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Uptake of nutrient by soilless culture on radish (*Raphanus sativus*) for significant utilization of NUE

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Abstractfv
Invariably, some of the world's agricultural fields lack one or more of the vital nutrients required to sustain healthy plants. In the current scenario, soil-less culture is becoming more essential in order to contend with these challenges. Plants are raised without soil in a soil-less culture. Improved methods of food production in the soil-less society of space and water conservation. Currently, with 6 billion people, it is just 0.25 ha and will hit 0.16 ha by 2050. Arable land under cultivation would further decrease due to rapid urbanisation and industrialization, as well as the melting of icebergs as an obvious result of global warming. Again the state of soil fertility has reached a degree of saturation, and with an increased level of fertilizer use, productivity does not increase further. Acidity, alkalinity, salinity, anthropogenic processes, nature of farming, and erosion can lead to soil degradation. Effective utilization of nutrients under hydroponic system made an enhanced plant growth and development on Radish (*Raphanus sativus*). Amendments are essential for a proper nutrient supply and maximum yields. Estimates of overall efficiency of applied fertilizer have been reduced under soil less culture. Treatments like T1N1 Control, T2N2 (10% POP) recommended fertilizer, T3N3 (20% POP), T4N4 (30% POP) and T5N5 (40% POP), T6N6 (50% POP), T7N7 (60% POP) and T8N8 (70% POP). Biochemical chemical parameters like Stomatal density and Chlorophyll pigment composition, Germination percentage was noticed for each treatment under different percentages. Randomly selected seedlings were shifted in hydroponic system containing different POP (package of practice) doses. Various growth parameters like root length, plant height, root weight, number of leaves, and total dry weight were recorded for each treatment. Utilization of nutrients and differences are attributed to morphological, physiological and biochemical processes in plants and their interaction is significantly increased under hydroponic system. An improved NUE in plants can be achieved by significant utilization of nutrient under this soilless culture.

Keywords: Nutrient use efficiency, hydroponics, radish, package of practices

Introduction
Plants that are efficient in absorption and utilization of nutrients greatly enhance the efficiency of applied fertilizers, reducing cost of inputs, and preventing losses of nutrients to ecosystems. Inter- and intra-specific variation for plant growth and mineral nutrient use efficiency (NUE) are known to be under genetic and physiological control and are modified by plant interactions with environmental variables. There is need for breeding programs to focus on developing cultivars with high NUE. Identification of traits such as nutrient absorption, transport, utilization, and mobilization in plant cultivars should greatly enhance fertilizer use efficiency.

Radish (*Raphanus sativus* L) belongs to the family Brassicaceae, genus Raphanus and species sativus. It is one of the most important and popular root vegetable grown in tropical, subtropical and temperate regions of the word. It is grown both as an annual and a biennial vegetable crop deepening upon the purpose of which it is grown. Radish is predominantly a cool season vegetable crop. But Asiatic types can tolerate higher temperature than European varieties. In the mild climate, radish can be grown almost all year round except for few months in summer.

World population is expected to increase from 6.0 billion in 1999 to 8.5 billion by 2025. Such an increase in population growth will intensify pressure on the world’s natural resource base (land, water, and air) to achieve higher food production. Increased food production could be achieved by expanding the land area under crops and by increasing yields per unit area through intensive farming. About 1.44 billion ha of the world's land is arable and is under permanent cropping (FAO 1992, 1993) [35-36]. Most of the land that could be brought under cropping has been utilized with exception of some land in Sub-Saharan Africa and South America (Borlaug and Doswell, 1993) [19]. Intensive cultivation invariably leads to degradation of land and lowers its fertility and productivity. Many agricultural soils of the World are deficient in one or more of the essential nutrients to support healthy and productive plant growth. Acidity, alkalinity, salinity, erosion, anthropogenic processes and farming practices have contributed to soil degradation and lowering of fertility across different agroecosystems. Mineral stress problems in various soil orders of the world are due to the nature of parent materials and climatic factors (Dudal, 1976) [27]. Acidic soils occupy close to four billion ha of the ice-free land area in the world. The total area of salt affected soils in the world is about 950 million ha. Worldwide elemental deficiencies for essential macro and micro nutrients and toxicities by Al, Mn, Fe, S, B, Cu, Mo, Cr, Cl, Na, and Se, have been reported (Baligar and Fageria, 1997) [10].

Chemical fertilizers are one of the expensive inputs used by farmers to achieve desired crop yields. Currently, about 12 million tons of N, 2 million tons of P, and 4 million tons of K are being used annually in North American agriculture. Recovery of applied inorganic fertilizers by plants is low in many soils. Estimates of overall efficiency of these applied fertilizers have been about 50% or lower for N, less than 10% for P, and close to 40% for K (Baligar and Bennett, 1986, a, and b) [6-7]. These lower efficiencies are due to significant losses of nutrients by leaching, run-off, gaseous emission and fixation by soil. These losses can potentially contribute to degradation of soil, and water quality and eventually lead to overall environmental degradation. These are compelling reasons of the need to increase NUE.

Best management practices are the best external alternative that can be applied to improve NUE. Plant genetics and physiological mechanisms and their interaction with BMPs are also a tool that can be used to increase efficiency of cropping systems. Our objective is to present a broad spectrum of NUE in plants. Several other authors have reported extensively on this topic (Baligar and Duncan, 1990; Baligar and Fageria, 1997; Barber, 1995; Blair, 1993; Duncan, 1994, Duncan and Carrow, 1999; Epstein,1972; Fageria, 1992; Fageria *et al*., 1997a; Gerloff and Gabelman, 1983; Marschner, 1995; Mengal and Kirkby, 1982; and Vose, 1987) [8, 10, 13, 17, 30, 29, 31, 39, 47, 50, 56].

Estimation of NUE in Plants

The evaluation of NUE is useful to differentiate plant species, genotypes and cultivars for their ability to absorb and utilize nutrients for maximum yields.

The NUE is based on (a) uptake efficiency (acquire from soil, influx rate into roots, influx kinetics, radial transport in roots are based on root parameters per weight or length and uptake is also related to the amounts of the particular nutrient applied or present in soil), (b) incorporation efficiency (transports to shoot and leaves are based on shoot parameters) and (c) utilization efficiency (based on remobilization, whole plant i.e. root and shoot parameters).

Some of the commonly used efficiency definitions are given below. For the extensive coverage of this area, readers are referred to Baligar and Duncan (1990) [8]; Baligar and Fageria (1997) [10]; Blair (1993) [17]; Fageria (1992); and Gerloff and Gablemen (1983) [39].

Nutrient efficiency ratio (NER) was suggested by Gerloff and Gabelman (1983) [39] to differentiate genotypes into efficient and inefficient nutrient utilizers.

NER= (Units of Yields, kgs) kg kg-1 (Unit of elements in tissue, kg)

Agro physiological efficiency (APE) has been defined as the economic yield obtained per unit of nutrient absorbed. Overall NUE in plant is a function of capacity of soil to supply adequate levels of nutrients, and ability of plant to acquire, transport in roots and shoot and to remobilize to other parts of the plant. Plants interaction with environmental factors such as solar radiation, rainfall, temperature and their response to diseases, insects and allelophathy and root microbes have a great influence on NUE in plants. Detailed discussion on these various areas are given in reviews by Baligar and Duncan (1990) [8]; Baligar and Fageria (1997) [10] and Blair (1993) [17].

Among other nutrient dynamics, these factors can affect mineralization and immobilization, fixation by adsorption and precipitation mechanisms, leaching, runoff, and gaseous losses via denitrification and ammonia volatilization (Baligar and Fageria, 1997) [10]. Adverse soil physical properties affect the longitudinal and radial root growth, root distribution, morphology by stunting, thickening, reduction of second and third order lateral roots and root anatomical changes (Bennie, 1996; Russell, 1977; Taylor *et al.*, 1972) [15, 53]. High mechanical impedance leads to loss of root caps and reduction in radial thickening primarily due to shorter and wider cells with the same volume in the cortex (Camp and Lund, 1964) [21] and a thicker cortex. This may also cause changes in cell structure of the endodermis and pericycle. Such changes in the size and internal and external morphology of roots due to the adverse soil physical conditionswill influence the root's ability to explore larger soil volume and reduce nutrient and water availability and uptake, leading to low NUE and lower yields.

Leaching and crop removal of basic cations, N2 fixation by legumes, use of heavy levels of organic and inorganic N fertilizers, and atmospheric deposition of N and sulfur oxides are major factors for soil acidification that leads to degradation and lower productivity and soil quality in temperate and tropical regions of the world (Baligar and Ahlrich, 1998; Sumner *et al*., 1991) [6, 52]. Acidic soils have phyto-toxic levels of Al, Mn, Fe, and H and deficient levels of N, P, K, Ca, Mg, Mo, and Zn to support good plant growth (Baligar and Fageria, 1997; Fageria *et al*., 1990; Sumner *et al*., 1991) [10, 52]. Both of these factors are largely responsible for reduced growth and lower NUE (Baligar and Fageria, 1997; Fageria *et al*., 1990; Foy, 1992; Marschner, 1995 Sumner *et al*., 1991) [10, 47, 52].

During recent decades the soil concentrations of elements such as Cd, Cr, Ni, Pb, Cu, Zn, As, Co, and Mn in some agricultural soils have been increasing due to use of soil amendments, pesticides and other anthropogenic activities (Adriano,1986; Alloway, 1995; Kabata-Pendias and Pendias, 1992) [3, 42]. These trace elements, if present at excess levels pose phyto-toxicity and can reduce plant growth and nutrient uptake and eventually reduce NUE (Baligar *et al*., 1998a; Kabata-Pendias and Pendias, 1992; Marschner, 1995) [7, 47, 42]. The availability of these heavy metals will be affected by soil pH, temperature, redox potentials, anion ligand formation, and composition and quantity of soil solution among other factors (Alloway 1995) [3].

Root morphology parameters such as length, thickness, surface areas, density, root hairs and root growth rate expressed as dry mass and/or root: shoot ratios are affected by deficiencies of essential minerals and/or excess of minerals (Kafkafi and Bernstein,1996; Marschner, 1995) [43, 47]. Clark (1970) [22] reported that in solution culture studies with maize, reducing the supply of essential nutrients from full strength to none increased root: shoot ratio in P, Ca, S, and Zn treatments; however, root: shoot ratios decreased in NO3-N, Mg, Mn, and Cu treatments. Effects of soil organic matter (SOM) on physical parameters and nutrient dynamics and how they impact NUE have been reported by several authors (Von Uexkull, 1986) [54]. The SOM helps to maintain good aggregation and increase water holding capacity and exchangeable K, Ca, and Mg. It alsoreduces P fixation, leaching of nutrients and decreases toxicities of Al and Mn. Best management practices such as addition of crop residues, green manure, compost, animal manure, use of cover crops, reduced tillage and avoiding burning of crop residues can significantly improve the level of SOM and contribute to the sustainability of the cropping systems and higher NUE.

Changes in the soil nutrient reserve and alteration in root systems under different tillage systems might have direct bearing on the nutrient availability and uptake by crops. Tillage practices such as conventional, conservation and notillage are known to bring changes in SOM, nutrient concentrations, bulk density, water holding capacity and soil temperature among others. Higher contents of available P, Ca, K and organic C and N have been reported for no tillage than for conventional tillage (Blevins *et al*., 1983; Ismail *et al*., 1994; Lal, 1976; Mahboubi *et al*., 1993; Saffigna *et al*., 1989) [18, 41, 45]. Minimum tillage increases root growth in the top 12 cm of soil for barley (*Hordeum vulgare L*) and oat (*Avena sativa L*) cropping systems (Ehlers *et al*., 1983: Ellis *et al*., 1977). Minimum tillage has also been reported to increase root weight, length, and density, increasing the nutrient and water use efficiencies (Adkinson, 1990; Hackett, 1969; Mengal and Barber, 1974) [1, 40, 49]. Baligar *et al*., (1998b) [7] reported that shoot dry matter yields and root length and density of silage corn in no-till were significantly higher than in conventional tillage. Such improved root parameters contributed to higher yields and uptake efficiencies of N., P, Ca, S, Cu, Fe, and Zn. Improved tillage equipment and practices need to continue being developed to increase NUE across different agroecosystems.

Plant Factors

Selection of improved genotypes adaptable to a wide range of climatic changes has been a major contributor to the overall gain in crop productivity. Steady increase in the average yields of major crops during the second half of the 20th century has been achieved through genetic improvement coupled with improvement in best management practices. In spite of such advances, the average production of major crops at the farm level, are still two to four times lower than the recorded maximum potentials. Modern genotypes of rice (*Oriza sativa L*), corn, wheat (*Triticum aestivum L*) and soybean (*Glycine max L. Merrill*) are more efficient in absorption and utilization of nutrients as compared to older cultivars (Clark and Duncan, 1991; Fageria, 1992). Borlaug and Doswell (1994) [20] stated that soil fertility is the single most important factor that limits crop yields in developing countries. As much as 50% of the increase in crop yields worldwide during the 20th century is due to the use of chemical fertilizers. Genetic variability has been reported to explain the differences in NUE and the parameters of nutrient uptake (Baligar and Duncan, 1990; Baligar and Fageria, 1997; Barber, 1995; Clark, 1982; Clark and Duncan, 1991; Duncan, 1994; Duncan and Carrow, 1999; Epstein, 1972; Foy, 1983; Gerloff, 1987; Gerloff and Gabelman, 1983; Vose, 1984) [8, 10, 13, 30, 29, 31,39, 55, 23, 24]. Such differences in growth and NUE in plants have been related to differences in absorption, translocation, shoot demand, dry matter production per unit of nutrient absorbed, and environmental interactions (Clark and Duncan, 1991) [24]. Overall NUE in plants is governed by the flux of ions from the soil to the root surface and by the influx of ions into roots followed by their transport to the shoots and remobilization to plant organs. The root morphological factors such as length, thickness, surface area, and volume have profound effects on the plant's ability to acquire and absorb nutrients in soil These parameters influence the ability of the roots to penetrate high density soil layers, to tolerate temperature and moisture extremes, and toxicities and deficiencies of elements. (Baligar and Duncan, 1990; Barber, 1995) [8, 13].

Material and methods

The experiment was undertaken with the main objective to evaluate the Uptake of Nutrient by soilless culture on radish (*Raphanus sativus*) for significant utilization of NUE. For this, pot culture experiments were conducted. Experimental plants were maintained in pot culture. Observations on growth, physiological and biochemical parameters were recorded during crop period.

The experiment was conducted in department of Plant Physiology located at Sampoorna International Institute of Agriculture Sciences and Horticultural Technology, situated at Belekere, Channapatna. Planting material, crop radish (Raphanus sativus) plants were used for the study. The seed materials were procured from Sampoorna International Institute of Agriculture Sciences and Horticultural Technology. The experiment was laid out in CRD with nine treatments and two replications.

Procedure

After successful germination test (Plate 01) we shifted to pots, potted plants (3 plants/pot 2kg potting mixture) were used for this experiment. Plants were maintained different percentage of Nutrient treatment. Observations were taken at biweekly intervals, till stress period of two weeks (Plate 02 & 03). Observations were taken from average of three replication after 25 DAS day after sowing.

Observations: Growth Parameters

1. **1. Number of Leaves**

Total numbers of leaves in the experimental plants were counted.

2. **2. Root Weight (g)**

The roots of plants were cut at the base level and washed free of adhering soil with low jet of water. The roots were then ov

3. **3. Root length (cm)**

The root of the plants was calculated as length of root in centimeter.

4. Root weight (g)

The sum of root and shoot dry weights were taken as the total root weight yield.

Physiological and Biochemical parameters

Chlorophyll pigments (mg g-1)

Chlorophyll content of leaf samples were estimated as per the procedure described by Arnon (1949). A weighed quantity of leaf sample (0.5g) was taken from fully expanded third leaf and cut into small bits. These bits were put in test tubes and incubated overnight at room temperature, after pouring 10 ml DMSO: 80% acetone mixture (1:1 v/v). The coloured solution was decanted into a measuring cylinder and made up to 25 ml with the DMSO-acetone mixture. The absorbance was measured at 663, 645, 480 and 510nm. The chlorophyll content was measured by substituting the absorbance values in the given formula en dried and dry weight was recorded.

$$TotalChl(a+b) = (8.02 \times A_{663} - 20.2 \times A_{645}) \times \frac{V}{1000} \times \frac{1}{fresh\,weight}$$

Stomatal density (no.mm2)

Stomatal density refers to the number of stomata per unit area of leaf. A thick mixture of thermocol and xylene was prepared and this was smeared on both the surfaces of leaves and allowed to dry. It was peeled gently after drying and the peel was observed under microscope and counted using a 40X objective and 10X eyepiece. The field of the microscope was measured using a stage micrometre and stomatal frequency per unit area was calculated.

$$Stomatal\,frequency = \frac{Number\ of\ stomata}{Area\ of\ the\ microscopic\ field}$$

Statistical analysis

The experiment used a CRD with three treatments and each treatment was analysed with three replications. Statistical analysis was performed using ANOVA. P values d $\leq$ 0.05 were considered as significant.

Results and discussion

The current experiment entitled evaluate the Uptake of Nutrient by soilless culture on radish (*Raphanus sativus*) for significant utilization of NUE was undertaken with the objective to study the effect of nutrient use efficiency under soil less culture on radish under varying different nutrient percentages. Three sets of pot culture experiments were conducted during 2020. The experiments were laid out in CRD factorial.

Alteration in growth performance of radish under the studied by treatment of nutrient level analyzing the parameters *viz* leaf number, root weight, root length and total root weight accumulation were significantly increasing.

Plate 1: Plants under soilless culture.

Plate 2: Experimental setup of soilless culture on radish

(Fig 04) was also observed under different percentage of nutrients. Highest values in biochemical parameters were recorded for total chlorophyll content (2.46 mg g-1) (Fig 02), Stomatal density (213.12 n/mm2) (Fig 03). Among the different nutrient plants responded better under low concentration in T4N4 treatment.

Conclusions

Increased NUE in plants is vital to enhance the yield and quality of crops, reduce nutrient input cost and improve soil, water and air quality. NUE in plants need to be clearly defined and carefully selected to reflect the end use. Much can be achieved by selecting nutrient efficient genotypes and to incorporate these in breeding programs. However, the poorly developed state of nutritional genetics of plants and its response to environmental variables and management practices and the difficulty of identifying nutrient efficiency traits by rapid and reliable techniques have contributed to a lack of progress and success in breeding plant cultivars with high NUE. Plant species and cultivars within species differ in absorption and utilization of nutrients and such differences are attributed to morphological, physiological and biochemical processes in plants and their interaction with climatic, soil, fertilizer, biological and management practices. An improved NUE in plants can be achieved by hydroponic system for upcoming climatic changing condition.

Table 1: Comparison of physiological growth parameters under soilless culture in radish.

Treatments	No. of Leaves	Root length (cm)	No of root (No.)	Root weight (g)
T1N1 Control	10.56	16.62	10.68	4.85
T2N2 (10% POP)	12.52	14.87	9.36	3.26
T3N3 (20% POP)	11.35	13.68	8.38	3.35
T4N4 (30% POP)	13.90	18.39	16.35	5.98
T5N5 (40% POP)	9.68	12.35	11.36	4.28
T6N6 (50% POP)	9.35	11.28	10.78	3.87
T7N7 (60% POP)	8.67	13.87	11.35	3.85
T8N8 (70% POP)	7.33	13.25	10.88	3.44
CD (0.05)	1.218	1.736	1.612	1.126
SE± (m)	0.402	0.634	0.485	0.218
SE± (d)	0.639	0.931	0.736	0.443

Significant differences at CD (0.05), Replication-3, T- Treatment

Table 2: Comparison of biochemical parameters under soil less culture in radish.

Treatments	Chlorophyll pigment composition	Stomatal Density (n/mm2)	Germination percentage (%)
T1N1 Control	1.68	198.12	82.79
T2N2 (10% POP)	1.26	165.35	84.33
T3N3 (20% POP)	1.44	152.37	85.46
T4N4 (30% POP)	2.46	213.12	89.34
T5N5 (40% POP)	1.87	166.35	79.36
T6N6 (50% POP)	1.75	152.48	82.22
T7N7 (60% POP)	1.64	166.35	84.36
T8N8 (70% POP)	1.49	162.66	84.17
CD (0.05)	0.457	0.752	1.348
SE± (m)	0.030	0.325	0.463
SE± (d)	0.041	0.298	0.375

Significant differences at CD (0.05), Replication-3, T- Treatment

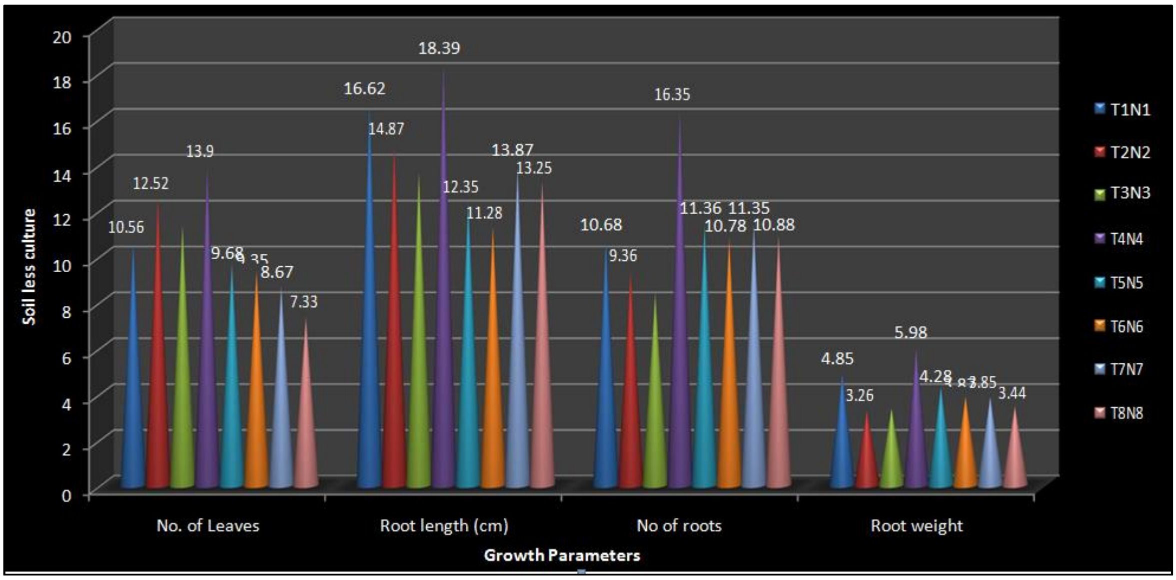

Fig 1: Physiological growth parameters under soilless culture in radish.

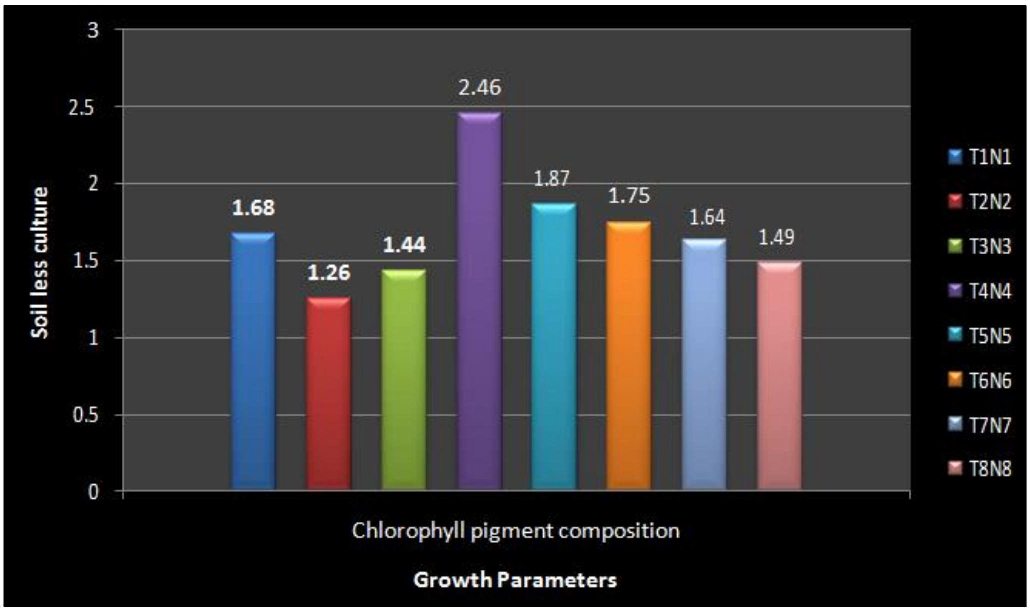

Fig 2: Effect of Pigment composition under soilless culture in radish.

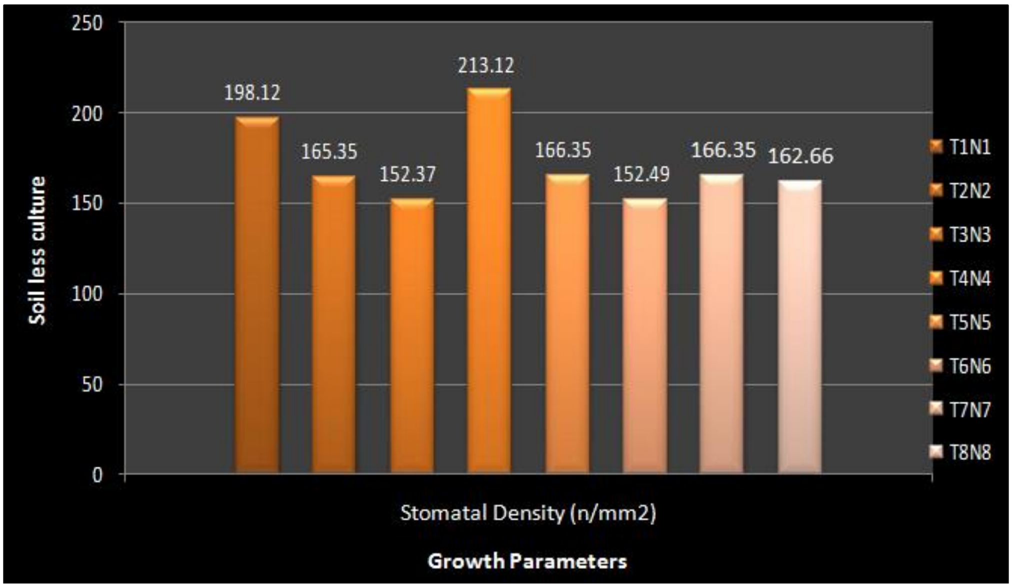

Fig 3: Effect of Stomatal density under soilless culture in radish.

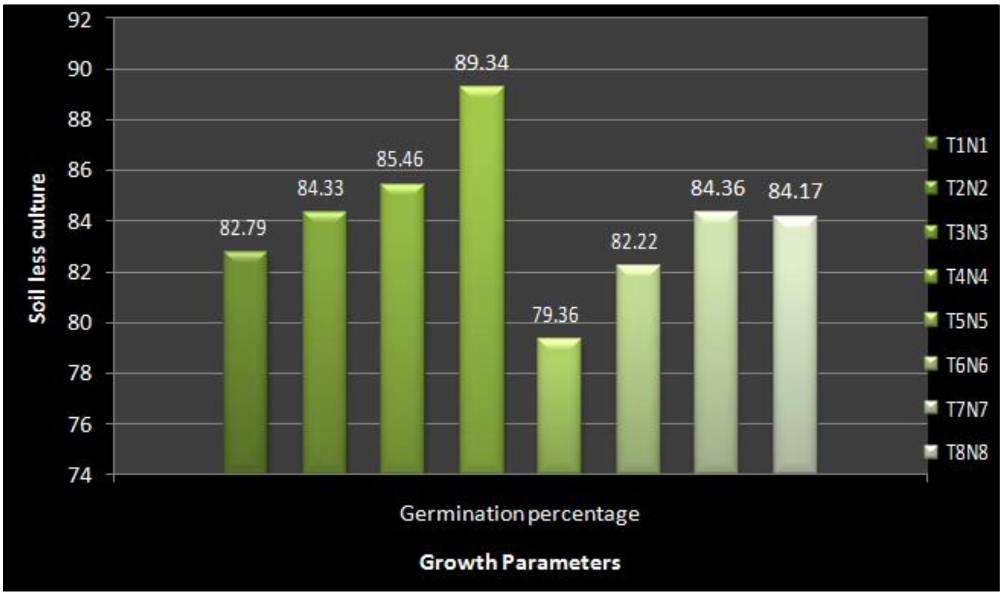

Fig 4: Effect of Germination percentage under soilless culture in radish.

Plate 3: Preparation of Hydroponic system unit in department of Plant physiology SIIASHT.

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