plant growth regulators and the proper use and effectiveness of selected organic manures and also their suitable combinations for successful okra production. The experiment consisted of two factors: factor A: growth regulators as - G_0: control (water), G_1: GA_3 (100 ppm) and G_2: Miraculan (1000 ppm) and factor B: organic manures as - OM_0: control (no manure), OM_1: vermicompost (9 t/ha) and OM_2: poultry manure (11.5 t/ha). The combined use of GA_3 and poultry manure produced the tallest plants. Both the growth regulators and organic manures enhanced early flowering. In case of growth hormone, the highest yield (16.67 t/ha) was recorded from G_1 followed by G_2 (16.49 t/ha). The highest yield (18.03 t/ha) was found from OM_2, closely followed by OM_1 (17.59 t/h). Considering the treatment combinations, the highest yield was harvested from G_1OM_2 (19.62 t/ha), followed by G_1OM_1 (19.01 t/h), G_2OM_1 (18.42 t/h) and G_2OM_2 (18.30 t/h), respectively.

Geeta *et al.* (2014) conducted an experiment to find out the effect of plant growth regulators on leaf biochemical parameters (chlorophyll pigments, sugars, nitrate reductase activity, total phenols) and fruit yield bitter gourd (*Momordica charantia* L.) was studied. The experiment consisted of foliar treatment with three plant growth regulators, GA_3 (20, 40 and 60 ppm), NAA (50 ppm) and CCC (100 and 200 ppm) in two bittergourd varieties, MHBI-15 and Chaman Plus at 45 days after sowing (DAS). Results revealed significant difference between treatments on chlorophyll, sugar, total phenol content as also on nitrate reductase activity. Foliar application of CCC (200ppm) recorded maximum amount of total sugars (18.03% over Control), total phenol content (10.93%) as also nitrate reductase activity (16.12%). Among the treatments, application of GA_3 (20ppm) recorded maximum chlorophyll content (18.03% over Control). Highest increase in mean fruit yield over Control was recorded with application of GA_3 (20ppm) (39.88%), followed by CCC (200ppm) (34.15%) in both the cultivars.

Mohammadi and Khah (2014) conducted an experiment to study the effect of foliar application of gibberellic acid (GA_3) to okra at an early stage of plant growth (3-4 leaves) on plant growth, pod and seed characteristics in relation to harvest time. GA_3 was applied at concentrations of 0 (Control), 50, and 100 mg L^{-1} to four okra cultivars ('Boyiatiou', 'Veloudo', 'Clemson' and 'Pylaias') and pods were harvested 30, 35, 40 and 50 days after anthesis (DAA) from the lower part of the plant. From the results it was found that GA_3 application increased plant height irrespective of cultivar and GA_3 concentration (50 and 100 mg L^{-1}), but without increasing flower induction or pod set. Similarly, GA_3 had no effect on pod dimensions (which were determined by genotype) or mean 100 seed weight, except in Boyiatiou. Similarly, GA_3 application did not consistently affect seed moisture content, but it did however, increase the number of seeds per pod. Germination was either promoted ('Veloudo'), inhibited ('Boyiatiou') or not affected ('Pylaias', 'Clemson') by GA_3. Differences in germination were apparently related to the incidence of hard seeds. Storage of seeds for 18 months improved germination. Overall, pod and seed characteristics were affected more by genotype and harvest time than by GA_3 application.

Kumar *et al.* (2014) was conducted with the objective to determine the effects of Gibberellic acid (GA_3) on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety Golden, and six treatments with five levels of gibberellic acid (GA_3-10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm). The highest plant height, number of leaves, number of fruits, fresh fruit weight, ascorbic acid and total soluble solid (TSS) was found from GA_3-350 ppm.

Moniruzzaman *et al.* (2014) reported that the GA_3 (Gibberellic acid) and NAA (Naphthalene acetic acid) had no significant effect on plant height and stem diameter at the end of the crop period and days to 100% flowering. NAA 40 ppm produced highest percentage of long and medium styled-flower, leaf photosynthesis and Fv/Fm (efficiency of photosystem II). The variety BARI Begun-5 was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Begun-10. NAA 40 ppm coupled with BARI Begun-5 gave the maximum Fv/Fm and long-styled flower percent.

Shahid *et al.* (2013) conducted an experiment with different concentrations (0, 50, 100 & 200 ppm) of gibberellic acid (GA_3) and naphthalene acetic acid (NAA), alone or in different combinations were sprayed on okra plants at 2-true leaf stage, to ascertain their impact on plant growth, pod production, seed yield and seed quality. All variables regarding vegetative and reproductive growth were significantly influenced by different concentrations of the growth regulators except number of days taken to flowering. Growth regulators were less effective when applied individually as compared to their combined use; however, performance of plants treated with individual PGR was better than the untreated plants. The number of leaves plant^{-1} and plant height was higher in plants when sprayed with GA_3 and NAA @ 200+100 ppm as well as with GA_3 and NAA @ 200+200 ppm. The number of pods plant^{-1}, pod length, pod fresh and dry weight, seed yield and seed quality (in terms of germination percentage and 1000-seed weight) was maximum in plants receiving foliar spray of both GA_3 and NAA @ 200+200 ppm. These results signify the role of GA_3 and NAA in okra pod production for fresh consumption as well as for seed yield.

Ayyub *et al.* (2013) revealed that the increase in number of foliar application of GA_3 (100 mg/kg) substantially improved the vegetative growth of okra comparing to control plants. It was found that application at different growth stages of okra predominantly boosted the stem elongation and number of leaves per plant, number of pods per plant, number of seeds per pod, seed weight and seed yield. Therefore it can be concluded that foliar application of GA_3 may be an effective strategy for maximizing the growth and yield of okra.

Prasad *et al.* (2013) found that there was a linear increase in growth parameters like plant height and number of branches per plant with increasing level of GA_3 and NAA. The maximum plant height was recorded as 85.3 cm and 82.3 cm with the application of GA_3 @ 80 ppm and NAA @ 100 ppm, respectively after 60 days of transplanting in tomato. The maximum fruit yield (483.6 q/ha and 472.2 q/ha) was obtained with the use of 80 ppm GA_3 and 100 ppm NAA, respectively in tomato.

Shahid *et al.* (2013) reported that growth regulators were less effective when applied individually as compared to their combined use however performance of plant treated with individual PGR was the better than untreated plants. The numbers of pods per plant, pod length, pod fresh and dry weight, seed yield and seed quality (in terms of germination percentage and 1000 seed weight) was maximum in plants receiving foliar spray of both GA_3 and NAA @ 200+200 ppm. These results signify the role of GA_3 and NAA in okra pod production for fresh consumption as well as for seed yield.

Choudhury *et al.* (2013) observed that maximum plant height at 60 DAT (86.01cm), number of flowers cluster per plant (10.60), number of flowers per plant (39.69), number of fruits per plant (36.54), single fruit weight (74.01 g) and yield (28.40 t/ha) were found the minimum for all the parameters in tomato were found in control.

Dhage *et al.* (2011) found that significant effect for plant height (107.74 cm) and intermodal length (3.1 cm) in treatment GA_3 at 150 ppm whereas, numbers of branches (3.53) were found maximum in the treatment IAA at 100 ppm. However, significantly minimum numbers of days required for first flowering (39.67 days) were recorded in treatment GA_3 at 150 ppm in okra. Significant effect for minimum number of days required for first harvesting (44.67 days) were also recorded in treatment GA_3 at 150 ppm in okra. The significantly maximum parentage of fruit set (74.79) and fruit yield per hectare were observed in same treatment.

Emongor (2011) examined that the effects of GA_3 on the growth, development and seed yield of cowpeas (*Vigna unguiculataL*). Three field trials were carried out to evaluate the exogenous application of GA_3, 7 days after emergence at 0, 100, 200 or 300 mg L^{-1} significantly increased cowpea plant height, first node height, leaf area and leaf number plant^{-1}, nodulation, plant dry matter, pod length, pod number plant^{-1}, seed number pod^{-1}, 100-seed weight, harvest index and seed yield.

Bhagure and Tambe (2011) observed application of GA_3 (50 and 100 ppm) at 30 and 45 days after sowing increase the height of plant, number of leaves, number of internodes, induce early flowering, increase number of flowers, fruit set, number of fruits, and high yield per plant in okra.

Unamba *et al.* (2010) reported that the effect of low concentrations (0,1,5,10,20 and 30 ppm) of gibberellic acid on the growth of *Abelmoschus esculentus* (dwarf) and showed that gibberellic acid significantly stimulated internode elongation, plant height, number of leaves and caused a reduction in the petiole length in both treatment methods. Gibberellic acid also stimulated earlier flowering. The foliar spray application was found to have a significant effect on the plant height when compared with the seed soaking application technique. Although GA_3 stimulated internode elongation, it had no effect on the number of internodes in both the treated plants and the control indicating that dwarfism of this variety of Okra may be due to the absence of adequate endogenous gibberellic acid.

Patil and Patel (2010) reported that GA_3 at 15 mg/l produce the highest percentage of seed germination, stem girth, number of branches, number of leaves per plant and early flowering in okra while GA_3 at 45 mg/l found to be beneficial with respect to plant height, number of internodes and intermodal length. GA_3 at 15 mg/L recorded maximum fruit girth, fruit length, fruit weight, fruit yield per plant and fruit yield per hectare in okra. However, GA_3 at 30 mg/L produced maximum number of fruits per plant. From the economics point of view, NAA 10 mg/L was found to be profitable as compared to rest of treatments.

Surendra *et al.* (2006) revealed that the growth regulators and micronutrients used in this experiment significant increased the plant height. However, among the growth regulators significant increase in plant height was noticed with GA_3 (25 and 50 ppm) and among micronutrients $FeSO_4$ (0.5%) has shown significant increase in plant height. Among the growth regulators and micronutrients the foliar application of GA_3 (25 and 50 ppm) and $FeSO_4$ (0.5%) at 60 days after sowing (DAS) registered significantly higher fresh fruit yield over other treatments. The increase is due to increase in yield attributing components ***viz.***, total number of flowers, fruits per plant, fruit length, number of seeds per fruit, seed weight and harvest index. The benefit: cost ratio was higher with application of GA_3 (50 ppm) over all other treatments. It was also indicated that the increase in fruit yield was significantly higher in GA_3 (25 and 50 ppm) as compared to other treatments and was found lowest in control.

Hoque, *et al.* (2002) investigated two varieties of Mungbean to study the effects of seed treatment and foliar application of GA_3 at 0, 50, 100 and 200 ppm on the growth, yield and yield contributing characters. Seed treatment with GA_3 at 50 ppm increased plant height, number of leaves, fresh and dry weight. Foliar application of GA_3 at 200 ppm had higher plant height and number of leaf, while that at 100 ppm greater number of pods, higher fresh and dry weight of pod, number of seeds whereas 50 ppm GA_3 resulted higher pod length and ultimately seed yield. The mungbean variety V_2 performed better than V_2 with foliar application of GA_3. This study indicates high potentiality to increase yield of mungbean in Bangladesh by the application of GA_3.

2.3 Role of vermicompost for vegetable production

Singh *et al.* (2019) conducted a field experiment to study the assessment of performance of balanced fertilization and integrated use of vermicompost on yield of okra (*Abelmoschus esculentus* L.) *var.* Kashikranti. The treatments involved was T_1 - Farmers practice (use of only urea 120kg/ha), T_2 - 100% recommended dose of fertilizers (120:60:40kg/ha), T_3 - 50% recommended dose of fertilizers + 50% of vermicompost (12.5q/ha) and T_4 - 100% of vermicompost (25q/ha). The results revealed the application of T_3 brought a significant effect on growth and yield of Okra. Field experiment showed that the maximum plant height (116.10cm), 50% flower initiation (40.00DAS), number of branches per plant (4.50), number of fruits per plant (22.24), fruit length (16.20cm), fruit diameter (5.24cm), fruit weight (25.30g), fruit yield per plant (151.44g) and yield per hectare. (132.24 q/ha). Vermicompost applied at very low rate (2.5 ton/ha) can significantly increase yield of highly valuable vegetable and fruit crops. Combination of vermicompost and inorganic chemical fertilizer resulted in the maximum number of flowers and fruits per plant of okra plant. Hence, the combined application of appropriate dose of vermicompost and chemical fertilizers in the field acts as growth promoter resulting in higher yield of okra.

Lakra *et al.* (2017) carried out a field experiment during *Rabi* season 2016-17 having three factors with three levels of N, P, K @ 0, 50, and 100 % ha^{-1}, three levels of vermicompost @ 0, 50 and 100% ha^{-1} respectively. The result obtained with treatment T_5 - (NPK@ 50% + Vermicompost @ 100%) that showed the highest yield regarding, gave the best results with respect to plant height 115.69 cm, number of leaves per plant 49.33, number of branch 48.50, number of fruit per plant 20.71, it gave highest yield, 199.21 q ha^{-1}. The maximum cost benefit ratio was recorded 1: 8.55and net profit. Rs. 37,154.6 ha^{-1} in treatment combination T_5 – (50% N P K ha^{-1} + 100% vermicompost ha^{-1}) combined use of N, P and K resulted in significant increase on enrichment of soil fertility status. Vermicompost (t ha^{-1}) was found to be significant among other treatments in okra cultivation and soil quality improvement. It was also revealed that the application of NPK with vermicompost were excellent source for fertilization than fertilizers. The treatment (T_5) also showed greater benefit cost ratio followed by other treatments.

Sundararasu (2017) carried out the work to evaluate the impact of vermicompost and vermiwash on growth and yield of bottle gourd plants. Available nutrients of the soil both in control and experimental plots were studied and interrupted results. Plant growth, number of leaves per plant, number of flowers and fruits were recorded. Vermicompost and vermiwash treated soil showed increased plant growth, number of leaves, flowers and fruits compared to control soil. Significant yield was recorded on vermicompost and vermiwash added field. The present study suggested that both vermicompost and vermiwash were favorable vigorous yield of bottle gourd.

Nagar *et al.* (2017) studied an experiment on effect of organic manures and different levels of NPK on growth and yield of bottle gourd. The application of vermicompost (5.0 t ha^{-1}). Recorded length of main vine (4.09), number of primary branches per vine (11.85), length of leaf 65 days after sowing (27.35 cm), percent fruit set (55.61), number of fruit per vine (9.8), length of fruit (40.48 cm), girth of fruit (24.96 cm), weight of fruit (954.30 g), yield per vine (8.99), yield (242.70 q ha^{-1}). These finding clearly indicated that vermicompost played a significant role on enhancing the growth of bottle gourd. .

Oroka (2016) carried out a study was to assess the relative efficiency of vermicompost, mineral fertilizer (NPK) or mixture of both on the morphological and yield attributes of okra. The vermicomposts (VC) were prepared from organic wastes (mixtures of food wastes, vegetable clippings, fruit wastes, animal manures and other organic residues). The test crop was okra (var. NHAE 47-4). Six treatments, namely: control (no application), 100%NPK, 100%VC, 85%VC + 15%NPK, 50%VC+ 50%NPK and 15%NPK + 85%VC. The six treatments were arranged in a randomized complete block design with three replicates. Plant morphological characters studied were plant height, leaf number, internode length, shoot fresh weight, shoot dry weight and relative water content while number of pods per plant, pod yield per plant and harvest index were the yield attributes. Crop growth parameters such as plant height, leaf number and internode length tended to significantly ($P<0.05$) increase with higher quantity of vermicompost. The fresh and dry weights per plant significantly increased with addition of organic amendments in form of vermicompost into the soil. On the average 100%NPK recorded the highest relative water content, with 100% vermicompost indicating the least. The response of yield and yield components of okra to soil organic amendments was significant ($P<0.05$). The 100% vermicompost consistently gave higher number of pods per plant and pod yield per plant. The results showed that vermicompost alone and in mixture with NPK significantly increased the plant morphological parameters and yield and yield components.

Sarma and Gogoi (2015) carried out a study to understand the effects of different soil organic amendments on germination and seedling vigour of Okra *(Abelmoschus esculentus* L.). Five treatments with organic amendments (farmyard manure, vermicompost and biochar) and mineral fertilizers were designed. Results showed that organic amendments significantly enhanced percent seed germination and emergence speed index compared to inorganic fertilizer. Plant height, root length and leaf area were higher in vermicompost and biochar than farmyard manure. Both allocation of biomass to above ground parts and Dickson quality index were highest in seedlings from the plots amended with vermicompost. The study revealed that compared to biochar, vermicompost and farmyard manure significantly enhanced the germination and growth of Okra seedling, but the stimulation was best in vermicompost-amended plots.

Namayandeh and Shirdareh (2015) conducted an experiment on The Effect of Compost, Vermicompost and Urea fertilizers on Operation and Operation Facture on Pumpkin Msmayy (*Cucurbita pepo* L.). The results of this experiment showed that the effect of vermicompost and compost has been more than urea in making the number of female flower in Pumpkin Msmayy (*Cucurbita pepo* L). The highest number of female flowers was observed in the conditions of using compost which was concluded in an increase in the number and function of the fruit. The results obtained from this experiment express this matter that the diameter of the fruit causes the diameter of squash fruit to be increased in conditions of using three kinds of the studied fertilizers in this experiment; but compost and vermicompost have shown much more effect on the fruit.

Das *et al.* (2014) conducted a field experiment to study the response of chemical fertilizer and vermicompost on okra (*Abelmoschus esculentus* L.) var. Pravani kranti. The treatments involved was T_1-100 percent chemical fertilizer + 0 percent vermincompost, T_2-75 percent chemical fertilizer + 25 percent vermincompost, T_3-50 percent chemical fertilizer + 50 percent vermicompost, T_4 - 25 percent chemical fertilizer + 75 percent vermincompost, and T_5 - 0 percent chemical fertilizer + 100 percent vermincompost. The results revealed that the application of T_3 had a significant effect on growth and yield of okra. Field experiment showed that maximum plant height (106.13cm), node per plant (7.75), pod per plant (18.65), pod yield per plant (149.46 g), length of pod (17.60cm), 50 percent flower initiation (40 DAS) and yield per ha (110.24 q) were produced with T_3 whereas number of seed per pod were found with the T_1. Vermicompost can increase growth, flowering and yield of vegetable. Vermicompost applied at very low rate 2.5-5 ton/ha can significantly increase yield of highly valuable vegetable and fruit crops. Combination of vermicompost and inorganic chemical fertilizer resultant in maximum number of flowers and pods of okra plants. Hence, the application of appropriate ratio of vermicompost and chemical fertilizers in the field they acts as growth promoter for okra. Proper combination least damage the soil and help to maintain its fertility for a longer period.

Sundari and Gandhi (2013) conducted an experiment to study the effect of vermicompost prepared from water hyacinth (*Eichhornia* sp.), leaf litters and cowdung on growth and yield of okra (*Abelmoschus esculentus*) under greenhouse conditions. Vermicomposting of organic wastes was carried out by using surface burrowing type of earth worms *(Eudrilus eugineae)*. The pot experiment was conducted with four treatments *via* T_1 - control, T_2 - cow dung vermicompost, T_3 - leaf litter vermicompost and T_4 - *Eichhornia* vermicompost. The vegetative growth characters of okra such as plant height, number of leaves per plant and reproductive parameters like number of days of flowering, fruit length, fruit diameter, fruit weight and number of fruits per plant were observed at 20^{th} day, 40^{th} day, and 60^{th} day from the date of planting. There was maximum value of growth parameters observed in leaf litter vermicompost followed by *Eichhornia* vermicompost, cowdung vermicompost and control. Yield parameters also showed the similar trend of growth parameters. The investigation clearly reveals that the biochemical properties of vermicompost play major role in growth and yield of okra.

Anuja and Archana (2011) carried out to an investigation to find out the effect of soil and foliar application of organic nutrients on flowering and fruit set percentage of bitter gourd (*Momordica charantia*) cv. Long Green. Results of the experiment revealed that the application of FYM @ 25 t ha^{-1} and vermicompost @ 5 t ha^{-1} along with panchagavya 3 percent foliar spray improved the number of female flowers and fruit set percentage of bitter gourd cv. Long Green. The same treatment was found to register early maturity of fruits.

Yadav and Yadav (2010) conducted an experiment on okra and observed that the integrated application of 75 percent RDF with vermicompost @ 6.5 t ha^{-1} gave significantly higher marketable fruit yield (86.40 g ha^{-1}), which was at par with the treatments namely 50 percent RDF with vermicompost @ 6.5 t ha^{-1} and 75 percent RDF + Neemcake @ 3.5 t ha^{-1}.

Sharma *et al.* (2010) recorded that application of 5 t vermicompost ha^{-1} recorded significantly higher values of yield attributes, fruit yield (69.2 ha^{-1}) and protein content (18.0%) as well as B:C ratio (2.11) with net returns of rupees 35614 ha^{-1} in okra crop.

Azarmi *et al.* (2009) conducted an experiment on the effect of sheep-manure vermicompost on quantitative and qualitative properties of cucumber (*Cucumis sativus* L.) grown in the greenhouse. The effect of vermicompost on leaf number and height stem was same at 30, 60 and 90 days after transplanting. Plants in plots treated with vermicompost showed increase in growth parameters like leaf area, chlorophyll content, stem dry weight and leaf dry weight than with plots receiving inorganic fertilizer only. Leaf number, plant height and chlorophyll content were significantly affected by vermicompost treatments for both varieties (Sultan F_1. and Storm F_1 at 30, 60 and 90 days after transplanting. Plots with 20 and 30 t ha^{-1} vermicompost had greater leaf numbers than plot without vermicompost at 30, 60 and 90 days after transplanting for both varieties. Application of vermicompost increased stem heights in response to different rates of vermicompost for both varieties at 30, 60 and 90 days after transplanting. 30 days after transplanting, the highest chlorophyll content was obtained at 20 and 30 t ha^{-1} vermicompost, while at 60 and 90 days after transplanting the maximum chlorophyll content was obtained at 30 t ha^{-1} vermicompost for both varieties. The results showed that application of vermicompost had significantly effect on leaf area. The plots treated with vermicompost at 30 t ha^{-1} increased leaf area 18% for cv. Sultan F_1 and 22% for cv. Storm F_1 compared to the control. At 20 and 30 t ha^{-1} of vermicompost, the plants had significantly greater stem and leaf dry weight than the control. This indicates positive effects of vermicompost on growth of cucumber. The results indicated that 20 t ha^{-1} vermicompost was adequate to supply the desirable amount of growth promoting substance for higher growth and yield of cucumber.

Sharma *et al.* (2009) reported that highest yield of okra was recorded in the treatment comprising 100 percent recommended NPK + vermicompost @ 10 t ha^{-1}. Similarly, maximum yield of onion was observed in plant receiving 100 percent recommended NPK + 25 t vermicompost ha^{-1}. The highest yield (11.10 and 11.63 t ha^{-1}) of okra was recorded under the treatment comprising 100% recommended NPK + vermicompost @ 10 t ha^{-1}, during 2003 and 2004, respectively. Similarly, maximum yield of (9.83 and 14.67 t ha^{-1}) was observed in 2003-04 and 2004-05, respectively. Yield of onion obtained at the application of 12.5 t vermicompost ha^{-1} plus 100% NPK (8.38 and 12.56 t ha^{-1}) was at par with that under 25 t farm yard manure ha-^{1} + 100% NPK (8.86 and 12.08 t ha^{-1}) during 2003-04 and 2004-05. This demonstrated that superiority of vermicompost over farm yard manure in okra onion sequence.

Kondappa *et al.* (2009) studied the effect of integrated nutrient management on growth, yield and economics of chilli cv. Byadgi Dabbi and concluded that use of integrated application of vermicompost with fertilizers remained beneficial.

Bairwa *et al.* (2009) reported that okra produced highest number of fruits (18.36), fruit yield (182.50 g plant^{-1} and 135.18 q ha^{-1}), fruit weight (17.65 g), length of fruits (12.26 cm) and thickness of fruits (1.898 cm) with the application of neem cake 6 q ha^{-1} + vermicompost 10 q ha^{-1} + *Azotobacter* + PSB + 60 percent recommended dose of NPK through inorganic fertilizers.

Surindra Suthar (2009) observed that the maximum range of some plant parameters *i.e.* root length, shoot length, leaf length, fresh weight, number of cloves in garlic were in the treatment using 15 t ha^{-1} vermicompost + 50 percent NPK and with applied vermicomposted FYM showed a comparatively better result of plant production than composted manure.

Manivannan *et al.* (2009) studied that the increased growth and yield of the bean, *(Phaseolus vulgaris)* influences the physical conditions of the soil and supported better aeration to the plant roots, absorption of water, induction of N, P and K exchange there by resulting better growth of the plants.

Peyvast *et al.* (2007) showed that an addition of vermicompost to soil can increase plant height and number of leaves significantly in spinach. Similarly, Vitakar *et al.* (2007) reported that treatment with 50% N through vermicompost and 50% N through neem cake produced the highest plant height, number of primary branches, number of fruits per plant, fruit weight, fruit length, fruit diameter and total yield per hectare compared to recommended dose of fertilizers in chilli crop.

Rajan and Mahalakshmi (2007) reported that the number of leaves produced in radish and cowpea seedlings were higher in treatment containing 75 percent vermicompost. The leaf area, tuber length, and wet weight of radish were higher in 100 percent vermicompost applied plots.

Application of 100 percent nitrogen as vermicompost registered the higher plant height and number of branches per plant of tomato and it was significantly superior over supplementation of 100 percent N through urea and FYM (Kannan *et al.* 2006).

Chander *et al.* (2005) recorded the highest yield of okra in the treatment comprising 100 percent recommended NPK + vermicompost @ 10, 11.10 and 11.63 t/ha and maximum yield (14.67 t ha^{-1}) of onion was observed in plots receiving 100 percent recommended NPK + 25 t vermicompost ha^{-1}.

A progressive increase in plant height and leaf area index of soyabean was observed with the conjunctive use of 75 percent N through vermicompost and remaining 25 percent N through chemical fertilizer and was found at par with 100 percent N through vermicompost alone. The additive benefit realized from vermicompost application (Govindan and Thirumurugan, 2005) might be ascribed to its higher nutrient contents and their availability to crop.

Yadav and Vijyakumari (2004) carried out an experiment to assess the effect of vermicomposted vegetable waste on the biochemical characters of chilli and found that the protein was higher on 60 (113.37 mg/g) and 90 days (79.69 mg/g) after sowing. The carbohydrate content (15.34 mg/g) was higher in vermicompost treatment on 60 days after sowing. On 60 days after sowing, higher chlorophyll b (2.61 mg/g) and total chlorophyll (3.62 mg/g) contents were observed while on 90 days after sowing higher chlorophyll a (1.01 mg/g) and total chlorophyll (1.92 mg/g) content were observed with vermicompost alone.

Jat and Ahlawat (2004) reported that the vermicompost application @ 3 ton ha^{-1} significantly increased the growth and yield attribute (pods/plant), and seed straw yield of chick pea over control.

Hashemimajd *et al.* (2004) revealed that the treatment vermicompost produced from raw dairy manure (RDM) along with some other composts (sewage sludge + rice hull) gives greatest shoot and root dairy matters (DM) of tomatoes than the control (soil + sand).

Rajkhowa *et al.* (2003) observed that application of vermicompost @ 2.5 t ha^{-1} being at par with 2.5 FYM t ha^{-1} significantly increased the number of pods per plant, seeds per pod and 1000 grain weight of green gram over control.

Netwal (2003) conducted a field experiment at Jobner during *kharif* season of 2001 and reported that application of vermicompost of 5 t ha^{-1} significantly increased the pods per plant, seed per pod, harvest index and seed and straw yield of cowpea over control 5 t FYM and 2.5 t vermicompost ha^{-1}.

Arancon *et al.* (2003) reported that when vermicompost applied at 5 t ha^{-1} or 10 t ha^{-1} the marketable tomato yield in all vermicompost treated plots were considerably greater than yield from the inorganic fertilizer plots.

Kumar *et al.* (2003) reported that plant height and dry matter accumulation per plant of mungbean improved significantly with application of vermicompost @ 5 t ha^{-1} over control. Vermicompost @ 5 t ha^{-1} produced 16.5 and 9.5 percent higher grain yield of mungbean compared to FYM at 5 t ha^{-1} and vermicompost at 2.5 t ha^{-1}, respectively.

Samawat *et al.* (2001) reported that vermicompost had a significant effect on root and fruit weight of tomatoes. In 100 percent vermicompost treatment, fruit weight and shoot and root weight were three, five and nine times more than the control, respectively.

Shreeniwas *et al.* (2000) working with ridge gourd cv. Pusa Nasdar found that the increased rates of vermicompost increased fruit yield. The vermicompost @ 10 t ha^{-1} + 50:25:50 kg NPK ha^{-1} increased the fruit volume, fruit weight, fruit yield per vine in ridge gourd.

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken to study okra production in the fish pond through the application of gibberellic acid and vermicompost. This chapter deals with the materials and methods those were used conducting the study are described below:

3.1 Experimental site

This experiment was carried out on fish pond near the Horticulture farm at the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during July to October 2019. Location of the experimental site was 23°74'N latitude and 90°35'E longitude at an altitude of 8.6 meter above the sea level, which have been shown in the Appendix I.

3.2 Climatic conditions

The experimental site is situated in the subtropical monsoon climatic zone. Generally this zone is characterized by heavy rainfall during the months from April to November in kharif season. The overall weather condition at the experimental site during the cropping season July to October 2019 have been presented in Appendix II including minimum and maximum temperature, rainfall, relative humidity and sunshine hours etc.

3.3 Dissolved nutrients in pond water

Physical and chemical analysis of pond water where the present study was conducted was done in the Laboratory of Fisheries Biology and Genetics, Sher-e-Bangla Agricultural University, Dhaka-1207. The characteristics of pond water have been presented in the following Table 1.

Table 1. Physical and chemical properties of pond water

Item	Characteristics
Temperature	29°C
pH	7.6
Dissolved oxygen (DO)	6.40 mg L^{-1}
Ammonia (NH_3)	0.03 mg L^{-1}
Phosphate (PO_4)	0.74 mg L^{-1}
Nitrate (NO_3)	0.07 mg L^{-1}

3.4 Planting materials

Seeds of high yielding okra - Lal Teer hybrid dheros were purchesed from Krishibid Nursery, Sher-e-Bangla Nagar, Dhaka and used for the present study.

3.5 Treatments of the experiment

The experiment consisted of two factors:

Factor A: Gibberellic acid (GA_3)

1. G_0 = 0 ppm GA_3 (Control)
2. G_1 = 100 ppm GA_3

Factor B: Vermicompost

1. V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water)
2. V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water
3. V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

3.6 Design and layout of the experiment

The experiment was laid out in a Completely Randon Design(CRD) with five (5) replications. The 30 plants were planted in the 30 plastic pots. One plant was transplanted per plastic pot. The plastic pot size was 21 cm in height with the depth of 17 cm. Sample setup of the experiment according to the layout is presented in Plate 1.

Plate 1. Setup of the experiment in the fish pond

3.7 Sowing of seeds

Seeds were sown in selected pots on 29th July 2019. Two seeds were sown in each pot. One seedling was removed keeping another healthy and vigorous seedling in each pot.

3.8 Raft preparation

Raft was prepared by cork sheet and bamboo slits strongly tied with rope. The raft was 3 ft in length and 2 ft in breadth. The prepared raft was shown in Plate 2.

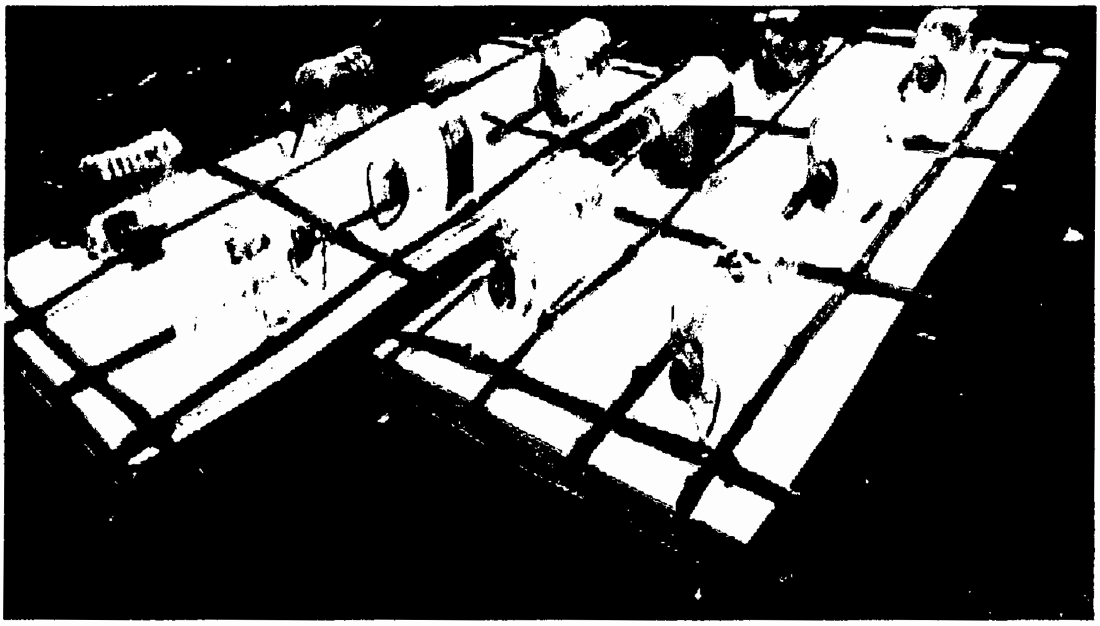

Plate 2. Raft preparation with cork sheet and bamboo slit

3.9 Pot preparation

Before sowing of seeds, pots were prepared with coco peat, broken bricks and vermicompost according to the treatment assigned. Pots were made completely stubbles and weed free. Sample pot preparation is presented in Plate 3.

Plate 3. Pot preparation with vermicompost, coco peat and broken bricks

3.10 Manure and fertilizer application

No chemical fertilizer was used. Only vermicompost was used according to the treatments in each pot.

3.11 Application of growth regulator

The selected growth regulator (GA_3) was applied at three times on foliage, first at 25 days after sowing (DAS), second at 32 DAS and third at 42 DAS with the help of hand sprayer.

3.12 Intercultural operations

Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were weeding, staking, etc.

3.12.1 Stalking

Stalking was given to each plant by bamboo sticks for support, when the plants were well established.

3.12.2 Weeding

Weeding was done whenever it was necessary, mostly in vegetative stage for better growth and development.

3.12.4 Pest control

No insect attack was found during cropping duration and also there was no incidence of disease. So, no insecticide and fungicide was applied in the crop during the experimental period.

3.13 Harvesting

Several times harvesting was done started from 5 October, 2019. Harvesting was done based on eating quality at soft and green condition from every plant of every pot. Data on yield parameters were recorded at each harvest.

3.14 Data collection

Recording of experimental data started from 30 days after sowing (DAS) and continued until last harvest. The following data were recorded during the experimental period.

3.14.1 Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Chlorophyll content at 50 DAS
5. Average foliage coverage (cm^2)
6. Stem base diameter (cm)

3.14.2 Yield contributing parameters

1. Number of flowers plant^{-1}
2. Number of fruits plant^{-1}
3. Fruit length (cm)
4. Fruit diameter (cm)

3.14.3 Yield parameters

1. Single fruit weight (g)
2. Fresh weight of fruits plant^{-1} (g)
3. Fruit yield (t ha^{-1})

3.14.4 Quality parameters

1. Vitamin C content

3.15 Procedure of recording data

3.15.1 Plant height (cm)

Plant height was measured from the sample plants in centimeter from the ground level to the tip.To observe the growth rate plant height was recorded at 30, 50 and 70 days after sowing.

3.15.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was measured from the sample plants and total leaves were counted from each plant of each pot considering each replication and mean value was calculated. Number of leaves plant^{-1} was recorded at 30, 50 and 70 days after sowing.

3. 15.3 Number of branches plant^{-1}

The total number of branches plant^{-1} was counted from each pot at 50 and 70 days after sowing and mean values was calculated.

3.15.4 Chlorophyll content

Chlorophyll content was measured from okra leaves from each replication with the help of SPAD meter and it was measured at 50 DAS.

3.15.5 Foliage coverage (cm^2)

Foliage coverage was measured by leaf length multiplied by leaf breadth and was expressed in cm^2 from each plant of each pot. It was measured at 30, 50 and 70 days after sowing.

3.15.6 Stem base diameter (cm)

Diameter of stem base was measured from each plant of each pot with a digital slide calipers-515 (DC-515) and average was taken and expressed in cm.

3.15.7 Number of flowers plant^{-1}

Total number of flowers was counted from each plant of each pot. It was done at ten days interval after first flowering to ensure all flowers to be counted.

3. 15.8 Number of fruits plant^{-1}

The number of fruits in every plant of each pot was counted at every harvest and thus the total number of fruits per plant was recorded and average number of fruits was calculated.

3.15.9 Fruit length (cm)

Length of 10 randomly selected fruits per pot was measured and then the average was taken and expressed in cm.

3.15.10 Fruit diameter (cm)

Diameter of 10 randomly selected fruits per pot was measured and then the average was calculated in cm.

3. 15.11 Single fruit weight (g)

The weight of randomly selected 10 fruits per pot was recorded and then the average weight per fruit was calculated in gram.

3.15.12 Fresh weight of fruits plant^{-1} (g)

To estimate weight plant^{-1}, all fruits weight from the plant of each pot was recorded from all harvest and total weight were recorded. Thus the yield per pot was measured. Fresh weight of fruits plant^{-1} was expressed in gram.

3.15.13 Fruit yield (t ha^{-1})

To estimate yield, all harvest fruits weight of each plant of each pot was considered. Total fruit weight per pot was measured. The yield per hectare was calculated considering the area covered by each pot.

3.15.14 Vitamin C content

Vitamin C was determined by using the procedure as outlined by Food Analysis Laboratory Manual using Indophenol method (Nielsen, 2017) and AOAC International Methods (AOAC, 1990). 10 g of each of the samples with the exception of okra was accurately weighed and ground using mortar and pestle with an additional of 20 ml of metaphosphoric acetic acid. The mixture was further ground and strained through muslin and the extract was made up to 100 ml with the metaphosphoric-acetic acid mixture. 5 ml of the metaphosphoric-acetic acid solution was pipetted into three of the 50 ml Erlenmeyer flask followed by 2 ml of the samples extract. The samples were titrated separately with the indophenol dye solution until a light rose pink persisted for 5 s. The amount of dye used in the titration were determined and used in the calculation of vitamin C content.

3.16 Statistical analysis

The recorded data on different parameters were statistically analyzed using MSTAT software to find out the significance of variation resulting from the experimental treatments. The mean for the treatments was calculated and analysis of variance for each of the characteristics was performed by F (variance ratio) test. The differences between the treatment means were evaluated by LSD test at 5% probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted on utilization of fish waste, vermicompost and GA_3 for quality okra production in the fish pond through the application of gibberellic acid and vermicompost. This chapter comprises the arrangement and discussion of the results obtained due to the application of two different GA_3 and three different vermicompost applications on okra. The results have been presented, discussed, and possible interpretations have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

Plant height of okra increased at different growth stages in the fish pond through the application of gibberellic acid compared (GA_3) to control. Significant variation was found on plant height of okra as influenced by GA_3 except at 30 DAS (Figure 2 and Appendix III). However, results revealed that the highest plant height (13.23, 54.31 and 79.65 cm at 30, 50 and 70 DAS, respectively) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest plant height (12.25, 49.55 and 73.33 cm at 30, 50 and 70 DAS, respectively) was found from control treatment G_0 (0 ppm GA_3). Similar result was also observed by Tahir *et al.* (2019), Chormule and Patel (2017), Mehraj *et al.* (2015), Mohammadi and Khah (2014) and Shahid *et al.* (2013) who observed significantly higher plant height, than untreated controls.

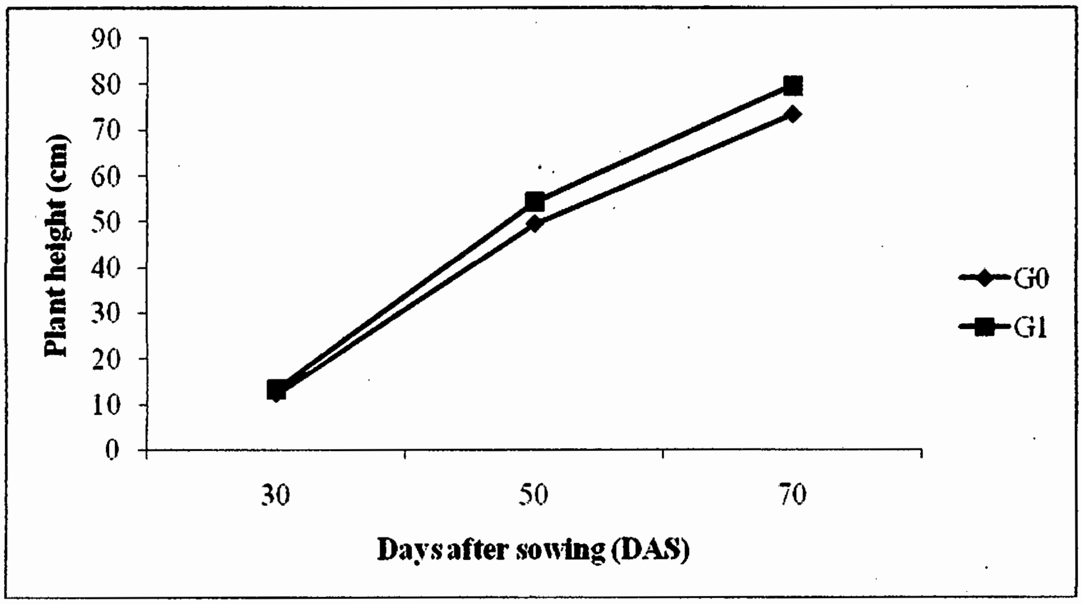

Figure 2. Plant height of okra in the fish pond through the application of gibberellic acid ($LSD_{0.05}$ = NS, 1.24 and 2.08 at 30, 50 and 70 DAS, respectively)

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

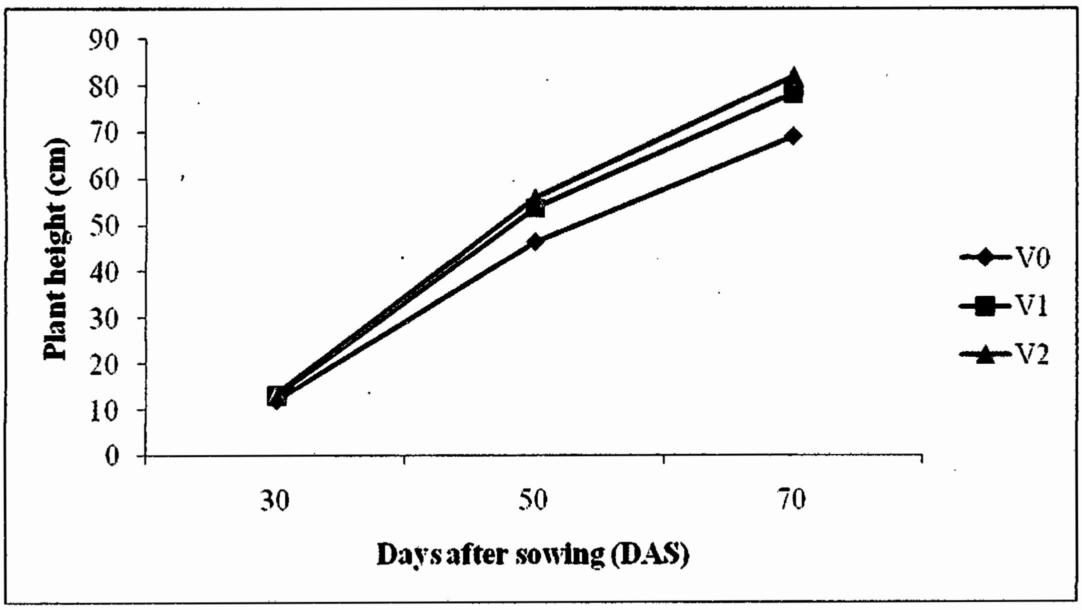

Figure 3. Plant height of okra in the fish pond through the application of vermicompost ($LSD_{0.05}$ = NS, 2.11 and 2.24 at 30, 50 and 70 DAS, respectively)

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Table 2. Plant height of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Plant height (cm)		
	30 DAS	50 DAS	70 DAS
G_0V_0	11.88 d	44.56 d	67.29 f
G_0V_1	12.32 cd	50.38 c	74.03 d
G_0V_2	12.54 c	53.71 b	78.66 c
G_1V_0	11.94 d	48.22 c	70.98 e
G_1V_1	13.63 b	56.79 a	82.58 b
G_1V_2	14.11 a	57.92 a	85.38 a
$LSD_{0.05}$	0.45	2.43	2.61
CV(%)	6.36	8.51	7.27

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

The recorded data on plant height of okra at different growth stages was significant except 30 DAS influence by vermicompost cultivated under soillesssystem in the fish pond (Figure 3 and Appendix III). Results showed that the highest plant height (13.33, 55.81 and 82.02 cm at 30, 50 and 70 DAS, respectively) recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest plant height (11.91, 46.39 and 69.13 cm at 30, 50 and 70 DAS, respectively) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). The results indicated gradually increased plant height was achieved with increased levels of vermicompost and tallest plant was produced at different growth stages by the maximum application of vermicompost than that of control with ensuring the better growth and development. Similar result was also observed by Singh *et al.* (2019), Lakra *et al.* (2017), Sarma and Gogoi (2015) and Das *et al.* (2014).

Considerable influence was observed on plant height of okra at different growth stages in the fish pond as persuaded by combined effect of GA_3 and vermicompost (Table 2 and Appendix III). Results revealed that the highest plant height (14.11, 57.92 and 85.38 cm at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_1V_2 which was statistically identical with G_1V_1 at 50 DAS but at 30 and 70 DAS, it was significantly different from other treatment combinations. The lowest plant height (11.88, 44.56 and 67.29 cm at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_0V_0 which was significantly different from other treatment combinations at 50 and 70 DAS, but at 30 DAS, it was statistically similar with the treatment combination of G_1V_0 and G_0V_1.

4.1.2 Number of leaves plant^{-1}

Compared to control, number of leaves plant^{-1} of okra was increased with GA_3 application under soillesssystem in fish pond. GA_3 had significant influence on number of leaves plant^{-1} at different growth stages (Figure 4 and Appendix IV). It was found that the highest number of leaves plant^{-1} (12.24, 18.81 and 22.64 at 30, 50 and 70 DAS, respectively) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest number of leaves plant^{-1} (10.25, 16.93 and 19.73 at 30, 50 and 70 DAS, respectively) was found from control treatment G_0 (0 ppm GA_3). This result indicated that highest number of leaves plant^{-1} at different growth stages was produced by the application of GA_3 compared to control which was similar with the findings of Tahir *et al.* (2019), Chormule and Patel (2017) and Mehraj *et al.* (2015).

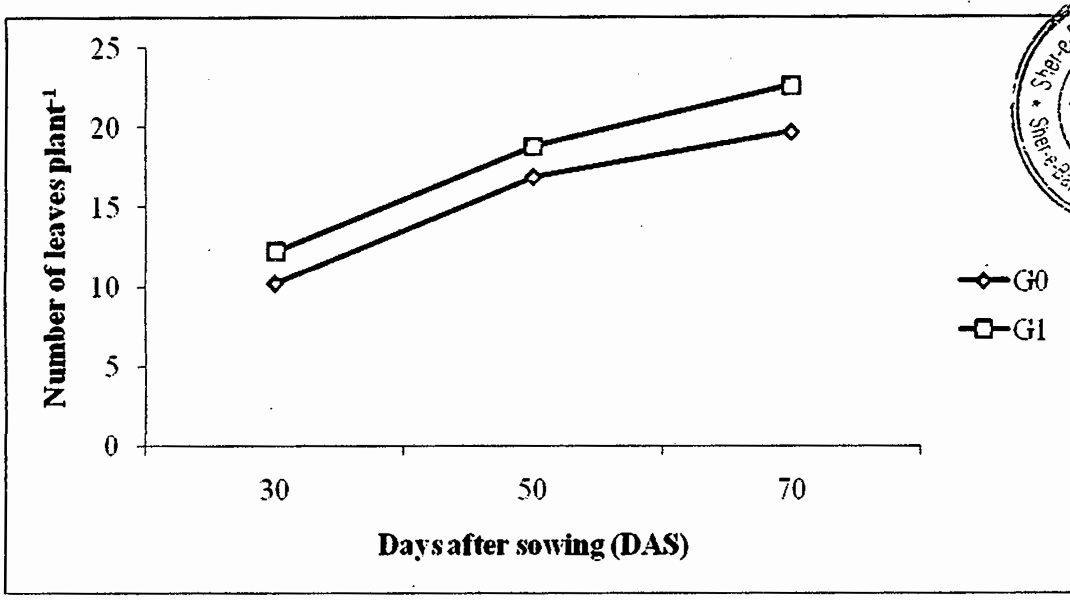

Figure 5. Leaves plant^{-1} of okra in the fish pond through the application of gibberellic acid ($LSD_{0.05}$ = 0.34, 0.56 and 0.61 at 30, 50 and 70 DAS, respectively)

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

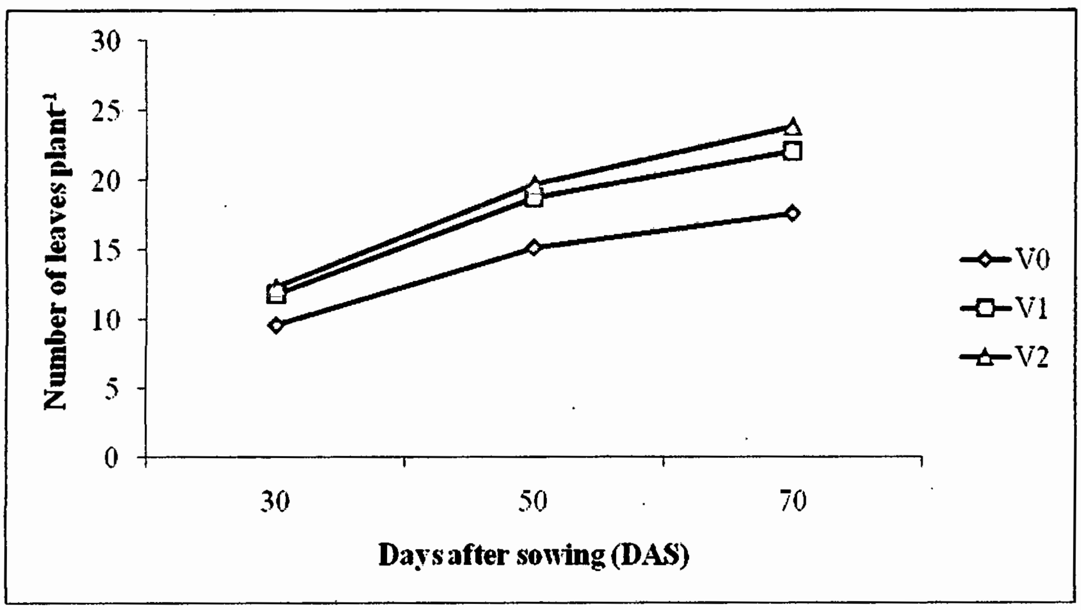

Figure 6. Leaves plant^{-1} of okra in the fish pond through the application of vermicompost ($LSD_{0.05}$ = 0.48, 0.77 and 0.68 at 30, 50 and 70 DAS, respectively)

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Table 3. Number of leaves plant^{-1} of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Number of leaves plant^{-1}		
	30 DAS	50 DAS	70 DAS
G_0V_0	8.93 d	14.07 e	16.17 e
G_0V_1	10.55 bc	17.70 c	20.35 c
G_0V_2	11.27 b	19.02 b	22.65 b
G_1V_0	10.25 c	16.27 d	19.08 d
G_1V_1	13.13 a	19.79 ab	23.83 b
G_1V_2	13.35 a	20.38 a	25.02 a
$LSD_{0.05}$	0.8619	1.162	1.179
CV(%)	5.08	7.03	6.69

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

There was a significant variation on number of leaves plant^{-1} of okra as influenced by different vermicompost levels at different growth stages (Figure 5 and Appendix IV). Okra cultivation in the fish pond through the application of vermicompost, results showed that higher vermicompost doses gave higher number of leaves plant^{-1}. The highest number of leaves plant^{-1} (12.31, 19.70 and 23.84 at 30, 50 and 70 DAS, respectively) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was statistically identical with V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) at 30 DAS but at 50 and 70 DAS this was significantly different from other treatments. The lowest number of leaves plant^{-1} (9.59, 15.18 and 17.63 at 30, 50 and 70 DAS, respectively) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). The results indicated gradually increased number of leaves plant^{-1} was obtained with increased levels of vermicompost and highest number of leaves plant^{-1} was produced at different growth stages by the maximum application of vermicompost than that of control with ensuring the better growth and development. Similar result was also observed by Lakra *et al.* (2017), Sundari and Gandhi (2013) and Sundararasu (2017).

Significant variation was observed on number of leaves plant^{-1} of okra as affected by combined effect of GA_3 and vermicompost in the fish pond (Table 3 and Appendix IV). The highest number of leaves plant^{-1} (13.35, 20.38 and 25.02 at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_1V_2 which was statistically similar with the treatment combination of G_1V_1 at 30 and 50 DAS but significantly different from other treatment combinations at 70 DAS. The lowest number of leaves plant^{-1} (8.93, 14.07 and 16.17 at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_0V_0 which was significantly different from other treatment combinations at all growth stages.

4.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} of okra was significantly varied due to GA_3 application at different growth stages under soillesssystem in the fish pond (Table 4 and Appendix V). Application of GA_3 showed higher number of branches plant^{-1} compared to control. The highest number of branches plant^{-1} (4.68 and 6.14 at 50 and 70 DAS, respectively) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest number of branches plant^{-1} (3.67 and 5.12 at 50 and 70 DAS, respectively) was found from control treatment G_0 (0 ppm GA_3). This results indicated that maximum branches per plant were produced by the application of GA_3 comparing with control. Chormule and Patel (2017), Mehraj *et al.* (2015) and Dhage *et al.* (2011) also found similar result which supported the present study.

Table 4. Number of branches $plant^{-1}$ of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Number of branches $plant^{-1}$	
	50 DAS	70 DAS
Effect of GA_3		
G_0	3.67 b	5.21 b
G_1	4.68 a	6.14 a
$LSD_{0.05}$	0.10	0.11
CV(%)	5.59	5.82
Effect of growing media		
V_0	3.21 c	4.64 c
V_1	4.29 b	5.84 b
V_2	5.03 a	6.54 a
$LSD_{0.05}$	0.18	0.14
CV(%)	5.59	5.82
Combined effect of GA_3 and growing media		
G_0V_0	3.11 e	4.37 e
G_0V_1	3.66 d	5.28 d
G_0V_2	4.25 c	5.98 c
G_1V_0	3.31 e	4.91 d
G_1V_1	4.93 b	6.41 b
G_1V_2	5.80 a	7.10 a
$LSD_{0.05}$	0.35	0.40
CV(%)	5.59	5.82

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

At different growth stages, significant influence was noted on number of branches $plant^{-1}$ of okra in the fish pond through the application of vermicompost (Table 4 and Appendix V). The highest number of branches $plant^{-1}$ (5.03 and 6.54 at 50 and 70 DAS, respectively) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest number of branches $plant^{-1}$ (3.21 and 4.64 at 50 and 70 DAS, respectively) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). The result obtained from the present study was similar with the findings of Singh *et al.* (2019), Lakra *et al.* (2017), Nagar *et al.* (2017) and Peyvast *et al.* (2007) who indicated that maximum number of branches plant^{-1} were produced by the higher rate of vermicompost than the control, which ensure the maximum number of fruits and yield of okra.

Remarkable variation was observed on number of branches plant^{-1} at different growth stages of okra influenced by combined effect of GA_3 and vermicompost in the fish pond (Table 4 and Appendix V). Tthe highest number of branches plant^{-1} (5.80 and 7.10 at 50 and 70 DAS, respectively) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations at all growth stages followed by G_1V_1. The lowest number of branches plant^{-1} (3.11 and 4.37 at 50 and 70 DAS, respectively) was observed from the treatment combination of G_0V_0 which was also significantly different from other treatment combinations at all growth stages.

4.1.4 Foliage coverage (cm^2)

Average foliage coverage at different growth stages in the fish pond varied significantly due to GA_3 application (Table 5 and Appendix VI). Application of GA_3 gave higher foliage coverage compared to control. The highest foliage coverage (277.32, 287.62 and 363.02 cm^2 at 30, 50 and 70 DAS, respectively) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest foliage coverage (257.33, 266.58 and 338.98 cm^2 at 30, 50 and 70 DAS, respectively) was found from control treatment G_0 (0 ppm GA_3). Mehraj *et al.* (2015) also found that maximum foliage coverage of okra was produced by the application of GA_3 compared to control. Similar result was also observed by Verma *et al.* (2019), Ravat and Makani (2015) and Emongor (2011) who indicated higher foliage coverage with GA_3 application compared to control.

Table 5. Foliage coverage of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Average foliage coverage (cm^2)		
	30 DAS	50 DAS	70 DAS
Effect of GA_3			
G_0	257.33 b	266.58 b	338.98 b
G_1	277.32 a	287.62 a	363.02 a
$LSD_{0.05}$	7.52	8.97	6.43
CV(%)	8.69	8.73	10.02
Effect of growing media			
V_0	240.20 c	252.90 c	319.00 c
V_1	274.90 b	281.90 b	361.90 b
V_2	286.80 a	296.50 a	372.10 a
$LSD_{0.05}$	4.40	5.00	5.11
CV(%)	8.69	8.73	10.02
Combined effect of GA_3 and growing media			
G_0V_0	234.10 f	246.60 f	307.80 f
G_0V_1	260.50 d	267.30 d	349.50 d
G_0V_2	277.40 c	285.90 c	359.70 c
G_1V_0	246.40 e	259.20 e	330.30 e
G_1V_1	289.30 b	296.50 b	374.40 b
G_1V_2	296.20 a	307.20 a	384.40 a
$LSD_{0.05}$	6.81	7.22	5.38
CV(%)	8.69	8.73	10.02

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Significant variation was remarked on foliage coverage as influenced by vermicompost application to okra in the fish pond at different growth stages (Table 5 and Appendix VI). It was observed that the foliage coverage increased with the increase of vermicompost rate and the highest average foliage coverage (286.80, 296.50 and 372.10 cm^2 at 30, 50 and 70 DAS, respectively) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1

(20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest foliage coverage (240.20, 252.90 and 319.00 cm^2 at 30, 50 and 70 DAS, respectively) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). This result indicated that maximum foliage coverage was produced by the higher rate of vermicompost than the control, which ensures the optimum growth and development of okra. Sarma and Gogoi (2015), Azarmi *et al.* (2009) and Rajan and Mahalakshmi (2007) also found similar result which supported the present study.

Average foliage coverage was found significant in the fish pond through the combined application of gibberellic acid and vermicompost at different growth stages (Table 5 and Appendix VI). The highest foliage coverage (296.20, 307.20 and 384.40 cm^2 at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations at all growth stages followed by the treatment combination of G_1V_1. The lowest foliage coverage (234.10, 246.60 and 307.80 cm^2 at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_0V_0 which was significantly different from other treatments at all growth stages of okra.

4.1.5 Stem base diameter (cm)

Variation on stem base diameter was found at different growth stages except at 30 and 50 DAS as influenced by GA_3 application to okra in the soillessfish pond (Table 6 and Appendix VII). However, the highest stem base diameter (1.02, 1.73 and 2.00 cm at 30, 50 and 70 DAS, respectively) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest stem base diameter (0.97, 1.62 and 1.81 cm at 30, 50 and 70 DAS, respectively) was found from control treatment G_0 (0 ppm GA_3). Chormule and Patel (2017) also recorded higher stem base diameter with the application of GA_3 compared to control. Similar result was also observed by Verma *et al.* (2019), Moniruzzaman *et al.* (2014) and Patil and Patel (2010).

Table 6. Stem base diameter of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Stem base diameter (cm)		
	30 DAS	50 DAS	70 DAS
Effect of GA_3			
G_0	0.97	1.62	1.81 b
G_1	1.02	1.73	2.00 a
$LSD_{0.05}$	NS	NS	0.04
CV(%)	4.59	6.74	6.98
Effect of growing media			
V_0	0.96	1.56 c	1.72 b
V_1	1.00	1.69 b	1.95 a
V_2	1.04	1.78 a	2.05 a
$LSD_{0.05}$	NS	0.09	0.11
CV(%)	4.59	6.74	6.98
Combined effect of GA_3 and growing media			
G_0V_0	0.95	1.51 d	1.65 d
G_0V_1	0.98	1.63 c	1.86 c
G_0V_2	0.99	1.72 b	1.91 bc
G_1V_0	0.96	1.60 c	1.78 cd
G_1V_1	1.03	1.74 b	2.04 ab
G_1V_2	1.08	1.85 a	2.19 a
$LSD_{0.05}$	NS	0.06	0.15
CV(%)	4.59	6.74	6.98

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Okra production in the fish pond, the recorded data on stem base diameter at different growth stages was significantly influenced by different levels of vermicompost application except at 30 DAS (Table 6 and Appendix VII). However, the highest stem base diameter (1.04, 1.78 and 2.05 cm at 30, 50 and

70 DAS, respectively) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which were statistically identical with V_1 at 70 DAS. The lowest stem base diameter (0.96, 1.56 and 1.72 cm at 30, 50 and 70 DAS, respectively) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). This result indicated that maximum stem base diameter was obtained from the higher rate of vermicompost and it was gradually increased with the increase of vermicompost level which might be due to cause of proper nutrition, available aeration and moisture and also increased soil fertility with higher doses of vermicompost which facilitate to increase stem base diameter.

Considerable influence was observed on stem base diameter of okra at different growth stages except at 30 DAS in the fish pond due to combined effect of GA_3 and vermicompost (Table 6 and Appendix VII). The highest stem base diameter (1.08, 1.85 and 2.19 cm at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_1V_2 which was statistically similar with the treatment combination of G_1V_1 at 70 DAS. the lowest stem base diameter (0.95, 1.51 and 1.65 cm at 30, 50 and 70 DAS, respectively) was observed from the treatment combination of G_0V_0 which was statistically similar with the treatment combination of G_1V_0 at 70 DAS.

4.1.6 Chlorophyll content

Chlorophyll content in leaves of okra grown in the fish pond varied significantly due to GA_3 application compared to control (Table 7 and Appendix VIII). Results showed that the application of GA_3 showed higher chlorophyll content compared to control. The highest chlorophyll content at 50 DAS (59.96) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest chlorophyll content at 50 DAS (56.63) was found from control treatment G_0 (0 ppm GA_3). The result obtained from the present study was similar with the findings of Geeta *et al.* (2014) who found higher chlorophyll content with GA_3 application wher no application of GA_3 gave lower chlorophyll content.

Table 7. Chlorophyll content of okra grown in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Chlorophyll content at 50 DAS
Effect of GA_3	
G_0	56.63 b
G_1	59.96 a
$LSD_{0.05}$	1.03
CV(%)	5.28
Effect of growing media	
V_0	52.11 b
V_1	60.70 a
V_2	62.08 a
$LSD_{0.05}$	4.71
CV(%)	5.28
Combined effect of GA_3 and growing media	
G_0V_0	51.06 c
G_0V_1	59.30 b
G_0V_2	59.55 b
G_1V_0	53.16 c
G_1V_1	62.10 a
G_1V_2	64.61 a
$LSD_{0.05}$	3.62
CV(%)	5.28

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Significant variation was remarked on chlorophyll content of okra leaves cultivated in the fish pond as influenced by different levels of vermicompost (Table 7 and Appendix VIII). Higher rate of vermicompost application contributed to higher chlorophyll content of okra leaves. The highest chlorophyll content at 50 DAS (62.08) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was statistically identical with V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest chlorophyll content at 50 DAS (52.11) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Azarmi *et al.* (2009) also found similar result with the present study who found that higher vermicompost doses gave higher chlorophyll content compared to control.

In case of okra cultivation in the fish pond, chlorophyll content of okra leaves was affected significantly by the application of GA_3 and vermicompost combination (Table 7 and Appendix VIII). The highest chlorophyll content at 50 DAS (64.61) was observed from the treatment combination of G_1V_2 which was statistically identical with the treatment combination of G_1V_1. The lowest chlorophyll content at 50 DAS (51.06) was observed from the treatment combination of G_0V_0 which was statistically identical with G_1V_0.

4.2 Yield contributing parameters

4.2.1 Number of flowers plant^{-1}

GA_3 had significant influence on number of flowers plant^{-1} of okra cultivated in the soillessfish pond (Table 8 and Appendix IX). Results indicated that the higher number of flowers plant^{-1} was produced with the application of GA_3 compared to control. The highest number of flowers plant^{-1} (32.66) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest number of flowers plant^{-1} (29.57) was found from control treatment G_0 (0 ppm GA_3). Tahir *et al.* (2019) and Mohammadi and Khah (2014) also indicated maximum number of flowers plant which was produced with application of GA_3 compared to control that supported the present finding.

Table 8. Yield contributing parameters of okra grown in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Yield contributing parameters			
	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)
Effect of GA_3				
G_0	29.57 b	24.87 b	14.42 b	1.42 b
G_1	32.66 a	28.09 a	16.76 a	1.54 a
$LSD_{0.05}$	1.11	0.84	0.46	0.10
CV(%)	6.86	7.87	4.03	7.90
Effect of vermicompost				
V_0	27.50 b	23.34 c	12.99 c	1.34 b
V_1	32.23 a	27.51 b	16.53 b	1.51 a
V_2	33.61 a	28.59 a	17.24 a	1.59 a
$LSD_{0.05}$	1.57	0.69	0.61	0.15
CV(%)	6.86	7.87	4.03	7.90
Combined effect of GA_3 and vermicompost				
G_0V_0	26.28 e	22.52 e	11.55 d	1.32 e
G_0V_1	30.55 c	25.55 c	15.37 c	1.43 cd
G_0V_2	31.88 c	26.52 c	16.33 b	1.51 c
G_1V_0	28.73 d	24.15 d	14.43 c	1.36 de
G_1V_1	33.91 b	29.48 b	17.69 a	1.59 b
G_1V_2	35.35 a	30.65 a	18.15 a	1.68 a
$LSD_{0.05}$	0.52	1.14	0.94	0.08
CV(%)	6.86	7.87	4.03	7.90

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Number of flowers plant^{-1} was significant due to the application of vermicompost (Table 8 and Appendix IX). Okra production in the fish pond through the application vermicompost, it was found that higher doses of vermicompost produced higher number of flowers plant^{-1}. The highest number of flowers plant^{-1} (33.61) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was statistically identical with V_1 (20%

vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest number of flowers plant^{-1} (27.50) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Sundararasu (2017) and Das *et al.* (2014) reported that vermicompost can increase flowering of okra which supported the present study.

Variation on number of flowers plant^{-1} was found influenced by combined effect of GA_3 and vermicompost under soillessfish pond cultivation system (Table 8 and Appendix IX). The highest number of flowers plant^{-1} (35.35) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by G_1V_1. The lowest number of flowers plant^{-1} (26.28) was observed from the treatment combination of G_0V_0 which was significantly different from other treatment combinations.

4.2.2 Number of fruits plant^{-1}

Okra cultivation process in the fish pond, GA_3 showed significant variation on number of fruits plant^{-1} of okra (Table 8 and Appendix IX). Results indicated that the higher number of fruits plant^{-1} was produced with GA_3 application where no application of GA_3 produced lower number of fruits plant^{-1}. Results revealed that the highest number of fruits plant^{-1} (28.09) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest number of fruits plant^{-1} (24.87) was found from control treatment G_0 (0 ppm GA_3). The result on number of fruits plant^{-1} obtained from the present study was conformity with the findings of Tahir *et al.* (2019), Chormule and Patel (2017), Mehraj *et al.* (2015) and Shahid *et al.* (2013) who found higher number of fruits per plant with GA_3 application.

Number of fruits plant^{-1} varied significantly due to different levels of vermicompost application (Table 8 and Appendix IX). Okra production in the fish pond through vermicompost, higher number of fruits plant^{-1} was produced with higher levels of vermicompost and the highest number of fruits plant^{-1}

(28.59) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). The lowest number of fruits plant^{-1} (23.34) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Similar result was also observed by Sundararasu (2017) and Das *et al.* (2014) who obtained maximum number of fruits plant^{-1} with higher vermicompost rate compared to control.

Okra production in the fish pond through the combined application of gibberellic acid and vermicompost showed considerable influence on number of fruits plant^{-1} (Table 8 and Appendix IX). It was found that the highest number of fruits plant^{-1} (30.65) was observed from the treatment combination of G_1V_2 which was significantly different from other treatments followed by G_1V_1 whereas the lowest number of fruits plant^{-1} (22.52) was observed from the treatment combination of G_0V_0.

4.2.3 Fruit length (cm)

Fruit length of okra, cultivated in the fish pond varied significantly due to GA_3 application (Table 8 and Appendix IX) and higher fruit length was achieved with GA_3 compared to control. Under the present study, the highest fruit length (16.76 cm) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest fruit length (14.42 cm) was found from control treatment G_0 (0 ppm GA_3). Similar result was also observed by Chormule and Patel (2017) and Mehraj *et al.* (2015) which supported the present study.

Significant variation was recorded on fruit length of okra as influenced by vermicompost which was cultivated in the fish pond (Table 8 and Appendix IX). Under the present study, higher vermicompost rate gave higher fruit length of okra. Results revealed that the highest fruit length (17.24 cm) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1 (20%

vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest fruit length (12.99 cm) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Singh *et al.* (2019), Sundari and Gandhi (2013) and Das *et al.* (2014) also obtained higher fruit length with higher rate of vermicompost which supported the present study.

Okra production in the fish pond, the recorded data on fruit length was significantly influence by combined effect of GA_3 and vermicompost (Table 8 and Appendix IX). The highest fruit length (18.15 cm) was observed from the treatment combination of G_1V_2 which was statistically identical with the treatment combination of G_1V_1. The lowest fruit length (11.55 cm) was observed from the treatment combination of G_0V_0 which was significantly different from other treatment combinations.

4.2.4 Fruit diameter (cm)

Under the present study, fruit diameter varied significantly due to GA_3 application (Table 8 and Appendix IX). GA_3 gave higher fruit diameter compared to control. Regarding the present study, the highest fruit diameter (1.54 cm) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest fruit diameter (1.42 cm) was found from control treatment G_0 (0 ppm GA_3). Supported result was also observed by Mehraj *et al.* (2015) and Chormule and Patel (2017).

The recorded data on fruit diameter was significantly influence by vermicompost application (Table 8 and Appendix IX). Under the present study, it was found that the higher rate of vermicompost application gave higher fruit diameter of okra. The highest fruit diameter (1.59 cm) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was statistically identical with V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest fruit diameter (1.34 cm) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Singh *et al.* (2019) and Sundari and Gandhi (2013) achieved higher fruit diameter using the higher vermicompost doses which was similar with the present finding.

Combined effect of GA_3 and vermicompost showed significant variation on fruit diameter under the present study (Table 8 and Appendix IX). The highest fruit diameter (1.68 cm) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by G_1V_1. the lowest fruit diameter (1.32 cm) was observed from the treatment combination of G_0V_0 which was statistically similar with the treatment combination of G_1V_0.

4.3 Yield parameters

4.3.1 Single fruit weight (g)

Okra cultivation in the fish pond through the application of gibberellic acid showed higher single fruit weight compared to control treatment which differed significantly (Table 9 and Appendix X). The highest single fruit weight (14.35 g) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest single fruit weight (13.48 g) was found from control treatment G_0 (0 ppm GA_3). Tahir *et al.* (2019), Singh *et al.* (2017) and Shahid *et al.* (2013) found similar result with the present study.

Increased single fruit weight of okra cultivated in the fish pond was found with increased level of vermicompost application. Significant variation was observed on single fruit weight as influenced by vermicompost (Table 9 and Appendix X). The highest single fruit weight (14.69 g) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was statistically identical with V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest single fruit weight (13.01 g) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat +

10% broken bricks + dissolved nutrients of fish pond water). Singh *et al.* (2019) and Sundararasu (2017) also found similar result with the present study.

Table 9. Yield parameters of okra in the fish pond through the application of gibberellic acid and vermicompost

Treatments	Yield parameters		
	Single fruit weight (g)	Fresh weight of fruits plant^{-1} (g)	Fruit yield (t ha^{-1})
Effect of GA_3			
G_0	13.48 b	336.03 b	3.36 b
G_1	14.35 a	405.66 a	4.06 a
$LSD_{0.05}$	0.24	12.94	0.20
CV(%)	8.00	6.43	7.45
Effect of vermicompost			
V_0	13.01 b	303.80 c	3.04 c
V_1	14.05 a	387.70 b	3.88 b
V_2	14.69 a	421.00 a	4.21 a
$LSD_{0.05}$	0.73	13.38	0.13
CV(%)	8.00	6.43	7.45
Combined effect of GA_3 and vermicompost			
G_0V_0	12.90 e	290.60 f	2.91 f
G_0V_1	13.52 d	345.60 d	3.46 d
G_0V_2	14.02 c	371.90 c	3.72 c
G_1V_0	13.13 de	317.00 e	3.17 e
G_1V_1	14.57 b	429.80 b	4.30 b
G_1V_2	15.35 a	470.10 a	4.70 a
$LSD_{0.05}$	0.41	11.81	0.19
CV(%)	8.00	6.43	7.45

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Combined effect of GA_3 and vermicompost showed considerable influence on single fruit weight of okra under soillessfish pond cultivation system (Table 9 and Appendix X). The highest single fruit weight (15.35 g) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by G_1V_1. The lowest single fruit weight (12.90 g) was observed from the treatment combination of G_0V_0 which was statistically similar with the treatment combination of G_1V_0.

4.3.2 Fresh weight of fruits plant^{-1} (g)

Fresh weight of fruits plant^{-1} varied significantly due to GA_3 application under the present study (Table 9 and Appendix X). Results revealed that higher fresh fruits weight plant^{-1} was produced with GA_3 application compared to control. It was found that the highest fresh weight of fruits plant^{-1} (336.03 g) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest fresh weight of fruits plant^{-1} (405.66 g) was found from control treatment G_0 (0 ppm GA_3). Chormule and Patel (2017), Singh *et al.* (2017), Maity *et al.* (2016) and Mehraj *et al.* (2015) achieved higher fresh weight of fruits plant^{-1} with GA_3 application compared to control which supported the present investigation.

Significant variation was remarked on fresh weight of fruits plant^{-1} as influenced by vermicompost application under the present study (Table 9 and Appendix X). It was found that the fresh fruits weight plant^{-1} was increased with the increase of vermicompost rate. The highest fresh weight of fruits plant^{-1} (421.00 g) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest fresh weight of fruits plant^{-1} (303.80 g) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Singh *et al.* (2019) and Sundararasu (2017), Lakra *et al.* (*2017*) and Das *et al.* (2014) also found similar result with the present study.

Fresh weight of fruits plant^{-1} was significant with the combined effect of GA_3 and vermicompost (Table 9 and Appendix X). Results revealed that the highest fresh weight of fruits plant^{-1} (470.10 g) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by the treatment combination of G_1V_1. The lowest fresh weight of fruits plant^{-1} (290.60 g) was observed from the treatment combination of G_0V_0 which was significantly different from other treatment combinations.

4.3.3 Fruit yield (t ha^{-1})

Okra cultivation in the fish pond, fruit yield of okra varied significantly due to GA_3 application (Table 9 and Appendix X). Compared to control, application of GA_3 showed better results on yield of okra. Results indicated that the highest fruit yield (4.06 t ha^{-1}) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest fruit yield (3.36 t ha^{-1}) was found from control treatment G_0 (0 ppm GA_3). Generally yield of a crop depends on its yield contributing characters. Under the present study, application of GA_3 showed higher number of fruits per plant, single fruit weight, fresh fruit weight per plant, fruit length and diameter etc. which resulted highest yield per ha with GA_3 compared to control. Supported result was also observed by Tahir *et al.* (2019), Singh *et al.* (2017), Dhage *et al.* (2011).

Results indicated that higher vermicompost doses showed higher fruit yield of okra. Production of okra in the fish pond, significant variation was remarked on fruit yield as influenced by vermicompost (Table 9 and Appendix X). Results revealed that the highest fruit yield (4.21 t ha^{-1}) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) which was significantly different from other treatments followed by V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest fruit yield (3.04 t ha^{-1}) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). It can be noted that the treatment V_2 might have facilitated proper aeration and minimum losses of water through evaporation and helped plant in proper flowering and fruiting. However, the highest yield obtained from V_2 because of best yield contributing parameters like number of fruits per plant, single fruit weight, fresh fruit weight per plant, fruit length and diameter etc. were obtained from this treatment which resulted highest yield of okra. Similar result was also observed by Singh *et al.* (2019), Lakra *et al.* (2017) and Das *et al.* (2014) which supported the present investigation.

Under the present study (okra production in the fish pond), combined effect of GA_3 and vermicompost showed significant variation on fruit yield of okra (Table 9 and Appendix X). Results showed that the highest fruit yield (4.70 t ha^{-1}) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by G_1V_1. The lowest fruit yield (2.91 t ha^{-1}) was observed from the treatment combination of G_0V_0 which was significantly different from other treatments.

4.4 Quality parameters

4.4.1 Vitamin C content

Vitamin C content of fruits varied significantly due to GA_3 application (Table 10 and Appendix XI). The highest vitamin C content (22.02) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest vitamin C content (21.85) was found from control treatment G_0 (0 ppm GA_3).

Variation on vitamin C content of okra fruits under the present study was found significant as influenced by vermicompost application (Table 10 and Appendix XI). The highest vitamin C content (22.12) was recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) followed by V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas the lowest vitamin C content (21.73) was recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water).

Table 10. Effect of GA_3 and growing media on vitamin C content of okra grown in the fish pond

Treatments	Vitamin C content
Effect of GA_3	
G_0	21.85 b
G_1	22.02 a
$LSD_{0.05}$	0.05
CV(%)	6.27
Effect of growing media	
V_0	21.73 c
V_1	21.97 b
V_2	22.12 a
$LSD_{0.05}$	0.09
CV(%)	6.27
Combined effect of GA_3 and growing media	
G_0V_0	21.70 d
G_0V_1	21.90 c
G_0V_2	21.95 bc
G_1V_0	21.77 d
G_1V_1	22.02 b
G_1V_2	22.28 a
$LSD_{0.05}$	0.08
CV(%)	6.27

In a column means having similar letters) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0 = 0 ppm GA_3 (Control), G_1 = 100 ppm GA_3

V_0 = Control (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water), V_1 = 20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water, V_2 = 40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water

Okra cultivation system in the fish pond, significant variation was recorded on vitamin C content of okra fruits as influenced by combined effect of GA_3 and vermicompost (Table 10 and Appendix XI). The highest vitamin C content (22.28) was observed from the treatment combination of G_1V_2 which was significantly different from other treatment combinations followed by G_1V_1 whereas the lowest vitamin C content (21.70) was observed from the treatment combination of G_0V_0.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Horticulture Farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during July to October 2019 to determine the utilization of fish waste, vermicompost and GA_3 for quality okra production in the soillessfish pond aquavegeculture system. The experiment considered of two factors, Factor A: GA_3 (2 levels) *viz.* (i) G_0 (0 ppm GA_3) (control) and (ii) G_1 (100 ppm GA_3) and Factor B: Vermicompost (3 levels) *viz.* (i) V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) (control), (ii) V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) and (iii) V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data were collected in respect of the okra growth, yield and yield contributing characters. The data obtained for different characters were statistically analyzed to find out the significance of the difference among the treatments.

In terms of GA_3 application, all the studied parameters showed significant distinction among the treatments. Regarding growth parameters, at 30, 50 and 70 days after sowing (DAS), the highest plant height (13.23, 54.31 and 79.65 cm, respectively), number of leaves plant^{-1} (12.24, 18.81 and 22.64, respectively), foliage coverage (277.32, 287.62 and 363.02 cm^2, respectively) and stem base diameter (1.02, 1.73 and 2.00 cm, respectively) were found from the treatment G_1 (100 ppm GA_3) whereas the lowest plant height (12.25, 49.55 and 73.33 cm, respectively), number of leaves plant^{-1} (10.25, 16.93 and 19.73, respectively), foliage coverage (257.33, 266.58 and 338.98 cm^2, respectively) and stem base diameter (0.97, 1.62 and 1.81 cm, respectively) were found from control treatment G_0 (0 ppm GA_3). Again, at 50 and 70 DAS, the highest number of branches plant^{-1} (4.68 and 6.14, respectively) was found from the treatment G_1 whereas the lowest number of branches plant^{-1} (3.67 and 5.12, respectively) was recorded from control treatment G_0. Similarly, the highest chlorophyll content at 50 DAS (59.96) was found from the treatment G_1 (100 ppm GA_3) whereas the lowest (56.63) was found from control treatment G_0 (0 ppm GA_3). Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (32.66), number of fruits plant^{-1} (28.09), fruit length (16.76 cm), fruit diameter (1.54 cm), single fruit weight (14.35 g), fresh weight of fruits plant^{-1} (336.03 g) and fruit yield (4.06 t ha^{-1}) were found from the treatment G_1 whereas the lowest number of flowers plant^{-1} (29.57), number of fruits plant^{-1} (24.87), fruit length (14.42 cm), fruit diameter (1.42 cm), single fruit weight (13.48 g), fresh weight of fruits plant^{-1} (405.66 g) and fruit yield (3.36 t ha^{-1}) was found from control treatment G_0. In terms of vitamin C content in fruits, the highest (22.02) was found from the treatment G_1 and the lowest (21.85) was found from control treatment G_0.

Considering vermicompost application, all the studied parameters showed significant difference among the treatments. Considering growth parameters, at 30, 50 and 70 DAS, the highest plant height (13.33, 55.81 and 82.02 cm, respectively), number of leaves plant^{-1} (12.31, 19.70 and 23.84, respectively), foliage coverage (286.80, 296.50 and 372.10 cm^2, respectively) and stem base diameter (1.04, 1.78 and 2.05 cm, respectively) were recorded from the treatment V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) whereas at 30, 50 and 70 DAS, the lowest plant height (11.91, 46.39 and 69.13 cm, respectively), number of leaves plant^{-1} (9.59, 15.18 and 17.63, respectively), foliage coverage (240.20, 252.90 and 319.00 cm^2, respectively) and stem base diameter (0.96, 1.56 and 1.72 cm, respectively) were recorded from control treatment V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). Likewise, the highest number of branches plant^{-1} at 50 and 70 DAS (5.03 and 6.54, respectively) was recorded from the treatment V_2 whereas the lowest number of branches plant^{-1} (3.21 and 4.64, respectively) was recorded from control treatment V_0. Similarly, the highest chlorophyll content at 50 DAS (62.08) was recorded from V_2 whereas the lowest chlorophyll content at 50 DAS (52.11) was recorded from control treatment V_0. Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (33.61), number of fruits plant^{-1} (28.59), fruit length (17.24 cm), fruit diameter (1.59 cm), single fruit weight (14.69 g), fresh weight of fruits plant^{-1} (421.00 g) and fruit yield (4.21 t ha^{-1}) were recorded from the treatment V_2 whereas the lowest number of flowers plant^{-1} (27.50), number of fruits plant^{-1} (23.34), fruit length (12.99 cm), fruit diameter (1.34 cm), single fruit weight (13.01 g), fresh weight of fruits plant^{-1} (303.80 g) and fruit yield (3.04 t ha^{-1}) were recorded from control treatment V_0. In terms of vitamin C content, V_2 showed the highest result (22.12) whereas control treatment V_0 gave the lowest vitamin C content (21.73).

Considering combined effect of GA_3 and vermicompost application, all the studied parameters showed significant variation among the treatments. Concerning growth parameters, at 30, 50 and 70 DAS, the treatment combination of G_1V_2 gave the highest plant height (14.11, 57.92 and 85.38 cm, respectively), number of leaves plant^{-1} (13.35, 20.38 and 25.02 a, respectively), foliage coverage (296.20, 307.20 and 384.40 cm^2, respectively) and stem base diameter (1.08, 1.85 and 2.19 cm, respectively) whereas at 30, 50 and 70 DAS, treatment combination of G_0V_0 gave the lowest plant height (11.88, 44.56 and 67.29 cm, respectively), number of leaves plant^{-1} (8.93, 14.07 and 16.17, respectively), foliage coverage (234.10, 246.60 and 307.80 cm^2, respectively), and stem base diameter (0.95, 1.51 and 1.65 cm, respectively). Again, at 50 and 70 DAS, the highest number of branches plant^{-1} (5.80 and 7.10, respectively) was observed from G_1V_2 whereas the lowest number of branches plant^{-1} (3.11 and 4.37, respectively) was observed from G_0V_0. Similarly, the highest chlorophyll content at 50 DAS (64.61) was observed from the treatment combination of G_1V_2 whereas the lowest chlorophyll content at 50 DAS (51.06) was observed from the treatment combination of G_0V_0. Under the consideration of yield and yield contributing parameters, the treatment combination of G_1V_2 showed the highest number of flowers plant^{-1} (35.35), number of fruits plant^{-1} (30.65), fruit length (18.15 cm), fruit diameter (1.68 cm), single fruit weight (15.35 g), fresh weight of fruits plant^{-1} (470.10 g) and fruit yield (4.70 t ha^{-1}) whereas G_0V_0 gave the lowest number of flowers plant^{-1} (26.28), number of fruits plant^{-1} (22.52), fruit length (11.55 cm), fruit diameter (1.32 cm), single fruit weight (12.90 g), fresh weight of fruits plant^{-1} (290.60 g) and fruit yield (2.91 t ha^{-1}). In case of vitamin C content, G_1V_2 gave the highest result (22.28) whereas G_0V_0 gave the lowest vitamin C content (21.70).

From the study, it might be concluded that both plant growth regulator (GA_3) and vermicompost had the positive effect on the growth parameters, yield attributes and yield of okra. Among the two treatments of GA_3, the highest positive result was obtained from G_1 (100 ppm GA_3) compared to control G_0 (0 ppm GA_3). Again, among the three treatments of vermicompost, significantly the highest positive effect was recorded from the plant treated with V_2 (40%vermicompost + 50% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) compared to control V_0 (0% vermicompost + 90% coco peat + 10% broken bricks + dissolved nutrients of fish pond water) and V_1 (20% vermicompost +70% coco peat + 10% broken bricks + dissolved nutrients of fish pond water). In terms of interaction effect of GA_3 and vermicompost, the treatment combination of G_1V_2 showed the best results on growth, yield attributes and yield parameters of okra whereas G_0V_0 showed lower performance. So, this treatment combination (G_1V_2) can be treated as the best among all the treatment combinations.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

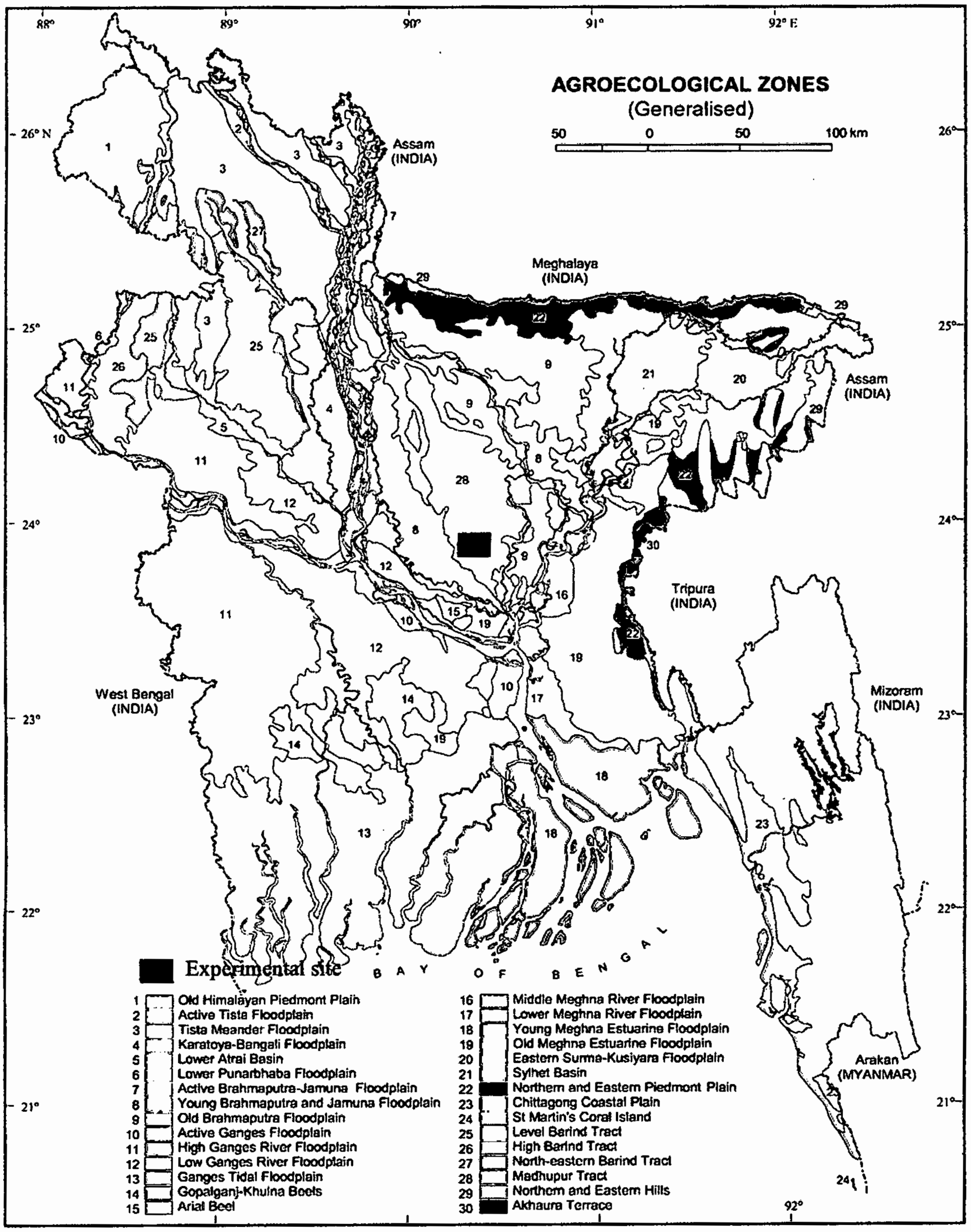

Figure 6. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from July to October 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	July	30.52	24.80	27.66	78.00	536
2019	August	31.00	25.60	28.30	80.00	348
2019	September	30.8	21.80	26.30	71.50	78.52
2019	October	30.42	16.24	23.33	68.48	52.60

Source: Bangladesh Meteorological Department (July-October, 2019).

Appendix III. Plant height of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		30 DAS	50 DAS	70 DAS
Replication	3	0.251	1.541	0.250
Factor A	1	NS	135.89*	239.65*
Factor B	2	NS	194.15*	351.95*
AB	2	1.303	4.241**	12.059*
Error	15	0.091	0.613	3.003

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IV. Number of leaves plant^{-1} of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		30 DAS	50 DAS	70 DAS
Replication	3	0.204	0.138	0.778
Factor A	1	23.80*	21.18*	51.04*
Factor B	2	16.95*	45.50*	82.09*
AB	2	0.792**	0.426**	0.605**
Error	15	0.327	0.294	0.612

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Number of branches plant^{-1} of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}	
		50 DAS	70 DAS
Replication	3	0.097	0.033
Factor A	1	6.070*	5.245*
Factor B	2	6.691*	7.402*
AB	2	1.003*	0.225**
Error	15	0.054	0.026

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Foliage coverage of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of average foliage coverage (cm^2)		
		30 DAS	50 DAS	70 DAS
Replication	3	37.843	6.820	20.770
Factor A	1	2396.00*	2655.24*	3465.60*
Factor B	2	4686.21*	3940.38*	6336.16*
AB	2	13.581**	18.014*	13.438*
Error	15	20.429	22.989	12.747

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Stem base diameter of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of stem base diameter (cm)		
		30 DAS	50 DAS	70 DAS
Replication	3	0.004	0.001	0.002
Factor A	1	NS	NS	0.234*
Factor B	2	NS	0.104**	0.233*
AB	2	NS	0.001**	0.011**
Error	15	0.002	0.001	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Chlorophyll content of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of chlorophyll content at 50 DAS
Replication	3	2.448
Factor A	1	84.37*
Factor B	2	78.51*
AB	2	6.904*
Error	15	1.036

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Yield contributing parameters of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)
Replication	3	0.367	0.284	0.170	0.001
Factor A	1	73.11*	62.40*	32.80*	0.095**
Factor B	2	68.53*	61.53*	41.50*	0.132**
AB	2	4.072*	3.860*	0.562**	0.011**
Error	15	0.493	0.576	0.395	0.003

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Yield parameters of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of yield parameters		
		Single fruit weight (g)	Fresh weight of fruits plant^{-1} (g)	Fruit yield (t ha^{-1})
Replication	3	0.388	33.23	0.034
Factor A	1	4.507*	2908.14*	2.912*
Factor B	2	5.718*	2919.99*	2.925*
AB	2	0.655**	289.971*	0.289**
Error	15	0.077	16.366	0.016

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI. Vitamin C content of okra in the fish pond through the application of gibberellic acid and vermicompost

Sources of variation	Degrees of freedom	Mean square of vitamin C content
Replication	3	0.001
Factor A	1	0.177**
Factor B	2	0.301*
AB	2	0.037**
Error	15	0.003

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level