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Effect of Protected Cultivation with Drip Irrigation System on Growth and Yield of Tomato under North Eastern Hilly Region Conditions

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Abstract—*A field experiment was carried out at the experimental field located in hilly terrain of Department of Agricultural Engineering, Assam University, Silchar during October 2014 to April 2015 to investigate growth and yield of tomato crop under different conditions of cultivation with drip irrigation system. There were three conditions of cultivation viz. under green house, shade-net house and open field. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications of tomato crop in each condition of cultivation. Data were recorded on various parameters and subjected to statistical analysis. The different conditions of cultivation had significant variation in almost all the growth and yield components. Number of branches per plant, number of leaves per plant, number of fruits per plant, days to first flowering, day to first and last harvest, fruit length, fruit width, individual fruit weight, yield per plant and yield per unit area were found to be significantly differed with the differing of cultivation practices. The maximum average plant height of 173 cm inside green house was recorded followed by 158 cm in shade-net house and 93 cm in open field. Out of four rows of plantation from each condition of cultivation, the average of fruit number per plant, individual fruit weight, fruit yield per plant, fruit yield per plot and fruit yield in q/ha were calculated and it was found that the maximum is from green house cultivation and the open field has the minimum. Considering the cultivation in green house, shade-net house and open field, the yield of fruits in quintal per hectare were 438.09, 346.44 and 179.36 respectively. Thus, protected cultivation could be the only one alternative to control the environment for maximizing crop productivity percent area and increasing the quality of vegetables produce round the year in the hilly terrain of north east India.*

Keywords: *Hilly terrain, growth, yield, tomato, drip irrigation system, green house, shade-net house.*

1. INTRODUCTION

The north-east region of India has several unique features: fertile land, abundant water resources, evergreen dense forests, high and dependable rainfall, mega biodiversity and agriculture-friendly climate. Yet it has failed to convert its strengths optimally into growth opportunities for the well-being of the people. The region suffers from weaknesses such as subsistence agriculture with poor infrastructure like roads and markets [5]. The high vulnerability to natural calamities like floods, submergence, landslides, soil erosion, etc. has resulted in low and uncertain agricultural productivity.

Tomato is one of the most important and has the highest acreage of any vegetable crop in the world and also one of the most important protective food crops of India. India is the second largest producer of Tomato and is grown in 0.458 M ha area with 7.277 M mt production and 15.9 mt/ha productivity. Tomato is rich source of vitamins A, C, potassium, minerals and fibers. Tomatoes are used in the preparation of soup, salad, pickles, ketchup, puree, sauces and also consumed as a vegetable in many other ways.

Greenhouse is the most practical method of achieving the objectives of protected agriculture, where natural environment is modified by the use of sound engineering principles to achieve optimum plant growth and yield (more produce per unit area) with increased input use efficiency. Greenhouse is the most practical method of accomplishing the objectives of protected cultivation. Tomato, Capsicum and cucumber are the most extensively grown vegetables under green houses and give higher returns [1]. During winter season under north-east Indian conditions, it is difficult to grow tomato, capsicum, cucurbits, French bean, amaranth etc.in open field condition; however various types of protected structures have been developed for growing some high value crops continuously by providing protection from the excessive cold. This is called greenhouse technology which provides favorable environment condition to the plants.

Production of off-season vegetable nurseries under protected structure has become a profitable business [2]. The main purpose of raising nursery plants in protected structure is to get higher profit and disease free seedlings in off season to raise early crop in protected condition or/and open field condition [3]. The low cost Poly house is economical for small

and marginal farmers, who cannot afford huge cost of high-tech poly house [4].

Drip irrigation can distribute water uniformly, precisely control water amount, increase plant yields, reduce evapotranspiration (ET) and deep percolation, and decrease dangers of soil degradation and salinity. An easy-operation irrigation scheduling method is very stringent for tomato drip irrigation condition.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at experimental field located in hilly terrain of Department of Agricultural Engineering, Assam University, Silchar, Assam, India, during July 2014 to June 2015. The experimental field is situated at $24^0$41' N latitude and $92^0$45' E longitude at an elevation of 41 meters from the mean sea level. The climate of the north eastern region is subtropical, warm and humid. The average rainfall of the region is 3180 mm with average rainy days of 146 days per annum. The experiment was laid out in three different blocks viz. green house, shade-net house and open field with two replications in each block. In each block textural analysis of soil was performed by hydrometer method to evaluate the percentage of sand silt and clay. The soil physical characteristics were also determined for each set of experimental plot. There were in total 6 unit plots, each plot of 4m x 1m were made and raised by 10 cm which was separated by 0.50 m space. The treatments included 1 crop, 3 blocks and 2 replications.

2.2 Selection of Crop

The tomato crop is cultivated during winter and summer seasons. The crop cannot withstand severe frost. It grows well under an average monthly temperature range of 21^0 - 23^0 C but commercially it may be grown at temperatures ranging from 18^0 C to 27^0 C. Temperature and light intensity affect the fruit-set, pigmentation and nutritive value of the fruits. The best soil for tomato is a fertile loam soil with more sand in the surface layer, and clay in the sub-surface layers. The most favorable range of soil pH is 6.0–7.0. Hence, tomato seeds of Hybrid S-41 MAHY GOTYA from Mahyco with germination of 70% and purity 90% is selected. The seeds were sown in October 28, 2014. Seeds were soaked in water for 12 hour prior to sowing in half cut piece of poly tank and fifteen days old seedlings were transplanted in green house, twenty days old seedlings were transplanted in shade-net house and twenty five days old seedlings were transplanted in open field at each planting time with 2 cm depth maintaining single seedling per hill. The crop spacing for tomato was chosen as 50cm x 30cm which was recommended by Assam Agricultural University, Jorhat, Assam, India.

2.3 Nutrient Application

Plants need to be fertilized because most soil does not provide the essential nutrients required for optimum growth. Even the soil has the great garden soil, as plants grow, they absorb nutrients and leave the soil less fertile. Tasty tomatoes and beautiful roses took nutrients from the soil to build those plant tissues. There are six primary nutrients that plants require. Plants get the first three—carbon, hydrogen and oxygen—from air and water. The other three are nitrogen, phosphorus and potassium.

Half of the quantity of cow dung was applied during final land preparation. The remaining half of Cow dung, the entire quantity of MP and SSP and half of urea were applied during transplantation. The rest of Urea were applied in two equal splits, 25 and 50 days after transplanting in the main field (Table 1). After planting the seedlings, the intercultural operations were accomplished for their better growth and development.

Table 1: Recommended doses of manure and fertilizers applied for tomato

Element	Quantity
Cow dung	10 t/ha
Urea	75 kg/ha
MoP	50 kg/ha
SSP	55 kg/ha

2.4 Selection of Protected Cultivation Structures

Protected cultivation practices can be defined as a cropping technique wherein the micro environment surrounding the plant body is controlled partially/ fully as per plant need during their period of growth to maximize the yield and resource saving. Protected cultivation is future because Land and Water – Nature's gift to mankind is not unlimited and free forever [12]. Everyday population is increasing and due to modernization the infrastructure work is increasing and day to day agricultural land is becoming less and less and at the same time the land value is increasing [13]. Also world water resources are fast diminishing.

In the experimental site two different types of protected cultivation structures have been selected based on the condition, cost involvement and availability of resources. These are high-tech poly green house and low cost bamboo structured shade-net house.

Fig. 1: High-tech poly green house structure

High-tech poly green house is a tubular structure covered with 200 micron UV film and shade net, which is designed to withstand wind up to 120km/hr., and trellising loads up to 25 kg/m2, with 4-way fogger irrigation system and cooling system by foggers, cooling pads and exhaust fans (shown in Fig. 1). It's a high cost structure.

Low cost shade-net house is a bamboo structured of height 2.2 m with 50% shading shade nets with all the sides and ceiling are covered with the same shade net (shown in Fig. 2). It's a low cost structure [7].

Fig. 2: Low cost shade-net house structure

2.5 Drip Irrigation System

Water management and water scarcity in winter season is one of the major constraints on vegetable production in hilly terrain of North East. Soil moisture is one of the predominant factors influencing tomato productivity and drip irrigation is the best alternative. The water use efficiency of drip irrigation is 90-95%, whereas sprinkler has 70-80% and surface irrigation has 30-50% WUE. Drip irrigation involves technology for irrigating plants at the root zone through emitters fitted on a network of pipes (mains, sub-mains and laterals).

Fig. 3: Layout and installation of drip irrigation system

2.6 Monitoring and Analysis of Growth and Yield

Plots with transplanted seedlings were regularly observed to find out any damage or dead seedlings for its replacement and weeding was done as per requirement and also plant protective measures were done against insect and disease. The crops were irrigated when needed depending on the moisture status of the soil with the help tensiometer and requirement of plants. Data were collected from five plants of each plot were randomly selected for data collection on growth and yield characteristics during the growth of plants and at harvesting time of the crop. These were plant height (cm), number of branches per plant, number of leaves per plant, fruit length (cm), fruit width (cm), days to 1st flowering, days to 1st harvest, number of fruits per plant, individual fruit weight (g), yield per plant (g), yield per plot (kg) and yield in q/ha [6]. The recorded data for different characters were analyzed statistically to find out the significance of variation among the three conditions of cultivations.

3. RESULTS AND DISCUSSION

3.1 Assessment of Soil Characteristics

Textural analysis of soil was carried out by hydrometer method for each set of experimental plots to evaluate the percentage of sand silt and clay (Table 3.1). This method is based on Stoke's law governing the rate of sedimentation of particles suspended in water. The sample is treated with sodium hexa-metaphosphate to complex Ca++, Al3+, Fe3+, and other cations that bind clay and silt particles into aggregates.

Table 2: Textural analysis of soil using hydrometer method

Conditions	Soil Type
Green House	Sandy Loam
Open Field	Sandy Loam
Shade-net House	Loamy Sand

The soil physical characteristics such as moisture content, bulk density, field capacity, saturated moisture content and wilting point of soil of each plot were evaluated to provide the proper and accurate irrigation scheduling. A soil sample from each plot was weighed in a moisture box and allowed to dry at 105 0C to a constant mass in a Hot Air Oven for 24 hrs to get the moisture content of soil using the formula, water (%) by mass = (wet mass - dry mass / dry mass) x 100. The saturated soil sample is kept in pressure plate apparatus at 0.33 bar for 24 hrs to get field capacity and again the same sample is kept in pressure plate apparatus at 15 bar to get the wilting point of soil (Table 3).

Table 3: Soil physical characteristics

Conditions	Bulk Density (g/cm^3)	Moisture Content, %	Saturated Moisture Content, %	Field Capacity, %	Wilting Point, %
Green House	1.46	24.48	34.11	26.95	19.72
Shade-net House	1.82	8.82	20.76	18.16	13.65
Open Field	1.77	9.14	25.86	17.23	12.54

3.2 Monitoring and Analysis of Growth and Yield

The effect of protected cultivation were found to be significant on plant height at different stage of plant growth of tomato crop (Fig. 4). It was also found that the greenhouse produced the plants with higher plant height at all stages of plant growth as compared to other conditions of cultivation. The greenhouse cultivation produced the tallest plant (173 cm) and the shortest plant (93 cm) was obtained from the cultivation in open field at final harvesting stage. The results of the present study for this character are in agreement with the findings of Maya et al. [9] who stated that, plant height of sweet pepper was significantly increased with close spacing. Manchanda et al. [8] also expressed similar opinion on plant height of tomato. Also the duration of crop is found to be maximum in green house cultivation (166 days) followed by shade-net cultivation (145 days) and open field cultivation (123 days).

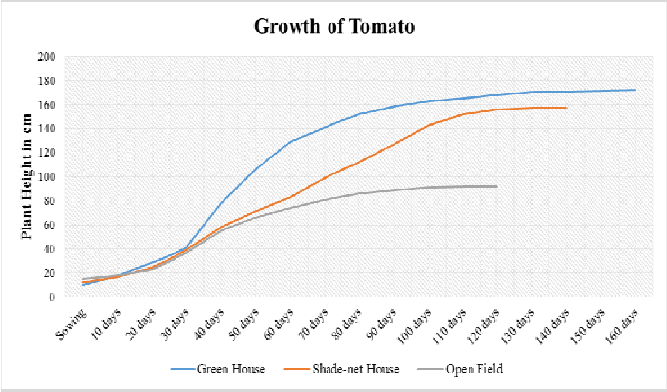

Fig. 4: Plant height at different growth stage of Tomato

The maximum average number of branches per plant, number of leaves per plant, 1st day of flowering and 1st and last day of harvesting also differed significantly with the different cultivation practices (Table 4).

Table 4: Plant growth parameters

Conditions	No. of branches per plant	No. of leaves per plant	1st flowering in days	1st harvesting in days	Last day of harvesting
Green House	32	192	44	97	166
Shade-net House	27	174	47	103	145
Open Field	18	108	49	88	123

Maximum average number of branches (32) per plant was recorded from green house cultivation and the lowest number of branches (18) per plant was recorded from the open field cultivation. The day to 1st flowering is also occurred early (44 days) in green house cultivation, 47 and 49 days for shade-net house and open field cultivation respectively, but the day to 1st harvesting is done early (88 days) than green house (97 days) followed by shade-net house (103 days). It indicates that the vegetative growth is more in green house and shade-net house cultivation as compared to open field cultivation as in open field condition the temperature and solar radiation is more and hence results in early maturity of crop with shorter plant height, lesser number of branches and leaves.

The number of fruits per plant varied significantly under different conditions of cultivation (Table 5). The highest average number of fruits (19.05) per plant was recorded from the green house cultivation which was significantly higher than those of shade-net house cultivation (16.74) and open field cultivation (11.46). As the growth in all respects like number of branches, number of flowers and plant height are more in green house cultivation, therefore the number of fruits per plant has come to be maximum.

Table 5: Average fruit numbers per plant

Conditions	Row 1	Row 2	Row 3	Row 4	Mean
Green House	19.15	18.09	20.31	18.65	19.05
Shade-net House	17.10	16.35	16.03	17.48	16.74
Open Field	11.50	10.85	12.25	11.23	11.46

There was also slight variation in fruit length and width of tomato due to different conditions of cultivation (Table 6). Slightly longer and wider fruits (57.51 mm and 55.77 mm) was obtained from the green house cultivation. The open field cultivation produced the shortest and narrowest fruits (52.87 mm and 49.69 mm) and the shade-net house produced the medium length and width fruits (55.87 mm and 49.69 mm).

Table 6: Average fruit length and width

Conditions	Length in mm	Width in mm
Green House	57.51	55.77
Shade-net House	55.35	53.10
Open Field	52.87	49.69

The individual fruit weight also varied for different conditions of cultivations (Table 7).

Table 7: Average fruit weight in g

Conditions	Row 1	Row 2	Row 3	Row 4	Mean
Green House	57.60	56.66	57.56	58.11	57.48
Shade-net House	51.12	52.34	50.70	52.74	51.72
Open Field	44.37	41.66	37.08	33.58	39.17

The maximum average fruit weight (57.48 g) from the 4 rows was obtained from green house cultivation, followed by shade-net house cultivation (51.72 g) which has got slightly lesser weight than green house tomatoes and the least fruit weight (39.17 g) was obtained from open field cultivation.

Yield per plant in average from 4 rows was significantly influenced by protected cultivation structures than the open field cultivation (Table 8).

Table 8: Average yield per plant in kg

Conditions	Row 1	Row 2	Row 3	Row 4	Mean
Green House	1.10	1.02	1.17	1.08	1.10
Shade-net House	0.87	0.86	0.81	0.92	0.87
Open Field	0.51	0.45	0.45	0.38	0.45

The maximum yield (1.10 kg) was recorded from the green house cultivation which differed significantly from the other two conditions of cultivations, i.e., from shade-net house (0.87 kg) and open field (0.45 kg).

Protected cultivation had significant effect on yield per plot and quintal per hectare (Table 9 and Fig. 5).

Table 9: Average fruit yield per plot in kg

Conditions	Row 1	Row 2	Row 3	Row 4	Mean
Green House	1.10	1.02	1.17	1.08	1.10
Shade-net House	0.87	0.86	0.81	0.92	0.87
Open Field	0.51	0.45	0.45	0.38	0.45

The green house cultivation produced the maximum yield of fruit (1.10 kg/plot and 438.09 q/ha) and the open field cultivation showed the minimum (0.45 kg/plot and 179.36 q/ha) fruit yield per plot and quintal per hectare.

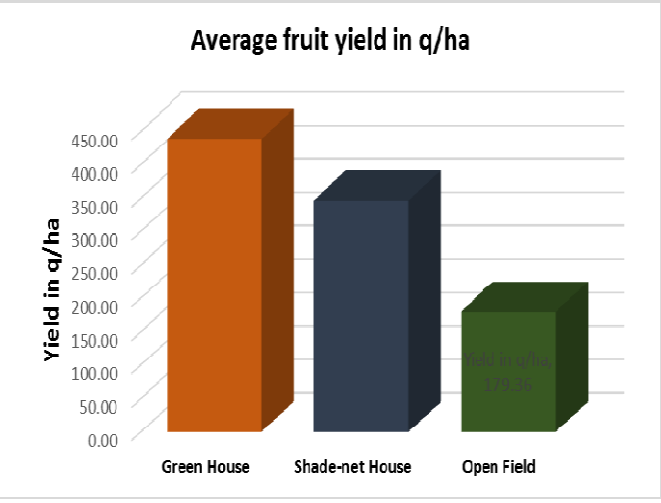

Fig. 5: Average fruit yield of Tomato in q/ha

It was observed that the yield of fruits per unit area was inversely related to the condition of cultivation i.e. the green house produced the higher yield of fruits per plot and per hectare.

4. CONCLUSIONS

The present study, it was evident from the above results that the protected cultivation structures are the only solution to produce the high value crop with higher income and more yield from small or marginal land of undulating north eastern hilly terrain. The higher yield of fruits was mainly contributed by the high-tech green house structure which got sufficient irrigation water through drip irrigation system, optimum temperature and humidity for plant growth and also provide protection from insects and pests. The initial cost involvement for cultivation in green house is quite higher as compare to low cost shade-net house cultivation. But during summer it is difficult to grow tomatoes in shade-net houses as in north eastern hilly region is a very high rainfall zone with heavy storms. So to produce off-seasonal tomatoes with higher return hi-tech green house is best suitable. Though, the protective cultivation with shade net provides more economic return [10] as compared to hi-tech green house, but the crop productivity is more with amenable to automation, conserve water and land longer sustainability. The protected cultivation could be the only one alternative to control the environment for maximizing crop productivity percent area and increasing the quality of vegetables produce year around in the hilly terrain of Assam.

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