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Comparative Performance of Spinach (*Spinacia Oleracea*) as Affected by Growing Media Hydroponics Vs. Soil

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ABSTRACT

Shrinking land resources, increasing residual toxicity load and depleting levels of safe water for drinking and agriculture have made it really challenging to ensure availability of safe food to ever growing population. Maintaining production and productivity through traditional agriculture system have become tough. Globally, one technology has been accepted as sustainable technology to tackle all these issues is Hydroponics (soil-less cultivation) which not only offers safe food but also ensures vertical utilization of space with higher water utilization efficiency and also mitigate environmental issues associated with crop productions. Results of present experiment have revealed that crop productivity under hydroponics system was more than 2 to 3 times over soil with better quality produce. Ascorbic acid and total chlorophyll content were the highest in the hydroponically grown spinach respectively (26.05mg/100g and 2.05mg/gFW).Spinach crop under hydroponics system developed profuse root system with average root length more than 15.40 cm almost 60 per cent superior over soil grown system. This paper deals with comparative performance of spinach under various growing systems.

INTRODUCTION

Shrinking land and water resources, increased levels of residual toxicity in vegetables, rapid growth rate of urban population as well as more awareness about the organically grown produce has drew the attention towards the use of intensive cropping system. This has paved the way for new technologies such as soilless culture and hydroponics, which are also opening possibilities of agriculture systems in space Hydroponics is a method of growing crops without soil with the help of nutrient solution [1-3]. The key advantages of hydroponics is that, it requires small space, could operate with any size of flow, greatly reduces soil borne diseases, eliminates weeds, doesn't require special drainage system, and allows utilization of vertical space. Globally, leafy vegetables has the major share among the crops grown in hydroponics followed by tomatoes [4]. Among the leafy vegetables, Spinach (*Spinacia oleracea L.)* is one of the most nutritious vegetables consumed worldwide [5]. Spinach provides dietary fiber, iron, and supplies high levels of both vitamins and minerals Leskovar et al. including substantial levels of the carotenoid's vitamin A, lutein and zeaxanthin [6,7]. It also contains molecules with high antioxidant properties such as vitamin C, vit. E and phenolic compounds including flavonoids [8]. In addition, spinach contains choline and inositol, the substances that help to prevent arteriosclerosis, or hardening of the arteries [9,]. Goldman described foods as "functional" when they have health benefits in addition to fulling the nutritional requirements of humans and spinach is one such food [10]. The present study was carried out to evaluate the effect of hydroponic system on productivity and quality of spinach in comparison to soil and soil-less grown system.

MATERIALS AND METHODS

Experimental site and details

The present study was carried out at Defence Institute of Bio-Energy Research, DRDO, Haldwani, Nainital, Uttarakhand, India to study the effect of three growing conditions i.e. hydroponics, soil less and soil condition on yield and quality of spinach. This experiment was conducted during the winter season of 2019-20. The monthly mean minimum and maximum temperature ranged from 0°C to 22°C and 23°C to 45°C, respectively. Monthly mean relative humidity ranged from 22 to 48% and 63 to 92%, respectively. Spinach var. All Green was selected for the experiment purpose. The nursery of spinach was grown in the plug trey during the month of October 2019. About 15to 18 days old seedling were transplanted under the three growing conditions i.e. hydroponics system, soilless system and field conditions (soil). Hydroponics system used for growing the crop was 'A' frame unit designed and fabricated in-house, which can accommodate 90 plants/unit. The unit made of commercially available PVC pipe of 4'' diameter. Nine pipes of equal length were fix on the frame and ten holes were made on each pipe to accommodate 10 plants.

Nutrient solution composition for hydroponics and soil-less cultivation

Nutrient solution supplied to grow the plants in hydroponics system carried all essential nutrients with pH ranging from 6.8 to 7.8 during the experimentation and Electrical Conductivity (EC) 1200+100 ppm. Concentration of elements in nutrient solution used for growing spinach crop was nitrogen (150 ppm), potassium (200 ppm), phosphorus (40 ppm), iron (5 ppm), calcium (50 ppm), magnesium (60 ppm), zinc (3 ppm), manganese (3 ppm), copper (less than 1 ppm), boron (4 ppm), molybdenum (less than 1 ppm), sodium (less than 1 ppm), and sulphur (50 ppm). Crop grown under soil-less cultivation system was vertical frame unit comprising PVC cups fixed on a vertical mesh and filled with the mixture of coco peat, vermiculite and perlite in the ratio of 3:1:1. The same nutrient solution used for growing crop in hydroponics system was used for growing crop here also. The crop grown in soil was as per standard cultural package of practices for spinach.

Data recording and analysis

Data were recorded randomly on five plants/replicate in four replicates and average was worked out. Data were recorded on leaf yield, fresh and dry weight of leaves and roots, number of leave and root length. Nutritional quality of freshly harvested spinach such as protein content, carbohydrate content, ascorbic acid content, fiber content and total sugar content were estimated by the methods as prescribed [11]. Chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll content were also estimated at full grown stage to visualize the green color appearance of the spinach leaves as an indicator of physical quality [12]. SPAD readings were also measured using the SPAD meter-502 (Konica Minolta) at the full-grown stage of crop. Data were analyzed as per standard statistical procedure [13].

RESULTS AND DISCUSSION

Effect on growth and yield of spinach

Effect of three growing conditions on growth of leaves was significant. Leaf size under hydroponics system was about 40% higher over soil grown spinach. Width of the leaf was also comparatively more under hydroponics (Table 1). Number of leaves per plant were the highest under soil grown crop (17.57) but statistically at par with hydroponically grown crop. It is pertinent to mention here that spinach crop grown under hydroponics system has developed profuse root system with average root length of 15.40 cm and fresh wt. of roots per plant 11.09 g whereas under soil grown system the average root length was minimum (8.59 cm) with minimum fresh wt. of roots per plants (7.42 g). This may be attributed to be better growth of spinach under hydroponics system and soil-less growing system because roots are responsible for the nutrient uptake to support the crop growth. Fresh weight and dry weight of leaves per plant were also the highest under hydroponically grown crop with superiority of about 63.0 and 37.6% over soil grown crop, respectively. Effect of three growing conditions on leaf yield of spinach was very prominent (Figure 1 & Table 1). The maximum yield was recorded in hydroponics system (4.02 kg/m2). Crop grown under the hydroponics and soil less systems exhibited increase in the productivity to the tune of 2.0 to 3.0 times as compared to soil grown crop (Table 1). This increase in productivity may be attributed to the fact that hydroponics and soil less system allowed to multi-tier cropping compare to soil thereby resulting into better yield from the same unit area. In addition to this, a greater number of leaves per plant and higher fresh weight of leaves per plant also observed under hydroponics and soil less system. Beneficial effect of protected conditions also contributed to better yield under hydroponics and soil less system. Gashgari et al. and Agarwal et al. has also reported that vertical farming system has been beneficial in increasing productivity over conventional system [14,15]. Jensen has also reported increase in yield of lettuce under hydroponics compared to open field conditions [16]. Among the various factors, temperature influences the partitioning of photo-assimilates in plants, and studies of have indicated differences in plant biomass due to light and temperature interactions under hydroponically grown vegetables [17,18]. In the present experiment also better regulation of temperature under polyhouse conditions might have favoured the plant growth.

Effect on nutritional quality of spinach

Spinach is one of the important leafy vegetable which is mainly consumed for its nutritive value therefore the effect of different growing systems on nutritional quality was studied. The results presented in Table 2 revealed the significant effect on growing conditions on spinach nutritional quality. Crop grown under soil-grown system exhibited the highest protein, carbohydrate, fiber and total sugar content over the hydroponics and soil-less grown systems. Whereas the ascorbic acid content was the highest in the hydroponically grown crop of spinach (26.05 mg/100g). Gichuhi et al. has also reported significant effect of nutrient delivery system on quality of hydroponically grown carrot in terms of beta carotene content, sweetness and fibrousness [19].

Total chlorophyll, chlorophyll “a” and chlorophyll “b” contents were the highest in spinach grown under hydroponics system (2.05 mg/g FW, 1.37 mg/g FW and 0.68 mg/g FW, respectively) and followed by crop grown under soil-grown and soil-less systems. Significant differences in chlorophyll content and ascorbic acid content in hydroponically grown spinach has been reported by Kimura due to the use of different growing solutions [20]. A strong correlation was also observed between the total chlorophyll content and SPAD values (R2 value=0.98) exhibiting the field-based detection of leaf quality using the instrument rather than laboratory-based method as also reported [21]. Significant differences in ascorbic acid and tocopherol content of lettuce grown under hydroponics and soil system has been reported by Buchanan and Omaye. Significant difference in quality of lettuce due to growing system has been overserved in our previous study on lettuce [15]. Daniela et al. has reported significant difference in quality of lettuce due to growing system variation [22].

Table 1: Effect of growing systems on growth and yield of spinach

Growing systems	Length of leaves (cm)	Width of leaves (cm)	No. of leaves/ plant	Root length (cm)	Fresh wt. of leaves/ plant (g)	Dry wt. of leaves/ plant (g)	Fresh wt. of roots/plant (g)	Dry wt. of roots/plant (g)	Leaf yield (kg/ m2)	Harvest Index (%)
Hydroponics	44.64±0.54	8.19±0.28	16.57±0.68	15.40±0.33	77.07±0.65	6.54±0.03	11.09±0.39	1.38±0.05	4.02±0.11	89.81±0.82
Soil-less Grown	38.42±0.57	7.98±0.43	14.63±0.49	12.32±0.82	55.26±0.68	4.64±0.04	11.73±0.10	0.92±0.01	2.84±0.10	87.98±0.46
Soil Grown	32.01±0.55	7.22±0.30	17.57±0.19	8.59±0.27	47.28±0.27	4.75±0.05	7.42±0.36	0.91±0.00	1.95±0.09	85.07±0.18
SEm ±	0.67	0.32	0.48	0.56	0.33	0.05	0.29	0.03	0.06	0.49
CD (P=0.05)	2.37	NS	1.75	1.96	1.15	0.16	1.02	0.11	0.25	1.72

Figure 1: Spinach crop during experimentation at DIBER (A) Under Hydroponics (B) under vertical Soil-Less system (C) Under Soil (D) A comparative picture of all three different systems

Table 2: Effect on nutritional quality of spinach grown under three different growing systems.

Growing systems	Protein content (g/100g)	Carbohydrate content (g/100g)	Ascorbic acid content (mg/100g)	Fiber content (g/100g)	Total Sugar content (g/100g)	Chlorophyll 'a' content (mg/gFW)	Chlorophyll 'b' content (mg/gFW)	Total Chlorophyll content (mg/ gFW)	SPAD reading
Hydroponics	2.85± 0.04	3.64 ± 0.02	26.05 ± 0.02	2.20 ± 0.00	0.42 ± 0.01	1.37 ± 0.03	0.68 ± 0.00	2.05 ± 0.02	42.75 ± 0.91
Soil-less Grown	2.66 ± 0.02	3.93 ± 0.02	18.95 ± 0.23	2.25 ± 0.01	0.46 ± 0.00	0.98 ± 0.01	0.43 ± 0.00	1.41 ± 0.00	36.21 ± 1.21
Soil Gown	2.93 ± 0.02	4.49 ± 0.00	24.99 ± 0.17	2.89 ± 0.07	0.49 ± 0.00	1.29 ± 0.00	0.59 ± 0.00	1.88 ± 0.03	40.93 ± 0.87
SEm ±	0.02	0.02	0.14	0.03	0.01	0.02	0.002	0.022	1.23
CD (P=0.05)	0.10	0.08	0.49	0.13	0.03	0.07	0.008	0.076	4.35

CONCLUSION

Although cultivation of crops under hydroponics and soil is altogether different and sometimes comparison between these two systems does not stands correct. This is because of lack of large scale cultivation experimental trials under hydroponics. Even though comparison of productivity and quality of vegetable crops grown under hydroponics against soil based system provides valuable information as these crops are nutrient packed food with high therapeutic values despite low volumes. Based on experimental findings, it can therefore be concluded that crop productivity under hydroponics system was more than 2 to 3 times over soil and soil-less system with better quality produce. Ascorbic acid and total chlorophyll content were the highest in the hydroponically grown spinach. Spinach crop under hydroponics system developed profuse root system with almost 60 per cent superior over soil grown system. There is a need to study environmental interactions for hydroponically grown crops for popularization of this technique to make it a house hold technology in future.

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