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Efficacy of different soilless substrates on tomato under hydroponic system

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Abstract

Hydroponic is an alternative food growing system to sustain agriculture in urban and water stress environment. The huge increase in population and alarming rate of water shortage caused more stress on agriculture resources thus there is a dire need to adopt this innovative agriculture of 21st century. It promises year round supply of quality vegetables with high yield. The performance and suitability of different substrates for the soilless culture of tomato (*Lycopersicum esculentum*) were studied at Institute of Hydroponics Agriculture, PMAS Arid Agriculture University Rawalpindi, over a two growing seasons under greenhouse condition, during 2015-17, employing five different treatment (substrates) viz. T_1 (coco imported), T_2 (indigenous coco), T_3 (indigenous coco +25% zero grade stone crush by weight), T_4 (rice husk), T_5 (rice husk +25% zero grade stone crush by weight). The results indicated that soilless substrates have significant effects on tomato production. First season study, demonstrated that the sole Coco-imported and indigenous rice husk is a very good substrate for greenhouse grown tomatoes. While during second growing season sole use of coco imported media significantly affected the tomato yield 7.03kg plant^{-1} followed by indigenous rice husk and lowest yield among the subtract was recorded in coco indigenous +25% zero-grade stone by weight. It was concluded from the study that the treatment T_1 containing imported coco had the best performance for tomato plant growth under soilless substrates.

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Introduction

Pakistan is predominately an agricultural country and thus its development depends upon the improvement of the agriculture sector. Sustainable crop production in Pakistan is threatened by several factors. One of the most outstanding limitations is drought due to high temperature/law rainfall, soil degradation due to salinity/sodicity. It is a major environmental constraint with severe negative impact on agricultural productivity and sustainability particularly in arid and semiarid regions of the world (Pitman and Lauchli, 2002, Qadir *et al.*, 2006). Economics of agriculture, especially our small farmers have been getting worse year after year due to loss of productivity of soils. Sodic and saline sodic soils account for more than 50% of world's salt affected area (Beltran and Manzure, 2005). In Pakistan, about 6.68m ha land is salt affected (Khan, 1998). Underground water also contains excessive amount of salts which aggravate the problems of soil salinity and sodicity in Pakistan. These salts are very harmful for young plants. Accumulation of both water soluble and exchangeable sodium in excessive amount, not only minimize the water availability to plants but also adversely affects the soil properties (Nazir, 1994). During last three decades, the country's population has registered an increase from 65 million to 180 million and is likely to reach 234 million by 2025 (Annymous, 2014). Per capita water availability has been declining at an alarming rate, from 5300 cubic meters in 1951 to about 850 cubic meters in 2013. An estimated per capita water availability in 2025 will be 659 cubic meters. Shortage of water has been estimated at 25 percent for the year 2010 and 33 percent for 2025 (Ahmad *et al.,* 2007). To feed this alarming population growth alternative food growing system hydroponic/soilless culture are the dire need of the day, that promise year round supply of quality vegetables with high yield. Different media are selected to support the roots, which provide water, nutrients and suitable aeration in root zone. Areas, where even there is no fresh water, crops can be grown hydroponically through the distillation of sea water. For provision of food in the urban, dry coastal belts and deserts which are nonarable and water scarce areas, hydroponics promise highest yield potential (Gruda *et al.*, 2006).

Tomato is cultivated on 53.4 thousand ha producing 561.9 thousand tons of tomato in Pakistan, whereas the tomato area in Punjab is 5.6 thousand ha producing 72.5 thousand tons of tomatoes. The quantity weighing 997147kg has the export value of 12453 thousand rupees for tomato. The quantity weighing 35860265kg has import value of 502286 thousand rupees (GOP, 2008). Increasing difficulties with greenhouse vegetable production is often due to soil borne root diseases. Yields can be limited even in the crop after soil sterilization as the disease organisms are persistent in the soil below the depth reached by normal doses of soil sterilants. This situation is common in old greenhouses. The problem can be solved by changing to soilless grown methods which can protect the crop from soil borne diseases. The applicability of mineral substrata, including mainly rockwool and perlite for greenhouse grown plants has been worked out. When considering costs of their production and management as post-production waste, the plant growing area in these substrate decreases. In recent years many studies have been conducted on using various organic materials in greenhouse growing, which are most frequently waste (cut rye and wheat straw, wood, sawdust, coconut fiber) as substrata for vegetables and ornamental plants (Ehret and Helmer 2009). The possibility was considered of using many organic materials for preparing substrata, depending on agricultural crops in particular regions. To maintain compost ground bamboo, rice straw, sawdust from various tree species, coconut fiber and fresh rice hulls were used. Adding such compost to peat (even up to 50%) a very good substratum is obtained for tomato and other plants grown in greenhouse. Interesting results obtained from tomato growing should be emphasized. There the substrata were rye straw, wheat straw cut into pieces and slabs made of shredded rye straw. High yield was obtained like from cultivation in rock-wool. The aim of the presented paper were studies on growth and yielding of tomato grown in greenhouse in the substrata of cut rape straw, mixture of rape straw with high peat, pine bark and rock-wool (Dysko *et al.* 2009). The development of growing media coincided with enhancing environmental awareness.

A lot of innovative growing procedures using new substrates are available (Gruda, 2009). Rice husk (RH), a by-product of the rice milling industry, accounts for about20 % of the whole rice grains. The annual average rice husk production in Pakistan is more than 1780 thousand tons of rice husk (one ton of rice paddy produces 200Kg of husk) are produced every year in Pakistan (Anonymous, 2010-11). However, the amount of rice husk available is far in excess of any local uses, and, thus, has created disposal problems. Rice husk was chosen to be applied as a precursor material due to its granular structure, insolubility in water, chemical stability, high mechanical strength and its local availability at almost no cost (Awang *et al.* 2009). The advantage in the application of rice husk is that there is no need to regenerate it because of its low production cost. However, the microanalysis of rice husk shows that C (37%), ash (20%) and the main constituents of the ash is SiO_2 (94%). Thus, this raw material can act as a sorbent for nutrients due to its high content from silica (Aly, 1992). Keeping in view the importance of soilless substrates on yield of tomato, present study was planned to study the efficacy of different soilless substrates on crop response. It was concluded from the study that the treatment T_1 containing imported coco had the best performance for tomato plant growth under soilless substrates.

Material and methods

Study area

The experiment was conducted at Institute of Hydroponic Agriculture of Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi for two cropping seasons (2015-16 and 2016-17.

Testing of soilless substrate

Five treatment (substrates/media) used were T_1 (coco imported), T_2 (indigenous coco), T_3 (indigenous coco +25% zero grade stone crush by weight), T_4 (rice husk), T_5 (rice husk +25% zero grade stone crush by weight).

Plant growth parameters under Hydroponics system

Tomato crop was grown under indigenous hydroponics system, crop parameter (plant height, stem diameter, number of flower trusses, number of cluster, inter cluster distance, number of fruits $^-$ plant^{-1} and yield plant^{-1}) for five treatment were recorded.

Statistical analysis

The data measured was statistically analyzed by using statistical software (Statisti x8.1) by applying completely randomized design and results were compared using least significant difference test (LSD).

Results and discussions

Coir dust has a total pore space of 86–94 percent and an air-filled pore space of 9–14 percent whereas the coir fibre has a total pore space (TPS) of 98 percent and an air-filled pore space (AFP) of around 70 percent (Raviv *et al.*, 2002). In past mainly gravel/stones and sand were applied to improve aeration and nowadays lighter substrates materials are extensively exercised (Raviv *et al.*, 2002; Gruda *et al.*, 2006). The peat mass have volume weight of 0.09–0.20g/cm^3. Volume weight influences choice of substrates (Raviv *et al.*, 2002; Wallach, 2008). A close relation exists between the water holding capacity of substrates and substrates particles < 1 mm. Fine wooden fiber used as a substrate for production of press pots for tomatoes seedlings, the maximum water retention capacity was about 95% with 100 percent of particles size < 1 mm, whereas for lager particle sizes maximum water capacity of 70 percent was recorded. The maximum water capacity is controlled by the quantity of fine particles (Gruda and Schnitzler, 2006). Total pore space for organic substrate is over 85–95 percent, whereas some other growing media contain 60–90 percent (Raviv at al., 2002). The effects of selected five treatments (growing media) have been studied and results discussed next.

Plant Height (cm)

Data regarding plant height showed the significant effects of different treatments (Table-I). Results showed that heights of plant heights (579) was measured in treatment T_1 (imported coco), followed by T_2 (indigenous coco) and T_4 (rice husk) which gave plant height of 556, which is non-significant with T_3 (indigenous coco +25% zero grade stone crush by weight), T_5 (rice husk +25% zero grade stone crush by weight) giving plant height of (552) and (552) respectively. However the minimum plant height (552) was recorded in T_5 (rice husk + zero grade stone) had as compared with other treatments.

The experiment was continued during 2016-17 and tomato was planted after proper fumigation. Plant heights were measured for various factors and statistically analyzed and showed the media statistically significant in their behavior towards plant height (Table-1). The plant height was found maximum (455) in treatment T_1 (imported coco), which was significantly high as compared to other treatments and followed by T_4 (rice husk) giving plant height (442). Performance was poor with respect to plant height was for treatment T_3 (indigenous coco + 25% stone crush zero grade), giving plant height (416) which is significantly low with all other treatments. Plant height in T_2 and T_5 are statistically non-significant with each other. The data presented in the Table-I regarding plant height indicated that significantly higher plant height was obtained in the treatment T_1 where imported coco was applied.

Table 1. Effect of different substrates on plant height (cm).

Treatment	Year-I	Year-II
T.1 (Imported Coco)	579 A	455 A
T.2 (Indigenous Coco)	556 B	425 C
T.3(Indigenous Coco +25% zero-grade stone by weight)	552 B	416 D
T.4(Rice husk)	556 B	442 B
T.5(Rice husk+25% zero-grade stone by weight)	552 B	426 C
LSD	10.131	8.4817

Plant Diameter (mm)

The differential response among growing Medias was gauged in terms of stem diameter of plants measured below the head leave during cropping season of 2015-16 and 2016-17. Plant diameter (Table-II) data was statistically analyzed and results found statistically at par for various treatments. Plant diameter were 2.58, 2.58, 2.57, 2.57 and 2.56mm for T_1 (imported impart coco), T_2 (indigenous coco), T_3 (indigenous coco + 25% stone zero grade by weight), T_4 (rice husk), T_5 (rice husk + 25% stone zero grade stone by weight) respectively. This means the diameter of a plant just below the top leaf is not a good representative of plant growth. The experiment was repeated for next cropping season 2016-17 in the above mentioned five treatments (substrates). Plant diameters (Table-2) were measured for various factors and statistically analyzed.

Diameter was 2.79, 2.73, 2.71, 2.74 for T_1 (imported impart coco), T_2 (indigenous coco), T_3 (indigenous coco + 25% stone zero grade by weight), T_4 (rice husk), T_5 (rice husk + 25% stone zero grade by weight) respectively, which indicates maximum diameter was recorded for T_1 which is statistically significant as compared to other treatments. Data indicated that the stem diameter was highest for T_1 (imported coco) and T_2 (indigenous coco) growing substrates; while the same was lowest in treatment T_3 (indigenous coco + 25% stone crush zero grades) and T_5 (rice-husk + 25% stone crush zero grades).

Table 2. Effect of different substrates on average stem dia. (mm).

Treatment	Year-I	Year-II
T.1 (Imported Coco)	2.58 A	2.79 A
T.2 (Indigenous Coco)	2.58 A	2.73 B
T.3(Indigenous Coco +25% zero-grade stone by weight)	2.57 A	2.71 B
T.4(Rice husk)	2.57 A	2.74 B
T.5(Rice husk+25% zero-grade stone by weight)	2.56 A	2.71 B
LSD	0.0621	0.0421

Number of Flower Trusses

The number of flower trusses is good indication of a yielding plant registering good performance. Total number of flower trusses of selected plants for different factors and their levels were measured for selected growing media during the cropping seasons of 2015-16 and 2016-17. Number of flower trusses was measured for various factors, statistically analyzed and found statistically at par in their behaviors towards five treatments. Number of flower trusses (Table-3) speaks of slightly better performance of treatment T_1 (imported coco) recording 18.39 flower trusses followed by T_4 (18.24 No) where rice husk was applied as compared with the other treatments during the year 2015-16. Experiment was continued for next cropping season 2016-17; number of flower trusses was observed for various factors, results indicated similar trend as in 1st year. Number of flower trusses was 13.72, 13.43, 13.22, 13.65 and 13.41 for T_1 (imported coco), T_2 (indigenous coco), T_3 (indigenous coco + 25% stone zero grade by weight), T_4 (rice husk), and T_5 (rice husk + 25% stone zero grade by weight) respectively.

Table 3. Effect of different substrates on Flower Trusses.

Treatment	Year-I	Year-II
T.1 (Imported Coco)	18.39 A	13.72 A
T.2 (Indigenous Coco)	17.79 A	13.43 A
T.3(Indigenous Coco +25% zero-grade stone by weight)	17.87 A	13.22 A
T.4(Rice husk)	18.24 A	13.65 A
T.5(Rice husk+25% zero-grade stone by weight)	17.74 A	13.41 A
LSD	1.1239	0.8295

Number of clusters

The numbers of clusters were recorded for cropping seasons of 2015-16 and 2016-17. Number of fruit clusters is not apparently different from one another (Table-4) for different treatments. Number of clusters was measured for various factors and statistical analysis revealed growing media was at par at 5% probability. Furthermore, it is interesting to note the overall number of flower trusses and the number of fruit cluster are respectively 18.00 (No) and 13.53 (No).

Similarly in the second year (2016-17) data regarding number of clusters showed significant effect of treatment (Table-4). It is inferred from the data that highest number of cluster (11.85) was recorded in the treatment where imported coco was used. Number of clusters were the highest for treatment T_1 (imported coco), followed by $T._4$ (rice husk) giving 11.19 number of cluster whereas lest number of clusters (9.93 No.) were recorded in $T._3$ (indigenous coco + 25 % zero grade stone by weight) respectively.

Table 4. Effect of different substrates on number of clusters.

Treatment	Year-I	Year-II
T.1 (Imported Coco)	13.70 A	11.85 A
T.2 (Indigenous Coco)	13.48 A	10.52 BC
T.3(Indigenous Coco +25% zero-grade stone by weight)	13.24 A	9.93 C
T.4(Rice husk)	13.76 A	11.19 AB
T.5(Rice husk+25% zero-grade stone by weight)	13.48 A	10.15 BC
LSD	1.1610	0.9004

Nodal distance

Nodal distances were recorded for cropping seasons of 2015-16 and 2016-17. Shorter the distance between the consecutive nodes of clusters larger would be number of flowers and consequently the yield of fruit. Therefore the experts always plan on reducing the nodal distance.

There is minor differential response of nodal distance in different treatments (Table 5). The statistical analysis of data represented revealed non-significant results during growing season 2015-16. In the second year (2016-17) similar trend was observed.

Table 5. Effect of different substrates on Nodal Distance.

Treatment	Year-I	Year-II
T.1 (Imported Coco)	27.26 A	21.21 A
T.2 (Indigenous Coco)	27.19 A	21.04 A
T.3(Indigenous Coco +25% zero-grade stone by weight)	27.31 A	21.10 A
T.4(Rice husk)	27.20 A	20.67 A
T.5(Rice husk+25% zero-grade stone by weight)	27.27 A	20.94 A
LSD	0.4866	0.5739

Number of Fruit

Total number of tomatoes in five selected growing media was calculated at the end of cropping seasons of 2015-16 and 2016-17. Number of fruit (Table-6) propose that T_1 (imported coco) as a grow media has ideal performance with nearly 38 fruits whereas T_4 (rice husk) giving 35 fruits scoured second position leaving behind even the indigenous coco. The experiment was continued for next season 2016-17; crop was planted in the same sheds after required fumigation. Number of fruits (Table-6) was measured for various factors and statistically analyzed. Statistical results showed that treatment T_1 (imported coco), measured maximum number of fruit (60) followed by T_4 (rice husk) while the lowest number of fruit (50) were recorded in T_3 (indigenous + 25 zero-grade stone by weight). The number of fruits in T_1 is statistically non-significant as compared to T_4; this indicated that treatment T_4 (indigenous rice husk) is a good replacement of T_1 (imported coco).

Table 6. Effect of different substrates on Number of Fruit.

Treatment	Year-I	Year-II
T.1 (Imported Coco)	38 AB	60 A
T.2 (Indigenous Coco)	32 A	52 BC
T.3(Indigenous Coco +25% zero-grade stone by weight)	31 B	50 C
T.4(Rice husk)	35 B	56 AB
T.5(Rice husk+25% zero-grade stone by weight)	31 BC	51 C
LSD	4.4044	4.0417

Yield per Plant (Kg)

Tomato yields different growing substrates were measured at the end of cropping seasons of 2015-16 and 2016-17. For various treatments fruit yields, once again, suggest the T_1 (imported coco) performed best among the growing materials showing a yield of 7.48 kilograms plant^{-1} Treatment T_4 (Rice husk) can be ranked at the second position whereas the T_2 (indigenous coco) indicated relatively poor performance. The production of treatment $T._1$ is significantly high as compared to T_2, T_3 and T_5, while it is non-significant as compared with T_4. The same experiment was conducted in the season 2016-17. Statistical analysis again showed the treatment T_1 (imported coco) was highly significant in their behaviors towards yield of tomatoes as compared with T_2 (indigenous coco), T_3 (indigenous coco+25%zero-grade stone by weight) and T_5 (rice husk +25%zero-grade stone by weight), however yield of T_1 (imported coco) was non-significant with T_4 (rice husk) so it could be a good replacement of imported coco. Treatment means differ significantly in both year of study (Table-7). Among treatments T_1 exceed in term of yield (7.48 kg plant^{-1}) equivalent to 89.76 tons acre$^{-1.}$ Results indicated that imported coco was best substrate as compared to other substrates used in the study. However minimum yield was recorded in $T._5$ (rice husk +25%zero-grade stone by weight). This might be due to stone that does not have any nutrition value like other organic substrates and cannot store mineral solution.

Table 7. Effect of different substrates on Yield per Plant.

Treatment	Year-I	Year-II
T.1 (Imported Coco)	7.48 A	7.03 A
T.2 (Indigenous Coco)	6.02 BC	5.97 BC
T.3(Indigenous Coco +25% zero-grade stone by weight)	5.65 C	5.59 C
T.4(Rice husk)	6.49 B	6.52 AB
T.5(Rice husk+25% zero-grade stone by weight)	5.83 BC	5.82 C
LSD	0.8213	0.5498

Conclusion

It was concluded from the study that the highest fruit yield of tomato was obtained with imported coco under soilless substrate in hydroponics.

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