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# Performance of bell pepper (*Capsicum annuum* L .) and its economics with different irrigation regimes and nutrient scheduling under protected structure in Island ecosystem

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**A**BSTRACT : An experiment was conducted to evaluate the effect of irrigation and nutrient scheduling on the yield and economics of bell pepper (*Capsicum annuum* L.) under protected structure during 2014 and 2015 at Calicut village, Andaman and Nicobar Islands. Four regimes of irrigation based on IW/CPE ratio ($I_1$-0.25; $I_2$-0.50; $I_3$- 0.75 and $I_4$-1.0) and nutrient levels consisted of five different composition of fertilizers to supplement the nutrient requirement of crop was used to find out the best treatment ($N_1$-100% recommended dose of NPK (inorganic form); $N_2$-50% of inorganic NPK + 50% organic manure; $N_3$- 75% of inorganic NPK + 25% organic manure; $N_4$- 25% of inorganic NPK + 75% organic manure; $N_5$- 100% organic manure). Combined variance analysis indicated that experimental seasons were not significantly different, but irrigation intervals and nutrient level both significantly influenced the performance and the total capsicum yield. Highest yield was recorded from the combination of irrigationat 0.75 IW/CPE ratio and nutrient application of 100 per cent recommended dose of NPK (inorganic form) ($I_3N_1$) treatments at par with the treatment of irrigation at 1.0 IW/CPE ratio and nutrient application of 100 per cent recommended dose of NPK ($I_4N_1$). However, with the lower irrigation frequency ($I_1$), lower yields were obtained with all nutrient levels. Both I and N significantly influenced the fruit weight, number of fruits per plant branches, quality of fruit and the total yield. The cost benefit ratio of 2.2:1 was recorded in the $I_3N_1$ (irrigationat 0.75 IW/CPE ratio and nutrient application of 100% recommended dose of NPK). Therefore, the conclusion, $I_3N_1$treatment is recommended for naturally ventilated polyhouse grown bell pepper in this Island ecosystem in order to attain higher yields with improved quality.

**K**EY **W**ORDS : Bell pepper, IW/CPE ratio, Nutrient scheduling, Benefit cost ratio

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Bell pepper (*Capsicum annuum* L.) is an important cool season vegetable crop of India and is mainly grown during the winter season when the temperature is very low. These Islands due to its subtropical evergreen forest receives heavy rainfall during 8-10 months in a year, thereby even during the winter season the minimum temperature ranges between 21-23°C and therefore, growing bell pepper in open condition

is not profitable. It is an expensive crop, in terms of its cultivation but it offers the potential of considerable profit if quality produce is obtained and marketing is properly managed. Therefore, green house bell pepper production is the only alternative which is based on a full year cycle. Green house production allows crop production under very diverse conditions, however there are number of variables that has to be managed to obtain maximum sustainable production. Irrigation water is one such limiting factor in the green house production during the severe summer for 2-4 months when the crop shall suffer water stress if not irrigated. As a result, efficient use of water for irrigation is important and alternative water application methods needs to be explored. Drip irrigation has gained wide spread popularity as an efficient method of fertilization because both time and rate of nutrients can be controlled to meet the crop requirement at each growth stages (Bar-Yosef, 1977). Despite the wide popularity of bell pepper as a vegetable, the optimum water requirement for its cultivation have received very little attention in India. Hegde (1988) has reported that high water potential in the soil is very desirable for higher fruit yield of bell pepper. This crop is susceptible to water stress particularly blossom stage being more sensitive period. The crop respond quickly to water deficit and also negatively to excess water given through irrigation or rainfall. Adequate amount of water is needed at the right time in order to get profitable yield and, therefore, irrigation scheduling is a must to determine the water consumption during various stages of crop growth. Fernandez *et al.* (2000) reported that in a green house cultivation water deficit substantially increased the propotion of unmarketable fruits. Similarly, it has been pointed out by Cochron (1936) that besides irrigation, nitrogen application is also essential factor influencing growth, development and productivity of bell pepper. The efficient use of irrigation water increases the fertilizer use efficiency. Several research in this aspects are carried out throughout everywhere, but this study is pertaining to the evaluation of irrigation and nutrient requirement for best performance and profitable returns of bell pepper in the Island ecosystem.

## RESEARCH PROCEDURE

Experiments were conducted during *Kharif* of 2014 and 2015 in a naturally ventilated polyhouse at Calicut village of South Andaman located at 11°35' N latitude and 92°42'E longitude at an altitude of 63 m above MSL and receiving annual rainfall of 3100 mm and temperature ranged from 23°-34°C. The climatic parameters were recorded at the Meteorological unit, Shadipur, A and N Islands. The total rainfall during the bell pepper growing season (May-November) was 2859.7 mm and 2810.9 mmduring 2014 and 2015, respectively. The monthly minimum and maximum mean temperature ranged from 25.1°C to 30.6°C in 2014 and 25° C to30.7°C in 2015. The relative humidity ranged from78-89 per cent during the crop season in 2014 and 82-90 per cent in 2015. The soil of the experimental plot was analysed for their physical and chemical properties by the standard procedures. The soil was Clay loam in texture with a pH of 6.2 (Jackson, 1967), OC 0.5 per cent (Walkely and Black, 1934) and available NPK 230:11:100kg/ha.Two sets of factors were selected for the study *viz.*, Four levels of irrigation regimes assigned to main-plots based on IW/CPE ratio at a depth of 5 cm ($I_1$-0.25; $I_2$- 0.50; $I_3$-0.75 and $I_4$-1.0) and five levels ofdifferent composition of fertilizers assigned to subplots ($N_1$- 100% recommended dose of NPK (inorganic form); $N_2$- 50% of inorganic NPK + 50% organic manure; $N_3$- 75% of inorganic NPK + 25% organic manure; $N_4$ -25% of inorganic NPK + 75% organic manure; $N_5$-100% organic manure). The experiment was carried out in a naturally ventilated polyhouse in a split plot design with three replications. Bell pepper variety California Wonder was chosen for the study. All agronomic practices and need based plant protection measures were adopted as per recommendation. Observations on growth and yield attributes were recorded. The data pertaining to the experiment were subjected to statistical analysis method suggested by Gomez and Gomez (1984).

## RESEARCH ANALYSIS AND REASONING

The results obtained from the present study on yield parameters related to yield of bell pepper and economic returns are presented in the following Table 1 to 3.

**Yield and yield parameters :**

A significant correlation has been established between bell pepper yield and yield parameters *i.e.* number of fruits, fruit weight, pericarp thickness and days to 50 per cent flowering (Table 1). From the result it is established that the number of irrigation and dose of fertilizer application have effect on fruit number and

quality of the fruit. Increase in irrigation intervals from 1.0 to 0.25 IW/CPE ratio significantly delayed the days taken to flowering. The number of days to 50 per cent flowering was 59.80 and 60.47 in 2014 and 2015, respectively as compared to 55.73 and 56.40 days in the treatment $I_3$(Irrigation at IW/CPE ratio of 0.75) which influenced the yield pattern. Hariprasad (1997) observed early flowering at 75 per cent depleting available soil moisture as compared to irrigation at 50 per cent depleting available soil moisture. The effect of water deficit on the yield parameters was more pronounced in the reproductive phase and the fruit abscission occurred shortly after pollination and fruit set. Similar results were also reported by Bekele and Tilahun (2007). In the experiment results reported by Adeoye *et al.* (2014) a significant correlation was established and they found that any agronomical practices adopted for the cultivation of bell pepper eventually had an effect on the yield. This experimental results recorded 8.13 and 7.29 number of fruits per plant which was the highest at IW/CPE ratio of 0.75. The treatment at IW/CPE ratio of 0.25 recorded the least with 6.89 and 6.25 numbers in the year 2014 and 2015, respectively. Gowda (1998) also reported that due to moisture stress accumulation of ABA and increase in ethylene resulted in abscission of flowers thus resulting in less number of fruits/plant, whereas irrigation at 0.75 and 1.0 IW/CPE ratio provide high soil moisture resulting in favourable plant water relation contributing to higher yield. The maximum fruit weight (120.92g and 116.02g) and the maximum pericarp thickness (0.58cm and 0.59 cm) during 2014 and 2015 were also recorded when irrigation was given IW/CPE ratio of 0.75 ($I_3$).

Similar to irrigation the nutrient scheduling also influenced the yield and yield parameters of bell pepper in a greenhouse cultivation. Under the naturally ventilated polyhouse condition maximum yield was recorded when the crop was supplied with nutrients in the form of inorganic fertilizer with 100 per cent recommended dose ($N_1$). The nutrient level significantly influenced the maximum number of fruits per plant. It recorded highest of 8.23 numbers and 7.36 numbers during both the years when the plants received 100 per cent of the recommended dose of fertilizer in the inorganic form. Shukla *et al.* (1997) stated that there was significant increase in the number of fruits per plant of bell pepper with higher application of nitrogen. The increase was 21.2 per cent over control. The maximum fruit weight (128.23g and 120.54g) and pericarp thickness (0.58cm and 0.60 cm) was also recorded for the treatment $N_1$. Ramas *et al.* (2003) and Imamsaheb *et al.* (2011) in a greenhouse experiment found that the highest yield and higher relative nitrogen recovery were obtained in the capsicum plants that received fertigation of recommended dose. Dharmatti *et al.* (1989) reported that due to the application of

**Table 1 : Effect of irrigation and nutrient management on the yield parameters of bell pepper (*Capsicum annuum* L.) grown in a naturally ventilated polyhouse**

| Treatments | Number of fruits per plant (nos) | | Fruit weight (g) | | Pericarp thickness (cm) | | Days to 50 % flowering | |
|---|---|---|---|---|---|---|---|---|
| **Irrigation levels** | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| $I_1$ | 6.89 | 6.25 | 106.65 | 103.82 | 0.55 | 0.50 | 59.80 | 60.47 |
| $I_2$ | 7.27 | 6.51 | 109.93 | 107.23 | 0.54 | 0.53 | 58.27 | 59.07 |
| $I_3$ | 8.13 | 7.29 | 120.92 | 116.02 | 0.58 | 0.59 | 55.73 | 56.40 |
| $I_4$ | 7.88 | 7.05 | 118.71 | 117.47 | 0.58 | 0.57 | 56.53 | 57.20 |
| S.E.± | 0.25 | 0.25 | 3.39 | 2.88 | 0.01 | 0.02 | 0.66 | 0.49 |
| C.D.(P=0.05) | 0.61 | 0.61 | 8.29 | 7.05 | 0.02 | 0.05 | 1.66 | 1.19 |
| **Nutrient levels** | | | | | | | | |
| $N_1$ | 8.23 | 7.36 | 128.23 | 120.54 | 0.58 | 0.60 | 56.33 | 56.92 |
| $N_2$ | 7.56 | 6.86 | 112.73 | 111.75 | 0.58 | 0.55 | 54.66 | 57.75 |
| $N_3$ | 8.09 | 7.24 | 123.46 | 119.36 | 0.56 | 0.59 | 56.25 | 56.75 |
| $N_4$ | 7.07 | 6.35 | 104.08 | 105.06 | 0.57 | 0.52 | 58.75 | 59.67 |
| $N_5$ | 6.78 | 6.07 | 101.75 | 98.94 | 0.54 | 0.49 | 58.92 | 60.33 |
| S.E.± | 0.18 | 0.16 | 3.63 | 3.50 | 0.02 | 0.01 | 0.64 | 0.70 |
| C.D.(P=0.05) | 0.36 | 0.33 | 7.39 | 7.13 | 0.03 | 0.03 | 1.31 | 1.42 |

**Table 2: Effect of irrigation and nutrient management on the yield (kg ha$^{-1}$) of bell pepper (*Capsicum annuum* L.) grown in a naturally ventilated polyhouse**

| Nutrient levels | Irrigation regimes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | | | 2015 | | | | |
| | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
| $N_1$ | 20.92 | 21.70 | 29.85 | 27.74 | 25.06 | 21.84 | 23.15 | 31.50 | 29.31 | 26.45 |
| $N_2$ | 19.99 | 19.67 | 21.09 | 21.74 | 20.62 | 19.13 | 20.84 | 22.54 | 22.83 | 21.34 |
| $N_3$ | 19.99 | 20.79 | 28.39 | 24.95 | 23.54 | 21.32 | 22.17 | 30.17 | 26.52 | 25.04 |
| $N_4$ | 15.14 | 17.19 | 18.59 | 18.75 | 17.42 | 16.04 | 18.25 | 19.57 | 19.67 | 18.38 |
| $N_5$ | 13.09 | 14.99 | 18.92 | 17.91 | 16.23 | 13.92 | 15.96 | 19.91 | 19.16 | 17.24 |
| Mean | 17.83 | 18.87 | 23.37 | 22.22 | | 18.45 | 20.07 | 24.74 | 23.49 | |

| | Irrigation regimes | | Nutrient levels | | I x N interaction | |
|---|---|---|---|---|---|---|
| | S.E.± | C.D. (P=0.05) | S.E.± | C.D. (P=0.05) | S.E.± | C.D. (P=0.05) |
| 2014 | 0.73 | 1.79 | 0.75 | 1.61 | 1.59 | 3.30 |
| 2015 | 0.65 | 1.59 | 0.70 | 1.46 | 1.41 | 2.95 |

**Table 3 : Effect of irrigation and nutrient management on the benefit cost ratio of bell pepper (*Capsicum annuum* L.) grown in a naturally ventilated polyhouse**

| Treatments | Expenditure (Rs./m$^2$) | | Gross returns(Rs./m$^2$) | | Net returns (Rs./m$^2$) | | BCR | |
|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **Irrigation at IW/CPE ratio 0.25($I_1$)** | | | | | | | | |
| $N_1$ | 129.23 | 129.00 | 313.80 | 327.75 | 184.57 | 198.75 | 1.4 | 1.5 |
| $N_2$ | 129.31 | 129.28 | 299.85 | 286.95 | 170.54 | 157.67 | 1.3 | 1.2 |
| $N_3$ | 129.28 | 129.25 | 299.85 | 319.88 | 170.57 | 190.63 | 1.3 | 1.5 |
| $N_4$ | 129.32 | 129.32 | 227.10 | 240.75 | 97.78 | 111.44 | 0.8 | 0.9 |
| $N_5$ | 129.38 | 129.35 | 196.35 | 208.88 | 66.97 | 79.53 | 0.5 | 0.6 |
| **Irrigation at IW/CPE ratio 0.50($I_2$)** | | | | | | | | |
| $N_1$ | 136.74 | 136.70 | 325.55 | 347.25 | 188.76 | 210.55 | 1.4 | 1.5 |
| $N_2$ | 136.81 | 136.78 | 295.05 | 312.60 | 158.24 | 175.82 | 1.2 | 1.3 |
| $N_3$ | 136.75 | 136.75 | 314.55 | 332.55 | 177.80 | 195.80 | 1.3 | 1.4 |
| $N_4$ | 136.85 | 136.82 | 257.85 | 273.75 | 121.01 | 136.94 | 0.9 | 1.0 |
| $N_5$ | 136.88 | 136.85 | 224.85 | 239.40 | 87.97 | 102.55 | 0.6 | 0.8 |
| **Irrigation at IW/CPE ratio 0.75($I_3$)** | | | | | | | | |
| $N_1$ | 147.99 | 147.96 | 447.75 | 472.50 | 299.76 | 324.54 | 2.0 | 2.2 |
| $N_2$ | 148.06 | 148.03 | 316.35 | 338.10 | 168.29 | 190.07 | 1.1 | 1.2 |
| $N_3$ | 148.03 | 147.99 | 425.85 | 452.55 | 277.82 | 304.55 | 1.9 | 2.1 |
| $N_4$ | 148.07 | 148.07 | 278.55 | 293.55 | 130.48 | 142.49 | 0.9 | 1.0 |
| $N_5$ | 148.14 | 148.10 | 283.80 | 298.65 | 135.66 | 150.55 | 0.9 | 1.0 |
| **Irrigation at IW/CPE ratio 1.0($I_4$)** | | | | | | | | |
| $N_1$ | 166.76 | 166.71 | 416.1 | 439.65 | 249.34 | 272.94 | 1.5 | 1.6 |
| $N_2$ | 166.81 | 166.78 | 326.10 | 342.45 | 159.29 | 175.67 | 1.0 | 1.1 |
| $N_3$ | 166.77 | 166.75 | 374.25 | 397.80 | 207.49 | 231.05 | 1.2 | 1.4 |
| $N_4$ | 166.85 | 166.82 | 281.25 | 295.05 | 114.405 | 128.24 | 0.7 | 0.8 |
| $N_5$ | 148.14 | 166.85 | 268.65 | 287.40 | 120.52 | 120.55 | 0.8 | 0.7 |

Nutrient schedule: ( $N_1$- 100% recommended dose of NPK (Inorganic form); $N_2$- 50% of inorganic NPK + 50% organic manure;$N_3$- 75% of inorganic NPK + 25% organic manure;$N_4$ -25% of inorganic NPK + 75% organic manure;$N_5$-100% organic manure)

120:100:60 kg of NPK per hectare along with the recommended dose of FYM, significant increase in fruit weight, pericarp thickness, fresh weight and dry weight of fruit in tomato was recorded compared to other NPK rates. In this experiment the yield per plant was recorded maximum with $I_3N_1$ and the total yield per hectare of 29.85 MT during 2014. The results were significantly influenced similarly in the year 2015 also (Table 2). This concludes that growth and yield performance of a crop is affected by the status of soil nutrients, especially N.

**Economics :**

The gross return (Rs.447.8/$m^2$ and Rs.472.5/$m^2$ ) and the net return of Rs.299.8/$m^2$ and Rs.324.5/$m^2$ was recorded in the treatment $I_3N_1$ with the benefit cost ratio of 2:1. High economic returns were recorded when irrigation was given at 0.75 IW/CPE ratio ($I_3$) and nutrient supplied by applying 100 per cent recommended dose of NPK in the inorganic form ($N_1$). The crop was grown in a controlled environment and therefore, plants experienced minimum pest and disease incidence and the calamities of weather, which resulted in more uptake of nutrients thereby increasing the photosynthetic rate which resulted in good performance of bell pepper. The results obtained in this research are in agreement with that of Dugo *et al.* (2007); Singh *et al.* (2011) and Manuel *et al.* (2012).

Irrigation at $I_3$ level (at 0.75IW/CPE ratio) gave higher yield and therefore, the benefit cost ratio is found to be 2:1 which was more because irrigation interval has significant effect on the yield of bell pepper as the total biomass production increases due to more nutrient uptake and higher photosynthesis. The plant under stress will tend to shorten their life cycle and therefore, will yield less as in the treatment $I_1$(irrigation at 1.0IW/CPE). The result was similar to the result established by Adeoye *et al.* (2014) which indicated that longer intervals of irrigation caused more stress to the plant which leads to reduction in plant height, number of leaves, leaf area and thereby less production of chlorophyll which ultimately influenced the total yield.

The plants grown with application of fertilizer as per the recommended dose (treatment-$N_3$ ) gave higher yield as the nutrient use efficiency is as high as 90 per cent compared to the conventional method. It was also reported by Solaimalai *et al.* (2005). Drip fertigation optimize the use of water and fertilizer enabling the harvest high crop yield simultaneously ensuring a healthy soil and environment. It has been reported by Taha (1999) that 100 per cent recommended dose through fertigation enhanced the overall root activity, improved the mobility of nutritive element and their uptake and thereby yield increased linearly. Similar results were reported by Natrajan *et al.* (2002) in a greenhouse experiment. Application of water soluble fertilizer at recommended level produced excellent quality fruits which resulted in higher profit per year with a benefit cost ratio of 3.22 : 1 (Imamsaheb *et al.*, 2011). Tumbare *et al.* (1999) revealed that application of 100 per cent recommended liquid fertilizer has given highest plant yield. Brahma *et al.* (2010) concluded that fertigation with 100 per cent recommended dose of N and K was the most efficient treatment with fertigation efficiency of 43.24 per cent and benefit cost ratio of 2.28:1.

**Conclusion :**

The irrigation scheduling coupled with the nutrient management has increased the performance of bell pepper crop. The results showed increase in yield of bell pepper with the recommended dose of NPK (150:80:80 kg/ha) combined with irrigation at 0.75IW/CPE ratio. These affected the number of fruits in each plant, fruit weight and the pericarp thickness which significantly influenced the yield pattern and the quality of bell pepper. These also gave higher net return and the benefit cost ratio of 2:1. The results indicated that bell pepper irrigated at 0.75 IW/CPE ratio with application of 100 per cent recommended dose of fertilizer is best suited under Naturally Ventilated Polyhouse in the A and N Island ecosystem.

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