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STUDIES ON PHOTOMORPHOGENESIS IN SOME ECONOMICAL PLANTS
III- REPRODUCTIVE GROWTH AND FRUIT YIELD OF TOMATO AND SWEET PEPPER PLANTS AS AFFECTED BY RED AND FAR-RED LIGHT REFLECTED FROM COLORED PLASTIC MULCHES.

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ABSTRACT

Under field conditions during 2001 & 2002 seasons; with the onset of flowering stage of tomato cv. Super Strain B and sweet pepper cv. Baladi grown above different applied mulch colors; several alterations in their economic characteristics were examined. Earliness of flowering, significant increase of flowers number accompanied with significant reduction in the percentage of flowers abscission and consequently significant increase in fruits number / plant were obtained in both tomato and sweet pepper with all applied mulch colors. The red mulch alone or over black one was more pronounced in this respect. Different applied mulch colors obviously increased the percentage of pollen grains fertility, whereas decreased the percentage of their sterility. Hence, significant increase in early and total fruit yield as well as economical and biological yields were achieved.

Furthermore, fruit quality was improved with those increases in its contents of N, P, K, crude protein, total sugars and carbohydrates, vitamin C, total soluble solids and tetratable acidity as well that obtained with different mulch colors, especially red mulch applied alone or over black one.

The present investigation strongly recommended the use of red color instead of black one for soil mulching cultivation systems for increasing the reflected red and far-red light and their absorption by growing plants. Thus, great alterations in all physiological process within plants through the phytochrome system were occurred and consequently, forcing plants to grow with earliness of flowering and fruiting as well as achievement significant increase of yielded fruits with high quality.

INTRODUCTION

Plastic mulches are widely used to conserve water by blocking evaporation from the soil surface, to control weeds with less herbicides and to keep soil from splashing onto the fruit in the production of tomato and other food crops (Bhella, 1988; Lamont, 1993 and Brown *et al.*, 1996). In this respect,

Kasperbauer (1992) hypothesized that changing mulch color could keep those benefits and reflecting a yield enhancing morphogenic light signal to the growing plants. So, a plant's ability to maximize its photosynthetic productivity depending on its capacity to sense, evaluate and respond to light quality, quantity and direction (Briggs and Olney, 2001).

The photon ratio of FR relative to R sets the photoequilibrum between the R-absorbing and FR absorbing forms of phytochrome (Rajapakse *et al*., 1999 and Kubota *et al*., 2000), which function as a regulator of photosynthate allocation (Britz and Sager, 1990; Smith, 1992; Aphalo and Ballare, 1995 and Ballare *et al*., 1995).

Niu *et al*. (1998) found that grain dry matter of spring wheat increased from 190mg plant^{-1} at anthesis to an average of 2115mg plant^{-1} in mulched wheat and 1726 mg plant^{-1} in unmulched wheat, by the fifth week after anthesis. They concluded that, compared with unmulched plants, the mulched plants accumulated greater (26%) dry matter at anthesis and produced 35% more grain yield. Application of plastic mulches (white clear) to spring wheat effectively increased dry matter production and mobilization from vegetative organs to grains.

Csizinsky *et al*. (1995) reported that tomato growth and yields were inconsistent with mulch colors during the three seasons of their study. Since, in the first season, in a once-over harvest, extra-large (C ≥70 mm diameter) and marketable fruit yields were higher (P≥0.05) on blue than on the conventional white mulch. Also, in the second season, early marketable yields on red mulch were higher than on black mulch.

Thereby, present study aimed to quantify the reproductive growth of tomato and sweet pepper plants. That included early and total fruit yields and economical and biological yields as well.

In addition, pioneer findings were obtained regarding those plenty of formed fruits on the same nodes.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm Station of the Faculty of Agriculture, Moshtohor, Benha University, Egypt during the two growing successive seasons of 2001 and 2002.

Two economical plants, i.e. tomato *(Lycopersicon esculentum*, Mill., cv. Super Strain B) and sweet pepper *(Capsicum annuum*, L., cv. Baladi), those known to be largely cultivated in Egypt in warm seasons, were taken as a botanical material in this study. Seeds of these two plants were secured from Vegetable Research Department, Agricultural Research Center, Ministry of Agriculture, Giza, Egypt.

These experiments were performed to study the effect of some new promising treatments, polyethylene mulch surface colors, on some reproductive growth characteristics and fruit yield of both tomato and sweet pepper plants compared to bare soil (unmulched).

The trickle irrigation system was used before covering the soil surface with either of black, red, red over black or blue plastic mulches as well as bare soil (control). Since the lateral lines used are line source tubing made with 16 mm diameter polyethylene hose. The applied emitter rates were 2.5 and 3 litter / hr. The trickle irrigation lines were laid on the surface of the experimental rows.

Polyethylene surface color was considered the main factor in this study. Polyethylene mulch sheets were of 1.20 m wide and 150μ. thick. The black, red and blue colors of mulch were used in this study.

Five-week-old tomato and sweet pepper seedlings (i.e., at 20th and 15th of February for 2001 and 2002 seasons, respectively) were transplanted to the experimental plots.

The mulch treatments (black, red, red over black, blue polyethylene mulch colors and the bare soil as control) were arranged in a randomized complete-block design with three blocks (replicates). Each block had five plots (30m length and 3m width). Each plot had three rows (30m length and 80 cm. width) as a replicate for tomato and pepper as well. There are three rows of bare soil (unmulched) between each two treatments to provide complete separation of different colors.

In the two assigned seasons, all agricultural practices of growing tomato and sweet pepper plants including equal amount of fertilizers were followed as recommended for the two species in case of trickle irrigation system (Cook *et al.*, 1982). Irrigation was for one hour two times weekly for different mulch colors treatment. But it was for 2 hours three times weekly for the bare soil. The fertilizer was applied weekly through the trickle irrigation system for 12 weeks starting 10 days after transplanting. That means that bare soil was consumed amount of water exceeded that consumed in trickle irrigation three times more during the tomato and pepper life cycles That was very necessary to prevent permanent wilting and to reach the normal growth of tomato and sweet pepper cultivated in bare soil (control).

Sampling date and collecting data:-

I- Flowering characteristics:-

Ten plants per each treatment in either tomato or sweet pepper were randomly taken, labeled and the following data were recorded:

(i) **Start of flower anthesis (days):-** Expressed as number of days passed from transplanting till anthesis the first flower.

(ii) **Earliness of flower anthesis (days):** Expressed as number of days that passed between the first flower anthesis in any treatment and the anthesis of first flower in control treatment.

(iii) **Total number of flower / plant:**

(iv) **Fruit setting percentage:** It was calculated according to the following equation:

$$\text{Fruit setting \%} = \frac{\text{No. of fruits / plant}}{\text{No. of flowers / plant}} \times 100$$

(v) **Flower abscission percentage:** It was calculated according to the following equation:

$$\text{Flower abscission \%} = \frac{\text{No. of flowers/plant} - \text{No. of setted fruits}}{\text{No. of flowers/plant}} \times 100$$

II- Pollen grains fertility:

Pollen grains fertility was estimated by the inspection and counting of fertile and sterile pollen grains mounted in dilute iodine solution and microscopically examined using the method described by Shaluine(1961).

III- Fruit yield and yield components:

a) Early yield:

Data of the first four pickings of marketable fruits in both tomato and sweet pepper in the two seasons were used to calculate the following:

(i) **Number of early fruits / plant.**

(i) **Early yield (kg) / plant.**

(iii) **Relative early yield / plant,** according to the following equation:

$$\text{Relative early yield / plant} = \frac{\text{Early yield (kg)/plant}}{\text{Total yield (kg)/plant}} \times 100$$

b) Total yield:

(i) **Total number of fruits / plant.**

(ii) **Total yield (kg) / plant.**

c) Harvest index:

To determine the total dry matter being accumulated among different organs; stems (including main stem) and leaves, dry weights in the end of growth period (i.e., at the end of experiments) were estimated, In addition, total fruits dry weight / plant (i.e., the economical yield) was also estimated. The harvest index was expressed as the proportion of the economical yield divided by the biological one (i.e., stems, leaves and fruits dry weights) according to Gardner *et al.* (1985) using the following equation:

$$\text{Harvest index \%} = \frac{\text{Economic yield (g)/plant}}{\text{Biological yield (g)/plant}} \times 100$$

IV- Quality characteristics of tomato and sweet pepper marketable fruits:

Five marketable fruits per each treatment in both tomato and sweet pepper were randomly taken to determine the averages of size (cm^3), fresh and dry weights (g), diameter, (cm) and length (cm) per fruit as well as fruit shape index (L/D).

V- Chemical constituents in the fruits:

Samples of both tomato and sweet pepper fruits at marketable stage were taken in the mid season (i.e., at the first packing after the fourth ones of early yield) to determine total carbohydrates (Dubois *et al.*, 1956), total and reducing sugars (Thomas and Dutcher, 1924), total nitrogen (Horneck and Miller, 1998), phosphorus (Sandell, 1950) potassium (Horneck and Hanson, 1998) and vitamin C (A.O.A.C., 1990). Crude protein was calculated using the following equation:

Crude protein = Total nitrogen X 6.25 (A.O.A.C., 1990)

Also, total soluble solids (T.S.S.) was measured in the juice of both tomato and sweet pepper fruits by using a hand refractometer.

VI- Statistical analysis:

Data of flowering and yield characteristics were statistically analyzed and the means were compared using the least significant differences test (L.S.D.) at 5% and 1% levels according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

I- Reproductive growth:

I.1- Flower characteristics:

I.1.1- Start of flower anthesis:

Data in Table (1) clearly show that tomato plants grown above different used mulch colors opened their flowers earlier than control plants. The most effective color in this respect was the red one followed by red + black, black and the blue one ranked the last. Here, days of earliness were 31.20, 28.60, 15.00 and 12.00 days for red, red + black, black and blue one during 2001 season, respectively, when compared with the control. In other meaning, plants grown above red, red + black and blue, their flowers were started anthesis at the age of 34.20, 36.80, 50.40 and 53.40 days after transplanting during 2001 season, respectively comparing with 65.40 days for the control plants. These days of flowering earliness e.g. with red color mulch reached to 47.71 and 47.90% less than control value during 2001 and 2002 seasons, respectively.

On the other hand, nearly the same positive effect upon flowering earliness was also existed in sweet pepper plants.

In this respect, other studies reported nearly similar effects of mulch color treatments upon the earliness of tomato flowering (Decoteau *et al.*, 1986 and Kasperbauer and Hunt, 1998).

These results may be considered as a pioneer of the present study. Since, earliness with 31 days (in case of tomato) may be followed by rapid development and growth of setted fruits, so earliness in repining of tomato and sweet pepper fruits being expected. The earliness of yielding fruits consider of great interest, because that will suit early marketing of such fruits. Moreover, also in this view only, fruits produced under tunnels are present in markets. So, the present study provide an alternative system for present repined fruit during the time of spring and early summer.

Table (1): Effect of polyethylene mulch surface color on flowering, fruit setting and flower abscission of tomato (*Lycopersicon esculentum*, Mill) and sweet pepper (*Capsicum annuum*, L.) plants during 2001 and 2002 seasons.

Character / Treatment		Start of flower anthesis (days)		Earliness of flower anthesis (days)		Earliness of flower anthesis % relative to the control		No. of Flowers/plant		Total No. of fruits / plant		Fruit setting (%)		Flower abscission (%)	
		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato															
Control		65.40	61.80	0.00	0.00	0.00	0.00	51.40	54.00	19.80	21.20	38.52	39.26	61.48	60.74
Black		50.40	53.20	15.00	8.60	22.94	13.92	58.80	60.60	29.40	27.20	50.68	44.88	49.32	55.12
Red		34.20	32.20	31.20	29.60	47.71	47.90	66.60	68.20	43.20	46.60	64.87	68.33	35.13	31.67
Red + Black		36.80	33.80	28.60	28.00	43.73	54.69	69.80	72.00	47.20	44.80	67.62	62.22	32.38	37.78
Blue		53.60	51.60	12.00	10.20	18.35	29.69	61.40	63.00	24.00	25.80	39.09	40.95	60.91	59.05
L.S.D	0.05	1.30	2.02	-	-	-	-	2.72	3.09	1.57	2.03	3.12	4.11	3.09	3.61
	0.01	1.79	2.78	-	-	-	-	3.75	4.26	2.17	2.80	4.31	5.56	4.26	4.98
Sweet pepper															
Control		69.20	66.80	0.00	0.00	0.00	0.00	65.20	70.40	20.40	23.20	31.29	32.95	68.71	67.05
Black		52.20	50.60	17.00	16.20	24.57	24.25	75.00	79.20	25.20	27.20	33.60	34.34	66.40	65.66
Red		43.00	40.80	26.20	26.00	37.86	38.92	97.40	104.80	47.00	50.20	48.25	47.90	51.75	52.10
Red + Black		41.40	43.20	27.80	23.60	40.17	35.33	102.00	113.60	50.60	54.40	49.61	47.89	50.39	52.11
Blue		52.80	54.80	16.40	12.00	17.34	17.96	82.40	88.40	26.00	29.60	31.55	33.48	68.45	66.52
L.S.D	0.05	1.43	1.38	-	-	-	-	2.98	2.74	1.54	2.71	2.35	2.88	2.35	2.84
	0.01	1.99	1.96	-	-	-	-	4.11	3.78	2.12	3.75	3.11	4.02	2.97	3.96

Earliness of flowers anthesis under different used mulch colors was preceded with vigorous growth of grown plants and high production of net assimilates in leaves of such plants (El-Desouky *et al.*, 2005a). Also, of interest to rember here measurement of light reflection as previously mentioned by (El-Desouky *et al.*, 2005a) revealed that the red color mulch reflected (46.58 & 49.87 and 49.72 & 52.67% of red and far-red light at mid-day of the April during 2001 and 2002 season, respectively) more red and far-red light comparing with other used mulch colors. The role of red and far-red light and percentage between them are of great interest, since the FR: R ratio plays a major role in promoting flowering during early stage of growth (Koornneff *et al.*, 1998 and Levy and Dean, 1998). The ratio acts through the phytochrome system to control flowering by floral evocation (Bagnall *et al.*, 1995 and Carre, 1998). Also, in this respect, Thomas and Vince-Prue (1997) reported that the photoperiodic control of flowering is brought about by the interaction of genes involved in the developmental control of floral initiation, the regulation of the circadian clock and the signal transduction of photoreceptors.

1.1.2- Number of flowers and fruit setting:

Data in Table (1) also indicate that in both plants, high significant increase in flowers number was dominantly existed with different used mulch colors during the two assigned seasons. In tomato, values were 69.80 & 72.00, 66.60 & 68.20, 61.40 & 63.00 and 58.80 & 60.60 in 2001 & 2002 seasons for red + black, red, blue and black colors, respectively. While, values were 51.40 & 54.00 in the two seasons, for the control plants. Meanwhile, with sweet pepper values were 102.00 & 113.60, 97.40 & 104.80, 82.40 & 88.40 and 75.00 & 79.20 flowers / plant in 2001 & 2002 seasons for red +black, red, blue and black mulch colors, respectively. Yet, values were 65.20 & 70.40 in the 2001 and 2002 seasons, for control plants.

The above mentioned high numbers of flowers existed with different mulch colors were followed also by increasing of total fruits number. That means a high percentages in setted fruits was produced. Data in the same Table show that red and red + black colors gave the highest existed values for each of total fruits number and the percentages of fruit setting as well.

On the other hand, abortion of flowers was decreased. Since, percentage of abscission was decreased to reach the high level of significance with all used colors except the insignificant decrease recorded with blue color during 2002 season in case of tomato. Also, it was noticed that each of red and red + black were more pronounced in this respect.

Since, in tomato, values of abscission were 35.13 & 31.67 and 32.38 & 37.78% in 2001 and 2002 seasons, respectively with red and red + black, meanwhile values were 61.48 & 60.74 in the same two seasons for the control plants.

In sweet pepper the percentage of flowers abscission was decreased to reach the high level of significance with red and red + black mulch colors during the two seasons. But it was significantly decreased (at 5% level) with black one

during 2001 season and insignificantly decreased with black and blue colors in 2002 season. These results are in agreement with those obtained by Hunt *et al.* (1990) and Mozley and Thomas (1995).

Recent molecular genetic studies of plant photoreceptors have demonstrated that the action of individual phytochromes and cryptochromes can either suppress or promote floral initiation and that a photoreceptor may function within the nucleus to affect transcription of the flowering-time genes. It remains unclear how photoreceptors control photoperiodic flowering. A photoreceptor may regulate flowering time in response to different photoperiods via its regulation of the circadian clock. Alternatively, the direct effect of a photoreceptor on floral initiation may be gated by the circadian clock, resulting in different responses in different photoperiods. It is conceivable that the expression level or activity of a photoreceptor signaling molecule may oscillate with distinct cycling phases in different photoperiods, and as such may serve as the hypothesized gating factor that determines the signal transduction of a photoreceptor (and thus the flowering time) in differed photoperiods. The identification of such factors and investigation of how the expression or activity of these factors affects the function of photoreceptors may shed light on the mechanism of photoreceptors in the control of flowering time (Lin, 2000).

1.1.3- Pollen grains fertility:

As shown in Table (2), various used mulch colors increased the fertility of pollen grains in tomato and pepper plants grown above them. Also, it was noticed that the red color gave the highest fertility but the black exhibited slight increase during 2001 season and decreased it during 2002 season.

These data being more evident when calculated on the control basis, since red mulch gave increases values of 28.92 & 20.61% in tomato and 48.08 & 30.39% in sweet pepper more than the control values during 2001 & 2002 seasons, respectively. On the other hand, the little reductions existed were of 12.09 and 9.09% less than the control during 2002 season with the black mulch in tomato and sweet pepper, respectively. The above mentioned results may be directly reflected upon the high percentages of fruit setting as previously mentioned (Table, 1). Since, red mulch also gave the lowest percentages of aborted flowers (Table, 3). In addition, the red color gave the lowest percentage of pollen grains sterility in the two seasons, those reached to 21.86 & 22.81% in tomato and were 18.69 & 23.09 in sweet pepper less than the control values, yet, each of black and blue colors exhibited the highest percentages of stetrility in both seasons. Moreover, the above mentioned results are of great interest, since fruits setting and number as well as early and total fruit yields are completely depend on them.

1.2- Early fruits and early yield:

As shown in Table (3) the first four pickings were considered as early fruits yield. In this respect, different used mulch colors increased the number of early fruits to reach the high level of significance in both tomato and sweet pepper . Also, each of red and red + black gave the highest values of this number followed by the black and blue colors.

Table (2): Effect of polyethylene mulch color on pollen grain fertility of tomato (*Lycopersicon esculentum*, Mill) and sweet pepper (*Capsicum annuum*, L.) plants during 2001 and 2002 seasons.

Character / Treatment	Fertility				Sterile				Sterility			
	%		%relative to the control		Morphol. normal %		Aborted %		%		%relative to the control	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato												
Control	60.61	64.00	100.00	100.00	21.21	19.20	18.18	16.80	39.39	36.00	100.00	100.00
Black	61.88	56.26	102.10	87.91	20.14	24.21	17.98	19.53	38.12	43.74	96.78	121.50
Red	78.16	77.19	128.92	120.61	12.57	11.70	9.29	11.11	21.86	22.81	55.50	63.36
Red + Black	74.84	74.29	123.48	116.08	14.29	13.56	10.87	12.15	25.16	25.71	63.87	71.42
Blue	69.92	64.47	115.36	100.37	14.46	17.36	15.53	18.17	30.18	35.53	76.62	98.69
Sweet pepper												
Control	54.91	58.99	100.00	100.00	24.50	23.01	20.59	18.00	45.09	41.01	100.00	100.00
Black	55.79	53.63	101.60	90.91	23.13	26.09	21.08	20.28	44.21	46.37	98.05	113.07
Red	81.31	76.92	148.08	130.39	11.62	14.35	7.07	8.73	18.69	23.08	41.15	56.28
Red + Black	75.98	72.00	138.37	122.05	15.09	17.14	8.93	10.86	24.02	28.00	53.27	68.28
Blue	57.88	62.43	105.41	105.83	25.15	23.56	16.97	14.01	42.12	37.57	93.41	91.61

Table (3): Effect of polyethylene mulch surface color on early and total fruit yield of tomato (*Lycopersicon esculentum*, Mill.) and sweet pepper (*Capsicum annuum*, L.) plants during 2001 and 2002 seasons.

Character / Treatment		Early fruits*				Early yield				Total fruits				Total yield				Relative early yield (%)	
		No./plant		%relative to the control		(kg)/plant		%relative to the control		No./plant		%relative to the control		(kg)/plant		%relative to the control			
		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato																			
Control		6.00	7.20	100.00	100.00	0.41	0.57	100.00	100.00	19.80	21.20	100.00	100.00	1.46	1.66	100.00	100.00	28.08	34.34
Black		11.00	12.20	183.33	169.44	0.99	1.02	219.51	178.95	29.80	27.20	150.51	128.30	2.41	2.28	165.07	137.35	37.34	44.74
Red		19.60	21.60	326.67	300.00	1.98	2.46	482.93	431.58	43.20	46.60	218.18	219.81	4.83	5.32	330.82	320.48	41.20	46.24
Red + Black		22.00	20.80	366.67	288.89	2.43	2.39	604.88	419.30	47.20	44.80	238.38	211.32	5.34	5.14	365.75	309.64	46.44	46.50
Blue		10.80	12.20	180.00	169.44	0.89	1.01	217.07	177.19	24.00	25.80	121.21	121.70	1.99	2.13	136.30	128.31	44.72	47.42
L.S.D	0.05	2.18	1.80	-	-	0.32	0.18	-	-	1.57	2.03	-	-	0.31	0.30	-	-	6.48	5.62
	0.01	3.00	2.48	-	-	0.44	0.25	-	-	2.17	2.80	-	-	0.43	0.41	-	-	9.44	7.75
Sweet pepper																			
Control		4.80	6.40	100.00	100.00	0.12	0.17	100.00	100.00	20.40	23.20	100.00	100.00	0.53	0.62	100.00	100.00	22.64	27.42
Black		10.20	12.80	212.50	200.00	0.27	0.35	225.00	205.88	25.20	27.20	123.53	117.24	0.66	0.74	124.53	119.36	40.91	47.30
Red		21.20	22.40	441.67	350.00	0.99	1.11	825.00	652.94	47.00	50.20	230.39	216.38	2.20	2.49	415.09	401.61	45.00	44.58
Red + Black		26.20	24.40	545.83	381.25	1.22	1.18	1014.67	694.18	50.60	54.40	248.04	234.48	2.64	2.85	498.11	459.68	46.12	41.40
Blue		10.60	13.20	220.83	206.25	0.30	0.41	250.00	241.18	26.00	29.60	127.45	127.59	0.73	0.91	137.74	146.77	41.10	45.05
L.S.D	0.05	1.72	1.40	-	-	0.18	0.11	-	-	1.54	2.71	-	-	0.32	0.29	-	-	10.37	6.27
	0.01	2.37	1.93	-	-	0.25	0.15	-	-	2.12	3.75	-	-	0.44	0.39	-	-	14.31	8.64

These results are also of great interest, since these number e.g. in tomato rose from 6.00 & 7.20 fruits in 2001 and 2002 season for control to 19.60 & 21.60 and 22.00 & 20.80 fruits during the two assigned seasons for red and red + black, respectively.

Also, the view will be more evident when these values related to the control one. Since, in tomato values reached to or even more than three times of control with these two efficient treatments i.e., red and red + black. Again, the importance of such treatments being strongly supplemented for this system of cultivation. That because not only enables farmers to sol a large part of their tomato and sweet pepper fruits with high prices but also they could minimize high costs of production under protected conditions (i.e. tunnels or green houses).

As for the weight of early yielded fruits, also high significant increase was existed with different used mulch colors. Data revealed that, in tomato, the treatment of red + black gave the highest weight (2.48kg) in 2001 season but the red mulch color gave the highest weight (2.46kg) during 2002 season. Again, the early yield of red + black exceeded the weight of control with more than six time and with more than four time by red colors during 2001 and 2002 seasons, respectively. Moreover, the lowest weight of early yield was existed with black and blue colors during the two seasons (0.90 & 0.89 and 1.02 & 1.01 kg, respectively) also exceeded the control with more than two times. Also, sweet pepper plant was nearly positively responded as in tomato.

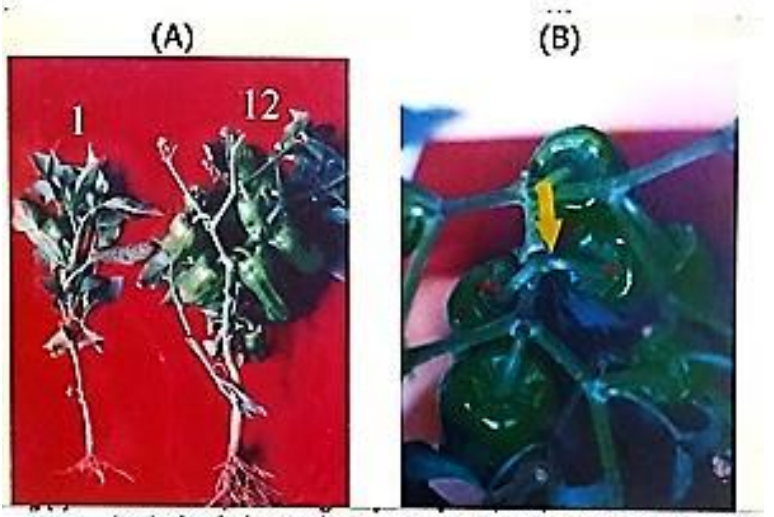
1.3- Total fruits yield:

Data in Table (3) reveal that high significant increase of the picked fruits along harvest time dominantly existed with different used colors during the two assigned seasons. The treatment of red + black and the red one gave the highest number of fruits/plant during both seasons, respectively. Meanwhile, black color ranked the second but blue one was the last in this respect.

Moreover, the obtained high number of yielded fruits was also accompanied with high significant increase in their weight (kg/plant). In tomato, e.g., the red mulch color gave 5.32 kg/plant during 2002 season but red + black exhibited 5.34 kg/plant during 2001 season. These data being of great interest when compared with total fruits weight of the control treatment (1.46 & 1.66 kg/plant during the two assigned seasons). Furthermore, mulch colors treatment gave not only highest increase of total fruits yield but also that part considered as early fruits yield. In addition these data being more evident when related them to the control ones.

The relative early yield, i.e. percentages of early fruits yield weight when related to the weight of total yielded fruits, in tomato was increased to reach the high level of significance with all used colors except its significant increase (at the 5% level of significance) with black color during 2001 season. In sweet pepper high significant increase was existed only with red mulch applied alone or over black one (Fig , 1).

These results summarize the bulk of interest of the present study, since the percentages of fruit yield weights e.g. reached to 47.24, 46.50, 46.25 and 44.74% during 2002 season with blue, red + black, red and black one, respectively. That means nearly about half of the yielded fruits considered as early ones.



developing fruit were formed on the same node (B) in comparison with the control (A-1).

Furthermore, Decoteau (1989) and Kasperbauer and Hunt (1998) concluded that mulch surface color can influence the plant microclimate sufficiently to affect the early and total yields of fresh-market tomatoes. Color of mulch affected both the plant light environment and soil temperatures. The beneficial effects of mulch color as compared to another are related to its effects on spectral distribution of upwardly reflected light as well as on soil temperature.

Biological and economical yields:

As indicated in Table (4) the economical yield of tomato and sweet pepper / plants, i.e. dry weight of yielded fruits was increased to reach the high level of significance with different used mulch colors during 2001 and 2002 seasons.

It was noticed that each of red + black treatment during 2001 season and the red one during 2002 season gave the highest values of economical yield that reached for tomato 236.28 and 234.98 (g)/plant, respectively. Yet, for sweet pepper values were 70.65 & 73.19 and 56.21 & 67.56 (g) / plant with red + black and red mulch colors during 2001 and 2002 seasons, respectively. Meanwhile, the black mulch ranked the second, yet, blue mulch gave the lowest increase in this respect. Here, of interest to note that different mulch colors especially the red one significantly increased that part of assimilates being allocated to the economical

part of tomato and sweet pepper plants, i.e. fruits. These data being more evident also when related to the control, e.g. during 2001 season dry matter accumulation in tomato fruits were more than the control values by three, six, six and two times with black, red, red + black and blue mulches, respectively.

Table (4): Effect of polyethylene mulch surface color on biological and economical yields as well as the harvest index of tomato (*Lycopersicon esculentum*, Mill.) and sweet pepper (*Capsicum annuum*, L.) plants during 2001 and 2002 seasons.

Character / Treatment		Economical yield (g)/plant		% relative to the control		Biological yield* (g)/plant		% relative to the control		Harvest index (%)	
		Seasons		Seasons		Seasons		Seasons		Seasons	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato											
Control		36.16	73.33	100.00	100.00	107.73	127.58	100.00	100.00	58.63	57.48
Black		106.42	100.76	294.30	137.41	180.67	182.43	167.71	142.99	58.90	55.23
Red		214.10	234.98	592.09	320.44	273.25	301.24	253.64	236.12	78.35	78.00
Red + Black		236.28	226.85	653.43	309.36	330.44	329.04	306.73	257.91	71.51	68.94
Blue		83.96	94.00	232.19	128.19	155.98	173.28	144.79	135.82	53.83	54.25
L.S.D	0.05	14.48	13.12	-	-	21.50	18.40	-	-	7.11	5.28
	0.01	19.81	18.10	-	-	29.66	25.37	-	-	9.81	7.28
Sweet pepper											
Control		14.15	16.87	100.00	100.00	58.11	66.33	100.00	100.00	24.35	25.43
Black		17.82	20.21	125.94	119.80	84.77	94.74	145.88	142.83	21.02	21.33
Red		56.21	67.56	397.24	400.47	133.25	148.90	229.31	224.48	42.18	45.37
Red + Black		70.65	73.19	499.29	433.85	159.26	171.35	274.07	258.33	44.36	42.71
Blue		20.02	24.88	141.48	147.48	83.52	95.29	143.73	143.66	23.97	26.11
L.S.D	0.05	9.21	6.13	-	-	18.58	14.89	-	-	6.42	5.00
	0.01	12.70	8.45	-	-	25.62	20.54	-	-	8.86	6.90

* The biological yield was calculated without dry weight of root system.

On the other hand, the biological yield of tomato and sweet pepper plants, i.e. total dry matter produced (including dry matter of shoots + fruits) was also exhibited high significant increase with different colors used mulches. Exception was only that significant increase in sweet pepper in the first season with blue mulch.

These results are of great interest because they mean that colored mulches not only increased dry matter accumulation in fruits but also in shoots. That in other meaning strictly proved that the used mulch colors obviously increased the efficiency of photosynthesis in plants grown above them. In addition, this stimulation of dry matter production considered as a direct result for that vigorous growth including the photosynthetic area and the content of photosynthetic pigments in leaves of tomato and sweet pepper plants during different stages of growth (El-Desouky *et al.*, 2005a).

With regard to the harvest index, i.e. the dry matter of economical yield divided by biological yield; results obtained in the present study may be considered as a pioneer ones in this respect. As shown in Table (4) only each of red and red + black mulches increased this index to reach the high level of significance during 2001 and 2002 seasons. Meanwhile, black color showed its insignificant increase only during 2001 season, yet, the rest of treatments insignificantly decreased it (i.e. black mulch during 2002 season and the blue mulch during the two assigned seasons).

The obtained reduction of the harvest index under the black and blue mulches being in objection with the increase of the economical and biological yields with the same treatments. This objection may be interpreted on the basis that both treatments increased each of economical and biological yields but the proportion of biological yield increase was more greater than that of economical one. That means that a great part of photo-assimilates being directed to allocate in shoots under the treatments of these two mulch colors.

Other studies, recently has been recommended the stimulative effect of red color mulches upon increasing of vegetative and reproductive growths of some vegetables (Fortnum *et al.*, 1997; Wang *et al.*, 1998; Loy *et al.*, 1999 and Runkle and Heins 2001).

I.5- Fruit quality:

I.5.1- Fruit characteristics:

Data in Table (5) clearly indicate that different colors applied mulches increased each of fruit size, fresh and dry weights of tomato and pepper fruits. These three characteristics of fruits were increased to reach the high level of significance with red and red + black mulches but showed only significant or insignificant increase with black and blue mulches.

The above mentioned data are of great interest, not only for increasing size of fruits and their contents of bioconstituents but also, it must be mentioned that each of red and red + black treatments reflected the greatest bulk of red and far-red wavelengths during the growing season. So, improvement of fruits growth and development could be also attributed to the effect of this light spectra upon many physiological processes including photosynthetic pigments synthesis and photosynthesis process itself or enhancement of some phytohormones creation as well as other essential bioconstituents.

Again, here it was noticed that even at the one fruit basis; red mulch nearly duplicated the dry matter accumulation in fruits when compared with that in fruits of control plants. Moreover, these data were accompanied with great histological alterations in the internal structure in leaves of tomato and sweet pepper plants (El-Desouky, *et al.*, 2005b).

On the other hand, fruit dimensions, i.e. length and diameter were variously responded. in this respect, in case of tomato fruit length was significantly decreased at the level of 5% during 2001 season and reduction reached 1% level in 2002 season.

with black mulch. But, it was insignificantly decreased during the two assigned seasons with each of red and red + black treatments. Meanwhile, it was only increased but insignificantly with blue mulch color.

Table (5): Effect of polyethylene mulch surface color on fruit characteristics of tomato (*Lycopersicon esculentum*, Mill.) and sweet pepper (*Capsicum annum*, L.) plants during 2001 and 2002 seasons.

Character / Treatment		Fruit size (cm)²		Fruit fresh weight (g)		Fruit dry weight (g)		Fruit dimensions: Length (cm)		Fruit dimensions: Diameter (cm)		Fruit shape index (L/D)*	
		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato													
Control		87.50	90.00	85.33	85.02	3.80	3.76	6.31	6.89	5.00	4.95	1.34	1.39
Black		89.30	91.55	86.95	87.37	3.99	3.96	6.22	6.97	5.05	5.04	1.23	1.30
Red		120.50	123.56	121.49	124.52	5.38	5.50	6.81	6.73	5.72	5.76	1.86	1.87
Red + Black		120.00	123.50	123.23	126.72	5.46	5.51	6.45	6.58	5.80	5.78	1.81	1.84
Blue		94.50	97.50	96.56	96.79	4.08	4.28	6.95	6.93	5.10	5.21	1.36	1.34
L.S.D	0.05	14.28	12.41	16.22	14.17	0.73	0.65	0.38	0.43	0.29	0.27	0.15	0.11
	0.01	19.14	16.63	21.75	19.54	0.97	0.86	0.51	0.57	0.39	0.37	0.21	0.15
Sweet pepper													
Control		53.50	54.00	21.99	21.42	0.59	0.64	7.54	7.17	3.98	4.25	1.82	1.69
Black		59.50	61.00	23.47	29.40	0.71	0.80	7.73	7.12	4.03	3.92	1.92	1.82
Red		98.50	100.50	41.83	44.46	1.13	1.21	8.34	8.61	5.09	5.41	1.72	1.59
Red + Black		103.00	104.00	43.56	47.42	1.23	1.32	8.93	8.31	5.21	5.37	1.71	1.55
Blue		79.00	73.00	29.66	31.56	0.80	0.85	8.69	7.83	4.25	4.32	2.05	1.98
L.S.D	0.05	13.03	11.60	5.33	5.70	0.15	0.17	0.93	0.62	0.45	0.37	0.24	0.21
	0.01	17.47	15.56	7.41	7.65	0.21	0.23	1.23	0.82	0.61	0.50	0.32	0.27

L= Length D= Diameter

On the other hand, fruit diameter was increased with the three used mulch colors to reach the high level of significance with each of red and red + black treatments but insignificantly it was only increased with each of black and blue colors.

It could be concluded that insignificant reduction of fruit length and high significant increase of its diameter being related with alterations in hormone profile (El-Desouky *et al.*, 2005b). Since, red color increased cytokinins content in shoots of tomato plants. Cytokinins has been reported not only to increase the wide growth on the account of longitudinal one but also to make fruits and other storage organs very active and strong sinks (Hopkins, 1995).

Therefore, fruit shape index, as shown in Table (5) considered as a light view for different effects of used treatments upon fruit characteristics.

I.5.2- Effect of mulch color on NPK and crude protein concentrations in tomato and sweet pepper fruits:

Data in Table (6) clearly show that various colors of used mulches increased N, P and K, concentrations in the marketable stage of tomato and sweet pepper fruits. In this respect, in tomato, red color was more pronounced for increasing all these elements during the two assigned seasons. That was true even when used alone for N & P or over the black mulch for K. Meanwhile, black and blue mulches ranked the second in this respect.

Table (6): Effect of polyethylene mulch surface color on NPK and crude protein concentrations in ripened marketable tomato (*Lycopersicon esculentum*, Mill.) and sweet pepper (*Capsicum annuum*, L.) fruits during 2001 and 2002 seasons.

Character	N (mg/g dry weight)		P (mg/g dry weight)		K (mg/g dry weight)		Crude protein (mg/g dry weight)	
	Seasons		Seasons		Seasons		Seasons	
Treatment	2001	2002	2001	2002	2001	2002	2001	2002
Tomato								
Control	18.32	20.42	3.25	3.36	16.82	20.06	114.50	127.61
Black	19.34	22.63	4.18	4.50	18.12	20.24	120.88	141.44
Red	27.18	24.48	4.90	4.94	24.70	26.42	169.88	153.00
Red +Black	21.28	23.64	4.75	4.72	26.40	26.80	133.00	147.75
Blue	19.70	23.25	3.48	3.56	22.72	24.12	123.13	145.32
Sweet Pepper								
Control	19.24	20.46	3.12	3.26	15.52	18.60	120.25	127.88
Black	22.56	23.32	3.38	3.42	20.18	20.82	141.00	145.75
Red	28.36	26.76	4.17	3.98	22.70	24.14	177.25	167.25
Red + Black	25.42	24.80	3.86	3.92	21.84	22.62	158.88	155.00
Blue	24.82	24.62	3.54	3.62	20.64	20.96	155.13	153.88

As for the crude protein, data in the same Table show that mulch color treatments increased its content in ripened tomato and pepper fruits during 2001 and 2002 seasons. Red mulch gave the highest content followed by red + black, blue and black in descending order.

The above mentioned results evidently indicated that mulch treatment increased the ability of tomato and sweet pepper fruits as sink organs. So, absorption of these elements and their translocation into fruits being highly stimulated under such treatment. That is also true for the crude protein content as one of the essential bioconstituents.

Here, it must mentioned that mulch treatment make tomato and sweet pepper fruits with high nutritive value, i.e. it increased their validity for human consumption.

As previously mentioned, alteration of R/FR ratio by mulch colors treatment has been reported to increase the ability of sink organs to accumulate more assimilates (Gan and Stobbe, 1996 and Niu *et al.*, 1998).

I.5.3- Effect of mulch color on some bioconstituents in tomato and sweet pepper fruits:

Data in Table (7) strongly showed that mulch treatments especially that red one recorded a positive and stimulative effects upon many bioconstituents production including each of total carbohydrates and sugars, vitamin C and total soluble solids as well.

Mulch treatments, obviously increased carbohydrates concentration especially red alone or when used over the black one.

Also, total sugars (reducing and non-reducing) were increased with mulch color treatments to reach its maximum with red one and red + black followed by blue and black mulches.

All used mulch colors, i.e. black, red and blue increased vitamen C concentration in fruits during the two assigned seasons. Also, it could be noticed that the highest increase of this vitamin existed with the red mulch treatment that reached in tomato 26.88 and 28.93 mg/100g fresh fruit during 2001 & 2002 seasons, respectively.

As for the total soluble solids, data in the same Table show that its percentage increased with different mulch colors to reach its maximum during 2001 season with red + black treatment, and with red one during 2002 season in tomato. In sweet pepper the red color gave the maximum in 2001 season and with red + black in the second one.

With regard to the titratable acidity percentage, results in Table (7) also indicate that with different mulch colors increased acidity. These results are being important from the view of fruit quality. Since, shelf time of such fruits being increased in case of mulch colors treatment, especially that of red one.

In this respect, Wang *et al.* (1998) has been reported such improvement of strawberry fruits quality by increasing its contents of total soluble solids and the titratable acidity, as well.

The present study clearly show that a significant increase in early and total tomato and sweet pepper fruit yields existed under red and red + black mulch treatments when compared with either other mulch colors (i.e. black and blue) or with the unmulched (bare soil) treatment. Great economical yields were not only the magnitude of the present study but also the quality improvement of yielded fruits.

Table (7): Effect of polyethylene mulch surface color on some bioconstituents in ripened marketable tomato (*Lycopersicon esculentum*, Mill.) and sweet pepper (*Capsicum annuum*, L.) fruits during 2001 and 2002 seasons.

Character / Treatment	Total carbohydrates (mg/g dry weight)		Sugars (mg/g fresh weight)						Vitamin C (mg/100g fresh fruit)		Total soluble solids (%)		Titratable acidity (%)	
			Reducing		Non reducing		Total							
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Tomato														
Control	702.81	711.04	15.87	14.33	9.73	10.88	25.60	27.21	20.44	21.05	4.12	5.04	0.512	0.510
Black	700.06	713.79	15.45	18.35	10.44	12.23	26.09	30.58	21.18	22.67	4.84	5.12	0.524	0.580
Red	735.75	741.24	21.85	26.15	14.57	17.43	36.42	43.58	26.88	28.93	6.19	6.79	0.752	0.695
Red + Black	743.59	749.48	22.18	23.95	14.79	15.96	36.97	39.91	27.64	28.84	6.80	6.59	0.689	0.651
Blue	716.53	727.52	17.92	17.74	10.99	13.16	28.91	32.90	23.42	25.17	5.43	5.98	0.634	0.541
Sweet pepper														
Control	710.22	705.55	84.94	87.15	34.28	41.01	118.22	128.16	124.50	121.18	3.18	3.34	0.298	0.302
Black	722.02	734.18	99.40	108.20	42.60	44.20	142.00	152.40	127.80	125.73	4.07	3.98	0.312	0.343
Red	790.66	778.92	130.65	129.34	55.99	60.86	186.64	190.20	130.17	131.40	5.17	5.45	0.415	0.470
Red + Black	767.12	772.34	113.85	120.10	44.27	46.70	158.12	166.80	131.73	133.58	4.82	5.02	0.407	0.480
Blue	730.26	740.22	108.71	116.09	40.21	38.69	148.92	154.78	128.14	126.44	3.73	4.34	0.318	0.314

Several investigators (Kasperbauer and Karlen, 1994; Kasperbauer and Hunt, 1998 and Kasperbauer, 2000) reported that red and far-red light are absorbed and act through a photoreversible regulatory pigment system, phytochrome. The photon ratio of FR relative to R sets the photo equilibrium between the R-absorbing and FR-absorbing forms of phytochrome, which functions as a regulator of photosynthate allocation and adaptive plant development. In the field, the amount of FR (and the FR/R ratio) received by a growing plant can be increased by reflection from the used of red mulch color led to improve plant growth, development and productivity. Thus, the yield of tomato, sweet pepper, strawberry and other crops are increased when grown above red mulch color relative to yield over stander black mulch.

In addition, Murchie and Horton (1997); Terashima *et al.* (2001) and Oguchi *et al.* (2003) found that the response to changes in light availability, plants differentiate sun and shade leaves, where sun leaves have higher photosynthetic capacity (light-saturated rate of photosynthesis on a leaf area basis), greater leaf thickness and greater nitrogen content than shade leaves. However, maintaining high photosynthetic capacity is costly and advantageous only under high light conditions.

The high photosynthetic capacity in sun leaves is supported by constructions of thick leaves with a large investment of nitrogen in photosynthetic enzymes. Since all photosynthetic enzymes are involved in chloroplasts, sun leaves need to have a large number of chloroplasts in the mesophyll cells.

Finally, present study strongly admits and supports the use of red mulch instead of that black one for getting the same benefits of black mulched soil, beside significant increase of yielded fruits as well as their quality characteristics and significantly earliness of fruit production as well.

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دراسات على التشكل الضوئى الظاهرى فى بعض النباتات الاقتصادية
٣- النمو الثمرى ومحصول الثمار لنباتات الطماطم والفلفل الحلو تحت تأثير الضوء الاحمر والاحمر البعيد المنعكس من الأغطية البلاستيكية الملونة.

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اجريت هذه الدراسة تحت ظروف الحقل خلال موسمى ٢٠٠١ ، ٢٠٠٢ وقد اظهرت النتائج انه مع حلول مرحلة الازهار فى كل من الطماطم صنف سوبر ستربن بى والفلفل الحلو صنف بلدى والنامية فوق الوان مختلفة لأغطية التربة البلاستيكية حدثت تغيرات فى العديد من الصفات الاقتصادية لتلك النباتات. حيث حدث تبكير فى موعد الازهار وزيادة معنوية فى عدد الازهار / نبات مصحوبة بنقص معنوى فى النسبة المئوية لتساقط الازهار وبالتالى حدثت زيادة معنوية فى النسبة المئوية لعقد الثمار وذلك لكل من الطماطم والفلفل مع كل الالوان المستخدمة من الأغطية البلاستيكية وكان الغطاء الاحمر سواء عند استخدامه بمفرده أو فوق الغطاء الأسود هو الأكثر تأثير فى هذا الشأن. وعلاوة على ذلك فقد ادت كل معاملات الأغطية البلاستيكية المستخدمة إلى زيادة فى نسبة الخصوبة ونقص فى نسبة العقم لحبوب اللقاح. ومن ثم تم الحصول على زيادة معنوية فى محصول الثمار المبكر والكلى وكذلك المحصول الاقتصادى والبيولوجى / نبات.

وفضلاً عن ذلك فقد تحسنت جودة الثمار بالزيادة التي حدثت في محتوياتها من كل من النيتروجين والفوسفور والبوتاسيوم ، البروتين الخام ، السكريات والكربوهيدرات الكلية ، فيتامين جـ وكذلك الجوامد الصلبة الكلية والحموضة وذلك مع كل معاملات الوان الأغطية البلاستيكية المستخدمة مع تفوق الأغطية الحمراء سواء عند استخدامها بمفردها أو فوق الأغطية السوداء في هذه الناحية.

وعلى ضوء ما تقدم فإن هذه الدراسة توصي بإمكانية استخدام اللون الأحمر من الأغطية البلاستيكية كبديل للون الأسود في نظم الزراعة المعتمدة على تغطية التربة. وذلك لزيادة كمية الضوء الاحمر البعيد المنعكسة وبالتالي زيادة الكمية الممتصة منهما بواسطة النباتات النامية. وهذا يؤدي بالتالي إلى حدوث تغيرات كبيرة في كل العمليات الفسيولوجية التي تحدث داخل النباتات من خلال نظام الفيتوكروم والتي تدفع النباتات للنمو والتبكير في الأزهار والاثمار ، ولذلك يمكن استخدام هذا النظام كبديل للزراعات المحمية. وأخيرا يمكن تحقيق زيادة معنوية في محصول الثمار وذو خصائص جودة عالية.