COMPARISON OF TWO NUTRIENT SOLUTION RECIPES FOR GROWING SPINACH CROP IN A NON- CIRCULATING HYDROPONIC SYSTEM

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ABSTRACT

Plants of spinach cv Local double were grown in nutrient solutions of two different strengths (Full and 1/2) of Cooper's 1988 and Imai's1987 recipes (using 13 litres plastic tubs) on a Randomized Complete Block Design (RCBD) in the green house facility of Institute of Biotechnology and Genetic Engineering (IBGE), NWFP Agricultural University, Peshawar Pakistan during the fall 2006. Cooper's solution recipe comprising (mg L^{-1}) N-236, P 60.0, K 300, Ca 185, Mg 50, S 68, Fe (EDTA) 12, Mn 2.0, Zn 0.1, Cu 0.1, B 0.3, Mo 0.2) proved better with regards to many of the parameters studied. The crop grown in Cooper's recipe(full and ½ strengths respectively) took significantly less number of days to first harvest (32.44 and 35.56 days after seeding), produced more number of leaves plant^{-1}(12.33 and 12.44), larger average leaf length (34.43cm and 31.90 cm),significantly larger leaf size / leaf area (LA) plant^{-1} (104.90 cm^2 and 78.45 cm^2),significantly more average number of roots plant^{-1} (118.45 and 107.67),longer average root length (82.42 cm and 70.95 cm plant^{-1}), significantly more average leaf yield plant^{-1} (25.87 g and 21.50 g of single harvest), significantly higher leaf yield pot^{-1} (794.40g and 645.21g), as well as higher average leaf yield container^{-1} (2.383 kg and 1.941 kg respectively), as compared to the corresponding(full and ½ strengths) solutions of the Imai'1987 recipe. The amounts of nutrient solution consumed (17.03 litres and 17.27 litres)were almost statistically the same for full strengths grown plants in both the recipes ,the average cost of nutrient solution consumed was significantly higher(Rs35.94 and Rs 20.86), the average total cost of growing spinach container^{-1}was also significantly higher(Rs 56.94 and Rs 40.86), the crop revenues obtained container^{-1} were also significantly higher (Rs 28.60 and Rs 23.29) for Cooper's recipe grown crop as compared to the crop grown in corresponding strengths of the Imai's recipe (mg L^{-1}), NO_3-N 140.0, P 35.05, K 360.22, Ca 160.16, Mg 48.60, Fe (EDTA) 3.0, Mn 0.5, Cu 0.02, Zn 0.05, B 0.5, Mo 0.01). However, the BCR values either on solution chemicals cost bases (1.25: 1.00 and 2.76: 1.00) or on total cost container^{-1} bases (0.58: 1.00 and 0.76: 1.00) were significantly higher for Imai's recipe grown crop.

Key Words: Hydroponics vegetables /spinach, Spinacea oleracae, Non-circulating hydroponics, Soil-less culture, Nutrients solution recipes, Benefits cost ratio

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INTRODUCTION

Over the past 22 years great advances in hydroponics technology have been made through extensive research and development programs in many of the advanced countries of the world (Mackowiak *et al.* 1996, Eversole 1999, Kao 2005 and Silberbush *et al.*, 2005). The concept of a non-circulating hydroponics developed earlier by Imai (1987) led him to conclude that a plant could develop two kinds of root systems, one for nutrients uptake and another one for oxygen uptake, and thus more serious complaint of root aeration in hydroponics have been addressed.. He suggested the installation of a simple water sensor or any other device to keep the water level constant in a non-circulating hydroponics growing container. A number of other studies on the nitrogen nutrition (form and rate) with varied levels of Fe had been conducted on growth and yield characteristics of the crops whose commercial consumption product is the plant leaves viz; spinach, lettuce, endive and cabbage (Bradley and Marulanda 2000, Simonne *et al.*, 2001, Wang and Li. 2004).

Jefferson (1999) mentioned of a 20 beds simplified hydroponics garden (40 m^2) that can add nutritional comforts of 1500 calories a day to a family by growing vegetables like potato, carrot, green beans, lettuce, tomato, and bell pepper etc. Kao (2005) developed a dynamic root floating (DRF) hydroponics technique for the year round growing of various kinds of vegetables including spinach. He reported that this technique proved ideal for growing various vegetables in a typhoon proof green house. The DRF technique comprised of a ridged bed, a concave panel, an aspirator, a nutrients level adjuster, a nutrients exchange box and a nutrients concentration controller. All the instruments were housed in a low cost typhoon proof green house. The nutrients in this system (DRF) were re-circulated by an automatic pump. Seedlings of vegetables including spinach were grown in poly-foam/ polystyrene sponge blocks for several days and then transferred into pre-cult holes in the panels. The concentration of the nutrient solution was (meL^{-1}) NO_3-N 6.0, NN_4-N 0.5, PO_4-P 3.0, So_4-S 1.5, K 4.0, Mg 2.0, Zn 0.01, Cu 0.01, Mo 0.01 ppm, pH 6.0 and EC of the solution was 1.0 mmho cm^{-1}. The spinach seed germinated in 3-4 days and the seedling stage lasted in 10-16 days. The crop took about 24 days to harvest with a production of 4.2 kg panel^{-1} (80 plants panel^{-1}) or 36.4 g plant $^{-1}$. The cost estimates of setting up of a DRF factory was US$ 27700 and the gross income was estimated as US$ 35718 showing a net profit of US$ 9528 year.

Likewise, Tsay *et al.* (1987) grew some leafy vegetables viz; leaf mustard, edible amaranth lettuce and pet-sai in a non-circulating hydroponics system comprising of polystyrene nutrient solution boxes of 25 cm (H) x 54 cm (L) x 34 cm (W)) covered with Styrofoam lid (2.5cm thickness) to which holes were made to fit the net-bottom pots (15 pots box^{-1}) filled with smoked rice hull (growing substrate). The composition of the nutrient solution was (In ppm) CaO 224, MgO 80.6, K_2O 434, P_2O_5 80.2 NO_3-N 140, Fe (EDTA) 3, Mn 0.5, Cu 0.02, Zn 0.05. B 0.5 and Mo 0.01. The leafy pet-sai that was sown in the middle of December took 46 days to edible maturity with a yield of 0.65 kg box^{-1}. While, the late Feb and late March sown crops (under Taiwan, R.O.C environment) took 32, 25 days to harvest with a production of 0.80, 0.38 kg box^{-1}, respectively. The present study was planned with a view to evaluate the efficacy of non-circulating hydroponics technology for the city dwellers of Peshawar, Pakistan. The main focus of this study was to evaluate two prominent nutrient recipes (Cooper's 1988 recipe and Imai's 1987 recipe) for growing various vegetables including spinach.

MATERIALS AND METHODS

The studies reported here were carried out in the green house facility of Institute of Biotechnology and Genetic Engineering (IBGE) at NWFP Agricultural University, Peshawar, Pakistan during the fall 2006. The design of the experiment was Randomized Complete Block (RCBD) having three replicates and four treatments. Each treatment comprised of 3 solution containers (10-15 plants in each pot and three pots in each solution container/13 litres plastic tub). Seeds of spinach cv Local-double were sown on Sep 30, 2006 in disposable plastics cups /pots of 9.5 cm length (with multi-holes at the lower portion for emerging roots) having smoked rice hull as growing medium. The pots/cups were fixed in a (2.5 cm thick) polystyrene lid placed on a plastic tub of 13 liters capacity (35 cm L x 25 cm W x 16 cm H). The tubs were filled up to 5cm from the top with the nutrients solution of both the recipes and later during the season further addition of solutions/water was also done when required.

The Cooper's 1988 recipe solution of full strength comprised of (mg L^{-1}) N-236, P 60.0, K 300, Ca 185, Mg 50, S 68, Fe (EDTA) 12, Mn 2.0, Zn 0.1, Cu 0.1, B 0.3, Mo 0.2) while, the half strength solution of this recipe comprised of (mg L^{-1}) N 118, P 30, K 150, Ca 92.5, Mg 25, S 34, Fe 6, Mn 1.0, Zn 0.1, Cu 0.1, B 0.15, Mo 0.2 (Table-I). The Imai's 1987 recipe solution of full strength comprised of (mg L^{-1}) N 140.0, P 35.05, K 360.22, Ca 160.16, Mg 48.60, Fe (EDTA) 3.0, Mn 0.5, Cu 0.02, Zn 0.05, B 0.5, Mo 0.01. While, the ½ strength solution of this recipe comprised of (mg L^{-1}) NO_3-N 70.0, P 17.52, K 180.11, Ca 80.08, Mg 24.30, Fe (EDTA) 3.0, Mn 0.5, Cu 0.02, Zn 0.05, B 0.5 and Mo 0.01(Table I). The solution containers (plastic tubs) were placed on green house benches. Data were recorded on various parameters as given below and analyzed statistically using M State-C software and LSD test as described by Gomez and Gomez (1984).

Parameters Studied

Average number of days to edible maturity/ first harvest, average number of leaves plant^{-1} , average leaf length (cm), average leaf area (LA)/ leaf size (cm ^{2}), average number of roots plant^{-1} , average root length (cm) , average leaf yield plant^{-1} (single harvest) (g), average leaf yield pot^{-1} (3 harvests) (g), average leaf yield container^{-1} (3 harvests container^{-1}) (g), average amount of nutrients solution consumed (Liters), average cost of nutrients solutions consumed (Rs) , average total cost of growing lettuce crop container^{-1} (Rs), average crop revenues obtained container^{-1} (Rs), benefits cost ratio of growing lettuce based on chemicals cost container^{-1} only (Rs), benefits cost ratio of growing lettuce crop based on average total cost container^{-1} (Rs).

RESULTS AND DISCUSSION

The results of this experiment (spinach grown in different strengths of two nutrient solution recipes) are laid down in Table II, Fig. 1-7, and discussed under parameter wise-headings in the following paragraphs in the light of the available literature reviewed.

Average Number of Days to First Harvest

Data related to the average number of days from sowing to the first harvest provided in Table-II revealed that the spinach crop took significantly lowest number of days from sowing till first harvest (32.44 days) when grown in full strength solution of the Cooper's 1988 nutrient recipe, while, in the ½ strength solution of the same recipe it took 35.56 days from sowing to the first harvest Whereas, it took 39.0 days in full strength solution of Imai's 1987 recipe, a delay of up to at least 10 days occurred in first harvest when grown in ½ strength solution of this recipe (Imai's 1987 recipe) which took significantly more number of days(42.78 days) from seed sowing (Table II).

The early maturity of spinach in full strength solution of Cooper's 1988 recipe was probably due to solution's higher Fe contents, and better solution pH. While, delay in maturity occurring in Imai's 1987 solution recipe could be attributed to the reduced Fe contents as well as lower concentrations of nitrogen that influenced vegetative growth in spinach plants. Similar observations have been reported by Mengel et al. (1994) who noticed micronutrients interactions with N forms which frequently changed the solution pH because of the change in rhizosphere and apoplastic pH as well as uptake ratio of cations and anions that influenced the shoot dry matter production. Likewise, Salberbush (2005) also mentioned that the presence of bicarbonates in a hydroponic solution reduced the growth of whole spinach plant and increased the Fe^{+++} reducing activity of roots.

Similarly, Romheld (2000) and Mengel (1995) also support our explanations. The results in our experiment for Imai's 1987 recipe are also not far away from the findings of Tsay *et al*. (1987) who harvested spinach crop grown in the same recipe in 46 days of sowing. Likewise, Kao (2005) who grew spinach in DRF hydroponics harvested the crop in 24 days of seedling transplantation (that excludes 3-4 days of seed germination and 10-16 days for seedling growth). Hence our results are almost in accordance with the finding of the above-mentioned scientists.

Average Number of Leaves Plant^{-1}

Data concerning the number of leaves plant^{-1} in spinach crop grown in different strengths of the two hydroponics nutrient solution recipes are presented in Table II and Fig. 1-7. There has been significant differences between the two recipes with regards to the number of leaves plant^{-1}, however, with in a recipe (whether the Cooper's 1988 or Imai's 1987 recipe) the effect of different strengths was non-significant.

Maximum numbers of leaves (12.44 plant^{-1}) were developed by spinach plants grown in ½ strength solution of Cooper's1988 recipe, which was followed by the plants grown in full strength solution of the same recipe (12.33 leaves plant^{1}). Whereas, the plants grown in full strength solution of the Imai's 1987 recipe developed 11.11 leaves plant^{-1}, while, 10.45 leaves plant^{-1} by ½ strength solution-grown plants (Table II). The differences noticed in number of leaves plant^{-1} between the two recipes were probably due to the nutrient solution ingredients and pH range which fluctuated more and was not much conducive in Imai's 1987 recipe that might has caused the reduction in the leaves number and also delayed the time /days to first harvest.

These results have indicated that the Imai's 1987 recipe was probably weaker one due to its ingredients, higher pH range and low Fe contents resulting in reduced leaves number as well as reaching the stage of harvestable maturity in more number of days. The findings of Romheld (2000) as well as Mengal (1995) also confirm our observations to a greater extent, who stated that the factors that inhibit/ restrict vegetative growth in leafy vegetables at higher solution pH, include the presence of bicarbonates and uptake ratio of cations and anions around the root rhizophere respectively.

Average Leaf Length (cm)

Data pertaining to this parameter given in Table -II reveals that the average leaf length of spinach grown in full strength solution of the Cooper's 1988 recipe was maximum (34.43 cm), followed by ½ strength solution grown plants of the same recipe (31.90 cm) and Imai's 1987 solution recipe of full strength (31.39 cm). While, the minimum leaf length (27.78 cm) was recorded for plants grown in ½ strength solution of the Imai's 1987 recipe. However, the average leaf length of spinach plants grown either in ½ strength solution of the Cooper's 1988 recipe or in the full strength solution of Imai's 1987 recipe was almost statistically similar. It is evident from these results that the Cooper's 1988 recipe proved superior in producing the longer leaves than the Imai's 1987 recipe, the full strength solution of which exhibited hardly equal to the ½ strength solution of the former recipe probably because of the better ingredients combinations that kept the solution pH within the optimal limits when prepared from ordinary tap water (the pH of which normally remains equals to 7.2-7.4).These results are in accordance with the findings of Mengel *et al.*(1994) who noticed micronutrients interactions especially the $Fe^{++}$with N forms that frequently changed the solution pH. The reduced growth of whole spinach plant was also observed by Salberbush *et al.* (2005) in hydroponic solution having high amounts of bicarbonates which increased the reducing activity of roots but reduced shoot growth. The Imai's 1987 recipe did have more amounts of Ca O and Mg O which used to increase the bicarbonates contents of the solution ultimately increasing the pH of the nutrients solution where plant growth slows down.

Average Leaf Area (LA) / Leaf Size (cm^2)

The data related to the leaf area (LA)/average leaf size of spinach plants grown in different strengths of the two hydroponics nutrient solutions are also laid down in Table-II. These results indicated that spinach plants grown in full strength solution of Cooper's 1988 recipe produced significantly larger sized leaves of 104.90 cm^2 which were followed by those obtained from plants grown in ½ strength solution of the same recipe (LA 78.45 cm^2) and full strength solution grown plants of Imai's 1987 recipe (63.44 cm^2). However, the smallest average LA/ leaf size of 59.95 cm^2 was recorded in plants grown in ½ strength solution of the Imai's 1987 recipe (Table II).

This depicted the superiority of Cooper's 1988 recipe over the Imai's 1987 recipe probably because of the nutrients ingredients ratios as well as the solution pH range that favoured the plant growth especially the vegetative growth/leaf expansion or increase in LA. Not much of the literature on this crop could have been accessed however, the results of the Romheld (2000) seem supportive to our experience in which the scientist had mentioned that the role of Fe contents and the presence of bicarbonates in the nutrients solution influenced the solution pH and uptake of nutrients affecting the leaf expansion or becoming the cause of leaf chlorosis**.**

Average Number of Roots Plant^{-1}

The data pertaining to this parameter shown in Table-II, have indicated that significantly more average number of roots (118.45 plant^{-1}) were counted for the spinach plants grown in full strength solution of the Cooper's 1988 recipe and very less number of roots (105.11 plant^{-1}) in ½ strength solution grown plants of the Imai's 1987 recipe. However, the ½ strength solution of Cooper's 1988 recipe and full strength solution of the Imai's1987 recipe were almost statistically alike regarding the average number of roots plant^{-1} (having 107.67 and 109.22 roots plant^{-1} , respectively). These results depict the superiority of the Cooper's 1988 recipe because of its better ingredient ratios that under ordinary conditions maintained the conducive pH range required for better growth of spinach plants. However, it has been noticed that the plants of *Spinacea oleraceae* var. Local-double could tolerate the higher pH more as compared to other leafy vegetables like lettuce.

Not enough literature could have been accessed regarding the nutrients solutions influence on spinach's root number, however, it could be inferred from these results that the conditions of the solution especially the pH ranges did influence the plants root production, which were more restricted in Imai's 1987 recipe solutions as compared to Cooper's 1988 recipe solutions.

Average Root Length (cm)

Data related to the average root length of spinach plants grown in different strengths of the two hydroponics nutrients recipes are given in Table II, which revealed significant differences between the two recipes and their different strengths. The maximum root length of 82.42 cm was recorded for plants grown in full strength solution of the Cooper's 1988 recipe, followed by 70.95 cm and 64.07 cm for the plants grown in ½ strength solution of the Cooper's 1988 recipe and full strength solution of the Imai's 1987 recipe respectively. Whereas, the minimum roots length of 59.89 cm was measured for the plants, which were grown in ½ strength solution of the Imai's 1987 recipe (Table-II).

Many of our earlier observations have also supported the superiority of the Cooper's 1988 recipe over Imai's 1987 recipe because of the nutrient ratios that can maintain better solution pH under ordinary conditions which favour plant growth as whole than that could be found in Imai's 1987 recipe's solutions. The other reason for this could be the amount and availability of the Fe contents in the nutrients solution, which were much better in Cooper's 1988 recipe as compared to the Imai's 1987 recipe. The findings of Romheld (2000) do support this view who reported that the root growth of spinach plants remained restricted at higher solution pH due to the presence of bicarbonates.

Average Leaf Yield Plant^{-1} of Single Harvest (g)

Data regarding the average leaf yield plant^{-1} of a single harvest are provided in Table –II, which have indicated significant differences in the average leaf yield of spinach plants (single harvest plant^{-1}) grown in almost all the strengths of two nutrient solution recipes. Maximum average leaf yield of 25.87g plant^{-1} (of single harvest) was recorded for plants grown in full strength solution of the Cooper's 1988 recipe, which was followed by (21.50 g plant^{-1}) plants grown in ½ strength solution of the same recipe (19.78 g plant^{-1}) and those plants grown in full strength solution of the Imai's 1987 recipe. However, the minimum average leaf yield of 18.30 g plant^{-1} was taken from the plants, which were grown in ½ strength solution of the Imai's 1987 recipe (Table II).

These results for Cooper's 1988 recipe to a greater extent are in closer proximity to those reported by Kao (2005) in his DRF hydroponics technique (single harvest yield of 36.4g plant^{1}). The little variations found in our experiment could be attributed to the solution's nutrient ratios and the technique used. However, the lower yields obtained in Imai's 1987 recipe were probably due to the lower nutrients uptake at non-optimal solution pH which restricted the roots and shoots expansion. The results of Mengel *(*1995) and Romheld (2000) favour this idea. Likewise, the observations of Kao (2005) are also supportive to this, who mentioned that a period of 24-30 days of growing petsai or spinach, in uncontrolled pH and EC could cause a loss of fresh yield from 34-36%.

Average Leaf Yield Pot^{-1} (g)

Data concerning the average leaf yield pot^{-1} (of three harvests) of spinach crop presented in Table-II, have shown that significant differences existed between both the nutrient solution recipes (Cooper's 1988 and Imai's 1987 recipes). Higher average leaf yield of 794.40 g pot^{-1} was obtained from the plants grown in full strength solution of Cooper's 1988 recipe, followed by 645.21 g plant^{-1} from those plants which were grown in ½ strength solution of the same recipe. However, the average leaf yield of spinach from either strengths of the Imai's 1987 solution recipe was almost statistically alike (609.25 g and 580.36g plant^{-1} respectively). Like-wise, the results of ½ strength Cooper's 1988 solution recipe grown plants were also statistically similar with those of full strength solution of Imai's 1987 recipe (Table II).

The average leaf yield pot^{-1} could be influenced by various factors such as; the planting density (the number of plants retained in a pot), the nutrient solution temperature and the solution pH. More yields obtained from the solution of Cooper's 1988 recipe grown plants are indicative of the balanced nature of this recipe in comparison to the Imai's 1987 recipe. Similar kinds of variations have been reported by Kao (2005) in the leaf yield of pet-sai and spinach at varying solution concentrations, solution pH and temperatures. Though his technique (DRF) had been a bit different than ours but his results are nearer to our observations.

Average Leaf Yield (kg container^{-1} / 13 litres plastic tub)

The data regarding average leaf yield container^{-1} (three pots container^{-1} and three harvests container^{-1}) of spinach crop grown in different strengths of the two nutrient solution recipes is provided in Table –II, which revealed significantly higher average leaf yield (2.383 kg container^{-1}) of plants grown in full strength solution of the Cooper's 1988 recipe, followed by (1.941 kg container^{-1}) from plants grown in ½ strength solution of the same recipe (1.828 kg container^{-1}) and from plants grown in full strength solution of Imai's 1987 recipe. Whereas, the lowest average leaf yield of 1.741 kg container^{-1} was bagged from the plants grown in ½ strength solution of the Imai's 1987 recipe .However, the results of either strengths of this recipe (Imai's 1987 recipe) were almost statistically alike (Table -II). The container^{-1} yield is dependent on the number of pots accommodated in a container, amount of solution, the nutrients concentrations, the solution pH and the season in which the crop is being grown. The differences in the precision of the technique and the skills of the user may also influence the yield container^{-1}.

Though we had many lackings in many aspects viz. the equipments/chemicals for monitoring and adjustments of pH and EC ranges and the skills, however, these results are not far away from those of Tsay *et al*. (1987) and Kao (2005), who obtained 1.0-4.0 kg box^{1} of petsai (15 pot box^{1}) and 4.2 kg penel^{-1}(>80 plant penel^{-1}) from a non-circulating hydroponics and DRF hydroponics techniques respectively.

Average Amount of Nutrient Solution Consumed (litres)

The data on average amount of nutrient solution consumed given in Table-II, have indicated that maximum amount of 19.77 litres nutrient solution was consumed by spinach crop grown in ½ strength solution of the Cooper's 1988 recipe, followed by plants grown in full strength solution of the Imai's 1987 recipe (17.27 litres) and 17.03 litres by those grown in full strength solution of Cooper's 1988 recipe. However, the differences in the nutrient solution consumption by spinach crop grown in the full strength solution of Cooper's 1988 recipe as well as in full strength solution of the Imai's 1987 recipe were statistically non-significant. The minimum average nutrients solution consumption was recorded for the spinach crop grown in ½ strength solution of the Imai's 1987 nutrient recipe (Table -II).

It has been noticed that the leaf size/LA, the solution pH and the prevailing temperature played their role in increasing or decreasing the amount of nutrient solution consumption by spinach crop/plants. The reduced amount of nutrient solution utilized by plants grown in ½ strength solution of Imai's 1987 recipe could be attributed to the aforementioned factors. Under adverse conditions (at higher pH levels), the interaction of micronutrients especially the Fe^{++} influences the root and shoot growth which ultimately reduces the uptake of cation and anions as well as the water in which these anions and cat ions are present. This explanation is supported by various researchers (Mengel 1995; and Romheld 2000).

Average Cost of Nutrient Solution Chemicals (Rs) Used for Growing Spinach Crop Container^{-1} (13 Litres Plastic Tub)

The data on average cost of nutrient solution consumed by spinach crop grown in 13 litres containers having nutrients solution of different strengths of the two nutrient recipes are provided in Table II. These data indicate that the cost invested for growing spinach crop in full strength solution of Cooper's 1988 recipe was significantly higher (Rs.35.94 container^{-1}) , followed by those grown in ½ strength solution of this recipe (Rs.20.86 container^{-1}) and those grown in full strength solution of Imai's 1987 recipe (Rs.17.61 container^{-1}). However, the average cost of growing spinach in ½ strength solution of the Imai's 1987 recipe was the lowest (Rs.7.56 container^{-1}). The higher costs of growing spinach plants in Cooper's 1988 recipe solution could be attributed to the initial higher costs of the nutrient ingredients chemicals (Merk's lab grade chemicals) which were of a foreign/ imported origin and their costs were higher. Whereas, some of the ingredients chemicals used for making Imai's 1987 recipe solution were partly of the domestic companies and their cost was comparatively lower. However, these costs could be further reduced by utilizing the domestically manufactured chemicals/fertilizers as well as improving the skills.

Average Total Cost (Rs) of Growing Spinach Crop Container^{-1}(13 litres Plastic Tub)

Data pertaining to the average total cost (nutrients solution cost + containers and other materials cost) of growing spinach crop in different strengths of the nutrient solution recipes presented in Table II, showed that the highest average total cost (Rs.56.94 container^{-1}) was spent on growing spinach crop in full strength solution of Cooper's 1988 recipe, followed by the one spent on growing spinach in ½ strength solution of this recipe (Rs.40.86 container^{-1}), and full strength solution of Imai's 1987 recipe (Rs.37.61 container^{-1}). The lowest average total cost (Rs.27.56 container^{-1}) was invested on growing spinach crop in ½ strength solution of Imai's 1987 nutrients recipe. The lower average total costs container^{-1} observed for either type of ½ strength solutions were mainly due to their ½ amounts of the nutrient chemicals. Moreover, the chemicals used for making the Cooper's 1988 solution were of foreign origin (Merk's Lab grade/imported ones) and hence their costs were higher. The average total cost for growing spinach could be reduced greatly by using the locally made fertilizers/ chemicals as well as by using the low cost containers made up of Styrofoam.

Average Crop Revenues Obtained (Rs) from Spinach Crop Container^{-1}(13 Litres Plastic Tub)

Data related to the average total crop revenues from the spinach crop grown in different strengths of the two nutrient solution recipes are laid down in Table-II, revealed that significantly higher revenues (Rs.28.60 container^{-1}) were obtained from the crop grown in full strength solution of Cooper's 1988 recipe, followed by those grown in ½ strength solution of this recipe (Rs.23.29container^{1}). Whereas, the revenues obtained from the spinach crop grown in either strengths of the Imai's 1987 nutrients recipe apart from being lower than Cooper's 1988 solution recipe grown plants, were statistically similar (Rs.21.94 and Rs.20.89 container^{-1} respectively).

Though spinach is not a high value crop that could fetch high prices in the market, prices of this also fall very quickly because of its high perish-ability and rapid water loss. Hence, the revenues are more linked to the quick disposal of the produce in a nearby market. Moreover, the revenues are also dependent on the quantity produced. The variations in average crop revenues container^{-1} that existed between the two prominent nutrient solution recipes (Cooper's 1988 and Imai's 1987) were mostly due to the limited production which could definitely be increased through improving the skills, better maintenance of solution pH, EC, and selling of produce in the super markets or quality conscious restaurants.

Benefit Cost Ratio (BCR) of Growing Spinach Crop Container^{-1}(13 Litres Plastic Tub) based on Nutrient Solution Chemicals Cost only

The BCR values as shown in Table II, demonstrate the returns for every Rupee spent/invested. These were calculated/derived using the formulae given by Kapp and Vasta (2003) which states that: BCR or CBR= Benefits / Cost. BCR values are considered feasible/acceptable when these are greater than one (> 1). While, these ratios are not acceptable / not feasible, when are less than one (<1). The suggestions/ guidelines of Sugden and Williams (1985) were also kept in view while calculating these ratios.

The best BCR (2.76**:**1.00) was obtained from spinach crop grown in ½ strength solution of the Imai's 1987 nutrient recipe, followed by the full strength solution grown plants of the same recipe (.1.25**:** 1.00). The BCR of spinach crop grown in either strengths of the Cooper's 1988 solution recipe were though acceptable (1.12**:**.1.00) in ½ strength and 0.80**:** 1.00 in full strength solutions, but these were significantly lower than those obtained from plants grown in solutions of Imai's 1987 recipe. The better BCR obtained in Imai's 1987 nutrient solution recipe were due to the reason that spinach plants are more tolerant to alkaline conditions i.e. the higher pH of the nutrient solution and hence survived and produced crop the yield of which overshadowed the investment cost.

Benefit Cost Ratio of Growing Spinach Crop Container^{-1} (13 Litres Plastic Tub) based on Average Total Cost Container^{-1}

Data regarding the benefits cost ratio (BCR) for growing lettuce (based on nutrient costs + other materials cost container^{-1}) as given in Table-II, was also derived according to the guidelines of Kapp and Vasta (2003), Sugden and Williams (1985). The results indicated that the benefits obtained were lower than the cost invested in almost all the cases. Significantly better BCR values (0.76**:** 1.00) were recorded for the crop grown in ½ strength solution of Imai's 1987, followed by (0.58**:** 1.00) for the crop grown in full strength solution of Imai's 1987 recipe, and(0.57: 1.00) for ½ strength solution grown crop in Cooper's 1988 recipe. The lowest BCR value (0.51: 1.00) was calculated for spinach crop grown in full strength solution of Cooper's 1988 recipe.

None-the less average cost of growing spinach was higher than the benefits obtained because of very low market value of the produce at selling time, little experience in maintaining the nutrient solution pH, however better results are still possibly be obtained and the cost could be lowered by increasing yield container^{-1} by accommodating more number of pots container^{-1} and by using locally manufactured chemicals and low cost containers/materials.

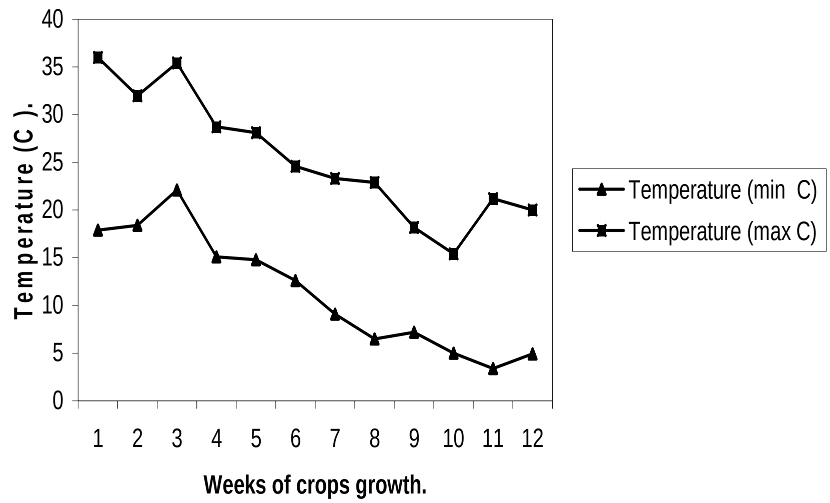

Fig. 1. ***Temperature conditions (^oC) during the growth period of spinach crop inside the green house at IBGE NWFP -AUP***

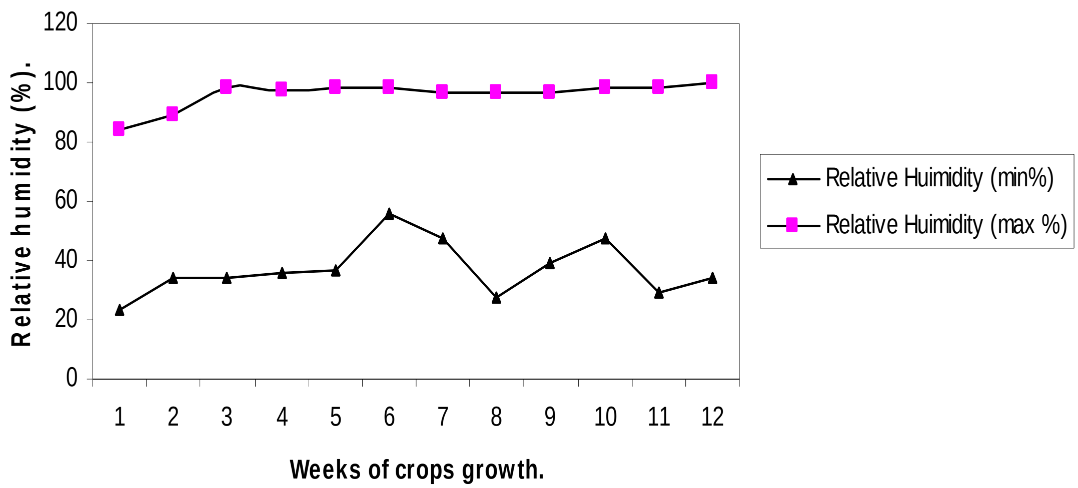

Fig. 2. ***Relative humidity situation (%) during the growth period of spinach crop inside the green house at IBGE, NWFP -AUP.***

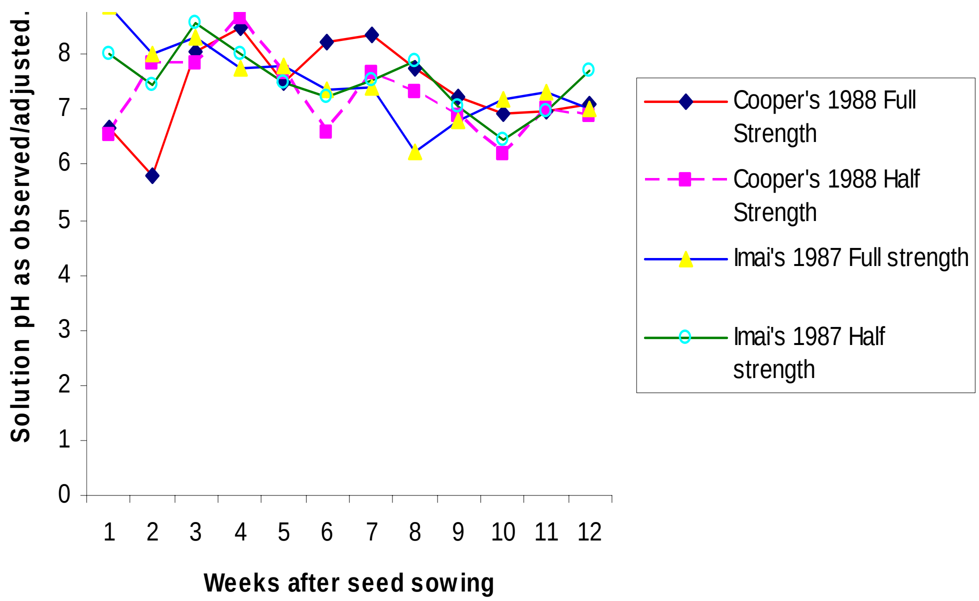

Fig. 3. ***Nutrients solutions pH as observed/adjusted during the spinach crop growth period***

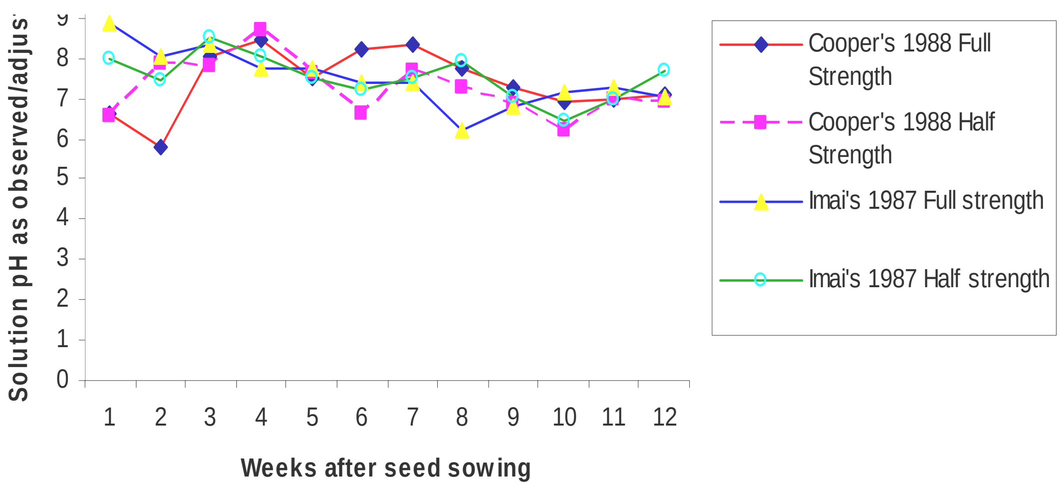

Fig. 4. ***Nutrients solutions EC as observed/adjusted during the spinach crop growth period***

(1)

(2)

(3)

(4)

Fig. 5. ***Photograph 1, 3 showing the initial stages of spinach crop cultivation in Imai's recipe solutions while, the photographs 2, 4 depict spinach growth in Cooper's solutions when grown in a non- circulating hydroponics system.***

(5)

(6)

(7)

(8)

Fig. 6. ***Photograph 5, 6 showing spinach crop being grown in Imai's 1987 recipe solutions while, photographs 7, 8 reveal the stage of harvestable maturity in spinach when grown in Cooper's 1988 recipe solutions in a non- circulating hydroponics system***

(9)

(10)

Fig. 7. ***Photographs 9,10, depict the bolting stage of spinach crop when grown in different strengths of the two nutrients solution recipes in a non circulating hydroponics system***

Table I. ***Nutrient recipes and their strengths used (mgL^{-1})***

Nutrients	Cooper's 1988 recipe		Imai's 1987 recipe	
	Full Strength	**Half Strength**	**Full Strength**	**Half Strength**
N	236	118	140.00	70.00
P	60	30	35.05	17.52
K	300	150	360.22	180.11
Ca	185	92.5	160.16	80.08
Mg	50	25	48.60	24.30
S	68	34	------	------
Fe(EDTA)	12	6	3.00	3.00
B	0.3	0.15	0.50	0.50
Mn	2.0	1.00	0.50	0.50
Zn	0.1	0.10	0.05	0.05
Cu	0.1	0.10	0.02	0.02
Mo	0.2	0.20	0.01	0.01

Table II. ***The results of spinach cv Local-double plants grown in different strengths of the two nutrients solution recipes in a non-circulating hydroponics system***

Parameters	Recipes and their strengths				LSD≤0.05
	Cooper's 1998 recipe		**Imai's 1987 recipe**		
	Full strength	½ strength	Full strength	½ strength	
Average number of days to first harvest	32.44 d	35.56 c	39.00 b	42.78 a	1.830
Average number of leaves plant^{-1}	12.33 a	12.44 a	11.11 b	10.45 b	0.911
Average leaf length (cm)	34.43 a	31.90 b	31.39 b	27.78 d	1.260
Average leaf size/ LA (cm^2)	104.90 a	78.45 b	63.44 c	59.95 d	2.171
Average number of roots plant^{-1}	118.45 a	107.67 b	109.22 b	105.11 c	1.777
Average root length (cm)	82.42 a	70.95 b	64.07 c	59.89 d	1.519
Average leaf yield plant^{-1} (Single harvest) (g)	25.87 a	21.50 b	19.78 c	18.30 d	0.155
Average leaf yield pot^{-1} (3 harvests) (g)	794.40 a	645.21 b	609.25 bc	580.36 c	38.60
Average leaf yield container1 (3 harvests) (g)	2.383 a	1.941 b	1.828 c	1.741 c	0.109
Average amount of nutrient solutions consumed (litres)	17.03 b	19.77 a	17.27 b	14.83 c	1.500
Average cost of nutrient solution consumed @ Rs 2.11 L^{-1} for Cooper's recipe and Rs 1.02 L^{-1} for Imai's recipe (Rs)	35.94 a	20.86 b	17.61 c	7.56 d	2.179
Average total cost of growing spinach container^{-1} (Rs)	56.94 a	40.86 b	37.61 c	27.56 d	2.179
Average total crop revenues obtained container^{-1} @ Rs 12.00 kg^{-1} (Rs)	28.60 a	23.29 b	21.94 c	20.89 c	1.337
Benefits cost ratio of growing spinach container^{-1} based on nutrients chemical cost (Rs)	0.80 d	1.12 c	1.25 b	2.76 a	0.126
Benefits cost ratio of growing spinach container^{-1} (Rs) (based on average total cost container^{-1})	0.51 d	0.57 c	0.58 b	0.76 a	0.002

CONCLUSION AND RECOMMENDATION

The Cooper's 1988 solution recipe (of full and ½ strengths) proved significantly better than the Imai's 1987 solution recipe with regards to most of the parameters studied. The BCR values (both on solution chemicals cost basis as well as on total cost basis) were though acceptable for Cooper's recipe grown spinach crop but these ratios were much better for Imai's recipe grown crop because the lower costs of some ingredients/chemicals (which were partly of the local origin) than the ingredients used for Cooper's recipe(imported ones). In order to keep the crop in vigorous condition and to draw maximum benefits, time to time adjustments in the nutrient solution pH and EC with the addition of acids or bases solutions and water are recommended. More over, there is a need to accommodate more number of planting pots in each solution container/ tub, if the lid of the container / tub is not too weak so that the yield/returns container^{-1} is increased.

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