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EFFECT OF HOAGLAND SOLUTION FOR GROWING TOMATO HYDROPONICALLY IN GREENHOUSE

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ABSTRACT : The present study was done to evaluate the effect of Hoagland solution for growing tomato hydroponically in greenhouse. The experiment was carried out in fan pad cooled greenhouse, using substrate with cocopeat, perlite and vermiculite (3:1:1 v/v). A NFT was developed for hydroponically grown tomatoes to supply nutrient solution to plants placed in net pots in PVC pipes. The experiment consists of 3 replications and 3 treatments. Nutrient solution was placed in 100L of tank. There were 9 tanks for the experiment. Three kinds of nutrient solution were used for each replication: 1) Hoagland solution at 100% concentration as treatment 1; 2) Hoagland solution at 75% concentration as treatment 2 and 3) Hoagland solution at 50% concentration as treatment 3. Plant growth, total fruit yield, TSS (total soluble solids) and titrable acidity were higher in Hoagland solution at 100% concentration than the others, but there was no significant difference between the three solutions in terms of diameter of stem, moisture content, firmness and lycopene. The result showed that Hoagland solution at 100% concentration increased the height of plants as well as total fruit production including fruit quality i.e. TSS and titrable acidity. Cost analysis for the hydroponic system was also done.

Keywords : *Tomato, Hoagland solution, hydroponic system, NFT, greenhouse*

Hydroponics technology in the developed world has gone much ahead, however it is not too late to start the use of this technology, which does not involve much of the initial investment and could be considered as a method of suspended pots in a nutrient solution container for growing fresh vegetables. The entire crop could be grown in a nutrient solution container and everyone can practice this technique with little care to produce fresh vegetables on a roof top without using soil as a growing medium (Imai, 3; and Kratky, 5). Plants grown on hydroponics have more mineral salts rather than those of conventional system and the levels of heavy metals is less (Massantini *et al.*, 7). Many formulas have been proposed for nutrient solution *e.g.* Hoagland, Schwartz, Resh, Verver and Graves (Jensen *et al.* 4) but most of these solutions are considered suitable for special plants.

To achieve year-round production of plants through artificial regulation of indoor environment like temperature, relative humidity, lightening, nutrient solution etc, plant growth factories use series of plant growth. On controlling the growth conditions, plants can produce more crops more efficiently than outdoor cultivation methods (Ikeda *et al.,* 2). Research was expanded in the late 1960s and early 1970s, the National Aeronautics and Space Administration (NASA) created the Controlled Ecological Life Support System (CELSS) program to conduct research on bio regenerative life support using candidate plant species (MacEloroy and Bredt, 6), including sweet potato and peanut, as potential food sources for humans on extended space missions. Both crops are being grown hydroponically with the nutrient film technique at Tuskegee University NASA Center for Food Environmental Systems for Human Exploration of Space (CFESH).

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MATERIALS AND METHODS

The present study was conducted in Demonstration Farm of soil and water engineering, PAU, Ludhiana. The system was made up of PVC pipes of 4 inch diameter placed on angle iron frame. The angle iron frame was at 75 cm height from the ground surface. The holes were drilled in the pipe of the size of net pots at spacing of 30cm as shown in Fig 1. The Hoagland solution was used in this experiment at a 100%, 75% and 50 % concentration.

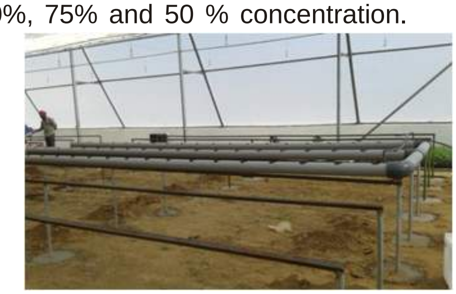

Fig. 1 : PVC pipes of 4 inch diameter with 6 m length each was placed on 27 Iron angle rods.

The standard composition of Hoagland solution is shown in Table 1. The Hoagland nutrient solution was prepared in laboratory. Hoagland solution consists of calcium nitrate tetra hydrate, potassium nitrate, mono potassium phosphate, magnesium sulphate hepta hydrate, trace elements and iron chelates. To make 1 L solution of calcium nitrate tetra hydrate, potassium nitrate, mono potassium phosphate and magnesium sulphate hepta hydrate of quantity 236.1 g, 101.1 g, 136.1g and 246.5 g, respectively were mixed with distilled water in the four beaker separately then finally each nutrient was poured in the 1 L of flask. To make 1 L solution of trace elements, boric acid, manganese chloride tetra hydrate, zinc sulphate hepta hydrate, copper sulphate penta hydrate and sodium molibdate of quantity 2.8 g, 1.8 g, 0.2 g, 0.1 g and 0.025 g respectively were mixed with distilled water. To make 1 L of iron chelate, firstly 56.1 g of potassium hydroxide were taken then mixed with distilled water to make volume of 900 ml and pH of potassium hydroxide was adjusted to 5.5 using sulphuric acid (H_2SO_4). Then ethylene dia amine tetra acetic acid and iron sulphate hepta hydrate were added in the solution of potassium hydroxide. Standard composition to make 1L Hoagland solution consisting of quantity 7 ml, 5 ml, 2 ml, 2 ml, 1 ml, and 1 ml of calcium nitrate tetra hydrate, potassium nitrate, mono potassium phosphate, magnesium sulphate hepta hydrate, trace elements and iron chelates were used and mixed with distilled water as listed in Table 2. The nutrient solutions were changed after 15 days of interval in the starting age of crop after transplanting in NFT system. The pH of the nutrient solutions were maintained in the range of 5.5 - 6.5 for optimum growth of plants. The EC of the nutrient solutions were maintained in the range of 1.5 – 2.5 dS/m. The time interval for changing nutrient solution was changed according to the days after transplanting of plants.

Table 1 : List of nutrients in Hoagland solution.

1.	Calcium nitrate tetra hydrate ($Ca(NO_3)_2.4H_2O$)	236.1 g/l
2.	Potassium nitrate (KNO_3)	101.1 g/l
3.	Mono potassium phosphate (KH_2PO_4)	136.1 g/l
4.	Magnesium sulphate hepta hydrate ($MgSO_4.7H_2O$)	246.5 g/l
5.	Trace elements (made up to 1 L)	
(a)	Boric acid (H_3BO_3)	2.8 g
(b)	Manganese chloride tetra hydrate ($MnCl_2.4H_2O$)	1.8g
(c)	Zinc sulphate hepta hydrate ($ZnSO_4.7H_2O$)	0.2 g
(d)	Copper sulphate penta hydrate ($CuSO_4.5H_2O$)	0.1 g
(e)	Sodium molibdate ($NaMoO_4$)	0.025 g
6.	Iron Chelate (FeEDTA)	
(a)	Ethylene dia amine tetra acetic acid (EDTA. 2Na)	10.4 g
(b)	Iron sulphate hepta hydrate ($FeSO_4.7H_2O$)	7.8 g
(c)	Potassium hydroxide (KOH)	56.1 g

Table 2 : Composition of nutrients of Hoagland solution in 1L.

1.	$Ca(NO_3)_2.4H_2O$	7 ml
2.	KNO_3	5 ml
3.	KH_2PO_4	2 ml
4	$MgSO_4.7H_2O$	2 ml
5.	Trace elements	1 ml
6.	FeEDTA	1 ml

pH and EC of nutrient solution

The pH and EC of Hoagland solution in the hydroponic system was to be maintained for the growth of crop. The optimum nutrient solution pH ranges between 5.5 to 6.5, a range in which the maximum number of elements are at their highest availability for plants (Taiz and Zeiger, 10). The pH value of nutrient solution must not increase above 6.5 because iron, copper, zinc, boron and manganese are unavailable above 6.5. When pH rises above 6.5 some of the nutrients and micro-nutrients begin to precipitate out of the solution and can stick to the walls of the reservoir and growing chambers. But if it increased then nutrient solution i.e. Hoagland solution have to be changed.

EC is an index of salt concentration that indicates the total amount of salts in a solution. EC of the nutrient solution is a good indicator of the amount of nutrients to the plants in the root zone (Nemali and Van, 8). EC range from 1.5 dS/m to 2.5 dS/m to obtain proper results (Greenway and Munns, 1). The EC of nutrient solution must not decrease but if decreases then nutrient solution have to be changed. The EC of nutrient solution decreases due to consumption of nutrients from the nutrient solution. In general, EC>2.5 dS/m may lead to salinity problems while EC<1.5 dS/m may lead to nutrient deficiencies. In greenhouse, the high input of fertilizers is the main cause of the salinity problems (Li 2000). Higher EC reduces the nutrient uptake by increasing osmotic pressure, whereas the lower EC may affect the plant health and yield (Samarakon *et al.,* 9).

RESULTS AND DISCUSSION

Height of plants

Plant height was recorded after 20 days of transplanting as shown in Table 3. The average height of plant in T_1 was more *i.e.* 56.02 cm than other two treatments T_2 and T_3 showing 52.17 cm and 49.91 cm respectively. Position of the treatments effect the height of the plants. Plants height was recorded after 30 days of transplanting as shown in Table 3. The average height of plants in T_1 was more *i.e.* 76.42 cm than other two treatments T_2 and T_3 showing 74.01 cm and 73.35 cm respectively. Position of the treatments effect the height of the plants. Plants height was recorded after 46 days of transplanting as shown in Table 3. The average height of plants in T_1 was more *i.e.* 134.15cm than other two treatments T_2 and T_3 showing 121.59 cm and 105.19 cm, respectively. The variation was due to the concentration of nutrient solution. Plants height was recorded after 72 days of transplanting as shown in Table 3. The average height of plants in T_1 was more *i.e.* 185.98 cm, than other two treatments T_2 and T_3 showing 170.50 cm and 166.53 cm respectively. The variation was due to the concentration of nutrient solution.

Statistical analysis for different treatments (Table 3) revealed that there was non significant effect of Hoagland solution on plant height up to 30 DAT. The effect of Hoagland solution from 46 DAT to and 72 DAT was found to be significant.

Diameter of stem

The results obtained are shown in Table 3 where the variation in stem of plants of different treatments were recorded. These values were taken on 14th May 2016 after 15 days of transplanting (15 DAT) with the help of vernier caliper. The T_2 shows more diameter of stem of plants *i.e.* 9.40 mm followed by T_1 and T_3 showing 9.25 mm and 8.76 mm respectively. The variation was due to light effect. The Table 4 shows the variation in stem of different plants according to the treatments. These values were taken on 31st May 2016 *i.e.* 30 DAT with the help of vernier caliper. The T_2 shows more diameter of stem of plant *i.e.* 11.65 mm followed by T_1 and T_3 showing 11.32 mm and 10.99 mm respectively. This variation was due to light effect. The treatments showing the more diameter of stem were more expose to sunlight. The Table 4 shows the variation in stem of different plants according to the treatments. These values were taken on 14th June 2016 *i.e.* 45 DAT with the help of vernier caliper. The T_2 shows more diameter of stem of plant *i.e.* 13.34 mm followed by T_1 and T_3 showing 12.70 mm and 12.55 mm respectively. This variation was due to light effect. The treatments showing the more diameter of stem were more exposed to sunlight.

Statistical analysis for different treatments are given in Table 3 revealed that there was non significant effect of Hoagland solution on diameter of stem up to 45 DAT.

pH of Hoagland solution before and after the consumption of nutrients from solution for treatment 1, treatment 2 and treatment 3

The result obtained by noting the value of pH of Hoagland solution before and after the consumption of nutrients by the plants after the interval of days for treatment 1 (100%), treatment 2 (75 %) and treatment 3 (50 %) as shown in Fig 2. Suitable range of pH of the nutrient solution. At this range of pH i.e. 5.5-6.5, the plants easily absorbed nutrients from the nutrient solution. The interval of changing of nutrient solution depends upon pH range and the age of crop after transplanting. pH will increase because some of the nutrients and micro-nutrients began to precipitate out of the solution and can stick to the walls of the tank (reservoir) and pipes (growing chambers).The variation of consumption of pH before and after changing the nutrient solution in T_1, T_2 and T_3 concentration is shown is Fig. 2 This variation is due to the precipitation of nutrients and micro-nutrients in the tank.

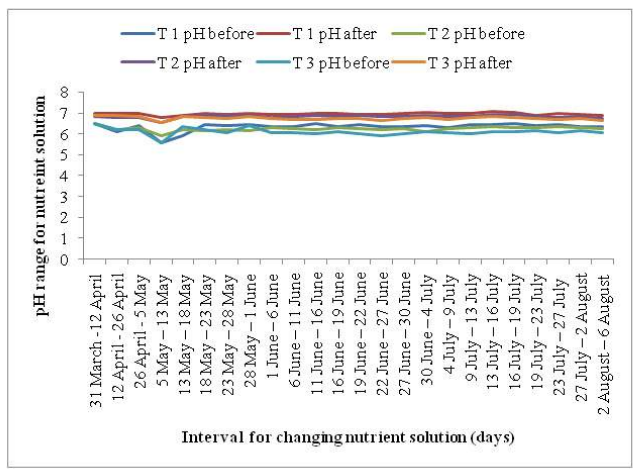

Fig. 2 : Variation of consumption of pH before and after changing the nutrient solution in T_1, T_2 and T_3 concentration.

EC of Hoagland solution before and after the consumption of nutrients from solution for treatment 1, treatment 2 and treatment 3

The result obtained by noting the value EC of Hoagland solution before and after the consumption of nutrients by the plants after a interval of days as shown in Fig. 3 in treatment 1 (100 %), treatment 2 (75 %) and treatment 3 (50 %). Suitable range of EC of the nutrient solution shown in Fig 3. The interval of changing of nutrient solution depends upon EC range and the age of crop after transplanting The EC will decrease due to consumption of nutrients from the solution. The variation of consumption of pH before and after changing the nutrient solution in T_1, T_2 and T_3 concentration is shown in Fig. 3. The EC in all the three treatments is decrease due the consumption of nutrients by the plants in the given treatment. The decrease in all the three treatments is comparable with each other as shown in Fig. 3.

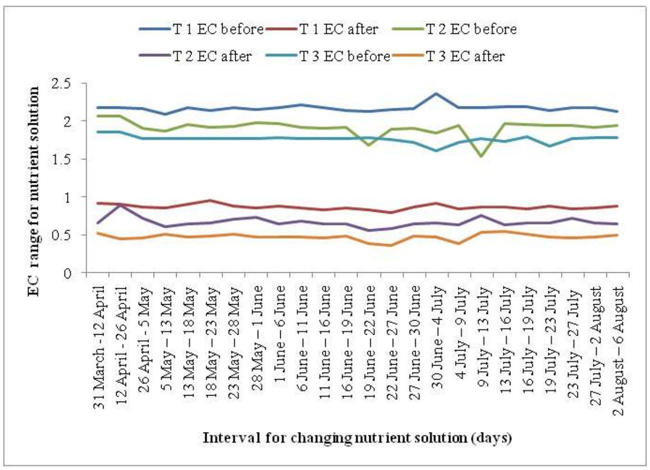

Fig. 3 : Variation of consumption of EC before and after changing the nutrient solution in T_1 (100 %) concentration.

Interval of changing of Hoagland solution after transplanting

The result obtained by changing the nutrient solution after interval of time was shown in Fig. 4. The solution was changed 24 times during the whole experiment as shown in Fig. 4. The solution was changed for 5 months. The consumption of nutrient solution depends upon the age of tomato crop. That is why with the increase in number of days of plants in PVC pipes, there is increase in the consumption of nutrient solution. Firstly, after 15 days, the nutrient solution was changed but with passing of days the consumption of tomato crop increases. Solution had been changed after 2, 3, 4, 5, 7 and 10 days depending on the age of crop. The increase in height of plants leads to increase in the consumption of nutrient solution. As the consumption rate of plants increases, the quantity of nutrient solution in the tank decreases so there was a need to change the nutrient solution. The main reason of changing of nutrient solution was increase in pH value and decrease in EC value. The value of pH should not increase 6.5 and value of EC should not decrease to 1.5 dS/m.

The various quality parameters were evaluated during experimentation was moisture content, titrable acidity, lycopene, firmness and total soluble solids are described below.

Moisture content

The result obtained for moisture content under different treatments are presented in Table 4. It can be seen from the data that the maximum moisture was found in treatment 1 followed by treatment 2 and treatment 3 as shown in Table 4. Statistical analysis for different treatments is given in Table 5 and revealed that there was no significant effect between T_1, T_2 and T_3 concentration of Hoagland concentration on moisture content of tomato.

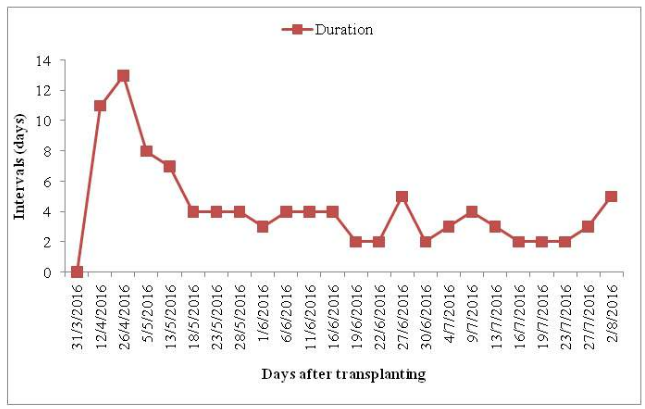

Fig.4 : Interval during the process of changing the nutrient solution Quality parameters.

Table 4 : The effect of concentration of Hoagland solution on the fruit quality parameters.

Treatments	T_1 (100%)	T_2 (75%)	T_3 (50%)	CD (P=0.05)
Moiture content (%)	59.220	56.757	50.990	NS
Titrable acidity (%)	0.16	0.16	0.10	0.01
Lycopene (%)	3.0	2.98	2.75	NS
Firmness (KgF)	0.643	0.573	0.557	NS
TSS (°brix)	7.37	6.6	5.2	1.17
Fruit yield (t/ha)	72.57	69.28	50.76	5.75

Titrable acidity

The result obtained for titrable acidity under different treatments are presented in Table 4. It can be seen from the data that the maximum titrable acidity was found in treatment 1 and treatment 2 followed by treatment 3 as in Table 4. The TSS in tomato decreases with decrease in concentration of Hoagland solution. Statistical analysis for different treatments is given in Table 6 and revealed that there was significant effect between T_1 and T_3 and T_2 and T_3 at 5% level on titrable acidity of tomato.

Lycopene

The result obtained for lycopene under different treatments are presented in Table 4. It can be seen from the data that the maximum lycopene content was found in treatment 1 followed by treatment 2 and treatment 3 as shown in Table 4. Statistical analysis for different treatments is given in Table 4 and revealed that there was no significant effect between T_1 and T_2 concentration of Hoagland concentration on lycopene of tomato.

Firmness

The result obtained for firmness under different treatments are presented in Table 4. It can be seen from the data that the maximum firmness was found in treatment 1 followed by treatment 2 and treatment 3 as shown in Table 4. Statistical analysis for different treatments is given in Table 4 and revealed that there was no significant effect between T_1, T_2 and concentration of Hoagland concentration on firmness of tomato.

Total soluble solids (TSS)

The result obtained for TSS under different treatments are presented in Table 4. It can be seen from the data that the maximum TSS was found in treatment 1 followed by treatment 2 and treatment 3 as in Table 4. The TSS in tomato decreases with decrease in concentration of Hoagland solution. Statistical analysis for different treatments is given in Table 4 and revealed that there was significant effect between T_1 and T_3 at 5% level on TSS of tomato.

Yield of tomato

The Total yield of tomato was higher in T_1 (100%) as compared with T_3 (50%) treatments as shown in Table 10. It can be seen from the data that the maximum yield was found with T_1 (100%) followed by T_2 (75%) and T_3 (50%). Higher yield was due to 100% concentration of Hoagland solution. This may be attributed to higher concentration of nutrients or better availability of nutrients which enhances the cell metabolisms resulting in better yield.

Statistical analysis for different treatments is given in Table 4 and revealed that there was a significant effect of concentrations of Hoagland solution on tomato.

Cost analysis for system

I. Hydroponic system

1) Angle iron rod used = 300 kg

Rate = ₹ 3500/q

Cost for angle iron rod = ₹ 10,500

2) Cost for grounting for 2 days with labour = ₹ 2400

3) Cost for 252 m in length PVC pipe = ₹ 48,500

II. Crop cultivation

1) Cost for 672 net pots = ₹ 4704

2) Cost for raising crop = ₹ 35000

III. Cost of nutrient solution = ₹ 34,500

IV. Polyhouse

Total area = 1008 m^2

Required area = 252 m^2

Rate = ₹ 450 / m^2

Cost for required area = 252 × 450 = ₹ 113400

V. Number of plants of tomato = 672

Average yield of tomato per plant = 15 kg

Yield of tomato = 672 × 15 = 10,080 kg

Cost for 1 kg of tomato = ₹ 60

Total cost for yield of tomato = 60 × 10080 = ₹ 6,04,800

B/C ratio

Total cost on the system = ₹ 249004

Total cost on yield = ₹ 604800

$$= \frac{604800 - 249004}{249004} = \frac{355796}{249004} = 142$$

Conclusion

Field experiment was conducted at the Demonstration Farm of the Department of Soil and Water Engineering, PAU, Ludhiana for study on the development of hydroponic system for greenhouse tomato. The experiment was laid out completely randomized design keeping three treatments as T_1 (100%), T_2 (75%) and T_3 (50%) of Hoagland solution. The different components of the hydroponic system were designed for the nutrient film technique (NFT).

The nutrient solution was circulated 24 × 7 schedule. This was designed based upon the volume of the water in the given length of the pipe. After optimizing the different design components, the system was installed in the fan pad cooled greenhouse of the size 1008 m^2. The effect of different concentrations of the Hoagland solution on the tomato crop for crop and quality parameters was carried out. The stem diameter of the tomato does not show any significant difference between the treatments. The plant height of the tomato crop does not show any significant difference for the initial days but after 46 days there was significant difference in the height of the plants. Higher concentration (100%) gave significantly better results as compared to lower concentration. The average variation in pH of nutrient solution in T_1 was 6.54 to 7.05 in T_2 was 6.27 to 6.86 and in T_3 was 5.99 to 6.70. The average variation in EC of nutrient solution in T1 was 2.15 dS/m, in T_2 was 1.90 dS/m and in T_3 1.77 dS/m. It was found that quality of fruits of treatment 1 (100%) was better than other two treatments *i.e.* treatment 2 (75%) and treatment 3 (50%). The TSS, firmness, titrable acidity, moisture content and lycopene were better in treatment 1 (100%) than other two treatments *i.e.* treatment 2 (75%) and treatment 3 (50%). It was observed that there was no significant difference in yield levels at concentration of 100% of Hoagland solution and 75% level. But it differed significantly as compared to yield at 50% concentration of the Hoagland solution.

REFERENCES

1. Greenway, H. and Munns R (1980). Mechanisms of salt tolerance in non halophytes. *Annu. Rev Plant Physio and Plant Molecu Biol.,* **31** : 149-90.
2. Ikeda, A., Tanimura, Y., Ezaki, K., Kawai, Y., Nakayama, S., Iwao, K. and Kageyama, H. (1991). Environmental control and operation monitoring in a plant factory using artificial light. *I Int Workshop Sensors Hortic.* **304** : 151–158.
3. Imai, H. (1987). Non-circulating hydroponics system. In: *Proc. Symp. on Hort. Prod. Under Structures.*18 19 Feb. 1987, Tai-Chung, Taiwan.
4. Jensen, M H and Collins, W. L. (1985). Hydroponic vegetable production. *Hort. Re*v., **7** : 483-558.
5. Kratky, B. A. (2002). A simple hydroponics growing kit for short term vegetables. Univ. of Hawaii, Cooperat. *Ext. Serv. Bullet.* Home Garden Series. HG 42
6. MacElroy, R. D. and Bredt, J. (1985). Current concepts and future direction of CELSS. NASA *Conf. Publ.* 2348.
7. Massantini, F., Favilli, R, Magnani G and Oggiano, N (1988). Biotechnology for high quality vegetables. *Soilless Cult.* **4** : 27-40.
8. Nemali, K. S. and Van, I. W. (2004). Light intensity and fertilizer concentration: i. estimating optimal fertilizer concentration from water-use efficiency of wax begonia. *Hort. Sci.,* **39** : 1287-92.
9. Samarakon, U. C., Weeransinghe, P. A. and Weerakkody, A. P. (2006). Effect of electrical conductivity (EC) of the nutrient solution on nutrient uptake, growth and yield of leaf lettuce in stationary culture. *Trop. Agric. Res.,* **18** : 13-21.
10. Taiz L. and Zeiger, E. (2002). *Plant Physiology* (3rd ed.) Sinauer Associates, ISBN : 0878938230, Massachusetts, USA.

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