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Full Length Article

Evaluating Performance of Ecologically Sound Organic Substrates under Different Temperature Regimes

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ABSTRACT

Greenhouse trials were carried out over two years to investigate the high temperature (25ºC, 30ºC & 35ºC) effects on ecologically sound untreated organic substrates viz., coconut coir and rice husk charcoal, in comparison to that of rock wool using tomato (*Lycopersicon esculentum* Miller) as a test crop. There were no significant differences in the root dry matter, stem dry matter, fruit dry matter, shoot and root ratio, ascorbic acid, total soluble solid, fruit acidity, leaf chlorophyll contents and pH of the fruit homogenate. Among the substrates, water holding capacity was larger in rock wool followed by coconut coir and rice husk charcoal. Bulk density and total pore space were lower in rice husk charcoal than coconut coir and rock wool. Regarding the chemical properties, rice husk charcoal and coconut coir had higher EC values compared to rock wool. Rice husk charcoal had relatively higher pH followed by rock wool and coconut coir. In the case of CEC rook wool showed significantly higher values than coconut coir and rice husk charcoal. It also appeared that rice husk charcoal and coconut coir gave similar and/or better crop performance and yield of tomatoes than rock wool under high temperature stress conditions namely 30^{o}C and 35ºC as compared with 25ºC. Thus, rice husk charcoal and coconut coir can be used successfully as growing media amendments for producing greenhouse tomato as well as other nursery crops.

Key Words: Organic substrates; Temperature; Stress; Tomato; Quality

INTRODUCTION

With increasing financial and environmental pressures on the nursery and vegetable industry, there is more emphasis on greater yield of better quality. The problems of waste disposal have led to demand for the greater use of organic materials. Rock wool (RW) is one of the popular substrate used in soilless culture due to its stable pH and air-water holding qualities (Hardgrave & Harriman, 1994). However, there are increasing number of growers who are worried about the harmful effects of RW on human health, problem of disposal after use and the susceptibility of crops to root diseases (Benoit & Ceustermans, 1995; Os Van, 1995; Yu & Komada, 1999). This has inspired a global search for indigenous materials, which are readily available, affordable and suitable for use as growing media (Nakano, 1994; Itagi, 1995; Oka, 1996; Ortega *et al*., 1996). Among them the natural organic substrates like rice husk and coconut coir are found in many part of the world especially the tropical and subtropical countries. Vegetables like lettuce, spinach, cabbage, tomato, cucumber, etc., which are directly consumed need to be maintained in high quality hygienic condition. However, due to shortage of agricultural labor and land, vegetables are currently produced on even in the polluted land and treated with chemical fertilizers and pesticides (Chow, 1990). Therefore, it is necessary to develop new simplified technique (s) to grow greenhouse and nursery crops using indigenous organic substrate materials. These materials may be used as an alternative to high valued growing media and may produce low cost and high quality products in countries where land availability for horizontal expansion of vegetable cultivation is a big problem. Furthermore, substrate culture also had advantages because this system is very simple and do not require the electricity power, make plants independent of soil, make possible to move the plants and to do planting, maintenance and harvesting at the most suitable place and under optimized labor conditions. This investigation was aimed at the practical uses of environment-friendly natural substrates under different temperatures using tomato as a test crop.

MATERIALS AND METHODS

Cultural methods and plant material. The experiment was conducted in three fully automatic greenhouses with three different temperature conditions namely 25^{o}C, 30^{o}C and 35^{o}C using Coconut coir (CC), Rice husk charcoal (RHC) and Rock Wool (RW). As a test crop tomato

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(*Lycopersicon esculentum* Mill. cv. Momotaro) was chosen because this crop covers a large area of world greenhouse as well as field horticulture. The night/day temperatures in the greenhouse were 16°C/25°C, 19°C/30°C and 22°C/35°C. The greenhouses were of 20 m length, 6.4 m breath and 4.3 m height (ESD electronic system development co., Tokyo, Japan), oriented north-south direction. Except for the temperature, the environmental conditions for the three greenhouses were similar.

The growing system was a bag culture (5 m length x 0.3 m width with 2% slope for drainage) of each substrate with recirculating drip irrigation. Seeds were sown in the above three substrates in plastic cell tray. Two weeks after sowing, seedlings with fully expanded cotyledons were transplanted to 12 cm pot with the same substrates. Nutrient solution of 1/8 strength (EC=0.73 dS m^{-1}) standard nutrient solution (major nutrients, as miliequivalent per liter, NO_3 16, NH_4^+ 1.3, P 4, K 8, Ca 8, Mg 4, S 4 & micronutrients, as ppm, Fe 3, B 0.5, Mn 0.5, Zn 0.05, Cu 0.02 & Mo 0.01) was given daily to the seedlings. Before planting all the substrates were fully saturated and watered thereafter with a standard tomato nutrient solution. As the plants grew, all lateral shoots were removed. Plants were detopped at 5th truss plus 3 leaves stage. At anthesis of each truss, 4-*p* chlorophenoxy acetic acid was sprayed for uniform fruit setting. Sixteen plants were planted onto each bag per substrate in each of three replications arranged in randomized block design. The plants in each bed were applied with 360 l nutrient solution given for 2 min h^{-1} during daytime. Morphological and yield contributing characteristics were measured at various stages of plant development. The data were analysed using ANOVA techniques. For significant properties, difference between means was tested by Duncan's new multiple range test.

Physical and chemical properties of the substrates and fruits. Physical and chemical properties of the substrates studied were measured and repeated for five times. Water holding capacity (WHC), bulk density (BD) ($g.cm^{-3}$) and total pore space (TPS) were determined using loose-packed cores and methods adapted from Byrne and Carty (1989). Electrical conductivity (EC) was determined using a Beckman EC meter and the pH was determined using a pH meter. Cation exchange capacity was determined using the ammonium saturation/displacement method (Brown & Warncke, 1988). Fruits that were wholly red were harvested every day. Ten fruits of similar size taken from 30 plants with each substrate were ground with a grater and filtered through a filter paper. Soluble solids content (Brix %) was measured using a digital refractometer. Titratable acidity was determined by titration of the filtered tomato juice with 0.01 N NaOH and is expressed as mg100 mL^{-1}. Ascorbic acid was analyzed using the fresh tomato juice by RQ-flex. The chlorophyll content of leaves was estimated using a Minolta digital chlorophyll meter.

Growth analysis. After each harvest, plants were divided into root, stem and leaves and fresh weight measured. These plant organs were dried in a forced air oven at 65°C for 7 days and weighed. Root, stem, leaf and fruit dry matter percentage was calculated as total dry mass per fresh mass. The leaf area was measured by video image analysis procedures using PC (VM 9801, NEC) and video camera (GT-20, Epson).

RESULTS AND DISCUSSION

Physical and chemical properties of the substrates. All physical properties tested differed significantly among substrates studied (Table I). Water holding capacity was higher in RW as compared to RHC and CC substrates. Rock wool substrate had higher total pore space and bulk density than other substrates studied. The average bulk densities were 0.18 g cm^{-3} for RW, 0.11 for RHC and 0.14 for CC substrates. Although the bulk density of CC and RHC substrates were below the minimum recommended level of 0.15 g cm^{-3} (Poole *et al*., 1981); however, the value in used substrates clustered around minimum value. The above results show that there were some differences regarding the physical characteristics among the treatments, which might be due to the difference in particle sizes between the substrates. Nevertheless, all the substrates studied exhibited acceptable range of the physical characteristics.

Extract pH and EC differed significantly among the three substrates studied (Table II). The pH values of all the substrates were ranged from 6.27 to 7.01. The EC value was relatively higher for RHC and CC than RW was not excessive for this crop. The CEC ranged from 13-39 Cmol kg^{-1}. This range is lower for sphagnum peat as well as commercial labels (Puustjarvi & Robertson, 1975). This discrepancy may be a result of age of the organic substrates. Nelson (1991) and Puustjarvi and Robertson (1975) reported that the process of decomposition increases the CEC of organic materials. Though RHC have a lower CEC compared to other substrates studied, it requires more frequent nutrient supplements. Therefore, the natural

Table I. Physical properties of the substrates used in the study

Substrates	Water Holding Capacity (% by mass)	Total Pore Space (% by volume)	Bulk Density ($g.cm^{-3}$)
Rock wool	962a	95.1a	0.18a
Rice husk charcoal	492c	69.9c	0.11c
Coconut coir	755b	89.2b	0.14b

Means within each column followed by the same letter are not significantly different at 5% level by Duncan's multiple range test

Table II. Chemical properties of the substrates used in the study

Substrates	EC (ds m^{-1})	pH	CEC (Cmol kg^{-1})
Rock wool	1.49c	6.44c	39a
Rice husk charcoal	1.75a	7.01a	13c
Coconut coir	1.73a	6.27c	35b

Means within each column followed by the same letter are not significantly different at 5% level by Duncan's multiple range test

Table III. Effect of ecologically sound organic substrates on fruit quality parameters of tomatoes

Substrates	Ascorbic acid (mg kg^{-1})	Brix (%)	Titrable acidity (mg.100^{-1} ml)	Relative leaf chlorophyll (SPAD value)	pH of the fruit homogenate
Rock wool	368a	6.14a	4831b	42.4a	4.66a
Rice husk charcoal	347a	6.25a	532a	39.9a	4.81a
Coconut coir	354a	6.08a	468b	43.2a	4.60a

Means within each column followed by the same letter are not significantly different at 5% level by Duncan's multiple range test; ns= not significant.

Table IV. Dry matter partitioning tomato plants as influenced by different substrates

Substrates	Root dry matter (%)	Stem dry matter (%)	Leaf dry matter (%)	Fruit dry matter (%)	Shoot:root ratio
Rock wool	29a	10,01a	10.47b	7.39a	10.79a
Rice husk charcoal	26a	8.97b	11.60a	7.28a	11.72a
Coconut coir	27a	9.90a	9.81b	7.19a	11.02a

Means within each column followed by the same letter are not significantly different at 5% level by Duncan's multiple range test; ns= not significant.

Fig. 1. Temperature responses of the ecologically sound organic substrates on plant height (cm) of tomato plants

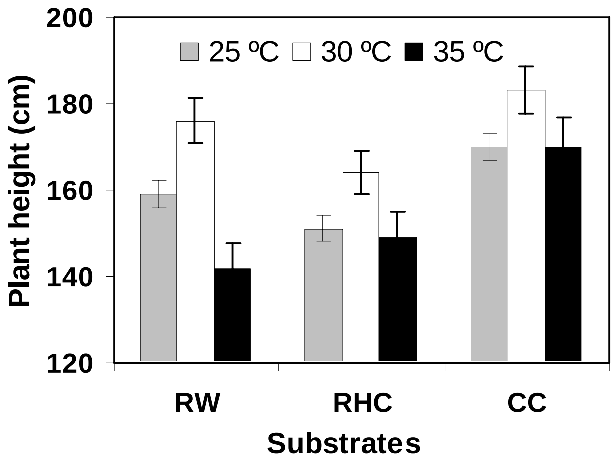
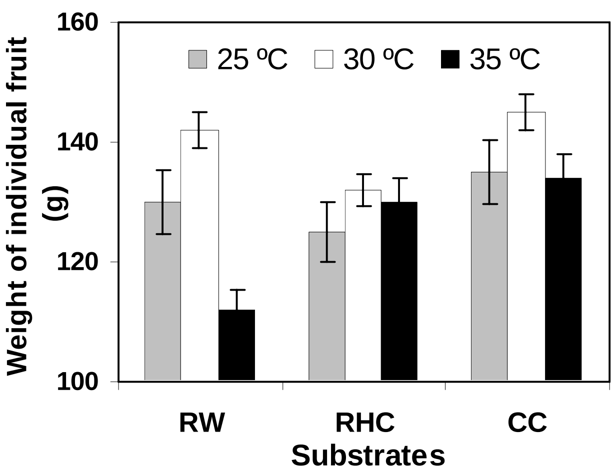


Fig. 2. Temperature responses of the ecologically sound organic substrates on weight of individual fruit (g) of tomatoes



organic substrates CC and RHC had most of the acceptable physical and chemical properties to be used as container substrates for growing of greenhouse and nursery crops.

Fig. 3. Temperature responses of the ecologically sound organic substrates on leaf area (cm^2) of tomato plants

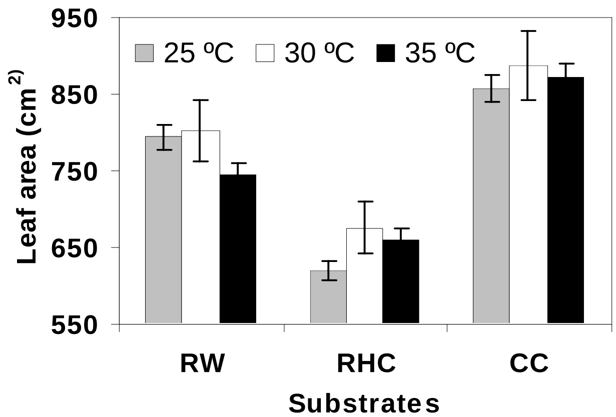
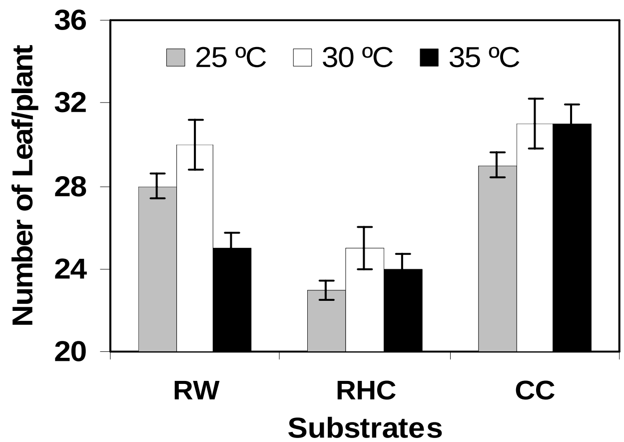


Fig. 4. Temperature responses of the ecologically sound organic substrates on number of leaf per plant of tomatoes



Morphological and yield attributes of the test crop. The temperature response on the quality characteristics of tomatoes as influenced by different organic substrates is shown in the Table III. There were no significant differences among the three substrates in case leaf chlorophyll contents and ascorbic acid, total soluble solids (% Brix) and pH of the tomato fruit homogenate. The results suggested that growing tomatoes on the test

Fig. 5. Temperature responses of the ecologically sound organic substrates on number of fruit per plant of tomatoes

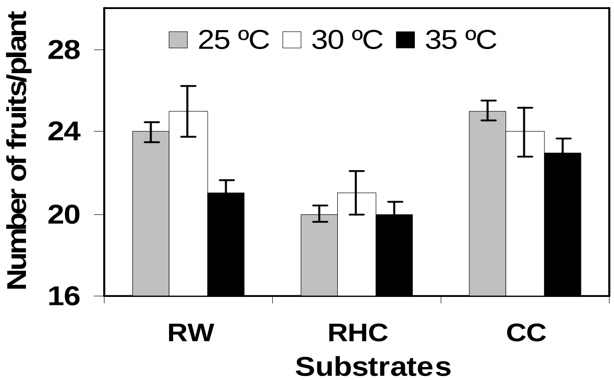
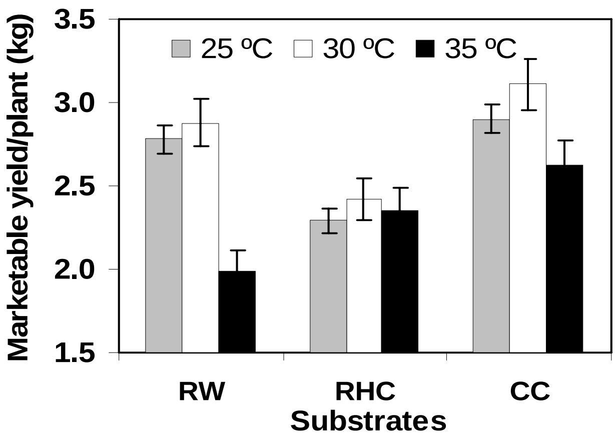


Fig. 6. Temperature responses of the ecologically sound organic substrates on marketable yield per plant (kg) of tomatoes



substrates under high temperatures had no adverse effect in terms of quality characteristics. Similar observations were made by Islam and Ito (2000).

Dry matter partitioning. Table IV shows the percent dry matter of root, stem, leaf, fruit and shoot/root ratio of tomato as influenced by RW, RHC and CC. There was no significant difference observed in case of root dry matter; fruit dry matter and shoot/root ratio of tomatoes among the treatments. But the organic substrates CRH produced higher leaf dry matter and lower stem dry matter as compared to RW and CC, while no significant difference was observed between RW and CC. The result suggested that there were no negative effects of the above organic substrates in relation to dry matter partitioning of tomato plants.

Temperature stress on morphological and yield contributing characters. Fig. 1-6 show the temperature responses of the ecologically sound substrates on the morphological and yield contributing characteristics of tomato plants. There were no significant differences in plant height (25^{o}C & 30^{o}C) weight of individual fruit (25^{o}C & 30^{o}C) (Fig. 1 & 2). But other parameters such as leaf area (Fig. 3), number of leaf per plant (Fig. 4), number of fruit per plant (Fig. 5) and marketable yield per plant (Fig. 6) differed significantly among the treatments. In almost all cases, RW gave better performance at the temperatures of 25 and 30^{o}C as compared to 35^{o}C. But it was apparent that in almost all of the parameters studied, the crop grown under rice husk charcoal and coconut coir substrates showed better crop performance as well as productivity than the popular substrate RW under high temperatures namely 30^{o}C and 35^{o}C as compared to 25^{o}C. This result indicates that the organic substrates CC and RHC has the potential to be used as growing media under high temperature stress conditions.

CONCLUSION

The organic substrates rice husk charcoal and coconut coir has all the potency as substrates due to their suitable physico-chemical characteristics, better performance on crop productivity, low price, ecologically soundness and with no environmental pollution after use. Furthermore it shows better performance under high temperature stress conditions.

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