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Impact of Environmental Variables on the Growth and Yield of Hydroponically Cultivated Tomatoes

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ABSTRACT:-

This experiment assesses the impact of environmental factors on the growth, yield, and protein yield of tomatoes grown in a hydroponic system. Tomatoes (*Solanum lycopersicum*) were first germinated in soil before being transferred to a controlled hydroponic system and then back to soil, simulating diverse environmental exposures. Characterization methods—morphological and biochemical analysis—showed that hydroponically grown tomatoes had greater protein yield (0.59 g/dl) than tomatoes grown in soil (0.47 g/dl). The results concur with existing research that claims hydroponics, through accurate nutrient supply and control of the environment, greatly increases plant growth and nutritional yield. This is a testament to hydroponics as an environmentally friendly, resource-saving cultivation system with potential to meet food security and nutrition issues, especially in areas where soil is poor or water scarce.

Keywords: Hydroponics, *Solanum lycopersicum*, environmental variables, tomato yield, protein content, nutrient optimization, sustainable agriculture, crop characterization, controlled environment agriculture.

INTRODUCTION: -

Tomato (*Solanum lycopersicum*) is one of the most cultivated and consumed vegetables worldwide, noted for its economic value and health significance. It belongs to the Solanaceae family, comprising potatoes, peppers, and eggplants. Tomatoes are essential sources of vitamins, particularly vitamin C, and carry numerous antioxidants, including lycopene, which are linked with numerous health benefits, such as minimizing the risk of chronic conditions like cancer and cardiovascular disease [1,2]

Tomato production has conventionally been carried out in soil-based agricultural systems, but with the growing need for sustainable farming practices, alternative production systems such as hydroponics are becoming more popular. Hydroponic systems, where plants are grown in a nutrient solution without soil, have several benefits, including increased yield, rapid growth, and improved management of environmental conditions such as water and nutrient supply [3]. It is established through research that tomatoes produced through hydroponic method are of superior quality, with enhanced shelf-life and lower pest and disease incidences. [4]

Hydroponics is particularly useful in countries with limited farmland that is soil-less or in regions where soil quality is poor, since it enables optimal use of space and water, two very important considerations for arid or semi-arid areas. Research into hydroponic tomato cropping has indicated various environmental factors such as temperature, light intensity, and nutrient levels may have profound effects on plant growth, fruit attributes, and yield. [5, 6]

Characterization in crop and plant science is the comprehensive assessment of plant characteristics under particular environmental, physiological, and biochemical conditions. It encompasses the determination of morphological, physiological, biochemical, and occasionally molecular characteristics to observe the growth pattern of the plant, productivity, and tolerance to stress. [7]

Characterization in hydroponic systems becomes a necessity to track the way plants such as tomatoes react to diverse environmental conditions like light, temperature, humidity, and nutrient supply. Characterization of crops produced through hydroponics enables scientists to regulate growing conditions for the highest yield and quality. [8]

These are advanced characterization methodologies that involve physical measurements (weight, size, height of plants; size of fruit), chemical analysis (uptake of nutrients, metabolite profiling), and stress tolerance screening (chlorophyll concentration, activity of antioxidant enzymes). [9] All these methods enable high-yielding cultivar development as well as optimized resource use practices, particularly in controlled environment agriculture. [10]

Characterization investigations are especially important for tomatoes because of their market value and susceptibility to environmental variation. Knowledge of differences in plant response to varying hydroponic treatments can improve production and fruit quality. [11]

REVIEW LITERATURE

Review on the Characterization of Tomato (*Solanum lycopersicum*)

Tomato (*Solanum lycopersicum*) is an important horticultural crop worldwide, appreciated for its nutritional value and economic significance. Accurate characterization of genotypes is crucial for breeding programmes for yield enhancement, quality improvement, and stress tolerance. The present review summarizes the recent improvements in morphological, biochemical, cytological, and molecular characterization of tomato with emphasis on their uses in cultivar improvement and genetic enhancement. [12]

Morphological Characterization

Morphological characteristics are used as key descriptors in the assessment of tomato germplasm. Research has shown high variability among genotypes for characteristics like plant height, leaf morphology, flower characteristics, and fruit characteristics. For example, research on 22 inbred lines indicated large variation for 27 morphological characteristics, such as hypocotyl color, leaf type, and fruit shape, which allowed for identification and selection of better genotypes. [13] Likewise, trichome density and morphology have been employed to separate between tomato varieties, with scanning electron microscopy yielding fine information on trichome morphology and distribution. [14]

Biochemical Characterization

Biochemical profiling is supplemented with morphological evaluation through supplying data on nutritional and phytochemical characteristics. Some of the important biochemical parameters are lycopene content, TSS (total soluble solids), phenolic compounds, and antioxidant activity. In a study that analyzed 140 F_4 progenies, high variability was reported for lycopene content (ranging from 15.2 to 27.18 mg/100g FW) and TSS (3.5 to 5.9 °Brix), suggesting prospects for selection of high-quality lines for breeding purposes [12]

Cytological Characterization

Cytological examinations, such as chromosome numbers and karyotyping, give information on the genetic stability and evolutionary history of tomato genotypes. The majority of cultivated tomatoes carry a diploid number of chromosomes, 2n = 24; however, some variations have been noted. For instance, one study found a genotype with 2n = 26 chromosomes, which is associated with distinct morphological features and lower heat tolerance, indicating chromosomal changes can affect phenotypic expression and stress resistance. [15]

Molecular Characterization

Molecular markers such as Simple Sequence Repeats (SSRs) have been widely used to evaluate genetic diversity and genotypic relationships in tomato. SSR markers provide high polymorphism and reproducibility and are ideal for genetic mapping and marker-assisted selection. The Researcher used 13 EST-SSR primers to screen 11 accessions of tomato and identified 61 alleles with a primer mean of 4.69 alleles and polymorphic information content (PIC) of 0.40 to 0.84, reflecting high genetic diversity. [16]

Integration of Characterization Methods

The integration of morphological, biochemical, cytological, and molecular characterization creates a complete knowledge of the tomato germplasm. These kinds of integrated approaches allow for the detection of elite genotypes possessing desirable characteristics, making it possible to develop better cultivars. For example, combining SSR marker information with phenotypic assessment enables the association of certain alleles with agronomic characteristics, improving the efficiency of selection for breeding programs. [15]

METHODS AND METHODOLOGY

Procedure:-

Solanum lycopersicum (tomato plants) were first grown in soil conditions for 10 days to facilitate initial germination and seedling establishment. The seedlings were then transferred into the hydroponic system, where distilled water served as the base medium. A balanced macronutrient and micronutrient solution was added, and the hydroponic solution was adjusted to pH 6.0 to provide the best nutrient uptake conditions.The plants were hydroponically cultivated under these conditions for about 10–15 days. In this stage, no flower initiation was seen. After that, the nutrient solution was stopped, and plants were subjected to distilled water alone (nutrient-free) for a further 15 days. In this stage, no marked variation in the height or morphology of the plants was seen.Following the nutrient-starved hydroponic period, the plants were shifted back to soil and cultivated under normal environmental conditions. Floral initiation and rampant vegetative growth (increase in height) were seen within a period of one month. But the fruit development was curtailed, though flowering was the case, the tomato fruits were small in size, and no increase in the size of the fruits was seen even after another 7 days. All of the experiments were done with seeds from a commercial cultivar of conventionally produced tomatoes.

Methodology for protein characterization

PRINCIPLE

Biuret method. Protein peptide bonds react with copper II ions in alkaline solution to produce a blue-violet ion complex (the biuret reaction), each copper ion being complexed by 5 or 6 peptide bonds. Tartrate is included as a stabilizer, while iodide is used to inhibit auto-reduction of the alkaline copper complex. The colour produced is proportional to the protein concentration and is measured at 546 nm (520-560).

RESULT

Comparative study was done to compare the protein content in tomatoes produced in usual soil-based conditions and those produced using hydroponic methods. The results are as follows:The traditionally cultivated tomato had a mean protein level of 0.47 g/dl.The hydroponically cultivated tomato, grown under controlled water and nutrient conditions, contained a greater protein level of 0.59 g/dl.This shows a significant elevation of protein content in hydroponically grown tomatoes over their soil-grown equivalents. The results are shown in the graph below:

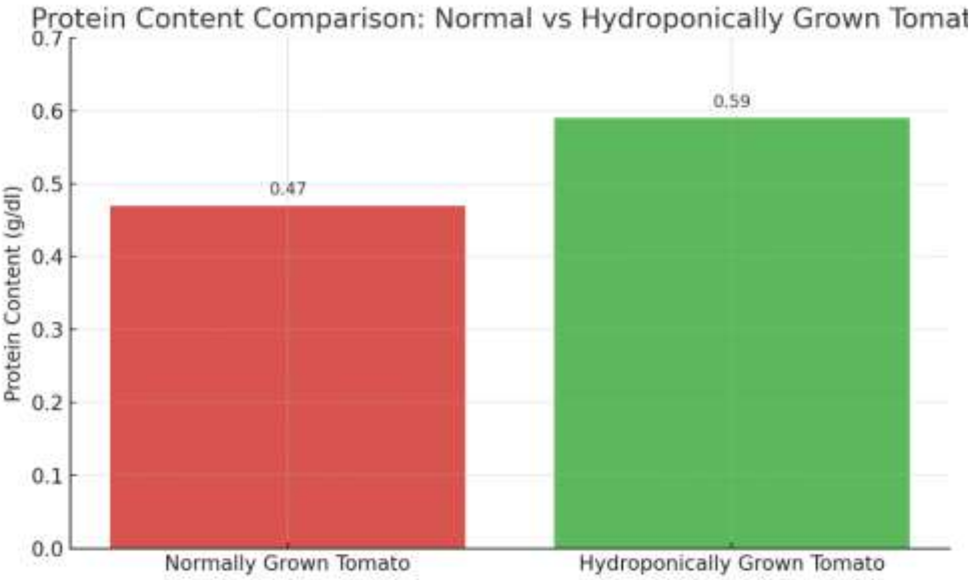

Figure 1:- Graph is showing comparison between protein content of Normally grown tomato and Hydroponically grown tomato

DISCUSSION

This current work illustrates that hydroponic tomatoes have greater protein concentrations (0.59 g/dl) than tomatoes cultivated in soil (0.47 g/dl). This is in conformity with past findings indicating that hydroponics has a positive impact on the nutritional value of fruits and vegetables because nutrient supply and environmental conditions are controlled.

Singh et al. (2020)[17] indicated that hydroponic production greatly enhanced the protein, vitamin C, and antioxidant content of tomatoes as compared to conventional soil agriculture. Their research explained the enhanced nutritional content due to optimal and uniform nutrient supply in hydroponics, which does not lead to leaching and ensures improved uptake by the plant root system.

Likewise, A Researcher highlighted that hydroponic systems have the ability to increase certain nutrient content in vegetables because of the accuracy with which growers are able to modify nutrient solutions to meet the requirements of plants. In tomato farming, this can result in enhanced metabolic processes in the plant, which can result in enhanced protein biosynthesis.[18] In addition, Another Researcher found that hydroponically raised lettuce and tomatoes had slightly lower or equivalent protein and antioxidant contents compared to soil-grown crops, indicating that the differences would depend on the plant variety and system management but that the controlled environment of hydroponics presents an advantage in nutrient optimization.[19]

Our results are consistent with these findings and propose that hydroponic growth not only provides improved yield and disease management but also improves nutritional quality, particularly protein content. This can have real-world applications to urban agriculture and nutritionally oriented agriculture, particularly in resource-scarce environments or areas of poor soils.

CONCLUSION

This research clearly illustrates that hydroponic tomatoes contain greater protein levels (0.59 g/dl) than conventional soil-cultivated tomatoes (0.47 g/dl). Hydroponic system-controlled nutrient supply and optimized crop growth conditions are likely to enhance protein synthesis in the plant. The results rekindle interest in hydroponics as a sustainable and nutrient-conserving method of crop cultivation compared to traditional agriculture.Hydroponic growing not only saves water and minimizes pesticide use but also enables one to produce throughout the year with better nutritional content. Thus, it is of huge promise to respond to global food security and malnutrition challenges.

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