Effect of Varying Concentration of Nutrients on Quality and Productivity of Bottle Gourd (*Lagenaria siceraria)* through Hydroponic Systems

THESIS

Submitted to the

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA, PUNJAB, INDIA

In partial fulfillment of the requirements for the award of degree of

MASTER OF SCIENCE
IN
(AGRONOMY)

BY

Yumnam Neeraj Singh
Registration Number: 11307541

Under the supervision of
Dr. Balkrishna Sopan Bhople

Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, India June, 2015

CERTIFICATION

This is to certify that the thesis entitled **"Effect of Varying Concentration of Nutrients on Quality and Productivity of Bottle Gourd (*Lagenaria siceraria)* through Hydroponic Systems"** submitted in partial fulfilment of the requirements for the degree of Master of Science with major in Agronomy of the Department of Agronomy, School of Agriculture and Food Technology, Lovely Professional University, Phagwara, is a record of bona-fide research carried out by Yumnam Neeraj Singh , Registration No. 11307541 under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(Signature of Supervisor)

…………………………………
Dr. Balkrishna Sopan Bhople (UID: 16709)
Designation: H.O.D
School of Agriculture
Lovely Professional University
Jalandhar, Punjab.

(Signature of Co-Supervisor)

…………………………………
Dr. Arun Kumar(UID: 17429)
Designation: Assistant Professor
School of Agriculture
Lovely Professional University
Jalandhar, Punjab

(Signature of Co-Supervisor)

…………………………………
Dr. Chandra-Mohan Mehta (UID:18376)
Designation: Assistant Professor
School of Agriculture
Lovely Professional University
Jalandhar, Punjab.

DECLARATION

I hereby declare that this thesis is a presentation of my own work and has been generated by me as the result of my own research work and efforts. This thesis is submitted by me in partial fulfillment of the requirement for the award of degree M.Sc. in Agronomy from Lovely Professional University, Phagwara, Punjab comprises only my original work and due acknowledgement has been made in the text to all other material used.

This thesis work was done under the guidance of my advisor.

(Signature of Student)

……………………………………

Yumnam Neeraj Singh
Reg. no 11307541
School of Agriculture
Lovely Professional University
Jalandhar, Punjab

(Signature of Major Advisor)

……………………………………

Dr. Balkrishna Sopan Bhople (UID: 16709)
Designation: H.O.D
School of Agriculture
Lovely Professional University
Jalandhar, Punjab.

ACKNOWLEDGEMENT

The success of this study cannot solely be attributed to efforts of one individual. Generally, there must be joining of efforts to make such an exercise a success. On that note, the following deserve my thanks and feelings of gratitude.

Primary, I would like to thank the Almighty God who gave us life and protection.

I wish to express my sincere gratitude to the administrative and teaching staff of the faculty of Agriculture, Lovely Professional University (LPU) for the favorable learning environment and cooperation during my stay at University.

I am indebted to my Supervisor Dr. Balkrishna S. Bhople (HOD, Agronomy), Assistant Professor, Soil Science, for undertaking the task of supervising this work, his willingness, his expertise, invaluable, criticism during the entire course of my investigations, guidance and assistance to identify gaps in this research. I gained a tremendous amount of knowledge under his supervision. It is his constant encouragement, constructive criticisms and suggestions that made this work possible.

I am thankful to esteemed Dr. Deepak Sapkal, Dr. Chandra Mohan Mehta, Dr. Arun Kumar, Dr. Madhu Sharma (HOD, Horticulture) and other faculty members of School of Agriculture for their proper guidance during the entire course of present studies.

I expressed my heartfelt thanks to my friends, classmates, roommates for their cooperation, encouragement, moral and timely help when required.

I avail the blessings, affection and moral encouragement of my gracious parents, brothers and sisters, constant moral encouragement inspired me to search ahead

Yumnam Neeraj Singh

CONTENTS

Content

List of Tables

List of Figures

Terminology

EC	Electrical conductivity
TDM	Total dry matter
cm	Centimetre(s)
mm	Millimetre(s)
%	Percent
DAT	Days after transplanting
$mg\ l^{-1}$	Milligram per litre
$\mu g\ l^{-1}$	Microgram per litre
ppm	Parts per million
^{o}C	Degree Celsius
g	Gram(s)
kg	Kilogram(s)
mg	Milligram(s)
L	Litre(s)
Ml	Millilitre(s)
v/v	volume/volume
hr	Hour(s)
min	Minute(s)
s	Second(s)
no.	Number(s)
N	Nitrogen

P	Phosphorus
P_2O_5	Phosphorus pentoxide
K	Potassium
K_2O	Potassium oxide
WUE	Water use efficiency
FUE	Fertiliser use efficiency

Abstract

The effect of different composition of Nitrogen, Phosphorus and Potassium concentration of modified Hoagland solution in the growth and development of Bottle gourd plant were evaluated in an experiment conducted on zaid season of 2015. Three different concentrations of NPK(recommended, 20% increased NPK and 30% increased NPK) and two hydroponic system (Nutrient flow technique and Wick system) under a factorial randomized design was used to evaluate the growth and quality parameters of bottle gourd plant. The experiment consisted of 6 treatments WSN(Wick system+ Hoagland solution recommended dose of NPK), NFTN(NFT system + Hoagland solution recommended dose of NPK), WS20(Wick system + Hoagland solution recommended dose of NPK + 20% enriched NPK), NFT20(NFT system + Hoagland solution recommended dose of NPK + 20% enriched NPK), WS(Wick system + Hoagland solution recommended dose of NPK + 30% enriched NPK) and T6(NFT system + Hoagland solution recommended dose of NPK + 30% enriched NPK). The same treatment were replicated 5 times and highest average mean was observed. Indivisual plants were transplanted to the hydroponic system at the fourth true leaf stage. The growth experiment gave significant result on the effects of different concentrations of NPK in the hydroponic solution. Significant increase in plant growth parameters (plant height, number of flowers per plant, number of fruiting bodies per plant and total dry matter concentration) . Plant tissue analysis showed that the Nitrogen and Phosphorus concentration in the tissue gradually increases with increasing concentration of NPK in the nutrient solution.

The overall value of growth and quality parameters was highest in 20% increased NPK grown in NFT system showing significant increase in the overall parameters with positive result than other treatment. Highest average mean value readings of 103.26 cm plant height, 15.9 flowers per plant , 8 fruiting bodies per plant and total dry matter concentration of 20.73 gram per plant was found for growth parameters of bottle gourd plant. Quality parameters recorded under Nitrogen phosphorus and Potassium concentration in the tissue of the plants revealed that the highest reading of Nitrogen content was found in T6 supplied with 30% increased NPK. Highest Phosphorus concentration in the plant tissue was observed in T6 supplied with 30% increased NPK solution. However, the Potassium concentration in the plant tissue was very low when the plants were treated with 30% increased NPK Hoagland solution. Comparing on the overall performance Hoagland nutrient solution when treated with 20% increased NPK is considered more suitable nutrient solution for growing Bottle gourd in Hydroponic. This study also concluded that NFT system is more suitable for the growth and development of Bottle gourd plant.

Keywords : Hydroponic. NFT system, Wick system, Bottle gourd, Hoagland, Concentration, Growth and development.

Chapter I

1. Introduction

The increased population, sub-urbanization of the forest (excluding land for commercial food production), improper agricultural practice which altered the soil pH, synthetic fertilizers, pesticides which drastically reduced the soil flora and fertility which made a quench for the new alternative technique for obtaining food and medicinal plants of better quality, yield and for growing fresh produce in non-arable areas of the world. Future food security must come from increased yields in both irrigated and non-irrigated agriculture. Controlled cultivation is a viable alternative and offers the opportunity to overcome the problems of phenotypic variation in bioactive compounds that are inherent in herbal extracts, misidentification, genetic and phenotypic variations, extract variability and instability, toxic components and contaminants. Considering the changing environment and climate conditions hydroponics has a bigger advantage than geoponics in terms of yield and quality. Commercial hydroponics systems have proved more productive than conventional systems of agriculture not only in the laboratory but even in actual practice. Hydroponics techniques have averaged around 20 to 25% higher than in conventional soil. In 1938 a recipe for a solution that provides every nutrient essential for plant growth was developed by Hoagland and Arnon . Over the years modification has been made to suit according to the requirements of the specific plants. The efficiency of hydroponic system depends on factors such as growing media, types of hydroponic system used and the nutrient solution. Growing media and hydroponic system used for cultivation effects the growth and development of the plant. Nitrogen, Phosphorus and Potassium plays a great role in growth and development of plants. Their deficiency or excess effects the growth and yield of crop. Fertilizer is a major part of the crop expenses for bottle gourd production, and it is critical for successful crop yields and high fruit quality. Fertilizer requirements of cucumber and bottle gourd are quite high due to its high yielding potential per unit area and time. Accordingly, mineral nutrition with suitable levels of nitrogen (N), phosphorus (P) and potassium (K) had a key role for improving the growth and fruit yield of bottle gourd, as well as influencing the bottle gourd plant's ability to withstand negative effects from pests, water, temperature, and other stresses. N, along with P and K, are classified as primary macronutrient, which are needed in relatively large quantities and are often deficient in crops not receiving fertilizer application (Marschner, 1986).

Bottle gourd, (*Lagenaria siceraria*), also known as opo squash or long melon is a vine grown for its fruit, which can either be harvested young and used as a vegetable, or harvested mature, dried, and used as a bottle. It is extensively grown all around the world in wide varieties of tropical and subtropical climate. The health benefits of bottle gourd is least known to many, yet unknowingly it is consumed in majority of the Indian families because of the low price tag it carries in the vegetable market and its wide availability. Bottle gourd is the only plant which contains the highest choline level along with the required metabolites/metabolic essential for brain function and development. The old native Indian traditional medicinal system, Ayurveda recommends the juice of bottle gourd in the treatment of acidity, obesity, indigestion and ulcers as it serves as an alkaline mixture. It is rich in, thiamin, vitamin C, zinc, iron and magnesium thus helping in improving overall health (Med India- Nutritional Guard-Bottle Gourd or Lauki).

The present study aim to assess the effect of different concentration of nitrogen, phosphorus and potassium on modified Hoagland solution. study will determine the suitable hydroponic nutrient and system for the cultivation of bottle gourd. The effect of NPK nutrition on the growth will provide a future reference for the cultivation of cucurbitaceae family. Increase of NPK to a particular level has shown improvement in yield and growth of plants. However, some crops are sensitive to a particular element than other. Therefore, one nutrient will work well for one crop but poorly for others. The ratio of concentration of the elements have a marked effect on plant absorption and growth (S.Ruamrungsri et al., 2015). Few studies examining the phosphorus and potassium fertility has been conducted on cucurbitaceae family but they are not specific to bottle gourd. However, very little research has been conducted regarding the nutrient solution, growing media and hydroponic system for cultivation of bottle gourd. Currently producers base the plants need according to the nutritional needs of other plants like lettuce, cucumber and tomatoes. Nutritional research is therefore needed for this crop species to determine precise nutritional requirements. Bottle gourd as it can be grown in wide varieties of climate and soil, these study will assess the suitability of hydroponic system for enhancing the productivity and yield of bottle gourd.

Objective of the Study

The aim and objectives of the experiment is to assessing the effect of different concentration of Nitrogen, Potassium and Phosphorus of Hoagland nutrient solution in the productivity and quality of Bottle gourd (*Lagenaria siceraria)* through Nutrient Flow Technique and wick system hydroponics.

- To study the effect of varying concentration of NPK on the growth and development of Bottle gourd.
- To study the difference in growth and development parameter under different hydroponics system.

Chapter II

2. Review of Literature

2.1 Hydroponic Plant Production

Hydroponics is a method or science of growing plants in a soil-less medium. It is an efficient, profitable, and sanitary technology for growing plants Physiologically there are no difference between a hydroponically grown plants and plants grown in soil. All the essential elements that are necessary for the growth and development of the plants are provided by their roots which feeds on nutrient rich solution. In order to make the inorganic elements available for the plant uptake both the organic and inorganic components needs to be decomposed into inorganic elements (Carpenter, 1994). However, the process of obtaining minerals by the plant from a soil solution and a hydroponic solution are different. Mineral nutrients that are required by the plants become available for plant uptake only when the soil colloids release minerals into the soil solution through solubilization of soil minerals and organic matter (Resh, 1995). On the other hand in hydroponic culture the dissolved nutrients are delivered to the plant in a solution rather than a soil solution. Therefore, we can maintain an ideal nutrient condition for the plants through hydroponics. However, the lack of buffering capacity results in great margin of error which can possibly result in plants nutritional stress or starvation. Hydroponic culture, increases yields because the competition among the roots is very less and also allows for increases in density spacing . For example, hydroponic organic basil production in California spaced their plants at 12.7 cm centers (Schoenstein, 1996). In regions with large, dense population or regions with less arable land Hydroponics turn out to be a very valuable method of growing plants(Schoenstein, 1996). In hydroponic solution herbs have the potential to grow 25 percent faster as compared to soil solution (Skagg, 1996). Hydroponically grown plants can have an increase in vitamins and minerals threefold times as compared to plants grown in soil (Skagg, 1996).

2.2 Nutrient Requirements of Substrate Grown Plants

The basic principles of mineral nutrition of crops have been reviewed by Epstein and Bloom (2005). The theory that the plant obtain its nutrients from soil-less medium is no different from that of soil grown plant although with difference in some aspects. Limited volume of substrates is required in soil-less grown plant as compared to soil grown plant, which is also a main factor that distinguishes between them. In addition to these plants grown on soil-less medium has many more benefits which include capabilities to control availability of water, pH and nutrient concentrations in the root zone (Silber and Bar-Tal, 2008) Consequently, soil-less culture methods offer unique benefits such as Plants absorb many elements through their roots, however not all are considered to be essential elements. Essential elements can be defined as one that is required for normal life-cycle of a plant and whose role cannot be assumed by another element (Silber and Bar-Tal, 2008). The elements required in largest quantities are the main structural elements which include nitrogen (N) and potassium (K). It is very important to supply the essential nutrients continuously for plants growing on soil-less medium because of the limited buffer capacity of the medium and its limited supply of nutrients (Savvas, 2001), as of cultivation in soils it not mandatory. The elements Mg, Ca, K, P, N, and S are considered macronutrients because they are required in relatively large concentrations in plant tissue (Spomer et al., 1997). The remaining elements (Fe, CI, B, Mn, Zn, Cu, Mo, and Ni) are considered micronutrients because they are required in lower concentrations (Spomer et al., 1997). To optimize growth both in the greenhouse and in the field, crops should be provided with appropriate levels of inorganic nutrients (Siddiqi et al., 1998). Certain inorganic nutrients applied at excessive levels may be detrimental to plant growth (Siddiqi et al., 1998). Chen et al. (1997) found that the growth of lettuce was significantly increased when the nitrate concentration of the solution was reduced below the highest concentration being used by a local commercial hydroponic grower. The exact amount of nutrient solution varies according to crop, stage of development, environmental conditions and irrigation regime (Silber and Bar-Tal, 2008),although many recommended tables for composition of solution for different types of crops have been published by many authors and organization.

2.3 NPK Nutrient Response Curve

There are considerable differences in the shape of nutrient uptake curves among crops. In many cases the uptake curve of a nutrient exhibits sharp changes with the plant's growth stage of development (Bar-Tal et al., 2003). Neglecting the variation of the uptake rate with time may results in periods of over- or under- fertilisation. Over-fertilisation may enhance environmental contamination and the salinity of soil while under-fertilisation may result to reduction of yields and nutrient deficiency (Bar-Yosef, 1999). According to Hochmuth (1992) the general uptake curve begins with a small amount of each nutrient, then increases with the rate of application of the nutrient as the crop growth rate and nutrient demand increases. Once the crop has reached maturity, nutrient applications can level off and even decrease slightly toward the end of the cropping period.

2.4 Role of Nitrogen, Phosphorus and Potassium in Hydroponic Cultivation

2.4.1 Nitrogen

Gaseous nitrogen are present in its inert form (N_2) in the atmosphere and hence, although plants surrounded by Nitrogen (N) in the atmosphere, it is not available directly. Plant available forms of nitrogen (N) are inorganic and include nitrate (NO_3), and ammonium, (NH_4) (Marschner, 1995). It is one of the essential constituent of proteins (RuBisCO) and chlorophyll (Taiz and Zeiger, 2010). It is a major component of chlorophyll (photosynthesis); amino acids (building blocks of protein such as enzymes); it is also a component of energy-transfer compounds such as ATP (adenosine triphosphate – energy in metabolism) and finally it is a significant component of nucleic acids such as DNA (Marschner, 1995). Amino acid which plays an essential role in the growth and development of the plants also include nitrogen as major component. Growth in plants is mostly influence by nitrogen than many other essential elements as within the range from deficiency to excess N level. These levels markedly affect growth of the plant, fruits yield and quality (Jones, 2005).

Nitrogen probably has a greatest total influence on plant growth than most other essential elements as within the range from deficiency to excess N level markedly affects plant growth as well as fruit yield and quality (Jones, 2005). Enhanced growth and development of both vegetative and yield attributed traits, including vine length, number of branches per vine, number of fruits per vine, weight of single fruit, weight of fruits per vine was found under ample N nutrition (Fageria and Baligar, 2005). Similar results have been found by Umamaheshwarappa *et al.*, (2003) who reported significantly higher fruit yield with the application of increasing N levels compared to control. Similarly, (Baloch 2012) reported that higher N levels improved the bottle vine growth and fruit yield remarkably. Number of branches per vine is a main and key trait that affects the number of fruits. In the present study, maximum numbers of branches have been recorded under higher N levels. More branches under higher N levels were mainly associated with a total vine length that ultimately affects the branches in a vine. The finding is agreement to that of Chonkar (1996) who reported that increasing N level produced a greater vine length and number of branches compared to lower doses. Number of fruits, weight of single fruit and fruit per vine are the main traits that determine the final yield. In the present study, there was a significant increase in the values of these parameters at higher N level. The greater values of these traits under higher N levels might be due to increased vine length, more branches per vine that eventually influence these parameters significantly.

2.4.2 Phosphorus

It has been documented that P is an important element in the synthesis of ATP, respiration, development of plant mass and essential oils, energy transfer and storage, formation of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) and in the germination of seeds (Liu & Zhong, 1998; Kapoor et al., 2004; Stern, 2006; Follett et al., 1981; Resh, 1995). Symptoms of a P deficiency in plants are characterized by a buildup of sucrose and starch, a decrease in photosynthesis, stunted growth, purpling of the lower leaves and hindered seed development (Duffus & Duffus, 1984; Stern, 2006; Follett et al., 1981).

Relationship between Synergistic and Antagonistic among nutrients were studied on NFT-grown young tomato plants. When the concentration of the external P is increased results in not only there is significant increase in plant P, N, K, and Mg but also decreased Fe and Mn concentration due to P nutrition (Gunes et al., 1998). Plant P was negatively correlated with plant Fe and Mn but it was positively correlated with plant Ca, Mg, K and N (Gunes et al., 1998).

2.4.3 Potassium

Potassium are considered to be one of the essential components in maintaining the ion balance for the plants .It also plays an important role in carbohydrate synthesis and its movement Many enzymes required potassium for their activation and positive ion(cation),K^+, is an important contributor to the osmotic potential of the cells. The functioning of stomata guard cells also depends on potassium, as deficiency of K reduces photosynthesis due to closure of stomata which reduces the transpiration and water uptake of the plants (Jones, 2005). Potassium is essential for carbohydrate metabolism, synthesis of proteins, chlorophyll, activation of various enzymes, regulation of the different activities to be performed by essential elements, adjustment of stomatal movement and water relations. It imparts increased frost and disease resistance to plants and counteracts the injurious effects of excess nitrogen in plants. Potassium is well known for its role in imparting colour, glossiness and dry matter accumulation in fruits.

Increasing plant vegetative growth, yield as well as fruit quality and chemical composition due to increasing potassium fertilization levels have been reported by many workers on different crops Nassar et al. (2001) and Fawzy et al. (2005) on bell pepper, Chen Zhen De et al. (1996) and Fawzy et al. (2007) on eggplant, Nanadal et al. (1998), Al-Karaki (2000) and Gupta and Sengar (2000) on tomato and Lester et al., (2006) on muskmelon. Potassium also has been shown to increase pepper yield (Baghour et al., 2001) and an adequate K content in the cytoplasm is required for N metabolism (Xu et al., 2002).

2.5 pH of the Nutrient Solution

The acidity and the alkalinity of a solution is measured in pH parameter. This value ranges between 0 to14 and it indicates the concentration of free ions H+ and OH- present in a solution. In hydroponic culture the productivity of the plant is closely related to the regulation of pH and amount of nutrient uptake by the plants . A nutrient solutions must contain the ions in solution and in chemical forms which can be easily absorbed by plants. (Marschner, 1995). Each nutrient shows its own specific responses to changes in pH of the nutrient solution.

The pH is a parameter that measures the acidity or alkalinity of a solution. This value indicates the relationship between the concentration of free ions H^+ and OH^- present in a solution and ranges between 0 and 14. An important feature of the nutrient solutions is that they must contain the ions in solution and in chemical forms that can be absorbed by plants, so in hydroponic systems the plant productivity is closely related with to nutrient uptake and the pH regulation (Marschner, 1995). Each nutrient shows differential responses to changes in pH of the nutrient solution.

2.5.1 Effect of pH on Nutrient Uptake

Phosphorus can be found as $PO_4{}^{3-}$, $HPO_4{}^{2-}$, and $H_2PO_4{}^{-}$ ions in the root zone; of these the last two ions are the main types of P which are absorbed by plants. On inert substrates, the largest amount of P available in a nutrient solution is presented when its pH is slightly acidic (pH 5). In alkaline and highly acidic solutions the concentration of P decreases in a significant way (Dyśko et al., 2008. The pH range that dominates the ion $H_2PO_4{}^{-2}$ on $HPO_4{}^{-}$ is between 5 and 6 (De Rijck & Schrevens, 1997). Potassium are usually present as a free ion in a nutrient solution of pH values from 2 to 9 .There are only few amounts of K^+ which can form a soluble complex with $SO_4{}^{-2}$ or can be bound to Cl^- (De Rijck & Schrevens, 1998). Like potassium, the availability of calcium and magnesium in plants depends on a wide range of pH; however, their availability is interfered by the presence of other ions due to the formation of compounds with different grade of solubility. As water naturally contains $HCO_3{}^{-}$, when the pH is higher than 8.3 the anion turns into $CO_3{}^{-2}$ and when the pH is less than 3.5, it turns to H_2CO^3 ; the H_2CO^3 is in chemical equilibrium with the carbon dioxide in the atmosphere. Thus at a pH above 8.3, the ions Ca^{2+} and Mg^{2+} can easily precipitate as carbonates (Ayers & Westcot, 1987). Also, as mentioned above, the $HPO_4{}^{2-}$ ion predominates when the pH of the nutrient solution increases which precipitates with Ca^{2+} when the product of the concentration of these ions is greater than 2.2, expressed in mol m-3 (Steiner, 1984). Sulphate also forms relatively strong complexes with Ca^{2+} and Mg^{2+} (De Rijck & Schrevens, 1998). As pH increases from 2 to 9, the amount of $SO_4{}^{2-}$, forming soluble complexes with Mg^{2+} as $MgSO_4$ and with K^+ as $KSO_4{}^{-}$ increases (De Rijck & Schrevens, 1999). At pH higher than 6.5 iron, copper, zinc, boron, and manganese, becomes unavailable (Timmons et al., 2002; Tyson, 2007). The manganese precipitation on root surfaces in *Triticum aestivum*, was correlated with a plant-induced rise in pH of culture above 5.5 (Macfie & Taylor, 1989).Boric acid is mainly absorbed by plants as a source of Boron. It usually does not dissociates until the pH is close to 7.Boric acid accepts hydroxide ions to form anionic species (Tariq & Mott, 2007) to greater pH values, . Therefore, at pH above 7 nutrient availability for plant uptake can be restricted due to precipitation of Fe^{2+}, Mn^{2+}, $PO_3{}^{-4}$, Ca^{2+} and Mg^{2+} to insoluble and unavailable salts (Resh, 2004). The proper pH values of nutrient solution for the development of crops lies between 5.5 and 6.5

2.6 Electrical Conductivity (EC)

Beside the addition of the nutrient elements mentioned previously, the osmotic potential is an important characteristic of nutrient solutions. Electrical conductivity (EC) is mostly use to measure the osmotic potential of nutrient solutions and is build up by mineral salts in nutrient solutions (Sonneveld and Voogt, 2009). A systematic measurement of the EC during crop production is of great importance in order to realise high productions and optimum quality because EC plays a very important role in maintaining the equilibrium between yield and quality of the harvested produce of many crops grown in substrate (Sonneveld and Voogt, 2009). According to Xu et al. (1995) electrical conductivity (EC) is the measurement of a solution's ability to conduct an electric current. For horticultural applications, the unit is often expressed as deci Siemens per metre (dS m-1). Electrolytes dissolved in the water determine how conductive it will be. Therefore EC can be an excellent indicator of: (i) water quality; (ii) soil salinity; and (iii) fertiliser concentration. The quantity of dissolved solids in parts per million (ppm) or mg l^{-1} by weight is directly proportional to the electrical conductivity decisiemens per meter (dS m^{-1}) per unit volume (Resh, 1995). However, the electrical conductivity (EC) varies not only to the concentration of salt present, but also to the electrical composition of the nutrient solution.

The use of EC measurement is only helpful in checking total salt concentrations in the solution, but the concentrations of individual nutrients will vary considerably from then desired concentration. This is because; this procedure only tells the grower the relative amount of total "salts" in the solution and nothing about each specific nutrient concentration in the solution (Hochmuth, 2008). The true concentration of N, P and K may even be deficient even though the EC is the same as before. According to Guzman and Olave (2006), maximum production is achieved up to a given threshold of salt concentration for each crop, determined by EC. Beyond this threshold there is a percentage of reduction in yield for each unit increase in electrical conductivity. In soil-less cultivation, this threshold usually is in the range of 2-5 dS m-1 (Ling Li et al., 2001). It is well known that high EC reduces yield (Chartzoulakis and Klapaki, 2000). This is due to high osmotic pressure which results to reduced uptake of water into the fruits and as a result the size of the is smaller (Sonneveld, 1988), no matter the accumulation of dry matter per fruit is unaffected (Ehret and Ho, 1986). When irrigation water has an EC>2 dSm^{-1} (high salinity), the crop will be sensitive to salinity, and the amount of ions added with the N or K must be reduced. This practice, according to Imas (1999) will diminish leaf burning due to the presence of Cl in excess. It is very important to select fertilisers with low salt index for greenhouse crops grown in containers with a very restricted root volume. According to Heinen et al (2003) crop growth reduction may occur when the fertigation nutrient solution has both low and high EC. At low EC, not enough nutrients may be available to the roots resulting in a decrease in nutrient uptake, which may reduce crop growth. At high EC, although ample nutrients are available a decrease in water uptake may occur due to osmotic effects, which may result in reduced crop growth. Besides growth and water uptake, the EC of the nutrient solution may affect other variables such as dry matter content (De Koning, 1996) and fruit quality (Mizrahi and Paternak, 1985).

2.7 Uses of Sawdust as a Growing Media in the Wick System

Sawdust is widely used as a growth medium component in areas with wood processing industries, because of its low cost, high moisture retention, high availability and can be easily discarded after use. Sawdust has been standard growing medium for the greenhouse industry in Alberta and Argentina for several decades (Sawan and Eissa 1996). Usually it forms a constituent (normally less than 50%) in mixtures rather than being used as a stand-alone growth medium. However, sawdust is prone to gradual decomposition which leads to unfavourable substrate physical properties converting it from ‘dry’ to ‘wet’ substrate with a higher volume of retained water and a deficiency of available oxygen. A study conducted on the growing medium of bell pepper and long English cucumber found out that perlite’s (as inorganic substrate) has higher stability but, there was no improvement in productivity found for bell pepper or long English cucumber when compared to sawdust (Nichols and Savidov 2009). Indeed, coir was the better substrate when compared to sawdust for the long English cucumber crop, but sawdust was preferable substrate for the bell pepper crop (Savidov 2005). A study on different ratio of sawdust, coco soil or pumice on hydroponically grown strawberry plants showed that the Leaf number doubled in plants grown in Saw-100. Organic matter (and as a consequence the organic carbon content) was also increased in Saw-100 compared with Coc-100. However, the effect of saw dust as growing media on bottle gourd is not well known.

2.8 Nutrient Flow Technique

NFT (Nutrient film technique) is the most common of the continuous flow systems. Here nutrient solution is pumped from a tank into the top of channels. It flows down the channel in a thin film and returns to the tank to be recalculated. The main advantage of the NFT system over other forms of hydroponics – bag, media and soil culture – is that the plant roots are exposed to adequate supplies of water, oxygen and nutrients. In all other forms of production there is a conflict between the supply of these requirements, since excessive or deficient amounts of one results in an imbalance of one or both of the others. NFT, because of its design, provides a system where all three requirements can be met at the same time, providing the simple concept of NFT is always remembered and practiced. The result of these advantages is that higher yields of high quality produce are obtained over an extended period of cropping.

2.9 Nutrients and Dry Weight Accumulation

During crop growth the demand for nutrients varies widely. The rate of nutrient requirement at each growth phase is associated with two predominant phases (I) formation of new vegetative plant tissues; and (ii) formation of reproductive organs (flowers, fruits, seeds etc) (Ravi and Loath, 2008). Various meteorological factors such as photosynthetically active radiation (PAR), air temperature and humidity, wind speed and direction of solar radiation affects the photosynthesis rate which are primarily related to the nutrient requirements for increasing dry weight (DW) (Thornley and Johnson, 1990).

2. 10 Bottle Gourd

2.10.1 Bottle Gourd Production

Bottle gourd (Lagenaria siceraria) is a very important vegetable crop belonging to the family cucurbitaceae. It originated in tropical Africa, the crop is being domesticated widely in Asia, Africa and New World. It is a common vegetable used in India. It is also found growing in Ethiopia, Africa, Central America and other warmer regions of the world. Bottle gourd fruit comes in different shapes but resembling a bottle. The most common shapes are cylindrical, round, oval and oblong. As, a vegetable it is easily digestable even by patients. Jaundice can be treated from a decoction made from the leaf which is very good a medicine . The pulp can act as an antidote against certain poison and it is also helps us in overcoming constipation, cough and night blindness.

2.10.2 Bottle Gourd Plant

Bottle gourd is a climbing annual with a duration of 3 ½ to 4 months. It is characterized by its large oxalate oval leaves and branched tendrils spreading or climbing upto 3-15m. The foliage is pubescent and emits a characteristic somewhat musky and unpleasant odour when bruised. Flowers are solitary, chalky white in colour and open at night. Fruits are fleshy and vary in shape and size. There are two main types of bottle gourd in India i.e., long and round. According to (Yawalkar ,1980) recommends the round one for early crop and the long variety for the rainy season. Bottle gourd is a typical warm season vegetable. Though crop tolerates cool climate better than musk melon and water melon, it cannot tolerate frost. Well drained fertile silt loam is ideal for cultivation of bottle gourd. Crop is quite suitable for river bed cultivation because of its deep tap root system. A deep soil supports vines for a long period. Several improved varieties have been shown to have better quality and productivity including Pusha Naveen, Arka Bahar, Punjab Karnal. Bottle gourd is a typical tropical plant requiring a hot and humid climate for best growth. The optimum temperature for growth are 24-27*C (Nath, 1987). It is highly sensitive to photoperiod. High rainfall amounts along with prolonged cloudiness results in a higher incidence of diseases and may drastically affect yield. Short days and humid climate promotes Femaleness (Chauhan, 1972).

Bottle gourd can be grown on all types of soils, but sandy loamy soil with higher organic matter content is considered best. Soil should be well drained and the pH between 6-7 is best suited for its cultivation. Fruits are harvested at tender stage when it grows to one third to half. Fruits attain edible maturity 10-12 days after harvesting and are judged by pressing on fruit skin and noting pubescence persisting on skin. At edible maturity seeds are soft. Seeds become hard and flesh turn coarse and dry during aging. Tender fruits with cylindrical shape are preferred in market. Harvesting starts 55-60 days after sowing and is done at 3-4 days intervals. While harvesting, care should be taken to avoid injury to vines as well as to fruits. Plucking of individual fruits is done with sharp knives by keeping a small part of fruit stalk along with fruit. Average yield is 20-25 t/ha for open pollinated varieties and 40-50 t/ha for F1 hybrids.

Chapter III

3. Rationale and Scope of the Study

The greatest challenge of 21st century in many developing countries is to produce the basic necessities namely food, fuel and fiber for human consumption and fodder for rearing domestic animals from the limited available land without soil degradation at the minimum amount of agriculture inputs. On the other hand, statistically, the world population is increasing continuously whereas and food grain production is not increasing proportionally due to various factors including decline in soil fertility and repercussions arising from climate change phenomenon as manifested by unpredictable patterns of rainfall and temperature. The availability of land for agriculture is also shrinking everyday as it is increasingly utilized for non-agriculture purposes while physical and chemical properties of soils are day to day changing improperly and this affects production and impact sustainable agriculture in different ways.

Considering the changing environment and climate conditions hydroponics has a bigger advantage than geoponics, mainly because these methods do not promote the use of chemicals fertilizers or pesticides and its role in developing a sustainable environment. The advancement in indoor and vertical hydroponic has created the urge for cultivating herbal medicines, vegetable and food crops to meet the market demand. Harvesting from the wild, the main source of raw material, is facing loss of genetic diversity, contaminants due to habitat destruction. Controlled cultivation is a viable alternative and offers the opportunity to overcome the problems of phenotypic variation in bioactive compounds that are inherent in herbal extracts, misidentification, genetic and phenotypic variations, extract variability and instability, toxic components and contaminants. Bottle gourd (*Lagenaria siceraria*) is extensively cultivated in India, Japan, Sri Lanka, Pakistan, China and Thailand for kitchen. As mentioned earlier the bottle gourd is useful for treating many diseases and disorder. It has the highest choline level for any known vegetable which serves as the precursor of neurotransmitter acetycholine, which is crucial for retaining and enhancing memory. The production of bottle gourd is determined by the availability of nutrients in the soil. Nitrogen potassium and phosphorus plays an important role in the yield and development of bottle gourd. However, information on the cultivation of bottle gourd is lacking and there has been few research conducted on the cucurbitaceae family.

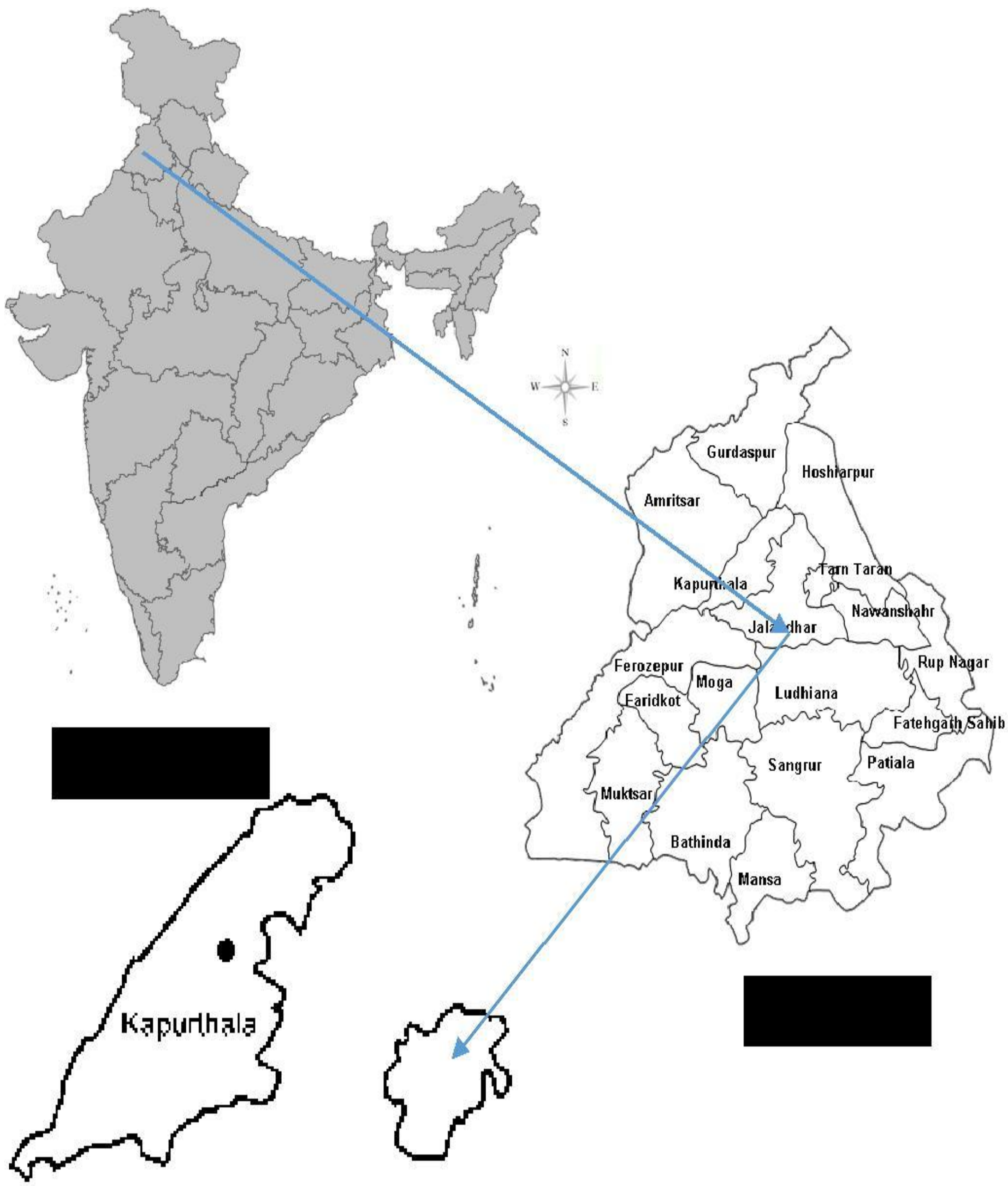
This information need to be generated urgently to provide information to the hydroponic growers and farmers of the regeion. Therefore understanding the effect of different concentrations of NPK in Hoagland solution and suitability of hydroponic system for the production of bottle gourd was the challenge of this study.

Chapter IV

4. Materials and Research Methodology

4.1 Situation of Experimental Site

The field experiment was conducted in the Research Farm of Department of Agronomy, Scholl of Agriculture, Lovely Professional University, Punjab (India) during Rabi season 2014 - 2015. Geographically is situated (31º 15‟ North latitude and 75^{o} 42‟ East longitude) at 235 m above mean sea level in Punjab. This experimental site falls in “Central Plain Zone (PB-3) of Punjab.



[redacted]

Fig 4.1 Location of the experiment

4.2 Climate and Weather

The climate of the experimental site is located in Punjab State which experiences by the extreme hot and extreme cold conditions. The annual temperatures in Punjab State range from 1 to 46^{O}C and can reach 49^{O}C during summer and 0^{O}C in winter. Its average rainfall ranges from 960 mm in the sub mountain region and 460 mm in the plains. It is also characterized by heavy rain in the northeast area near the foothills of Himalayas, whereas it receives less rainfall and high temperatures in the area lying in south and west. It experiences also three seasons as follows: Summer season from April and June and it is characterized by the rise in temperatures up to 38^{O}C; Monsoon season from July to September and it is during this period when the majority of rain occurs and Winter season from December to February with typical fall of temperatures up to 0^{O}C.

4.3 Meteorological Data during Growing Season

Weather and climate are important factors that determining the success or failure of agriculture. Weather influences agricultural operations from sowing to the harvest, the reason why it is important to present the variations of climate during growing season. The mean of weekly meteorological observations were recorded during entire growing season and are represented in Table 4.1. Crops were sown on 26/11/2014. Pea was harvest on 25/3/2015 and wheat was harvested on 22/4/2015. Maximum and minimum temperatures during growing season were 33.49^{o}C and 6.90^{o}C respectively, relative humidity varied between 63 and 85 per cent. There was a total rain of 190 mm during growing period.

Table 4.1 Monthly air temperature, relative humidity and total precipitation from November 2014 to April 2015

Month	Temperature (^{O}C)			RH (%)	Rainfall (mm)
	Maximum	Minimum	Average		
November	26.9	10.9	18.9	63	0
December	17.6	6.9	12.25	80	42.2
January	15.6	7	11.3	85	24.6
February	22.2	10.5	16.35	79	38.6

March	25.5	13.3	19.4	76	84.6
April	33.49	19.17	26.33	62.62	0
Total					190

Source: Department of Meteorology, PAU.

4.4 Varietal description

The plants used for the experiment was called Gagan. It is an F_1 hybrid having green and fruits oblong shape fruits and light green skin. Tolerant to CMV, early harvest (70 DAS), potential yield 40 t/ha ,Punjab Agricultural University, Ludhiana.

4.5 Experimental Design and Layout

The general layout of the greenhouse experiments is shown in figure. The experiment, laid out in a factorial design with 5 replicates, was used to compare different fertilizer concentrations. Each experimental unit consist of a nutrient storage tank which supported 5 pots for wick system and a PVC pipes 8cm X 8cm of length 1.5 metre supported by a frame . The nutrients were circulated constantly in a closed hydroponic system with the help of a small submersible pump. The flow of the water from the submersible pump was controlled by a regulator at the rate of 13800 ml/min. The nutrients were recollected in the tank through the outlet pipe.

Table 4.2 Detail of treatments evaluated in Bottle gourd during (feb-may2015)

Treatment No.	Treatment detail	Treatment Code
T_1	Wick system+ Hoagland solution recommended dose of NPK	WSN
T_2	NFT system + Hoagland solution recommended dose of NPK	NFTN
T_3	Wick system + Hoagland solution recommended dose of NPK + 20% enriched NPK	WSN20
T_4	NFT system + Hoagland solution recommended dose of NPK + 20% enriched NPK	NFT20
T_5	Wick system + Hoagland solution recommended dose of NPK + 30% enriched NPK	WSN30
T_6	NFT system + Hoagland solution recommended dose of NPK + 30% enriched NPK	NFT30

4.6 Nutrient Solution

Hoagland solution a well known hydroponic nutrient solution modified by Hershey, (1994) and Hershey, (1995), offering all the necessary macro and micro nutrients for healthy plant growth was used as a base nutrient and supplemented with extra Nitrogen, Phosphorus and Potassium. The basic formula of the preliminary growth study was composed of the following nutrients in ppm : N 210 ppm, K 235 ppm, Ca 200 ppm, P 31 ppm, S 64 ppm, Mg 48 ppm, B 0.5 ppm, Fe 1 to 5 ppm, Mn 0.5 ppm, Zn 0.05 ppm, Cu 0.02 ppm and Mo 0.01 ppm. For the nutrient treatment solutions N, P and K was increased by adding Potassium Nitrate, Calcium Nitrate, Magnesium Sulphate and Ammonium di hydrogen phosphate . The fertilizer sources used for the experiment were Potassium Nitrate KNO_3, Calcium Nitrate ($Ca(NO_3)_2$, Magnesium Sulphate ($MgSO_4$), Iron Chelate (FeEDTA), Ammonium di Hydrogen Phosphate($NH_4H_2PO_4$), Potassium Chloride (KCl), Boric Acid (H_3BO_3), Manganese sulphate ($MnSO4.H_2$ o), Zinc Sulphate ($ZnSO_4$), Ammonium Molybdate (H_2 Mo.O_4) and Copper Sulphate ($CuSO_4$. $5H_2O$).

Separate stock solutions of 500ml of Potassium Nitrate KNO_3, Calcium Nitrate ($Ca(NO_3)_2$, Magnesium Sulphate ($MgSO_4$), Iron Chelate (FeEDTA), Ammonium di Hydrogen Phosphate($NH_4H_2PO_4$) concentration and separate stock solutions of 2L of Potassium Chloride (KCl), Boric Acid (H_3BO_3), Manganese Sulphate ($MnSO4.H_2$ o), Zinc Sulphate ($ZnSO_4$), Ammonium Molybdate (H_2 Mo.O_4) and Copper Sulphate ($CuSO_4$. $5H_2O$) were prepared each time for all the experiments to avoid precipitation, Separate stock solutions of every sources was prepared and kept in a dark container to avoid photodegradation.

4.7 Nursery

The bottle gourd seeds were germinated on January 5, 2014 in 5 petridish. The seeds were covered by muslin cloth which was misted with water regularly while avoiding the starters getting soaking wet. In the month of January 2015, the temperature was low and foggy which inhibited the germination so it was carried out in an incubator at a control temperature of 25^o C. After germination each seedling were transferred to a plastic cup filled with cocopeat. At the fourth true leaf stage, individual plant were transferred to the hydroponic systems.

Figure 4.2 Status of bottle gourd plant at 20 DAT

4.8 Transplanting in the Hydroponic Wick System

In the wick system the plants were transferred to the pots 12 cm X 12cm containing saw dust which was self watered with cotton threads (Fig 5.3). The reservoir was attached to the growing tray containing 5 pots . Holes of 10cm X 10cm were drilled on the cover of the storage tank to support the pots. 5 pots spaced at a distance of 15 cm each was placed on the respective holes drilled on the cover of the container.

Each pot was attached with 6 cotton ropes for absorbing the nutrients from the tank. The wick uses capillary action to move the nutrients from the solution to the growing media and upto the plants roots.

Fig 4.3 Transplanting in saw dust (left) root status in the wick system 35 DAT (right)

4.9 Transplanting in NFT System

In the NFT system the plants were placed on holes 2cm X 2cm drilled on the PVC pipes supported by sponge on the sides of the stem to prevent the plants from submerging. The NFT systems were constantly pumped by a submersible pump at rate of 13800 ml/min.

Fig 4.4 NFT system at the experimental site 20 Days after transplanting

4.10 Determination of pH

The nutrient solution was collected from the outlet pipe in a 100 ml beaker. The pH was measured for every 2-3 days with the help of pH-meter. During the entire experiment the pH was maintained between 5.5 – 7.5.

4.11 Determination of EC

The nutrient solution was collected from the outlet pipe in a 100 ml beaker. The EC was measured for every 2-3 days with the help of EC-meter. During the entire experiment the electron conductivity of the nutrient solution was maintained between 1.4 - 2.5 dsm^{-1}.

4.12. Growth and Yield Parameters of Bottle Gourd

4.12.1 Plant height (cm)

The height of 5 tagged plants in each pot was recorded three times during crop growth (20 and 60 DAT) using a meter scale from ground level to the upper youngest leaf of the plant. Plant height was measured from the top of the pot to the top most of the leaf. The mean plant height is expressed in cm per plant.

4.12.1.2 Root length (cm)

The roots were gently rinsed in the de ionized water to remove the growing medium for wick system and then the lengths were measured from the point of root emergence to the tip of the root mass, using a measuring scale. The root length of 5 tagged plants in each pot was recorded three times during crop growth (20 and 60 DAT) using a meter scale from ground level to the upper youngest leaf of the plant. Plant height was measured from the top of the pot to the top most of the leaf. The mean plant height is expressed in cm per plant.

4.12.1.3 Number of flowers

The flowers obtained from the selected plants at different growth stages were counted two times during the crop growth (25 and 60 DAT) and expressed as number of flowers per plant.

4.12.1.4 Number of fruits

The fruits obtained from the selected plants at different growth stages were counted two times (45 and 65 DAT) during the crop growth and expressed as number of fruits per plant.

4.12.1.5 Determination of Dry Matter

The dry matter accumulation of bottle gourd was estimated at 40 and 60 DAT. The randomly selected plants were removed from each pot. Above plant samples were dried in an oven at 60^{o}C until weight become constant. The dry matter Percent was measured and expressing the remaining weight of sample after drying of the wet sample. ASTM D2974 (1995)

$$\text{Dry weight \%} = \frac{(\text{oven dry weight})}{\text{wet weight sample}} \text{X } 100$$

4.12.2 Quality Parameters of Bottle Gourd Plant

4.12.2.1 Plants Analysis

Randomly selected plants were removed from the field in each pot at 50 DAT, dried in an oven at 72^{o}C for 72 hours, subsequently the oven dried sample were grounded into a kind of floor and passed through 1mm sieve and stored in plastic bags for analysis. The analytical procedures followed for estimation of N, P and K content in plant sample are described below:

Table 4.3 Analytical methods employed for plant analysis

Sr. No.	Parameter	Method employed	Reference
1.	Nitrogen	Micro-kjeldahl method	Jackson (1967))
2.	Phosphorus	Vanado-molybdo-phosphoric acid yellow colour method	Richards, (1954)
3.	Potassium	Wet digestion method	Black (1965)

4.12.2.2 Procedures of Plant Analysis of Nitrogen

One gram of prepared plant material wrapped in a piece of filter paper, to a 300ml Kjeldahl's digestion flask, 10g of catalyst mixture ($CuSO_4$, K_2SO_4, Se, HgO in ratio 20:480:1:3) and 30ml of conc.H_2SO_4 was added then the contents in the flask was mixed , then starting digestion of the contents in the flask first on the low heat on and gradually the temperature increased until acid reached a boiling point. And heating was continued until the organic matter was destroyed and solution became a clear greenish color. The content was cooled and 100ml volume was made with distillated water.

10ml of 0.02N H_2SO_4 was pipette out, in a 150ml of conical flask and 3 drops of methyl red indicator was, added, the conical flask was placed under the delivery tube of condenser. 5ml of the aliquot was taken in the distillated flask and connected to the mouth of the distillation flask. 25ml of 45% NaOH was poured in the distillation flask containing the aliquot through the funnel attached to the distillation apparatus, the tab was closed and starting distillation. 30ml of distillate was collected and excess of 0.02N H_2SO_4 in conical flask was titrated against 0.02N NaOH. . Change of colour from pink to yellow was end point. Nitrogen percentage in plant sample was calculated by the following formula:

$$\mathbf{N}\% = (\mathbf{X} - \mathrm{Y})\mathrm{x}\ 0.028\ \mathrm{x}\ 25$$

Where: **X**: volume of 0.02N H_2SO_4 **Y:** volume of 0.02N NaOH used

4.12.2.3 Procedure of Plant Analysis for Phosphorous

One g of plant sample was transferred in 250ml Erlenmeyer flask, 20 ml of triple acid mixture (HNO_3, $HClO_4$ and H_2SO_4 in the ratio of 9:3:1),was added after swilling the content was heated on hot plate. The heating was continued till the contents of flask gave a yellowish green appearance, then the contents was cooled and made the volume of 100ml with distilled water, then filtered it through whatman No.1 filter paper.

5ml of plant filtrate in 25ml of volumetric flask, 2-3 drops of 2-4 dinitrophenol indicator and 4N Na_2CO_3 solution drop till yellow colour appears, and 6N HCl was added till disappearance of yellow colour, for getting pH of 4.8 2ml of 6N HCl in excess was added , 5ml of vanadate molybdate was added and the volume of 25ml was made and the colour was developed in 30 minutes , the intensity of yellow colour was read on spectronic -20 photoelectric calorimeter at a wavelength of 470 mµ. Phosphorous percentage in plant sample was calculated by the following formula:

$$\mathbf{P}\% = \frac{\text{ppm of p in given plant sample}}{10000}$$

4.12.2.4 Procedure of Plant Analysis for Potassium:

One gram of the plant material was taken in the conical flask. Five milliliters of the concentrated nitric acid and three milliliters of perchloric acid was added to it .The material was swirled and placed on hot plate and heated till the solution was colorless .The solution was removed from the hot plate and transferred to a 50 mL volumetric flask. The volume was made with distilled water. (Van Schouwenberg and Walinge, 1973 cited by Page et al, 1982). One mL of the extract was taken in a test tube and 5 mL distilled water was added to it followed by 4 mL lithium chloride solution .Test tube was shaken and potassium was determined using flame analyzer (Chapman and Pratt,1961 cited by Page et al., 1982).

Chapter V

5. Results and Discussion

This chapter summarizes results of the current study and tries to clearly define the meaning of those results. Statistical analysis was used to present data and their discussion was subsequently done with the information provided by previous researchers in the field of hydroponics. Three different doses of Hoagland solution i.e. recommended dose, 20% NPK increased and 30% increased NPK was studied under between two different hydroponic system i.e., wick system and NFT system. Data was recorded on plant height, number of flowers, and number of fruiting bodies, root length and dry weight. Plant tissue analysis on Nitrogen, Phosphorus and Potassium was also recorded. The data obtained from different growth parameters showed that plants grown in NFT system treated with 20% increased NPK showed significant result among the other treatments as they significantly increased the plant height, no. of flowers, no. of fruiting bodies and dry weight of bottle gourd. The Current study was conducted at Lovely Professional University during Zaid season (February- June) 2015 and Bottle gourd, (*Lagenaria siceraria*), was used as the experimental crop in Randomized Block Design with the following experimental treatments. The crop was harvested on 25th April 2015 i.e. 72 days after sowing.

The experimental results pertaining to the current study entitled "Effect of Varying Concentration of Nutrients on Quality and Productivity of Bottle Gourd (*Lagenaria siceraria)* through Hydroponic Systems*"* have been presented and analyzed in this chapter under following headings:

5.1 Plant Height

The data collected on the present research showed the performance of 3 different NPK concentration of hydroponic nutrient i.e. normal Hoagland solution, 20% increased NPK and 30% increased NPK on two different hydroponic systems (wick and NFT). The result showed that the plant height was significantly different between NFT and the wick system. The plant height gradually increases with increasing concentration. However, the plant height was found to be restricted when the concentration of NPK was increased to 30%. The application of 20% increased Hoagland solution in NFT resulted in the maximum height in 25 and 45 DAT having 15.26 cm and 103.26cm respectively. Data recorded during 25 DAT revealed that the growth rate of plants in the NFT system showed significant increase in growth and development compared to the wick system.

Table 5.1 Effect of treatments on Plant Height at 25 and 65 DAT

Treatment	25 DAT	60 DAT
WSN	9.54b±0.56	57.85b±7.79
NFTN	13.76a±0.56	86.14ab±17.37
WS20	7.10b±0.51	85.66ab±2.94
NFT20	15.26a±0.72	103.26a±7.72
WS30	7.65b±0.86	63.84b±6.44
NFT30	12.60a±0.94	82.80ab±4.02

Similar results were obtained from a study carried out by F.M. Oloyede on growth, yield and antioxidant profile of pumpkin as affected by NPK compound fertilizer. The application of NPK fertilizer progressively increased the vegetative growth and the yield of pumpkin leafy vegetable, though beyond 180 kg NPK ha^{-1}, there was no more significant yield increase. Plant heights are a general indication of plant health and a plant's ability to root in a medium. Plants grown in NFT gave significantly good result from the initial and throughout the experiment.

5.2 Root length

The data for root length was collected on the 25^{th} and 45^{th} days after transplanting with the help of a measuring scale. The present experiment showed the performance of 3 different NPK concentration of hydroponic nutrient i.e. normal Hoagland solution, 20% increased NPK and 30% increased NPK on two different hydroponic systems (wick and NFT). The result showed that there was no significant difference in the performance of root length in varying concentration of NPK. However the plants grown in wick system showed higher root length of

103.53 in WSN (wick system recomended dose), 103.6 in WS20 (20% NPK increased) and 107.33 WS30 (30% NPK increased) compared to plants grown in NFT system.

Table 5.2 Effect of treatments on root length at 25 and 60 DAT

Treatment	25 DAT	60 DAT
WSN	13.86ab±1.15	103.53a±2.05
NFTN	10.66cd±0.47	91.73b±3.34
WS20	13.33abc±1.00	103.6a±2.47
NFT20	10.13d±0.52	100.6ab±2.68
WS30	15.73a±1.32	107.33a±5.65
NFT30	11.13bcd±0.58	97.46ab±1.20

In the present study the roots in the wick system are found to be more concentrated in the wicks and gradually increases its absorption area and profuse downward towards the nutrients in the storage tank. The nutrient is supplied through wick system where the wetness zone is more in the wick and down towards the storage tank. A study conducted on cucumber plant using drip irrigation under greenhouse showed that the plant roots were restricted and concentrated more in the wet zone (Qasim, M., Ahmad, I., & Ahmad, T. 2008).

5.3 Number of flowers :

The number of flowers pants was recorded on 45 and 60 DAT. The data revealed that the different concentration of NPK significantly affected the rate flowering in bottle gourd plant. Plants treated with recommended dose of NPK and 20% increased NPK showed better result than the plants treated with 30% increased NPK. However, bottle gourd plants treated with 20% increased NPK gave significant result than the plants grown in recommended dose and 30% increased NPK.. Data recorded on 45DAT showed that the plants grown in NFT system has significantly higher rate of flowering than the plants grown in the wick system.

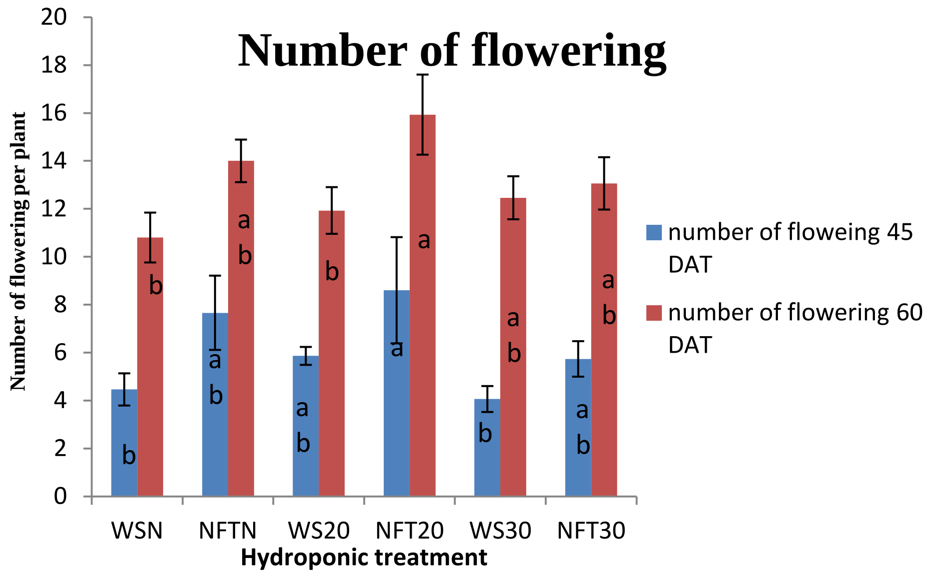


Fig 5.1 Number of flowering per plant at 45 DAT and 65 DAT

P. Umamaheswarappa et al., Studied on effect of varying levels of nitrogen, phosphorus and potassium on flowering, fruit set and sex ratio of cucumber showed that, increasing NPK levels had a significant effect on number of days required for initiation of first male and female flowers, number of male and female flowers per vine during 2001 and 2002. The early appearance and increased production of male and female flowers due to higher levels of nitrogen application may attributed to fast growth of vine which favoured flower forming hormone like Gibberlic acid (GA) these by inducing production of more female flowers. The above results are in conformity with the findings of earlier works performed by (Choudhari and More, 2002, E1-Aidy and Moustafa, 1978, Alshaf and A1-Khafagi, 1990, Cantliffe and Omran, 1978).

5.4 Number of fruiting bodies

The number of fruiting bodies per pants was recorded on 45 and 60 DAT. The data revealed that the different concentration of NPK significantly affected the rate flowering in bottle gourd plant. Plants treated with 20% increased NPK showed better result than the plants treated with 30% increased NPK and recommended dose of Hoagland solution. Data recorded on

45DAT showed that the bottle gourd plants grown in NFT system has significantly higher rate of fruiting bodies per plant than the plants grown in the wick system. However the bottle gourd grown in NFT system treated with 20% increased NPK and 30% increased NFT showed the best result with an average of 8 and 6.6 fruiting bodies per plant at 60th DAT.

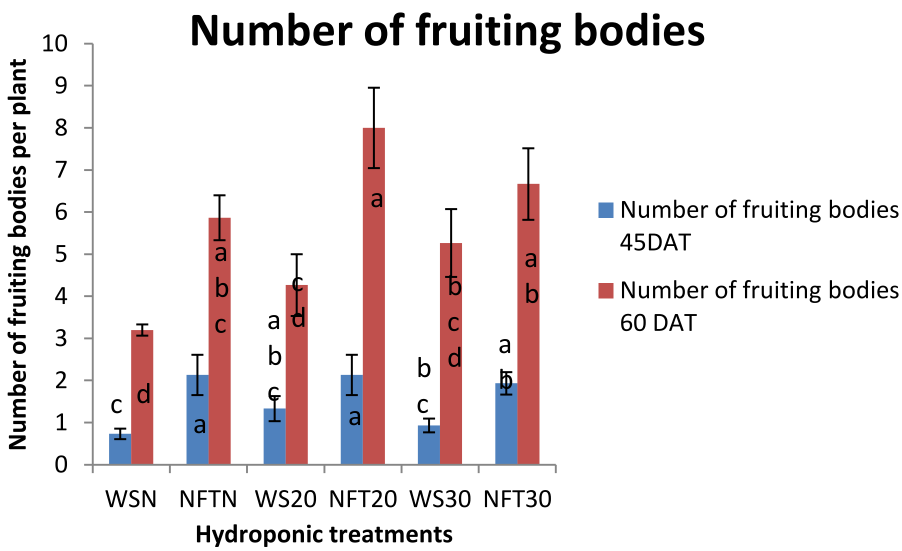


Fig 5.2 Number of fruiting bodies per plant at 45 DAT and 60 DAT

Baloch (2012) reported that higher N levels improved the bottle gourd vine growth and fruit yield remarkably. Similar results have been found by Umamaheshwarappa *et al*., (2003) who also reported significantly higher fruit yield with the application of increasing N levels compared to control. In the present study, there was a significant increase in the values of fruiting bodies, no. of flowers, plant height parameters at higher N level. The greater values of these traits under higher N levels might be due to increased vine length, more branches per vine that eventually influence these parameters significantly. The results of the present study are further supported by Patil *et al*., 1996, Umamaheswarappa *et al.*, (2008), Bairwa and Khandelwal (2010). These authors reported that higher level of N, P and K significantly increased the number of fruits, fruit weight and fruit yield per plant.

5.5 Total Dry Matter of Bottle gourd plant

The total dry weight was recorded on 40 and 60 DAT. The data revealed that there was no significant difference of varying concentrations of NPK in the dry matter concentration in bottle gourd plant. However, Plants grown in NFT system showed better result than the plants grown in wick system. The accumulation of dry matter in the bottle gourd plant was slow in the first observation recorded at 40 DAT and then increased markedly as the maturity stage began (Figure 5.3). Similar observation was also observed by other researchers (Marcussi et al., 2001). Data recorded on 45 and 60 DAT showed that the plants grown in NFT treated with 20% increased NPK has higher rate of total dry matter production and more suitable for cultivation of bottle gourd. The difference in the dry matter production due to different treatments can be related to the plant height (Fig 6.3). Significantly plants grown in NFT treated with 20% increased NPK gave normally higher dry weight than the other treatment. Higher leaf area contributed to more solar radiation interception, larger leaf area, carbohydrate synthesis (Silber et al., 2003) and resulted in higher yield.

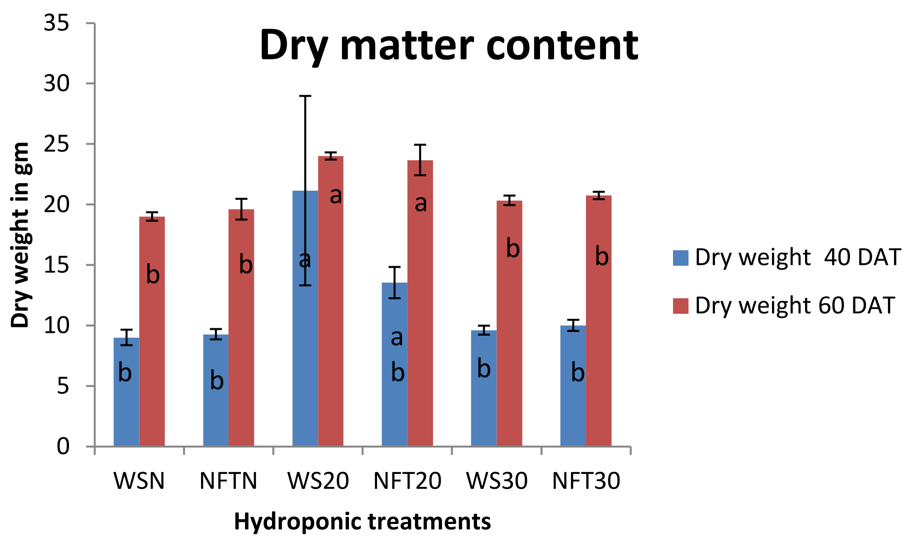


Fig 5.3 Dry matter accumulation per plant at 40 DAT and 60 DAT

5.6 Plant analysis of Nitrogen, Phosphorus and Potassium

Plant analysis of bottle gourd plant was performed after 50 DAT. Random plants were selected from each treatment. The analytical procedures followed for estimation of N, P and K content in plant sample revealed significant difference in the nutrient content of Nitrogen, Phosphorus and Potassium.

5.6.1 Nitrogen Content

The data collected on the present research showed the performance of 3 different NPK concentration of hydroponic nutrient i.e. normal Hoagland solution, 20% increased NPK and 30% increased NPK on two different hydroponic system (wick and NFT). The result revealed that there was no significant difference between NFT and the wick system. The Nitrogen concentration in the plant tissue gradually increases with increasing concentration of NPK.

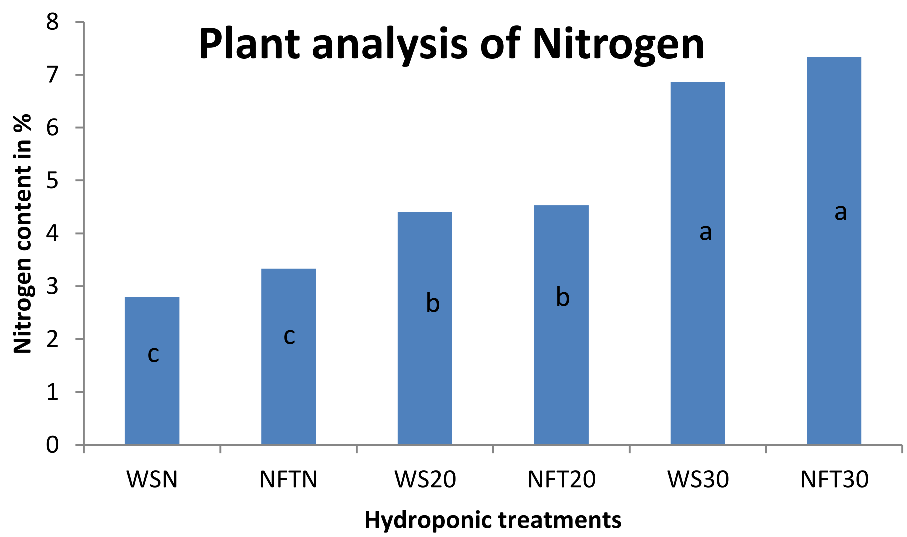


Fig 5.4 Plant analysis of Nitrogen at 50 DAT

5.6.2 Phosphorus Content

The data collected on the present research showed the performance of 3 different NPK concentration of hydroponic nutrient i.e. normal Hoagland solution, 20% increased NPK and 30% increased NPK on two different hydroponic system (wick and NFT). The result revealed that there was no significant difference between NFT and the wick system. The Phosphorus concentration in the plant tissue gradually increases with increasing concentration of NPK.

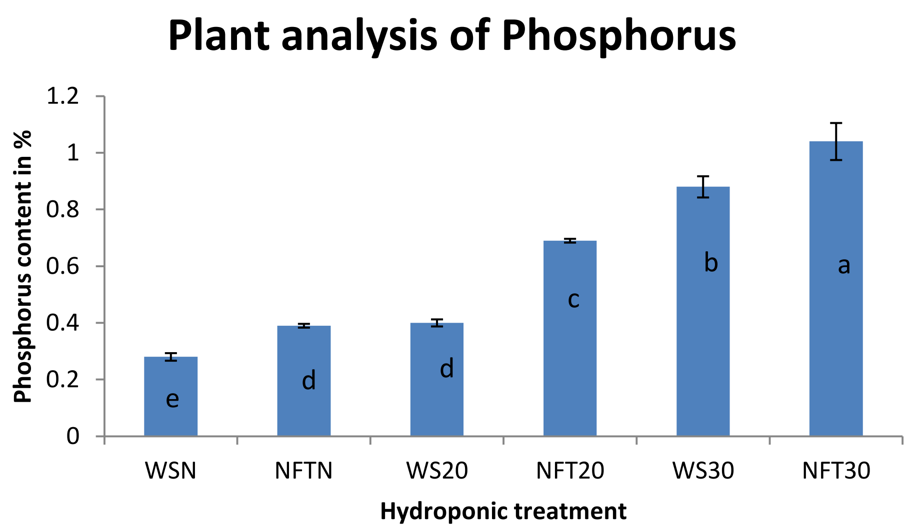


Fig 5.5 Plant analysis of Phosphorus at 50 DAT

5.6.3 Potassium Content

The data collected on the present research showed the performance of 3 different NPK concentration of hydroponic nutrient i.e. normal Hoagland solution, 20% increased NPK and 30% increased NPK on two different hydroponic system (wick and NFT). The result revealed that there was a sudden decrease in the potassium concentration of the plants treated with 30% increased NPK. The decrease in the potassium concentration can be linked with the inhibition of potassium uptake by the plant roots.

Increasing plant vegetative growth, fruit quality and chemical composition of potassium in the plants due to increasing potassium fertilisation levels have been reported by many workers on different hydroponically grown crops Nassar et al. (2001) and Fawzy et al. (2005) on bell pepper. Similar result was obtained with the increased concentration of potassium Chen Zhen De et al. (1996) and Fawzy et al. (2007*)* on egg plant , Nanadal et al. (1998), Al-Karaki (2000) and Gupta and Sengar (2000) on tomato and Lester et al., (2006).

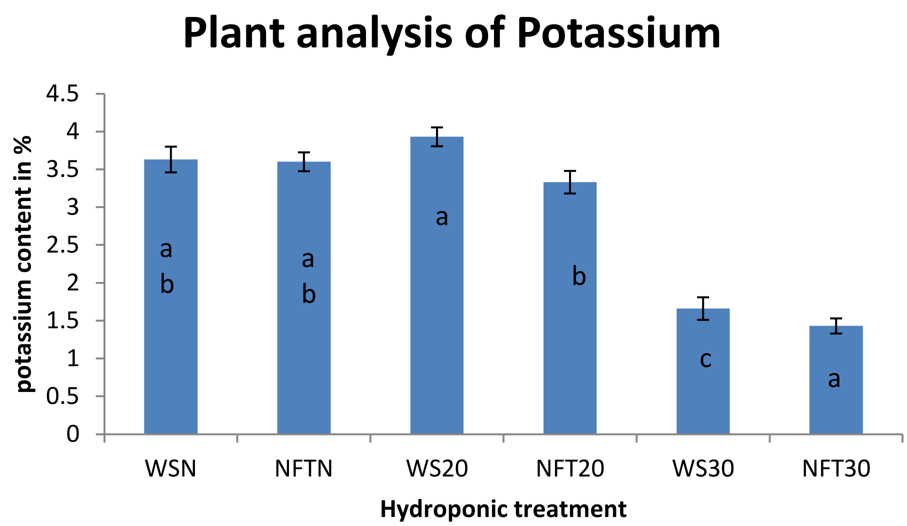


Fig 5.6 Plant analysis of potassium at 50 DAT

The increases in the leaf N, P and K concentrations on high fertigation frequency can be related to the continuous irrigation supplied in the closed hydroponic system which directly or indirectly affected the N, P and K concentration at the root surface (Raviv and Lieth, 2008). The direct effect of continuous irrigation is the frequent elimination of the depletion zone at the root surface by fresh supply of nutrient solution (Silber, 2005). Moreover, a higher irrigation frequency maintains higher dissolved N, P and K concentrations in the substrate solution by shortening the period during which precipitation takes place (Raviv and Lieth, 2008).

6. Conclusion

To investigate the effect of different composition of Nitrogen, Phosphorus and Potassium of modified Hoagland solution in the growth and development of Bottle gourd plant , an experiment was conducted on 6 treatments WSN, NFTN, WSN20,NFT20, WS30, NFT30 as shown in (table 4.1). The study gave significant results on the effect of different concentrations of NPK in the hydroponic solution. Significant increased in plant height, number of flowers per plant, number of fruiting bodies per plant, chemical concentration of Nitrogen and Phosphorus in the plant tissue were recorded.

However, the Potassium concentration in the plant tissue was very low when the plants were treated with 30% increased NPK Hoagland solution. The reason of low Potassium uptake can be related to the antagonistic and synergistic effect of Potassium with other nutrients. Potassium is known to interact with almost all of the essential macro, micro and secondary nutrients. Future improvements in yield and quality will require a better understanding and management of these interactions. Studies performed on the mineral interaction of potassium have also stated that Nitrogen form can affect K absorption. A study on the Interaction of micronutrients (Ujwala Ranade- Malv, 2011) with major nutrients with special reference to potassium revealed that high rates of Magnesium and Calcium fertilizers depress Potassium absorption by plants. Similarly, applications of potassium fertilizers reduce a plant’s ability to absorb Magnesium and Calcium. In our present research Calcium Nitrate was used as a Nitrogenous source for the Hydroponic nutrient solution. Apart from the mentioned nutrients which were increased the dosage of Magnesium Sulphate was also increased in the present research. The limiting uptake of potassium and restriction in the growth of bottle gourd with increased 30% NPK is not well known due to the limited analysis of only few nutrients.

In the present research NFT hydroponic system was found to be more suitable for commercial cultivation of Bottle gourd from every aspect except for root length. The overall value of growth and quality parameters was highest in 20% increased NPK grown in NFT system showing significant increase in the overall parameters with positive result than other treatment. Highest average mean value readings of 103.26 cm plant height, 15.9 flowers per plant , 8 fruiting bodies per plant and total dry matter concentration of 20.73 gram per plant was found for growth parameters of bottle gourd plant. Quality parameters recorded under Nitrogen phosphorus and Potassium concentration in the tissue of the plants revealed that the highest reading of Nitrogen content was found in T6 supplied with 30% increased NPK. Highest Potassium concentration in the plant tissue was observed in T6 supplied with 30% increased NPK solution. Comparing on the overall performance Hoagland nutrient solution when treated with 20% increased NPK is considered more suitable nutrient solution for growing Bottle gourd in Hydroponic. This study also concluded that NFT system is more suitable for the growth and development of Bottle gourd plant.

Bibliography

A,S, Habibur Rahman, Bottle gourd, (*Lagenaria siceraria*), A vegetable for good health.

Al-Karaki, G. N. 2000. Growth, sodium, and potassium uptake and translocation in salt stressed tomato. Journal of Plant Nutrition, 23**,** 369-379.

Al-Sahaf, F.M. and Al-Khafagi, B.G.S., 1990, Influence of N, P and K on growth, flowering and yield of cucumber (Cucumis sativus L.) in seed culture, Annals of Agricultural Science, 35(11) : 383-391.

Al-Sahaf, F.M. and Al-Khafagi, B.G.S., 1990, Influence of N, P and K on growth, flowering and yield of cucumber (Cucumis sativus L.) in seed culture, Annals of Agricultural Science, 35(11) : 383-391.

Ayers, C. J. & Westcot, D. W. 1987. La Calidad del Agua en la Agricultura. FAO. Serie Riegoy Drenaje No. 29. Roma, Italia.

Baghour, M., E. Sánchez, J. M. Ruiz, and L. Romero. 2001.Metabolism and efficiency of phosphorus utilization during senescence in pepper plants: Response to nitrogenous and potassium fertilization. Journal of Plant Nutrition, 24(11): 1731-1743.

Bairwa LN, Khandelwal SK. 2010. Effect of zinc on growth and seed yield of bottle gourd and their residual effect on succeeding carrot crop. Indus Journal of Horticulture, 67, 104-112.

Baloch GS**.** 2012. Effect of nitrogen and phosphorus on the growth and productivity of bottle gourd, *Lagenaria siceraria* Mal. M.Sc. Thesis submitted to Sindh Agriculture University Tandojam.

Baloch GS. 2012. Effect of nitrogen and phosphorus on the growth and productivity of bottle gourd, Lagenaria siceraria Mal. M.Sc. Thesis submitted to Sindh Agriculture University Tandojam.

Bar-Tal, A., Aloni, B., Karni, L. & Aktaf, H. 2003. Nutrition of protected fruit vegetables. The International Fertilizer Society, 527**,** 1-20.

Bar-Tal, A., Aloni, B., Karni, L., Oserovitz, J., Hazan, A., Itach, M., Avidan, A., Posalski, I. & Rosenberg, R. 2001a. Nitrogen nutrition of greenhouse pepper: II.

Bar-Yosef, B. 1999. Advances in fertigation Advances In Agronomy,, 65**,** 1-77.

Bar-Yosef, B. 2008. Fertigation managment and crops response to solution recycling in semi-closed greenhouses. In: Raviv, M. & Lieth, H. (eds.) Soilless culture: Theory and practice. San Diego, CA: Elseiver.

Carpenter, Tim. 1994. Growing media and nutrient delivery systems for greenhouse vegetables and other crops. Greenhouse Systems Automation, Culture, and Environment N.E. Regional Agricultural Engineering Service International Conference, New Brunswick, NJ.

Chartzoulakis, K. & Klapaki, G. 2000. Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages Scientia Horticulturae, 86, 247-260.

Chauhan, D.V.S., Vegetable production in India, Ram Prasad and Sons, Agra,1972.Epstein, E. & Bloom, A. J. 2005. Mineral nutrition of plants: Principles and Perspectives (2nd edn.), Sunderland, MA, Sinauer Associates.

Choudhari, S.M. And More, T.A., 2002, Fertigation, fertiizer and spacing requirement of tropical gynoecious cucumber hybrids. Proc. 2nd International Sym. on cucumbers. Acta Horticulturae,233-240.

Choudhari, S.M. And More, T.A., 2002, Fertigation, fertiizer and spacing requirement of tropical gynoecious cucumber hybrids. Proc. 2nd International Sym. On cucumbers. Acta Horticulturae,233-240.

Choudhari, S.M. And More, T.A., 2002, Fertigation, fertiizer and spacing requirement of tropical gynoecious cucumber hybrids. Proc. 2nd International Sym. on cucumbers. Acta Horticulturae,233-240.

De Koning, A. N. M. 1996. Development and growth of commercially grown tomato crop. Acta Horticulturae, 406, 99-104.

De Rijck, G. & Schrevens, E. 1998. Distribution of nutrients and water in rockwool slabs. Scientia Horticulturae, 72, 277-285.

Dyśko, J. ; Kaniszewski, S. & Kowalczyk, W. 2008. The Effect of Nutrient Solution pH on Phosphorus Availability in Soilless Culture of Tomato. Journal of Elementology, Vol. 13, No.2, (Jun 2008), pp. 189-198, ISSN 1644-2296.

Effects of nitrogen concentration and NO3:NH4 ratio on growth, transpiration, and nutrient uptake. HortScience, 36**,** 1252-1259.

Ehret, D. L. & Ho, L. C. 1986. The effect of salinity on dry matter partitioning and fruit growth in tomatoes grown in nutrient film culture. Journal of Horticulture Science, 61, 361-367.

El-Aidy, F. And Moustafa, A.S.A., 1978, Effect of plant density and fertilizer ratio on growth and yield of cucumber grown under plastic tunnels, Acta Horticulture, 84: 73-78.

El-Aidy, F. And Moustafa, A.S.A., 1978, Effect of plant density and fertilizer ratio on growth and yield of cucumber grown under plastic tunnels, Acta Horticulture, 84: 73-78.

Fawzy, Z. F., Behairy, A. G. & Shehata, S. A. 2005. Effect of potassium fertilizer on growth and yield of sweet pepper plants (Capsicum annuum, L.). Egypt Journal of Agriculture Research, 2**,** 559-610.

Fawzy, Z. F., El-Nemr, M. A. & Saleh, S. A. 2007. Influence of levels and methods of potassium fertilizer application on growth and yield of eggplant. Journal of Applied Science Research 3**,** 42-49.

Heinen,M., Marcelis, L. F. M., Elings, A., Figueroa, R. & Del Amor, F. M. 2003. Effects of EC and fertigation strategy on water and nutrient uptake of tomato plants. Acta Horticulturae, 593, 101-107.

Hernandez, Rafael I., Microfarms August 2004.

Hershey, D.R. 1994. Solution culture hydroponics: History and inexpensive equipment.American Biology Teacher. 56: 111-118.

Hershey, D.R. 1995. Plant Biology Science Projects. New York, Wiley. pp. 20-41.

Hochmuth, G. J. 1992. Fertilizer management for drip-irrigated vegetables in Florida. HortTechnology, 2**,** 27-31.

Hochmuth, G. J. 2008. Fertilizer management for greenhouse vegetables, Florida, Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Imas, P. 1999. Recenet techniques in fertigation of horticultural crops in Isreal. IPIPRII-KKV Workshop on: recent trends in nutrition management in horticultural crops. Daploi, Mahastra, India.

Jones, J. B. 2005. Hydrponics: A Practical Guide for the Soilless Grower, 2nd ed, CRC Press.

Kapoor, R., Giri, B. & Mukerji, K.G. 2004. Improved growth and essential oil yield and quality in Foeniculum vulgare Mill on mycorrhizal inoculation supplemented with P-fertilizer. Bioresource Technology. 93:307-311.

Lester, G. E., Jifon, J. L. & Makus, D. J. 2006. Supplemental foliar potassium applications with or without a surfactant can enhance netted muskmelon quality. HortScience, 41**,** 741-744.

Macfie, S. M. & Taylor, G. J. (1989). The Effects of pH and Ammonium on the Distribution of Manganese in Triticum aestivum Grown in Solution Culture. Canadian Journal of Botany, Vol.67, No.11, (Nov 1989), pp. 3394-3400 ISSN 0008-4026.

Marcussi, F. F. N., Boas, R. L. V., De Godoy, L. J. G. & Goto, R. 2001. Macronutrient accumulation and portioning in fertigated sweet pepper plants. *Scientia Agricola (Piracicaba, Brazil).*

Marschner, H. (1995). *Mineral nutrition of higher plants* (2nd ed., p. 864). Acad Press Limited

Marschner, H. 1995. Mineral nutrition of higher plants. London: Academic Press Limited, pp. 605-609, 641-645.

Med India – Nutritional Guard, Bottle gourd or Lauki, Webpage:http://www.medindia.net/patients/lifestyleandwellness/nutritional-guard-bottle-gourd.htm

Mikkelsen, R. L. (1989). Phosphorus fertilization through drip irrigation. J. Prod. Agric., 2, 279-286. http://dx.doi.org/10.2134/jpa1989.0279

Mizrahi, Y. & Paternak, D.1985. Effects of salinity on quality of various agricultural crops. Plant and Soil, 89, 301-307.

Nassar, H. H., Barakat, M. A., El-Masry, T. A. & Osman, A. S. 2001. Effect of potassium fertilization and paclobutrazol foliar application on vegetative growth and chemical composition of sweet pepper. Egypt Journal of Horticulture 28**,** 113-129.

Nath, P., S. Velayudhan, and D.P. singh, Vegetables for tropical Regeion, ICAR, New Delhi, 1987.

Nicholas M.A., Savidov N.A. 2009: Evaluation of greenhouse substrates containing zeolite. ISHS Acta Horticulturae, 843: 297–302

Patil, S.R., Desai, U.T., Pawar, B.G. And Patil, B.T., 1996, Effects of NPK doses on growth and yield of bottle gourd cv. Samrat. Journal of Maharashtra Agriculture University, 21 (1) : 65-87.

Qasim, M., Ahmad, I., & Ahmad, T. (2008). Optimizing fertigation frequency for Rosa hybrid. Pak. J. Bot., 40, 533-545.

Raun WR, Johnson GV. 1999. Improving nitrogen use efficiency for cereal production. Agronomy Journal, 91, 357–363.

Resh, H. M. (2004). Hydroponic Food Production, Newconcept Press, Inc., ISBN-10: 093123199X, Mahwah, NJ., U. S. A.

Resh, H. M. 1995. Hydroponic Food Production: A Definitive Guidebook of Soilless Food Growing Methods, New Jersey, USA, Woodbridge Press Publishing Company.

Savidov N.A. (2005) Evaluation of greenhouse substrates containing zeolite and secondary use of spent substrate. CDC South Annual Report. Greenhouse crops program. Alberta Agriculture Food and Rural Development, Brooks, Alberta.

Savvas, D. 2001. Nutritional management of vegetables and ornamental plants in hydroponics. In: Dris, R., Niskanen, R., And Jain, S.M. (ed.) Crop Management and Postharvest Handling of Horticultural Products, Vol.1 Enfied, N.H: Quality Management Science Publishers.

Schoenstein, Gil. 1996. Hydro-organics: growing basil during the off-season. Small Farm Today I3I) : 3 9-42.

Silber, A. & Bar-Tal, A. 2008. Nutrition of substrate-grown plants. In: Raviv, M. & Lieth, J. H. (eds.) Soilless Culture: Theory and Practice. Elsevier.

Silber, A. 2008. High frequency irrigations as means for enhancement of nutrient use efficiency: Soilless grown bell pepper as a model plant *Acta Horticulturae* 779.

Skagg, Kevin. 1996. The urban gardener. American Horticulturist: 9- 10

Sonneveld, C.& Voogt, W. 2009. Nutrient managment in substrate systems. In: Sonneveld, C. & Voogt, W. (eds.) Plant nutrition of greenhouse crops. Netherlands Springer.

Sonneveld, C. 1988. The salt tolerance of greenhouse crops. Netherlands Journal of Agricultural Science, 36, 63-73.

Taiz,L. & Zeiger, E. 2010. Plant physiology,Sunderland, MA, Sinauer Associates, Inc. Tariq, M. & Mott, C. J. B. (2007). The Significance of Boron in Plant Nutrition an environment-A Review. Journal of Agronomy, Vol.6, No.1, (Jan 2007), pp. 1-10, ISSN.

Thornley, J. H. M. & Johnson, I. R. 1990. Plant Crop Modelling, A Mathematical Approach to Plant and Crop Physiology, Oxford, Clarendon Press.
tomato. Journal of Plant Nutrition, 23(3): 369-379.

Umamaheswarappa P, Krishnappa KS, Murthy PV, Adivappar N, Muthu MP. 2009. Effect of NPK on dry matter accumulation and primary nutrient content in leaf of bottle gourd cv. Arka Bahar. Crop Research., 30 (2), 181-186.

Umamaheswarappa P, Krishnappa KS, Murthy PV, Adivappar N, Muthu MP. 2008. Uptake of NPK by plant and leaf chlorophyll content of bottle gourd cv Arka Bahar as influenced by various levels of N, P and K. Environment and Economics, 34 (12), 213-216.

Umamaheswarappa P, Krishnappa KS, Pitchai MM, Nachegowda V, Venkateshamurthy P. 2003. Effect of varying levels of NPK on growth and yield of bottle gourd in southern dry region of Karnataka. Mysore Journal of Agricultural Sciences., 37(1), 56-64.

Yawalkar, K.S., Vegetable Crops of India 2nd ed., Agric. Horticultural pub. House, Nagpur 1980, p .370.