

Original Research Article

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Comparative Cultivation and Biochemical Analysis of *Spinacia oleracea* Grown in Aquaponics, Hydroponics and Field Conditions

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ABSTRACT

Keywords

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Comparison between aquaponics, hydroponics and traditional method for cultivation of spinach was carried out. In this study, spinach was grown in the soilless media like perlite and sphagnum moss. Media were used to support plant growth. From these Media the perlite media was used in aquaponics and sphagnum moss was used in hydroponics. This study was carried out to examine different morphological characters like height, germination period, surface area, yield of spinach, and biochemical analysis like protein, carbohydrate, chlorophyll content. The height and surface area of the traditionally cultivated spinach (Height- 23 cm) (Surface area- 79 sq.cm) was more than the hydroponically (Height- 18 cm) (Surface area- 70 sq.cm) and aquaponically (Height- 20.5) (Surface area- 72 sq.cm) cultivated spinach. But the germination period of aquaponically and hydroponically cultivated spinach (4th day) was earlier than traditionally cultivated spinach (5th day). The protein and carbohydrate content was more in aquaponically (Protein – 2.9%), (Carbohydrate – 3.9) and hydroponically (Protein - 2.7%), (Carbohydrate – 3.8) cultivated spinach than traditionally (Protein– 2.6%), (Carbohydrate– 3.8) cultivated spinach. Chlorophyll content was highest (0.07%) in the traditionally grown spinach and (0.06%) in aquaponically as well as hydroponically grown spinach. In traditionally and hydroponically cultivated spinach, plants were provided with all the nutritional requirements externally but in aquaponics nutrients were provided naturally through fish excrete. In hydroponics nutrient requirement was less compared to traditional method. In this work, guppy fishes were used in aquaponics as a source of nutrients. For hydroponics, the N: P: K fertilizer named 19:19:19 was given in small quantities. For traditionally cultivated spinach the fertilizers like Urea, 19:19:19 and 15:15:15 were applied. The yield of the aquaponically cultivated spinach was measured (4455Kg/acre); it was slightly more than hydroponically cultivated spinach (3780 Kg/acre) and much more than the traditionally cultivated spinach (1615 Kg/acre).

Introduction

Open field based agriculture is facing some major challenges; most importantly decrease in percapital and availability. Due to rapid urbanization and industrialization as well as melting of icebergs are able land under cultivation is further going to decrease (Sardare *et al.*, 2013). Reducing agricultural

water use, while maintaining or improving economic productivity of the agricultural sector is a major challenge in arid and semiarid regions. To overcome this need the techniques like hydroponics and aquaponics are developed (Al-Karaki *et al.*, 2012).

Aquaponics is a food production system that combines aquaculture with hydroponics. Aquaponic systems use 10% or less of the water used in conventional soil based horticulture systems. These systems can be established in urban or harsh rural environments where land is very limited or of very poor quality. This advantage applies also to hydroponics and recirculating aquaculture systems. This is the core rationale for aquaponics and a significant advantage in those countries or locations where nutrient enrichment is a problem. The fish and plants in most aquaponic systems capture roughly 70% of the nutrients input in the form of fish feed and the residual solid waste is relatively easy to manage and may be applied to fruit trees or conventional horticultural crops (Hambrey *et al.*, 2013). Aquaponics is the symbiotic production of vegetables and fish. Fish eat food and release metabolites into the water derived from the food. These metabolites are further metabolized by bacteria and products of this metabolism are pumped into a plant growth bed where they are taken up by plants for nourishment (Ako, 2013). Fish effluent contains sufficient levels of ammonia, nitrate, nitrite, phosphorus, potassium and micronutrients to produce hydroponic plants. Lettuce, herbs, and specialty greens (spinach, chives, basil, and water cress) have low to medium nutritional requirements and are well adapted to aquaponic systems (Diver, 2006). In aquaponics, nutrient-rich effluent from fish tanks is used to fertigate hydroponic production beds. This is good for the fish because plant roots and rhizobacteria are move nutrients from the water. These nutrients generated from fish manure, algae, and decomposing fish feed are contaminants that would otherwise buildup to toxic levels in the fish tanks, but instead serve as liquid fertilizer to hydroponically grown plants. The nitrifying bacteria living in the grave land in association with the plant roots play a critical

role in nutrient cycling. Aquaponics can enable the production of fresh vegetables and fish protein in arid regions and on water limited farms, since it is water re-use system. Aquaponics is mainly divided in following type's viz. Nutrient Film Technique, Ebband Flow, Barrel Ponics System, Pivot Outlet, Siphon Types. Nutrient Film Technique is where the water pump runs continuously pumping water through the entire system. Ebband Flow is where the water is periodically pumped through the system either by means of a timer on the water pump (and drain holes in the grow beds). In the Barrel-Ponics system a toilet flush valve is mounted in the bottom of the flood tank assembly. When the water reaches the preset height (volume) in the flood tank a small siphon begins filling a counter weight attached to the flapper valve. As the counter weight fills and gets heavy enough to overcome the pressure and weight of the water, the valve is pulled open allowing the contents of the flood tank to empty in to the grow beds (Tezel, 2009). Guppy fish were introduced in India in 1910, to control the mosquito. Several warm-water and cold water fish species are adapted to recirculating aquaculture systems, including tilapia, trout, perch, Arctic char, and bass. But in this work guppy fish are used, because guppy fish establish itself in both fresh and polluted water. This guppy fish are quite tolerant of a variety of water conditions. Guppies have the capacity to survive and multiply in both fresh and polluted water (Shahjahan *et al.*, 2013).

Hydroponics is a method of growing crops and vegetables without soil with the help of nutrient solution (Heredia, 2014). The hydroponic nutrients are usually derived from synthetic commercial fertilizers, such as calcium nitrate, that are highly soluble in water (Diver, 2006). The suspended net pot, non-circulating hydroponic growing method is a unique and powerful technique for growing leafy, semi-head and small romaine

lettuce cultivars, because the entire crop can be grown with only an initial application of water and nutrients. Electricity and pumps are not needed, so the additional production costs and complexities associated with aeration and circulation in many conventional hydroponic systems are totally avoided by this method (Kratky, 2009). The need for hydroponics is that, it has the advantages of requiring small space, could operate with any size of flow, greatly reduces or eliminates soil borne weeds, diseases and parasites, doesn't require special drainage system, and grows almost any plant and in various spaces as available around the house (various containers, channels, pipes, etc.). Hydroponic systems are proved to have several advantages over soil gardening. The growth rate on a hydroponic plant is 30-50 percent faster than a soil plant, grown under the same conditions, in addition, in hydroponics waste water treatment and reuse systems there is no land used for crop production or soil damaged by salts and solids accumulations due to effluent reuse (Haddad *et al.*, 2009). Hydroponic farming can be useful because growing can take place in rough environments such as arid deserts and frozen tundra's (Heredia, 2014). Hydroponics is mainly divided in following types viz. Nutrient Film Technique, Hydroponic Plant Growth Technique, Aeroponic Technique, Flood and Drain System, Static Solution Culture System, Passive Sub-Irrigation System, Top Irrigation system, Deep Water Culture System. In Nutrient Film Technique the plants are grown directly on an impermeable surface to which a thin film of the large surface area traps and accumulates matter. In hydroponic plant growth system the plant growth takes place with the plant roots immersed in nutrient solution without soil. The plant growth requires a large volume of nutrient solution and frequent monitoring and adjustment. Aeroponic Growth System, the plants are grown with the roots suspended in air while

being sprayed continuously with a nutrient solution. In Flood and Drain System nutrient solution rises periodically to immerse plant roots and then recedes exposing the roots to moist atmosphere. In Static Solution Culture, plants are grown in containers of nutrient solution; a hole is cut in the lid of the reservoir for each plant. There can be one to many plants per reservoir. Passive sub-irrigation is a method where plants are grown in an inert porous medium that transports water and fertilizer to the roots by capillary action from a separate reservoir as necessary. In Top irrigation, nutrient solution is periodically applied to the medium surface. This may be done manually once per day in large containers of some media, such as sand. Deep Water Culture System consists of plant production by means of suspending the plant roots in a solution of nutrient rich, oxygenated water (Haddad *et al.*, 2009).

Materials and Methods

Sample collection

“All Green” variety of Spinach, different media like sphagnum moss, perlite media and nutrients like Fe, Mn, Zn, Cu, Mo, B, 15:15:15, urea and 19:19:19 were collected from local market of Naik krushi bhandar, Pune. Guppy fish (*Pocelia reticulata*) collected from fishery shop, Phaltan, Dist-Satara, Fish food collected from Paud, pune and D-klor collected from fishery shop, Pune.

Method

In traditional method, Ridges and Furrow type beds was prepared for growing the spinach. Watering was done after preparing the bed. Watering is carried out as per requirement, depending upon the climate and water holding capacity of soil. Seeds of spinach were sown in the bed. Chemical fertilizers like 19: 19: 19, 15: 15: 15 and urea

were applied as per requirement. As the growth of weeds was more weeding was carried out to remove the weeds by the sickle. Watering was done as per requirement. Harvesting of spinach was carried out in two intervals. First harvesting was done after 45 days and second harvesting was done after 60 days.

In aquaponics, assembly for aquaponics was prepared using bamboos. Bottles were attached to each other and were kept on the bamboos. On the bottles, near about 7sq.cm area was cut to place the cups. One third of the bottles were filled with the water, so that, the bottom of the perlite filled cup maybe 1-2 cm in the water. Fish were added in the bottles. Seeds of spinach was sown in the perlite media filled cups. Water rotation was done after several days intervals. The harvesting of spinach was carried out in two intervals. First harvesting was done after 45 days and second harvesting was done after 60 days.

In Hydroponics, assembly was prepared using bamboos. The bottles were attached to each other and were kept on the bamboos. On the bottles, circle area was cut with diameter of near about 4cm. One third of the bottles was filled with the water, so that, the bottom of the sphagnum moss containing cup may deep 1-2cm in the water. Macronutrients and micronutrients were supplied to hydroponics, by making the solution of those nutrients with suitable EC. Seeds were sown in the sphagnum moss containing cups. Harvesting of spinach was carried out in two intervals. First harvesting was done after 45 days and second harvesting was done after 60days.

Morphological analysis

Comparative morphological characteristics like the germination of spinach, height of plant, leaf surface and yield were analysed. Germination period was observed in spinach

grown traditionally, aquaponically and hydroponically. Height was measured in centimeter in between intervals of 5 days. Surface area was calculated by grid paper method (Pandey and Singh, 2011). Yield was calculated by L^2 for traditionally grown spinach and hydroponics, aquaponics by $L \times B$ where, L = length, B = breadth (Cavanagh, 2008).

Biochemical analysis

Harvested spinach was used for estimation of protein by Folin Lowery method (Sadasivum and Manickam, 2008), carbohydrate by Anthrone method by following formula:

Carbohydrate (mg/100g) =

$$\frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

Total chlorophyll estimation was carried out by Arnon method using following formula, (Rajlakshmi and Banu, 2008)

$$\text{Total chlorophyll/gm} = 20.2(A645) + 8.02(A663)$$

Results and Discussion

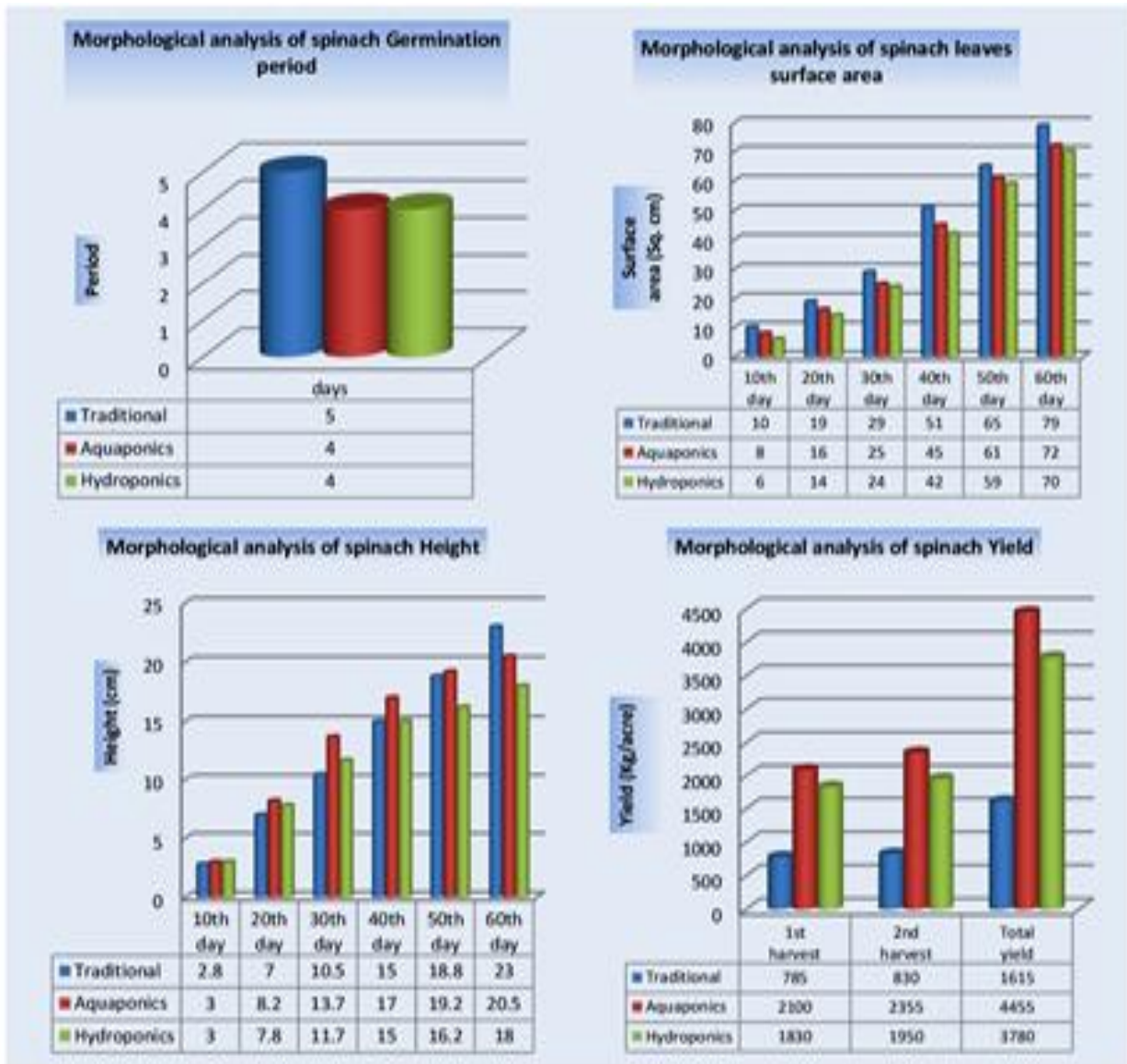
Morphological analysis

The germination period of spinach in hydroponics and aquaponics was earlier than the traditional method. Because, in hydroponics and aquaponics the water and nutrients supplied were directly provided to the roots due to which, the nutrients and water was absorbed in sufficient amount. The height of traditionally cultivated spinach was highest (60th day) which was 23 cm than the hydroponically (18cm) as well as aquaponically (20.5cm) cultivated spinach. The Height of aquaponically cultivated spinach was slightly more than the hydroponically grown spinach. The height of traditionally cultivated spinach was highest,

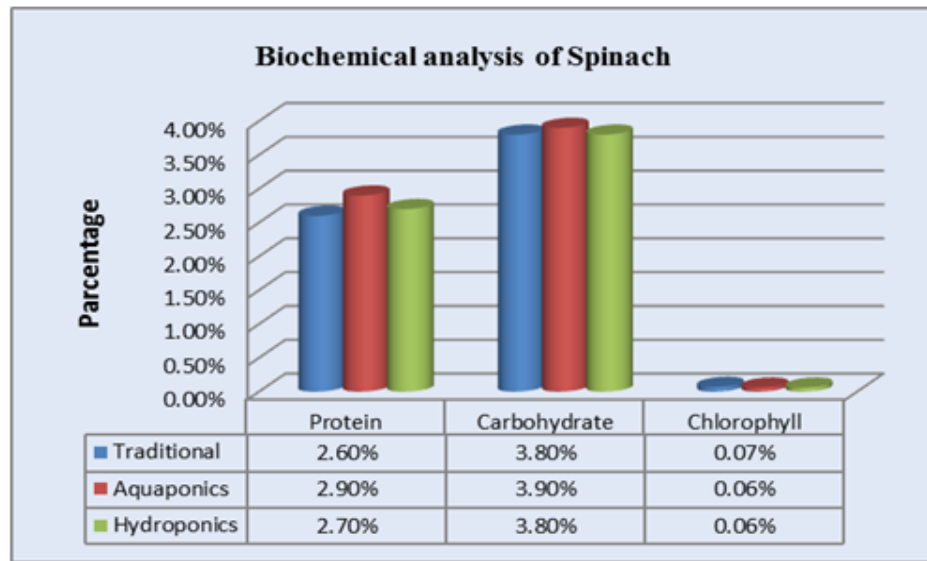
may be because, the area for roots were less developed in hydroponics and aquaponics, so the height was stunted. The surface area of traditionally cultivated spinach was highest (on 10th day it was 10sq.cm and 60th day It was 79 sq.cm) than the hydroponically (on 10th day it was 6sq.cm and on 60th day it was 70sq.cm) as well as aquaponically (on 10th day it was 8 sq.cm and on 60th day it was 72 sq.cm)

grown spinach. The surface area of aquaponically grown spinach is slightly more than the hydroponically grown spinach. The yield of aquaponically cultivated spinach (4455Kg) was highest than the hydroponically as well as traditionally grown spinach. The yield of hydroponically grown spinach (3780Kg) was slightly more than the traditionally cultivated spinach.

Graph.1 Morphological parameters and comparative analysis of spinach



Graph 2 Biochemical parameters and comparative analysis of spinach



But the yield of traditionally grown spinach (1615Kg) was much less as compared to aquaponically as well as hydroponically grown spinach because; it may be due to insufficient amount of water and nutrients, whereas the aquaponically and hydroponically grown spinach got them easily.

Biochemical analysis

The protein content was highest in the aquaponically (2.9%) grown spinach plant. It was slightly more than the hydroponically (2.7%) grown spinach. But the protein was much lower in the traditionally (2.6%) grown spinach. The carbohydrate content was highest (3.9%) in the aquaponically grown spinach plant. And it was lower (3.8%) in the traditionally grown spinach as well as hydroponically grown spinach. The chlorophyll content was highest (0.07%) in the traditionally grown spinach and (0.06%) in aquaponically as well as hydroponically grown spinach.

In conclusion, the aquaponics and hydroponics methods are little costly than

traditional but has a much more advantages like early germination, better yield, high amount of biochemical contents like carbohydrate and protein, etc. Thus, these methods are beneficial to human health as well as are more profitable than the traditional method. In Aquaponics and Hydroponics requirement of nutrients was less as compared to traditional method, as well as, less water was required as compared to traditional method and also water can be reused. Now a day there is the less availability of water and land, so there is need of using techniques which requires less amount of water and land.

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