Effect of Planting Density and Light on Yield of Spanish Pepper *Capsicum annum* L. var. Vasca Corta.

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ABSTRACT

A study was carried out to identify the light level and plant density on growth and yield of Spanish Pepper, *Capsicum annum* L. (var. Vasca Corta). Plants were grown in a rain shelter, with and without artificial light. Artificial light was provided for 12 hours from 6 am to 6 pm daily and three planting densities (30x30, 30x45, 30x60 cm) were used. The experiment was arranged in a split plot design with three replicates.

The effect of artificial lighting on average yield was significant and was 82.7% higher than the yield obtained under natural lighting. The high density planting (30x30 cm) increased the average yield per 1000 m^2 over medium density planting, (30x45 cm) and low density planting, (30x60 cm). Number of pods per plant was also significantly higher under artificial lighting and medium density planting over the others.

KEYWORDS: Spanish pepper, artificial light, plant density.

INTRODUCTION

The genus Capsicum is a member of the Solanaceae family that includes crops such as tomato, potato, tobacco, and brinjal. The Capsicum genus represents a diverse plant group, from the well-known sweet green bell pepper to the fiery hot, recently exploited habanero, red pepper. Capsicum had been domesticated for 7,000 years and its fruits are considered as vegetables, but are berries, botanically. The types usually are classified by fruit characteristics, such as pungency (sweet and hot peppers), color, shape, flavor, size, and use (NWREC, 2003).

World production of nearly 10 million metric tons of fresh pods on 1.1million hectares, rank peppers in the middle range of vegetables in terms of popularity (FAO, 1992). Forty six percent of the production is centered in Asia, with China the main producing country. The countries of Southern Europe are the second most important producing regions, with 24% of world production (Wien, 1996).

Pepper (*Capsicum annum* L.) is one of the most important cash crops grown in Sri Lanka. It has become an essential ingredient in Sri Lankan meals. Per capita consumption of hot pepper in the form of dry chilli is estimated as 2.32 kg and the national annual requirement of dry chilli is around 40,000 mt (DOA, 2005). Dry and intermediate zones are the major growing areas in Sri Lanka. Pepper contributes on an average of Rs.750 million to the GDP and creates employment of 14 million workdays annually (DOA, 2005). Hot pepper is extensively grown for dry chilli production, but part of the crop is harvested as green pods. The average extent under chilli at present is around 20,000 ha, of which 2/3 is cultivated in *Maha* season. Major hot pepper growing districts are Anuradhapura, Moneragala, Ampara, Vavuniya, Kurunegala, Hambantota and Mahaweli System H (DOA, 2005).

Capsicum is an essential ingredient in the fastest growing food sector in the United States, "Mexican or Southwestern food". They are the source of capsaicin, the most commonly used spice in the world (Andrews, 1984). In addition, many of the new uses of peppers are hidden within manufactured products. Capsicum or peppers are being used as a food flavoring, a coloring agent, a pharmaceutical ingredient, and in other innovative ways. The use, and uses, of the numerous cultivars within the five domesticated species has grown exponentially.

According to the present market trends, there is a large export potential for peppers. The Spanish pepper, in particular has a potential for exportation due to various consumption patterns and it is being extensively marketed in many restaurants, and hotels especially in Europe, Holland, Australia and USA. Yet producers are not being able to meet the demand. Being a characteristic low pungent product, the Spanish pepper is included in many sweet recipes. It is harvested and exported as a bottled product, where pods are immersed in wine vinegar as five pods per bottle. Final preparations are done after reaching its destination. It is also important to harvest pods at correct maturity stage (6 to 8 cm long pod more than 1cm in diameter) having required low pungency and olive green color. Several private sector companies have already started growing Spanish pepper in Sri Lanka on experimental basis and preliminary studies found to be successful (Prathapasinghe, 2004), mainly due to availability of favorable climatic, soil and other physiological factors preferred by the crop. Therefore, Sri Lanka has a potential to cultivate Spanish pepper for export in future. It will earn foreign exchange and create more employment opportunities in the country. Though varieties and management practices for cultivation of Spanish pepper have been developed in other countries, they are yet to be developed for Sri Lankan situation. Therefore, the objective of this study is to identify certain management practices to make cultivation of Spanish pepper feasible under Sri Lankan growing conditions.

MATERIALS AND METHODS

Experimental Site

The study was carried out at the Faculty of Agriculture and Plantation Management of Wayamba University, Makandura, situated in the Low Country

Intermediate Zone, at an elevation of 30 m above mean sea level. The experiment was carried out under a commercial rain shelter (Rovero systems) of 9x12 m in size with a covered roof of UV treated, 1000 gauge polythene with a 33% reduction in light intenisty.

Experiment was conducted during the period from November 2004 to March 2005.

Field Layout

Rain shelter was partitioned into two sections equally, using tin sheets and one section was provided with artificial light source as one of the main treatments (40 W florescent lights, 5 rows with 6 lights per row). The other section received only the natural light. Accordingly, the main treatments were,

1) L0 = without artificial light.
2) L1 = with artificial light.

Three replicates (size of the replicate was 9x1.45 m and size of a plot was 3x1.45 m) were allocated for each main treatment. Three plant densities (plant spacing levels) were tested and randomized in each replicate as sub treatment. The plant spacings were, S1=30x30 cm (111,111 plants/ha) S2 = 30x45 cm (74,074 plants/ha) and S3 = 30x60 cm (55,555 plants/ha).

Inter row distance was kept constant (30 cm) while changing the within row distance (30, 45, and 60 cm). Irrigation was done using a drip system. Spanish pepper seeds (var. Vasca Corta) obtained from Sun Frost Private Limited were sown in trays four weeks before field planting. Organic matter (cow dung) and basal inorganic fertilizers (Ammonium sulphate, triple super phosphate, potassium sulphate and magnesium sulphate at the rate of 500 kg/ha, 600 kg/ha, 600 kg/ha and 600 kg/ha, respectively) were applied for plots equally, 3 days before transplanting. After transplanting, Albert's solution (at the rate of 0.2 g/plant at the seedling stage, 0.4 g/plant at the growing stage, 0.6 g/plant at the flowering stage and 0.8 g/plant at fruiting stage) and fungicide applications were done once a week alternatively. First and second top dressings (Ammonium sulphate, triple super phosphate, potassium nitrate and calcium nitrate at the rate of 200 kg/ha, 100 kg/ha, 200 kg/ha and 200 kg/ha in each top dressing, respectively) were done first and second month after transplanting. After fruit setting 6 to 8 cm long pods were harvested once in two days. For harvesting and data recording five plants were selected randomly from each plot and following parameters were recorded.

Date of sowing, Date of transplanting, Average plant height (cm) (from ground level to terminal point), Number of branches per plant, Average pod length (cm), Pod diameter (cm), Number of pods per plant and Average pod yield per plant (g), Date of all cultural activities and chemical applications were recorded. All cultural and management practices were carried out according to the instructions provided by the Sun Frost Private Limited. Light levels of the main treatments were measured using a tube solarimeter.

RESULTS AND DISCUSSION

1. Temperature and Light Intensity

A wide variation was observed in temperature and light intensity among two main treatments in which the experiment was conducted. Auchter and Hartley (1924) and Cochran (1942) recorded that the production of flower primordial in C. *annum* peppers to be influenced by day length, occurring in the same time on the plants grown under photoperiods 7 to 15 hours long. Dorland and Went (1947), Baker and Van Uffelen (1988) reported that the rate of plant growth is strongly influenced by the air temperature, which affects both the rate of dry matter production and the partitioning of that dry matter in to leaf tissue. Under artificial lighting light duration given for the crop was constant (12 hours) and mean light intensity was higher (38mV) than in natural lighting (23.6mV) (Table 1). It was also observed that the air temperature under artificial lighting was higher (32.6^{0}C) when compared to that of natural lighting (30^{0}C) (Table 1).

Table1. Temperature and light intensity recorded during the experimental period.

Date	Temperature (^{0}C)			Light intensity (mV)					
	L0	L1	L	L0	%	L1	%	L	%
13 .1.05	31	33	29.5	31	40	48	62	77	100
2.2.05	31	33	28.5	20	27	36	49	74	100
4.3.05	29	32	33	20	32	30	48	62	100
Mean	30	32.6	30	23.6	33	38	53	71	100

L=open environment

Table 2. Effect of light levels and spacing on number of branches per plant and plant height in *Capsicum annum* var. Vasca Corta.

Treatment	Number of branches per plant						Plant height (cm)					
	1MAT		Mean	2MAT		Mean	1MAT		Mean	2MAT		Mean
	L0	L1		L0	L1		L0	L1		L0	L1	
S1	4a	4a	4	6a	8a	7	26.9a	30.5a	28.7	32.8a	36.6a	34.7
S2	5a	4a	4.5	8a	8a	8	30.2a	30.5a	30.3	36.3a	38.2a	37.3
S3	4a	4a	4	6a	8a	7	29.6a	30.0a	29.8	36.6a	36.4a	36.5
Mean	4.33	4	4.16	6.7	8	7.3	28.9	30.3	29.6	35.2	37.1	36.2

Treatment means (1MAT=1st month after transplanting and 2MAT=2nd month after transplanting) in a column (Number of branches per plant) having common letters are not significantly different at least significant difference test. R^2 = 0.80 CV=13.23. Treatment means (1MAT=1st month after transplanting and 2MAT=2nd month after transplanting) in a column (plant height) having common letters are not significantly different at least significant difference test. R^2=0.84 CV=9.36

2. Number of Branches Per Plant and Plant Height

2.1. Number of Branches per Plant

No significant differences were observed among main treatments (Table 2). However, higher mean number of branches per plant was recorded under artificial lighting (8) than in natural lighting (6.7) two months after transplanting.

No significant difference in number of branches observed in different plant densities (Table 2). However, higher mean number of branches (8) was observed two months after transplanting in medium density treatment (S2) while other two treatments had a value of 7 each for the same parameter.

2.2. Plant Height (cm)

Observations were recorded at first and second month after transplanting (Table 2). According to the results, the tallest plants (37.11cm) were observed two months after transplanting under artificial lighting (L1) than in natural lighting (L0) (35.29 cm). However, the differences among treatments were not significant. The different plant densities too, showed no significant differences among treatments in both 1st and 2nd months after transplanting (Table 2). The highest plant height (37.3cm) was recorded in medium density planting (S2) while the lowest (34.73cm) was recorded in high density planting (S1).

It is evident that the growing environment and planting density have lesser influence on vegetative growth of variety "Vasca Corta". Bruggink and Heuvelink (1987) reported that pepper has relatively slower growth rate than some of other vegetable crops. Comparative growth analysis of tomato, cucumber and pepper indicated that pepper had a 25% lower relative growth rate than the other two species. The slower growth rate of pepper was not due to a lower productivity per unit leaf area (net assimilation rate), but to a reduced production of leaf area. As suggested by Bruggink and Heuvelink (1987), in this study too, the plants showed relatively slower growth during the first two months and the treatment differences were not significant.

3. Pod Length and Diameter

Mean pod length at different harvesting dates was not significantly different (Table 3). Mean pod length for L0 and L1 light levels were 7.14 and 7.39, respectively. Under artificial lighting pod length ranged between 7.16 and 7.81 cm while under natural lighting a wide range was observed from 6.33 to 8.10 cm. Mean diameter of pods for both treatments were not significantly different (Table 3). However, artificial lighting showed higher mean pod diameter (1.17cm) when compared to natural lighting (0.98cm).

According to the results, the plants grown under artificial lighting has produced pods with a lower variation in length with higher diameter (1.17cm) through out the harvesting period. As a bottling product Spanish pepper required to produce pods which are uniform in length and diameter of more than 1cm. The artificial light has produced more uniform pods than under natural light through out the harvesting period. It was observed that under natural lighting, there was a tendency to reduce the length and diameter of pods towards the latter part of the crop. This may lead to higher percentage of rejection of pods for bottling from the later harvested pods.

Table 3. Effect of light on pod length and diameter with time in *Capsicum annum* var. Vasca Corta.

Date	Length		Diameter	
	L0	L1	L0	L1
7-Feb	8.10	7.42	1.10	1.23
12-Feb	7.51	7.61	1.01	1.42
16-Feb	7.72	7.81	1.02	1.31
21-Feb	6.74	7.38	1.10	1.21
25-Feb	7.49	7.52	0.98	1.35
28-Feb	6.99	7.22	1.00	1.12
4-Mar	6.85	7.23	0.93	1.00
7-Mar	6.53	7.19	0.90	1.10
9-Mar	6.33	7.16	0.78	0.81
Mean	7.14	7.39	0.98	1.17

4. Pod Weight

Table 4. Effect of light and planting density on pod weight in *Capsicum annum* var. Vasca Corta.

Treatment	L0	L1	Mean
S1	2.74a	2.77a	2.75
S2	2.63a	2.66a	2.64
S3	2.49a	2.60a	2.54
Mean	2.62	2.67	2.65

Treatment means in a column having common letters are not significantly different at least significant difference test. R^2=0.97 CV=3.56

Mean weight per pod for both treatments were not significantly different (Table 4). The higher weight per pod (2.67g) was recorded under artificial lighting while natural lighting showed slightly lower value (2.62g). High density planting also showed slightly higher value (2.75g) than medium density planting (2.64g) and low density planting (2.54g).

5. Number of Pods per Plant

Table 5. Effect of light and spacing on number of pods per plant in *Capsicum annum* var. Vasca Corta.

Treatment	L0	L1	Mean
S1	32a	60a	46
S2	42b	74b	58
S3	30a	56a	43
Mean	35	63	49

Treatment means in a column having common letters are not significantly different at least significant difference test. R^2=0.97 CV=7.23

Highest number of pods per plant (63) was recorded by artificial lighting while natural lighting recorded the lowest (35). Medium density planting has also given higher number of pods per plant (58) with compared to high density planting (46) and low density planting (43) (Table 5). The results showed that plants grown under artificial light with medium density gave significantly higher number of pods per plant.

Table 6. Effect of light and spacing on yield of *Capsicum annum* var. Vasca Corta.

Treatment	Yield per plant (g)			Yield per 1000 m^2 (1/4 acre) (kg)			Farmer income (Rs) per 1000 m^2 (1/4 acre) (kg)		
	L0	L1	Mean	L0	L1	Mean	L0	L1	Mean
S1	89.7a	163.8a	126.8	996.7a	1820.0a	1408.4	24917.50	45500.00	35208.75
S2	111.3b	195.1b	153.2	824.4b	1445.1b	1134.8	20610.00	36127.50	28368.75
S3	74.0c	143.8c	108.9	411.1c	798.8c	604.9	10277.50	19970.00	15123.75
Mean	91.7	167.6	129.6	744.0	1354.6	1049.3	18601.67	33865.83	26233.75

Treatment means in a column having common letters are not significantly different at least significant difference test. ***R^2=0.987 CV=5.52***

Further, artificial lighting has significantly increased the number of pods per plant in all treatments.

6. Average Yield

A significant difference was observed in mean yield per plant between two light levels (Table 6). Higher average yield (167.6g) was recorded under artificial lighting region while lower yield (91.7g) was recorded under natural lighting. Significantly higher average yield per pant (153.2g) was also obtained in medium density planting when compared to high density planting (126.8g) and low density planting (108.9g).

It is obvious that the significant yield increment under artificial lighting was not due to the vegetative growth of the plant (number of branches and plant height) or the pod weight at the harvest but due to the higher number of pods harvested under artificial light treatment. Increased light intensity (duration provided 12 hours) and high temperature could be the possible causes for this yield increase. Further, it is evident that the closer spacing (S1) gave significantly highest yield per 1000 m^2 under both light levels (L0-996.7 kg and L1-1820.0 kg). Though the number of pods per plant in S1 is lesser than S2 (Table 5), the yield per unit area was high in S1 than S2.

CONCLUSIONS

The study reveals that the artificial light with high and medium density planting would significantly increase the yield of, Spanish pepper, *Capsicum annum* L., variety Vasca Corta. Even though day length, light intensity and temperature differed among the treatments, the vegetative growth of the plants did not differ. However, number of pods significantly varied. Since this experiment showed a positive effect of artificial lighting and high and medium density planting on number of pods per plant and average yield of the variety Vasca Corta, it can be concluded that provision of artificial light for 12 hours and high density planting (30x30 cm) could significantly enhance the crop yield over other treatments. Therefore, it is recommended that these methods be tested in farmer fields for their adaptability and acceptance. It is also important to provide farmers with low cost technology with minimum inputs for sustainability of the crop.

ACKNOWLEDGEMENTS

The authors wish to thank the Sunfrost Ltd. for the valuable assistance given by in conducting this experiment. Sincere thanks are also due to Dr. B. Ranaweera, Head, Department of Horticulture and Landscape Gardening, for his advice and encouragement, Mrs. N.R. Abeynayake and Mr. K.H.M.I. Karunarathna, for assistng in statistical analysis. The help given by Mr. R.M.A. Padmasiri, Technical Officer, Mr. R.M. Sarathchandra, and other staff members of the Department of Horticulture and Landscape Gardening is greatly appreciated.

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