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Effect of Colour of Greenhouse Cover on Sweet Pepper (*Capsicum annum* L.) Growth and Production

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THE CURRENT studies were conducted at Dokki Protected Cultivation site, Giza Governorate, during 1997-1998 and 1998-1999 seasons in order to investigate the growth and production of sweet pepper (*Capsicum annuum* cv. Gedeon F_1 hybrid) under plastic cover of different colours. Seeds were sown on July 16th, 1997 & July 10th, 1998 and seedlings were transplanted on first of September 1997 & 1998, respectively. Four greenhouse cover colour treatments, *i.e.* red, blue, violet and yellow-green (normal) as control were applied. Significant differences among different treatments were observed. Light intensity under control treatment was higher than red followed by the blue and violet colour. Maximum and minimum air temperature, relative humidity, soil temperature, number of branches, number of leaves, internode diameter, total fresh and dry weight, total carbohydrates in leaves, vitamin C, percentage of the total soluble solids, total acidity and total carbohydrates contents in fruit, early and total fruit weight, under red treatment were higher than the other treatments, followed by the control, blue and violet colour. The highest plant height, internode length, total leaf area, total chlorophyll content in leaves were obsearved by the violet treatment compared to the other. The red treatment had the lowest plant height. Data had the same trend during the two experimental seasons.

Plastics greenhouse growing has increased dramatically changing the horticultural industry in many countries. Among the plastic sheets, more attention is given to different kinds of polyethylene films, because they have low cost and can be manufactured in a wide range of thickness, width, colour and quality.

Research to improve the quality of different kinds of greenhouse covering is conducted to improve the plastic films with better light and heat transmission characteristics (Hanras, 1970). Many scientists hypothesized that photosynthetic rate of plants would generally follow the intercepted light of the primary photosynthetic pigments. Many results indicated that under blue and red light photosynthesis theorized the group under white light, followed by blue, green, orange, yellow, violet, purple and green then ultraviolet. Effect of phytochromes unrelated to photosynthesis may have significantly benefited or been detrimental to the health of plants under certain wavelengths. All plants show a peak of light use in the red region, approximately 650 nm and a smaller peak in the blue region at approximately 450 nm (Salisbury and Ross, 1978 and Aldrich & Bartok, 1989). Abou-Hadid *et al.* (1988) found that there was a positive correlation between air temperature under plastic house and soil temperature. Results showed that the lowest soil temperature occurred during the period between January and March but it was lower than minimum soil thermal levels for peppers (15°C) in case of using either common plastic colour or red plastic film. On the other hand, through the same period, soil temperature recorded values less than the minimum soil temperature that pepper required when violet or blue plastic were used. Guariento & Ravelli (1978) and Medany *et al.* (1991) reported that minimum soil temperature should be maintained up to 15°C. Total plant mass and leaf area were optional at 20-22°C mean temperature, and declined outside this range (Bakker & Van Uffelen, 1988). Mansito & Caballero (1986) reported that soil temperature was affected by radiation intercepted by plastic cover. The growth rate of vegetable crops are proportionaly related to the light, except at very low light intensities (Challa & Schapendonk, 1984). Any loss of light at levels less than saturation resulted in a reduction in productivity. A linear relationship has been reported between the reduction in cumulative light and the decrease in final yield (Cockshull, 1988 and Castilla, 1991). Milivojevic & Tyszkiewicz (1992) mentioned that the most pronounced differences of the chlorophyll (Chl) a:b and Chl a: carotenoid ratios occurred in red and blue light. Red caused the greatest accumulation of Chl b and the greatest accumulation of Chl a:b proteins of the LHC-2 complex. The proportion of the photo systems 2 and 1 (PS2:PS1) Chl a protein core was lower in all light qualities than under the white of the same irradiance. The examined light qualities were favorable for the excitation of PS2. The Chl a:b ratio in chloroplasts that grown under blue, green or yellow treatments did not follow the level of LHC-2 proteins. There were number of processes which are affected by the quality of the light (blue light), these include phototropism, heliotropism, opening of stomata and assimilation of carbon dioxide (Brits & Sager, 1990 and Drozdova *et al.*, 1987). Violet colour of polyethylene sheets reduced the yield of most vegetables in green house. Generally, polyethylene infrared film positively influenced the yield (Grafiadellis, 1985). The low yield probably occurs under low radiation levels (Dayan *et al.*, 1986). Reducing sugar and starch concentrations were highest in plants irradiated with red light (Miura & Iwata, 1985). There were some indications that a large change in total solar radiation (under different colours of plastic sheets) induced a change in proportional dry matter distribution to the fruits (Marcelis *et al.*, 1994). Since light intensity can affect the temperature, variable effects can be expected from light depending upon the concurrent temperature. Carbohydrate content accumulates at low temperature but is rapidly dissipated at high temperatures, because high temperature accelerates respiration (Jones *et al.*, 1991). Rylski & Spigelman (1986) reported that irradiance levels averaged 28 MJ/m^2/day during the summer growing season, compared to 0.7-1.54 MJ/m^2 / day typical of glasshouses growing peppers in Holland in winter.

This study was conducted to test the hypothesis said that the plants grown under blue and red light will grow the fastest, largest and healthiest than other plants.

Material and Methods

The current studies were conducted at Dokki Protected Cultivation site, Giza Governorate, during 1997-1998 and 1998-1999 seasons in order to investigate the growth and production of sweet pepper (*Capsicum annuum* L. *cv.* Gedeon F_1 hybrid) under different plastic cover colours.

Treatments

Four greenhouse cover colour treatments, *i.e.* red, blue, violet and yellow-green (normal) as control were applied.

Plant material

Seeds of sweet pepper cv. Godeon F_1 hybrid were sown on August 16^{th}, 1997 and August 10^{th}, 1998. Seedlings were transplanted on September 1997 and 1998, respectively. Each plastic house was divided into five raised beds of 1m width, 0.6m space in between. Each bed was planted with double rows along the bed with 30cm between rows and 50cm between plants within each row. Irrigation, fertilization and other agriculture practices were carried out as commonly followed under greehouse conditions according to Anonymous (1996).

Measurements

Environmental measurements

Light intensity was measured in each plastic house daily at mid-day by portable Lux-meter (Model FMC- 10M) on 1m height. Maximum and minimum air temperature and relative humidity were recorded continuously by using a standard thermo-hygrograph in the middle part of each of the four plastic houses. The thermo-hygrographs were calibrated for four days against mercury thermometer and a reference hygrometer before the start of each season. Record sheets were used for daily readings and changed weekly. Soil temperature was measured daily at mid-day by using a soil thermometer at 20cm depth.

Plant growth parameters

Five plants were randomly selected from each of the three replicates to be used for all growth parameters. Plant height from cotyledons level to the terminal bud was measured by cm. Data were recorded monthly after 30 days from transplanting till the end of the season.

The first internode length and diameter after the branches were measured monthly after 30 days from transplanting date till the end of the season, using digital caliper with the sensitivity of $\pm$ 0.01mm . Number of branches and average number of leaves were counted monthly after 30 days from transplanting date till the end of the season. The fifth single leaf area from the top of the plant and total leaf area were destructively measured monthly after 30 days from transplanting date till the end of the season. LI-3000 portable area meter (Standard technique No. 5) was used. The total fresh and dry weights of the whole plant was determined in g/plant. Plants was air dried and then put into the oven at 105°C for 10hr. Data were recorded monthly after 30 days from transplanting date till the end of the season. Total fruit weight per plant was determined for each harvest. Early yield was estimated for the harvested period till Jan.15th for each season. Total yield for each replicate was divided by the number of plants in order to estimate average yield per plant.

Chemical characteristics

Total chlorophyll was measured monthly after 30 days from transplanting date till the end of the season, using Minolta Chlorophyll Meter SPAD-501. The fifth leaf from the top was randomly selected to be measured from three plants in each of the three replicates. Total carbohydrates were measured three times per season after 90, 150 and 245 days from transplanting date (Shaffer & Hartmann, 1921).

Experimental design

Complete randomize blocks of four treatments (each treatment consists of one greenhouse and 3 replicates) were used. Plant growth parameters were measured on five plants in each replicate and the average per plant was calculated.

Statistical analysis

Data analysis were made by an IBM computer, using Excel program for statistical analysis according to Snedecor & Cochran (1971). The LSD among means for all traits were tested for significance at 5% level.

Results and Discussion

Light intensity

Data presented in Table 1 show the average light intensity at noon under different plastic houses treatments through 1997-1998 and 1998-1999 seasons. Light intensity under the control treatment was higher than red followed by the blue and violet colours. The light intensity was decreased by 39% when violet plastic was employed compared to the common yellow greenish plastic (control). Meanwhile, the reduction of light intensity reached 34% in case of using blue plastic, however the decrease was 12% only in case of using the red plastic compared to the control. Data of the second season had the same trend as the first season. The influence of light on the productivity of pepper differs depending on whether one is considering a plastic house –crop during the low light conditions or a field of pepper growing in full sun (Demers *et al.*, 1991). Light penetrates transparent glass or plastic and the spectral distribution of light will differ with the colour of the transparent material (Mortensen & Stromme, 1987).

Air temperature

Data in Table 2 show maximum and minimum air temperature in all treatments during the two successive seasons. Maximum air temperature exposed to violet plastic decreased by 2.12°C, while the minimum air temperature decreased in average by 1.8°C; meanwhile the air temperature under the blue plastic cover decreased one degree in maximum and 0.95°C in the minimum. However, data indicated that maximum and minimum air temperatures were increased in case of using red plastic by 1.35°C and 1.15°C, respectively. The same trend of maximum and minimum temperatures under different types of plastic colours were obtained in the second season. On the other hand, data in Table 1 shows that violet plastic gave the lowest light intensity followed by lowest maximum and minimum temperatures, followed by blue and red colour compared to control. These results agree with Zabeltitz (1986) who demonstrated that transmission of rays affected the heat requirement of plastic house, and the development of the plant.

TABLE 1. Monthly average of light intensity (Lux) at noon under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments			
	Red cover	Blue cover	Violet cover	Control cover
	First season			
30	26800	21100	20000	27300
60	23220	16900	15200	25300
90	11150	9500	9000	14750
120	10000	8000	7100	12250
150	9000	7200	6390	11030
180	9250	7300	6500	10750
210	11000	8800	7810	13480
240	36190	22500	21000	37560
270	38390	25850	24100	39770
Second season				
30	32160	25320	24000	32760
60	27860	20280	18240	30360
90	13380	10800	11400	17700
120	12000	9600	8520	14700
150	10800	8640	7661	13230
180	11100	8760	7800	12900
210	13200	10560	9370	16170
240	43420	27000	25200	45070
270	46061	31020	28920	47720

Relative humidity (RH)

Data presented in Table 3 show monthly average of maximum and minimum RH under different treatments. Blue plastic house had lower RH percentage by 1.5% in maximum RH and 2% in minimum RH compared to the control. On the other hand, the red treatment had the highest RH, where it increased by 1% in maximum and 2% in minimum than RH in the control treatment. Data presented show that the maximum and minimum RH were between 25-95% under the control plastic house throughout the season, while maximum and minimum RH decreased especially during March and April, which was less than 20% in minimum under all treatments, however the maximum RH ranged between 80-90%.These results could be attributed to the effect of plastic colour on the increasing of maximum and minimum temperature in different types of covering material which indirectly affected the vegetative growth. Humidity is strongly influenced by outside humidity and temperature. These results were in agreement with Abou-Hadid *et al.* (1988) who mentioned that RH increases under the plastic houses, not only because of the plastic cover but also due to vegetative mass of the grown plants under the plastic house.

TABLE 2. Monthly average of maximum and minimum air temperature under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments							
	Red cover		Blue cover		Violet cover		Control cover	
	Max	Min	Max	Min	Max	Min	Max	Min
	First season							
30	42.53	21.40	40.76	19.50	39.76	18.40	41.91	20.70
60	38.81	18.94	36.52	16.45	35.77	15.90	37.00	17.45
90	30.53	15.37	28.93	13.37	27.10	12.47	29.57	14.37
120	25.95	11.24	23.00	8.57	22.67	8.00	24.00	9.53
150	23.35	10.11	20.70	7.71	20.40	7.20	21.60	8.58
180	30.48	9.90	27.90	8.13	26.10	7.24	29.50	8.81
210	33.86	10.00	31.00	9.30	29.00	8.05	32.52	9.79
240	40.50	18.20	38.30	15.70	37.00	14.40	39.00	17.10
270	43.20	22.61	41.10	20.11	40.20	19.20	42.00	21.10
Second season								
30	43.38	21.80	41.58	19.90	40.56	18.74	42.75	21.06
60	39.58	19.31	37.25	16.80	36.49	16.22	37.74	17.80
90	31.14	15.70	29.51	13.60	27.64	12.70	30.16	14.70
120	26.46	11.50	23.46	8.70	23.12	8.20	24.48	9.70
150	23.81	10.31	21.11	7.90	20.80	7.30	22.03	8.80
180	31.08	10.10	28.45	8.30	26.62	7.40	30.09	9.00
210	34.54	10.20	31.62	9.20	29.58	8.20	33.16	10.00
240	41.31	18.60	39.07	16.00	37.74	14.70	39.78	17.41
270	44.06	23.10	41.92	20.50	41.00	19.60	42.84	21.5

TABLE 3. Monthly average of maximum and minimum RH% under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments							
	Red cover		Blue cover		Violet cover		Control cover	
	Max	Min	Max	Min	Max	Min	Max	Min
	First season							
30	96.9	34.4	94.56	27.5	92.3	25.2	95.00	30.71
60	96.32	38.45	92.45	34.81	90.58	32.23	94.48	36.84
90	95.67	46.63	92.73	42.73	91.37	40.17	93.70	44.40
120	94.62	45.25	91.76	41.52	90.81	40.19	93.72	42.87
150	85.16	40.73	82.59	37.37	81.73	36.17	84.35	38.58
180	82.84	20.90	81.68	19.19	80.40	16.90	82.68	25.05
210	92.05	23.23	90.76	21.32	89.33	18.77	91.86	27.28
240	94.37	29.63	91.10	25.63	90.96	22.93	92.97	27.67
270	96.10	45.35	92.61	41.03	90.20	40.75	94.90	43.74
Second season								
30	97.8	34.7	95.5	27.7	93.2	25.4	96.0	31.0
60	97.29	38.84	93.38	35.15	91.49	32.55	95.43	37.21
90	96.62	47.10	93.66	43.16	92.28	40.57	94.64	44.84
120	95.57	45.70	92.68	41.94	91.72	40.59	94.66	43.30
150	86.01	41.13	83.41	37.75	82.55	36.53	85.20	38.97
180	83.67	21.11	82.50	19.38	81.20	17.06	83.50	25.25
210	92.97	23.46	91.67	21.53	90.23	18.96	92.78	27.50
240	95.31	29.93	92.01	25.89	91.87	23.16	93.90	27.94
270	97.06	45.81	93.54	41.44	91.10	41.16	95.85	44.18

Soil temperature

Data presented in Table 4 show monthly average of soil temperature under different treatments during the two successive seasons. It was clear evidence that average of soil temperature influenced by air temperature under the different types of plastic houses and the average of soil temperature varied according to the type of plastic colour. Soil temperature decreased in case of violet and blue film by 2.4°C and 0.9°C, respectively, while soil temperature increased by 1.4°C in case of red cover. These results were in agreement with Guariento & Ravelli (1978); Abou-Hadid *et al.* (1988) and Medany *et al.* (1991). They reported that monthly average of soil temperature shows that using red plastic cover treatment recorded the highest value followed by the control, blue and last by the violet. Data had the same trend during the two experimental seasons.

TABLE 4. Monthly average of soil temperature (°C) under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments			
	Red cover	Blue cover	Violet cover	Control cover
First season				
30	28.0	25.0	23.0	26.0
60	27.7	24.6	22.3	25.6
90	25.0	23.0	21.5	24.0
120	20.0	18.4	17.2	19.2
150	16.0	14.7	13.8	15.4
180	19.2	17.7	16.5	18.4
210	23.0	21.2	19.8	22.1
240	25.0	22.0	21.0	23.0
270	29.7	26.6	24.3	27.6
Second season				
30	28.6	25.5	23.5	26.5
60	28.3	25.1	22.7	26.1
90	25.5	23.5	21.9	24.5
120	20.4	18.8	17.5	19.6
150	16.3	15.0	14.0	15.7
180	19.6	18.0	16.8	18.8
210	23.5	21.6	20.2	22.6
240	25.5	22.4	21.4	23.5
270	30.3	27.1	24.8	28.2

Plant height and internode length

Plant height was the first vegetative growth parameters that have been examined. Data presented in Table 5 show that violet treatment had the highest significant plant height which had increased by 20% compared to control plants followed by the blue which was greater than control plants by 11%. However, the plants under red treatment had the lowest plant height values and decreased by 6% compared to control plants. Results of the second seasons had similar trend of the first season. These results were in agreement with Fjeld *et al.* (1993) who indicated that the red light significantly reduced plant height compared with white light whereas blue light significantly increased plant height.

TABLE 5 . Plant height (cm) under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
	First season				
30	32.17	39.20	42.00	35.17	1.67
60	60.83	71.00	74.00	63.00	2.74
90	74.00	82.50	87.83	78.83	3.23
120	78.50	88.50	92.30	83.40	3.60
150	82.67	91.97	100.33	87.23	4.37
180	83.20	100.10	110.10	92.30	4.20
210	91.07	109.93	119.10	98.00	4.41
240	110.20	133.80	148.90	120.60	4.03
270	140.50	165.40	178.40	148.90	4.00
Second season					
30	35.38	43.12	46.20	38.68	1.84
60	66.92	78.10	81.40	69.30	3.01
90	81.40	90.75	96.62	86.72	3.56
120	86.35	97.35	101.53	91.74	3.96
150	90.93	101.16	110.37	95.96	4.80
180	91.52	110.11	121.11	101.53	4.62
210	100.17	120.93	131.01	107.80	4.85
240	121.03	145.74	151.39	130.82	4.44
270	145.20	170.61	183.22	158.91	4.40

Table 6 shows that there were significant differences between the internode lengths in different treatments. The violet treatment caused an increase in the internode length by 5cm in average compared to control plants, while the blue treatment increased internode length by 3cm compared to the control. On the other hand, the red treatment supersedes the internode length by 47.1% compared to control and this happened along both seasons.

TABLE 6. Internode length (cm) under different plastic colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
	First Season				
30	3.33	7.64	9.16	2.76	2.12
60	3.64	9.31	11.07	5.86	2.12
90	3.90	10.33	12.20	7.43	2.12
120	4.12	10.95	12.87	8.23	2.13
150	4.30	11.33	13.27	8.63	2.14
180	4.45	11.56	13.50	8.84	2.16
210	4.58	11.70	13.64	8.94	2.18
240	4.68	11.79	13.72	8.99	2.19
270	4.77	11.84	13.77	9.02	2.20
Second Season					
30	3.99	9.16	10.99	2.50	2.55
60	4.37	11.17	13.28	6.84	2.55
90	4.68	12.40	14.64	8.92	2.55
120	4.94	13.15	15.44	9.92	2.56
150	5.16	13.60	15.92	10.40	2.57
180	5.34	13.88	16.20	10.63	2.59
210	5.49	14.04	16.37	10.74	2.61
240	5.62	14.15	16.47	10.79	2.63
270	5.73	14.21	16.53	10.82	2.65

Internode diameter

Table 7 shows the internode diameter under the different colour treatments. The red colour gave the larger significant internode diameter compared to the control, while violet treatment decreased the internode diameter, followed by blue treatment during the two experimental seasons. This was due to high temperature noticed and light quality transmission. These results were in agreement with Vanderhoef *et al.* (1979).

TABLE 7. Internode diameter (mm) under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First Season					
30	8.87	5.46	4.60	6.73	0.88
60	9.11	5.79	4.94	6.91	0.90
90	9.43	6.20	5.33	7.17	0.96
120	9.88	6.69	5.78	7.56	1.05
150	10.50	7.27	6.30	8.13	1.17
180	11.36	7.97	6.90	8.98	1.29
210	12.55	8.81	7.59	10.23	1.40
240	14.20	9.81	8.39	12.08	1.49
270	16.48	11.02	9.30	14.83	1.56
Second Season					
30	11.13	7.14	5.99	8.56	1.16
60	11.67	7.55	6.43	8.89	1.18
90	12.26	8.06	6.93	9.32	1.25
120	12.92	8.68	7.52	9.86	1.37
150	13.65	9.45	8.19	10.57	1.52
180	14.45	10.38	8.97	11.49	1.68
210	15.34	11.53	9.87	12.67	1.82
240	16.33	12.94	10.91	14.20	1.93
270	17.41	14.66	12.10	16.18	2.02

Number of branches

The number of branches is shown in Table 8 which reveals that there were no significant differences between red, blue and control treatments. However, the violet treatment reduced significantly number of branches compared to the control plants. The same trend was observed in both experimental seasons.

TABLE 8. Number of branches (per plant) under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First season					
30	4.87	2.90	2.47	4.23	0.59
60	13.07	10.57	9.50	11.67	2.48
90	15.97	12.83	11.40	14.70	1.85
120	17.00	14.10	12.10	15.20	1.86
150	18.03	14.97	13.50	16.20	1.89
180	20.10	16.50	15.00	18.10	2.50
210	23.37	18.17	15.83	21.07	3.03
240	26.23	22.50	18.93	24.00	4.01
270	28.50	24.50	20.20	26.20	5.00
Second Season					
30	[illegible]	3.19	2.71	4.66	0.64
60	14.37	11.62	10.45	12.83	2.73
90	17.56	14.12	12.54	16.17	2.04
120	18.20	15.60	13.30	17.00	2.36
150	19.84	16.46	14.85	17.82	2.08
180	22.50	18.50	16.00	20.40	3.00
210	25.70	19.98	17.42	23.17	3.34
240	28.86	24.75	20.83	26.40	4.42
270	30.40	26.50	22.40	28.70	5.00

Number of leaves

Table 9 shows the number of leaves per plant under the different plastic cover colours during both seasons. The red colour caused an increas in number of leaves as compared with control (23 leaves) while the violet and blue treatments reduced the number of leaves by 85 and 70 leaves, respectively, as compared with the control during 1997-1998 and 1998-1999 seasons.

TABLE 9. Number of leaves per plant under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First season					
30	28.43	21.53	20.33	25.23	3.61
60	82.03	65.37	62.00	73.57	4.77
90	160.57	128.80	119.07	147.83	5.65
120	180.10	150.20	135.00	170.40	5.70
150	198.50	169.17	153.33	187.67	5.75
180	260.30	210.50	195.48	242.33	6.31
210	323.93	250.70	237.63	297.00	6.87
240	405.33	312.70	298.90	382.63	8.30
270	409.39	315.83	301.89	386.46	8.38
Second season					
30	31.28	23.69	22.37	27.76	3.97
60	90.24	71.90	68.20	80.92	5.25
90	176.62	141.68	130.97	162.62	6.22
120	198.11	165.22	148.50	187.44	6.27
150	218.35	186.08	168.67	206.43	6.32
180	280.50	231.55	215.03	266.57	6.94
210	356.33	275.77	261.40	326.70	7.56
240	445.87	343.97	328.79	420.90	9.12
270	450.33	347.41	332.08	425.11	9.22

Single and total leaf area

Data in Table 10 reveal that violet colour treatment had the highest significant single leaf area by an increase of 85% compared to the control, followed by the blue treatment that increased the area by 15% compared to the control. This may be attributed to less temperature, which influenced the degree of stomatal closer. Penuelas *et al.* (1992) and Stanghellini (1994) mentioned that related to the higher efficiency of water use might be a reason on its own for the rapidly expanding leaf area of protected cultivations. On the other hand, the red treatment reduced the single leaf area sharply by 30% compared to the control. The same trend along with the two experimental seasons was found. Table 11 illustrates the total leaf area (cm^2/plant). It was found that violet and blue increased the total leaf area by 9% and 4.3%, respectively, while the red increased total leave area by 5.3% compared to the control.

TABLE 10. Single leaf area (5^{th} leaf) cm^2 under different polyethylene colour treatments during two growing seasons of 97-98 and 98–99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First season					
30	30.00	49.10	80.70	42.00	2.03
60	31.00	50.20	81.00	43.10	3.62
90	29.00	49.00	80.00	40.00	4.68
120	26.00	48.00	79.00	38.10	5.38
150	25.00	46.80	74.70	37.30	5.85
180	30.32	49.27	78.65	41.60	6.16
210	31.33	50.91	81.27	44.06	6.36
240	32.00	52.00	83.00	45.00	6.50
270	32.44	52.72	84.15	45.62	6.59
Second season					
30	30.90	50.57	83.12	43.26	6.40
60	31.93	51.71	83.43	44.39	6.30
90	29.87	50.47	82.40	41.20	5.62
120	26.78	49.44	81.37	39.24	6.46
150	25.75	48.20	76.94	38.42	7.02
180	31.23	50.75	81.01	42.85	7.39
210	32.27	52.44	83.70	45.38	7.64
240	32.96	53.56	85.49	46.35	7.80
270	33.42	54.30	86.67	46.99	7.91

TABLE 11. Total leaf area (cm^2/plant) under different polyethylene colour treatments during two growing seasons of 97-98 and 98–99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First season					
30	5563.57	6135.70	6415.57	5878.6	74.320
60	9979.02	11005.21	11507.18	10544.1	133.335
90	12906.00	14233.20	14882.40	13636.8	172.453
120	14846.29	16373.02	17119.82	15687.0	198.383
150	16132.50	17791.50	18603.00	17046.0	215.570
180	16985.13	18731.81	19586.20	17946.9	226.963
210	17550.33	19355.13	20237.95	18544.1	234.514
240	17925.00	19768.33	20670.00	18940.0	239.520
270	18173.37	20042.24	20956.40	19202.4	242.838
Second season					
30	6676.29	7362.85	7698.68	7054.332	89.1816
60	11974.82	13206.26	13808.62	12652.892	159.9987
90	15487.20	17079.84	17858.88	16364.160	206.9400
120	17815.55	19647.62	20543.78	18824.348	238.0552
150	19359.00	21349.80	22323.60	20455.200	258.6800
180	20382.15	22478.17	23503.43	21536.287	272.3512
210	21060.39	23226.16	24285.54	22252.936	281.4132
240	21510.00	23722.00	24804.00	22728.000	287.4200
270	21808.04	24050.69	25147.68	23042.919	291.4016

Total fresh and dry weight

Regarding the total fresh weight per plant (g/plant), Table 12 shows that red plastic cover treatment had the highest significant fresh weight per plant, followed by control treatment, then blue and finally the violet treatment. These results fit also the second experimental season.

Dry weight per plant had the same result trend as the fresh weight along with the two experimental seasons as shown in Table 13.

TABLE 12. Total fresh weight (g/plant) under different polyethylene colour treatments during two growing seasons of 97-98 and 98 –99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
	First season				
30	383.72	327.76	317.30	354.24	1.73
60	688.28	587.89	569.14	635.39	3.13
90	890.16	760.32	736.08	821.76	4.06
120	1023.99	874.63	846.74	945.30	4.67
150	1112.70	950.40	920.10	1027.20	5.07
180	1171.51	1000.63	968.73	1081.49	5.34
210	1210.49	1033.93	1000.96	1117.47	5.51
240	1236.33	1056.00	1022.33	1141.33	5.63
270	1253.46	1070.63	1036.49	1157.14	5.71
Second season					
30	460.47	393.29	380.80	425.09	2.14
60	825.93	705.45	682.98	762.46	3.78
90	1068.19	912.38	883.30	986.11	4.87
120	1228.78	1049.55	1016.09	1134.36	5.60
150	1335.24	1140.48	1104.12	1232.64	6.08
180	1405.81	1200.76	1162.47	1297.79	6.40
210	1452.59	1240.71	1201.16	1340.97	6.62
240	1483.60	1267.20	1226.80	1369.60	6.76
270	1504.16	1284.76	1243.80	1388.58	6.86

TABLE 13. Total dry weight (g/plant) under different polyethylene colour treatments during two growing seasons of 97-98 and 98–99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
First season					
30	79.86	66.11	63.10	75.51	1.42
60	143.26	118.58	113.19	135.46	2.56
90	185.28	153.36	146.40	175.20	3.31
120	213.14	176.42	168.41	201.54	3.81
150	231.60	191.70	183.00	219.00	4.14
180	243.84	201.83	192.67	230.57	4.36
210	251.95	208.55	199.08	238.24	4.50
240	257.33	213.00	203.33	243.33	4.60
270	260.89	215.95	206.15	246.70	4.66
Second season					
30	95.87	79.32	75.73	90.63	1.67
60	171.92	142.29	135.84	162.56	3.06
90	222.34	184.03	175.68	210.24	3.97
120	255.76	211.70	202.09	241.85	4.57
150	277.92	230.04	219.60	262.80	4.97
180	292.61	242.20	231.21	276.69	5.23
210	302.35	250.26	238.90	285.90	5.41
240	308.80	255.60	244.00	292.00	5.52
270	313.08	259.14	247.38	296.05	5.60

From the previous results, it was noticed that the increasing of shoot length, internode length, decreasing number of branches and number of leaves may be due to the reduction in light intensity, maximum and minimum air temperature and RH%, which occurred when violet and blue plastic sheet are employed.

These results were in agreement with Smith (1982) and Muir & Zhu (1983) who observed that shoot elongation, lateral branching and internode growth are most probably related to changing in the concentration of plant hormones, which are affected by light quality.

The low plant dry weight under violet and blue plastic could be attributed to reducing number of leaves and thus reduced carbon assimilation. This might be of particular importance in the first phase of plant growth until self-shading between plants took place.

Since the photosynthesis of plants mainly depends on the number of photons in the range of 400-700nm and not on light quality, the effect of light quality mainly could be attributed to plant morphogenesis. The differences in dry weight between the light qualities were relatively small. For greenhouse production, the most interesting effect of light quality seems to be the effect on stem elongation and lateral branching. Compact plants with many shoots are important in the production of pot plants (Mortensen & Stromme, 1987).

The response of stem elongation for increasing irradiance with constant light quality was not understood. It is known that the reduction in stem elongation to irradiance is proportional to the logarithm of irradiance. Such a simplistic response could arise if the concentration of a single component, directly proportional to pigment transformation, determined the rate of some subsequent first order reaction. Phytochrome could be that factor and be associated with irradiance-inhibition of stem elongation through effects on phytochrome cycling rate (Johnson & Tasker, 1979; Bartley & Frankland, 1982 and Fukshansky & Schafer, 1983). Our results agreed with McMahon *et al.* (1991) who reported that increasing of the red:far-red ratio reduced plant height and inter node length and increased chlorophyll content of *Dendranthema X grandiflorum* (Ramat.) Kitamura compared with controls for all plants.

The effect of blue light on the morphogenesis of *Phusolus vulgaris* cv. Prelude was examined. At constant photosynthetic photon flux decreasing amounts of blue light stimulated internode elongation and increased dry weight partitioning into internodes, mainly at the expense of leaf growth (Maas and Bakx, 1995).

Gaba & Black (1979) and Von Arnim & Deng (1996) reported that the plant stem elongation increases as P_{Fr}/P_R (Phytochrome far-red/ Phytochrome red) decreases, and as the intensity of blue and UV-light decrease.

On the other hand, our data illustrate that the red colour plastic affects negatively plant height, length of internode by 50%, leaf area and increase fresh weight and dry weight. These results were in agreement with many investigators who reported that the growth of many plant spieces can be altered by manipulating the amount of R relative to FR irradiance without altering the amount of photosynthetic photon flux (PPF) (Mortensen & Stromme, 1987). Red irradiation has been reported to inhibit stem elongation of maize (*Zea mays* L.) seedlings (Vanderhoef *et al.*, 1979) and pea (*Pisum sativum* L.) (Noguchi & Hashimoto, 1990), promote lateral shoot growth of tomato (*Lycopersicon esculentum* Mill. cv. Amberley Cross) (Tucker, 1975), prevent dark-induced leaf abscission on mung bean (*Vigna radiata* L. Wilczek) (Decoteau & Craker, 1984) and increase the number of tillers in perennial rye grass (*Lolium perenne* L.) (Deregibus *et al*., 1983). The effects of FR irradiation have been shown to be the opposite of the effects of R irradiation (Smith, 1982).

The effect of blue light on the morphogenesis of *P. vulgaris* cv. Prelude was examined. At constant photosynthetic photon flux decreasing amounts of blue light stimulated internode elongation and increased dry weight partitioning into internodes, mainly at the expense of leaf growth (Maas & Bakx,1995).

Chlorophyll content

Concerning the total chlorophyll percentage in leaves, the violet cover treatment got the highest percentages followed by the blue and finally the red which gave the lowest value compared to the control treatment along the two seasons. The differences among the treatments were significant as shown in Table 14.

The highest chlorophyll pigment content in leaves was observed in the period between mid of January until mid of March. This period was distinguished by low light intensity and minimum and maximum temperature. Similar results obtained by Xu-KZ (1987) who studied the effects of light quality on the morphology, chlorophyll content and leaf structure of ginseng. Growth was inhibited in blue and violet light, excessive in red and green light and normal in yellow and white light. Leaf chlorophyll contents were the highest under blue and violet light and the lowest was under the red and yellow light; chlorophyll a:b ratios were the lowest in blue and violet light. They found that leaves were thickens under yellow, blue, violet and white light, respectively. Also smaller leaf mesophyll cells developed in blue and violet light. There were fewest mesophyll cells in red, white and finally the green light.

Milivojevic & Tyszkiewicz, (1992) mentioned that the most pronounced differences of the chlorophyll (Chl) a:b and Chl a: carotenoid ratios occurred in red and blue light caused the greatest accumulation of Chl b and the greatest accumulation of Chl a:b proteins of the LHC-2 complex. The proportion of the photo systems 2 and 1 (PS2:PS1) Chl a protein core was lower in all light qualities than under the white of the same irradiance. The examined light qualities were favorable for the excitation of PS2. The Chl a:b ratio in chloroplasts that grown under blue, green or yellow treatments did not follow the level of LHC-2 proteins.

TABLE 14. Total chlorophyll content in leaves (%) under different polyethylene colour treatments during two growing seasons of 97-98 and 98 –99.

Days after transplanting	Treatments				
	Red cover	Blue cover	Violet cover	Control cover	L.S.D (0.05)
	First Season				
30	64.55	70.00	75.83	59.49	0.53
60	64.15	70.20	75.23	59.29	0.53
90	64.85	70.30	75.28	59.89	0.62
120	67.88	73.85	78.26	62.10	0.62
150	66.67	72.88	77.55	61.11	0.67
180	65.69	72.28	76.54	60.11	0.70
210	64.59	71.88	75.14	59.11	0.73
240	64.00	71.20	75.00	59.00	0.74
270	64.85	70.12	75.28	59.39	0.62
	Second Season				
30	65.20	70.70	76.59	60.08	0.28
60	64.80	70.90	75.98	59.88	0.50
90	65.50	71.00	76.03	60.49	0.64
120	68.56	74.59	79.04	62.72	0.74
150	67.34	73.61	78.33	61.72	0.80
180	66.35	73.00	77.31	60.71	0.84
210	65.24	72.60	75.89	59.70	0.87
240	64.64	71.91	75.75	59.59	0.89
270	65.50	70.82	76.03	59.98	0.90

Carbohydrates content

It is noticed from Table 15 that the red treatment had the highest value of the total carbohydrates in the leaves followed by the blue colour with a significant difference. Negative response of violet on the accumulation of carbohydrates or the effect of violet wavelength on rate of photosynthesis compared to control. These results were in the same trend with the second season. Similar results obtained by Barro *et al.* (1989), they studied the effect of light quality on growth, contents of carbohydrates and they found that red light stimulated carbohydrate accumulation.

There are number of processes which are affected by the quality of the light (blue light), these include phototropism, heliotropism, opening of stomata and assimilation of carbon dioxide (Brits & Sager, 1990 and Drozdova *et al*., 1987).

TABLE 15. Total carbohydrates content in leaves (%) under different polyethylene colour treatments during two growing seasons of 97-98 and 98–99.

Treatments	Days after transplanting		
	90	150	245
First Season			
Red cover	12.50	9.40	13.67
Blue cover	10.09	8.67	11.43
Violet cover	8.33	6.67	9.26
Control cover	9.42	7.53	10.46
L.S.D (0.05)	0.92	0.738	1.03
Second Season			
Red cover	14.60	11.08	16.00
Blue cover	12.50	9.60	14.11
Violet cover	10.00	8.00	11.11
Control cover	11.30	10.04	12.55
L.S.D (0.05)	1.11	0.89	1.23

Yield

Cumulative yields of pepper fruits under different plastic covers are shown in Table 16. Concerning the early and total fruit weight, the red polyethylene had the highest significant yield followed by the control, then blue and finally the violet treatment. This occurs along the two experimental seasons. This was due to high temperature noticed and light quality transmission.

In bud flowers low light – stressed plants, there was a similar lack of reducing sugars but there was no evidence that inverters activity had been adversely affected (Wien *et al.*, 1989 and Turner & Wien, 1994a,b). Violet colour of polyethylene sheets reduced the yield of almost all vegetables in green house. Generally, polyethylene infrared film positively influenced the yield (Grafiadellis, 1985). The low yield probably occurs under low radiation levels (Dayan *et al.*, 1986). Reducing sugar and starch concentrations were highest in plants irradiated with red light (Miura & Iwata, 1985). There were some indications that a large change in total solar radiation (under different colours plastic sheets) induced a change in proportional dry matter distributed to the fruits. Since light intensity can affect the temperature variable effects can be expected from light depending upon the concurrent temperature(Marcelis *et al.*, 1994).

TABLE 16. Early fruit weight and total fruit weight under different polyethylene colour treatments during two growing seasons of 97-98 and 98-99.

Treatments	Early fruit weight	Total fruit weight
	g/plant	g/plant
	First season	
Red cover	1269.27	4542.03
Blue cover	1234.40	4060.57
Violet cover	1230.83	4044.67
Control cover	1260.70	4355.27
L.S.D (0.05)	2.89	5.28
	Second season	
Red cover	1523.12	5450.44
Blue cover	1481.28	4872.68
Violet cover	1477.00	4853.60
Control cover	1512.84	5226.32
L.S.D (0.05)	3.47	6.34

Chemical characteristics

Vitamin C, percentage of the total soluble solid, total acidity and total carbohydrates contents in fruit, are shown in Table 17. The highest values were obtained in the fruit under the red colour followed by control, blue and then the violet treatments by a significant differences among the treatments during the two experimental seasons. Barro *et al.* (1989) indicated that the red light stimulated carbohydrate accumulation. Carbohydrate content accumulates at low temperature but was rapidly dissipated at high temperatures because high temperature accelerate respiration (Jones *et al.*, 1991).

TABLE 17. Chemical characteristics of fruits recorded under different polyethylene colour treatments during two growing seasons of 97-98 and 98–99.

Treatments	Vitamin C (mg/100g)	TSS (%)	Total acidity (mg/100 cm³)	Total carbohydrates (%)
First Season				
Red cover	69.20	9.50	0.345	18.71
Blue cover	63.03	5.94	0.335	14.44
Violet cover	60.37	3.72	0.331	12.11
Control cover	65.83	7.56	0.340	16.27
L.S.D (0.05)	1.84	1.54	0.008	1.69
Second Season				
Red cover	70.50	10.00	0.396	19.19
Blue cover	65.40	6.40	0.385	15.55
Violet cover	62.30	4.20	0.370	13.24
Control cover	67.50	8.40	0.390	17.41
L.S.D (0.05)	1.94	1.6	0.009	1.80

Conclusion

Light intensity under control treatment was higher than red followed by the blue and violet colour. Maximum and minimum air temperature, relative humidity, soil temperature, number of branches, number of leaves, internode diameter, total fresh and dry weight, total carbohydrates in leaves, vitamin C, percentage of the total soluble solid, total acidity and total carbohydrates contents in fruit, early and total fruit weight, under red treatment were higher than the other treatments, followed by the control, blue and violet colour. Violet treatment has the highest plant height, internode length, total leaf area, total chlorophyll content in leaves, followed by the blue and the control one. The red treatment had the lowest plant height. Data had the same trend during the two experimental seasons. From the obtained data, it might be recomeneded that polyethylene sheet of red and yellow-green (control) colours might be used during winter season, and of blue and vilot colours during summer season.

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تأثير لون الغشاء البلاستيكي للصوبة على نمو وإنتاجية الفلفل الحلو

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أجريت هذه الدراسة لبحث تأثير ألوان البلاستيك المستخدم فى تغطية الصوب على نمو وإنتاج نبات الفلفل الحلو المنزرع تحت الصوب البلاستيكية خلال الفترة من سبتمبر وحتى يونيو خلال موسمي ١٩٩٧-١٩٩٨، ١٩٩٨- ١٩٩٩ فى موقع الدقي للزراعات المحمية .حيث تم دراسة التأثيرات الناتجة عن ألوان البلاستيك الأحمر، والأزرق ، والبنفسجي، والكنترول (أخضر مصفر) على ارتفاع النبات، وطول السلامية، وقطر السلامية، وعدد الأفرع، وعدد الأوراق والمساحة الكلية للأوراق، والوزن الطازج والجاف، والمحتوى الكلي للكلوروفيل، والمحتوى الكلي للكربوهيدرات ، ومجموع المحصول المبكر والكلي، وفيتامين ج ومحتوى المواد الصلبة الذائبة الكلية، ومحتوى الكربوهيدات فى الثمار ،كما تم أيضا دراسة عوامل المناخ تحت معاملات ألوان البلاستيك المختلفة والتعرف عليها مثل درجة الحرارة والرطوبة ودرجة حرارة التربة وشدة الإضاءة . ويمكن تلخيص النتائج المتحصل عليها فيما يلي:-

كانت شدة الإضاءة أعلى تحت لون الكنترول ثم الأحمر ثم الأزرق وأخيراً البنفسجي.

كانت كلاً من درجة حرارة الهواء ، ودرجة حرارة التربة ، والرطوبة النسبية ، وعدد الأفرع، وعدد الأوراق ، وسمك السلامية، والوزن الطازج والجاف ونسبة الكربوهيدرات فى الأوراق والثمار ، وفيتامين ج ، TSS، والحموضة الكلية ، والمحصول المبكر والكلي ، كانت أعلى تحت اللون الأحمر ثم الكنترول ثم الأزرق وأخيراً البنفسجي.

كان كلاً من إرتفاع النبات ، وطول السلامية والمساحة الكلية للأوراق ، والمجموع الكلي للكلوروفيل ، أعلى تحت اللون البنفسجي ثم الأزرق ثم الكنترول وأخيراً الأحمر. وقد كانت النتائج متشابهة فى كل من الموسمين.

من النتائج المتحصل عليها يمكن التوصية باستخدام الصوب البلاستيكية ذات اللون الأحمر والأصفر المخضر (الكنترول) خلال موسم الشتاء ، ويمكن استخدام الصوب البلاستيكة ذات اللون الأزرق والبنفسجي خلال موسم الصيف.