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INFLUENCE OF COLOUR MULCHES ON PHOTOMORPHOGENESIS AND PRODUCTIVITY OF SWEET PEPPER (*Capsicum annum* cv. Baladi)

BY

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ABSTRACT

As the photomorphogenesis and the role of red light in plant growth and development now is being more clarified; this article aimed to study the response of sweet pepper to the red and black mulch colour using drip irrigation system. Branching, leaf area, leaves dry weight, flowering and fruiting as well as quality of fruits and their content of crude protein, amino acids and some elements were evaluated in two years study. Of the main results obtained were that significant increase of branches number and each of photosynthetic area and pigments as well in plants grown over red mulch.

Also, earliness of flowering and fruiting, increases of early and total yielded fruits as well as improving of fruit quality and their content of crude protein, amino acids and some elements in red mulch even when compared with black mulch or the bare soil were confirmed. Thereby, present study strongly admit the use of red mulch in pepper and other economic vegetables production. In addition, further studies about the mechanism of flowering evocation and the formation of more than one fruit on the same node as well as increasing the number of formed branches are being still needed further studies.

INDRODUCTION

Growth and development of photosynthetic plants those dependent on photosynthetically active radiation (PAR) as their source of energy; are intimately tied to changes in the light environment (Alba *et al.*, 2000).

In this respect, plastic mulches are widely used to conserve water by blocking rapid evaporation from the soil surface, enhanced soil biological activity, control weeds with less herbicides, increased plant growth and development, enhanced early yield, increased yield and improved quality and keep fruit clean in the production of tomato, pepper and other vegetable crops (Decoteau *et al.*, 1990; Lamont, 1993 and Kasperbaur and Hunt, 1998). Also, in this respect applying water through trickle-irrigation tubes located below the plastic mulch can provide enough water for optimal growth, improved water-use efficiency and avoid nutrient leaching by excessive rainfall.

Plants sense both the quantity (fluence) and quality (Wavelength) of light and respond in many ways, ranging from germination to timing of flowering. But for the various aspects of plant photomorphogenesis, phytochrome remains the most investigated photoreceptor (Kevi and Nagy, 2003).

Recently, many investigations hypothesized that changing mulch color could keep those benefits, while also reflecting a yield-enhancing morphogenic light signal to the growing plants (Kasperbauer and Hunt, 1998 and Kasperbauer, 2000).

Also, Briggs and Olney (2001) concluded that a plant's ability to maximize its photosynthetic productivity is depending on

its capacity to sense, evaluate and respond to light quality, quantity and direction. That is the colored of light received by a growing plant influences how and where the photo-synthates are used (Kasberbaure, 2000). In the field the amount of red light (R) absorbed and far red light (FR) sets the photo equilibrium of the ratio FR/R, which function as a regulator of photosynthates partitioning and allocation. Therefore, the amount of FR reveived by a growing plant is influenced by FR reflected either from nearby green plants (Oyaert *et al.*, 1999) or from the soil mulch surface (Greer and Dole, 2003). In this respect, Niu *et al.* (1998) concluded that compared with unmulched spring wheat plants the mulched ones accumulated greater than 26% of dry matter at anthesis, and produced 35% more grain yield. So, application of white clear plastic mulches to spring wheat affectively increased dry matter production and mobilization from vegetative organs to grains. Also, Kasperbauer (2000) reported that yield of strawberry per plant and size per berry were greater over the red mulch color than over the black one in the field experiments at a research centre and in a commercial strawberry farm.

Generally, as cropping systems continue to develop, the impact of reflected light on yield and quality of plant products needs to be exploited. Therefore, in the present study changes in the microenvironment in case of red and black colors of the applied mulch compared to bare soil (unmulched), include changes in the quantity and quality of light reflected from the mulch surface back to sweet pepper plants. Thereby, this study aimed not only to quantity vegetative and reproductive growths of sweet pepper plant, but also to determine the content of some nutrients and amino acids in ripened sweet pepper fruits.

MATERIALS AND METHODS

Two field experiments were concluded at the experimental farm station of the faculty of Agriculture Moshtohor, Benha University, Egypt, during 2005 and 2006 seasons to study the effect of black and red mulch colour on growth, yield and fruit quality as well as crude protein, total amino acids and micronutrient contents in fruits of sweet pepper (*Capsicum annum* L.). Five weeks old of sweet pepper seedlings (January 25th in the two seasons) were transplanted to the experimental plots. Before the soil surface of each treatment were covered with black, red and red over black mulch colours; the tubes of trickle irrigation system were strengthened. Polyethylene mulch sheets with thickness of 150 μ were divided into sheets with 120 min wide. Mulch treatments were arranged in a randomized complete block design with three blocks for each. Different recommended agricultural practices for this plant were followed.

Sampling and collecting data:

a) **Morphological characteristics:** different morphological characteristics at fifty days after transplanting were inspected as following:

- Number of branches and leaves/plant.
- Total leaf area (cm^2) using the disk method according to Derieux *et al.* (1973).
- Leaves dry weight: sample of each treatment were dried in oven at 70°C till the constant weight.

b) **Photosynthetic pigments:** chlorophyll a, b and carotenoids were colorimetrically determined according to the described by Inskeep and Bloom (1985).

c) **Flowering characteristics:**

- Number of flowers/plant.
- Fruit setting percentage was calculated as following:

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

d) **Fruiting:**

- Early fruits number/plant: was considered as the number of first four pickings.
- Total fruit number: was calculated as number of fruits in all pickings.

e) **Total amino acids determination:** Amino acids were determined in the dry matter of fruits according to the method described by Doumas *et al.* (1981).

f) **Elements determination:** The following elements were determined in the dry

matter of fruits i.e., N according to Hornek and Miller (1998) and P, S, Mg, Ca, B, Zn, Mn, Mo, Al, Cu and Fe according to the method described by Black *et al.* (1965).

g) **Crude protein was calculated** according to the following equation:
Crude protein = total nitrogen x 6.25 as described by A.O.A.C. (1990).

h) **Total soluble solids (T.S.S.)** was measured by using a hand refractometer.

i) **Vitamin C and titratable acidity** were determined according to the method described by the A.O.A.C. (1990).

j) **Statistical analysis:** Data of morophological, flowering and yield characteristics were statistically analyzed and the means were compared using the least significant different test (L.S.D.) at 5% and 1% levels according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1- Growth behaviour:

Fifty days after transplanting pepper seedlings above red, red over black and black mulches and bare soil as control; number of branches and leaves and the leaf area/plant as well as leaf content of photosynthetic pigments were greatly differed (Tables 1 & 2). In this respect, as indicated in Table (1) each of red and red over black mulches, high significantly increased number of the formed branches and leaves as well as the leaf area when compared with plants grown either in the bare soil or that covered with black mulch. Also, it could be noticed that black mulch increased the above mentioned characteristics but insignificantly when compared with the bare soil. In addition, it is of interest to note that, the increment of vegetative growth characteristics was completely reversed up on the dry matter accumulation of these plants in mulch treatment (Table, 1). That is being of significant value when a great part of this weight being to be directed towards or allocated to form fruits with onset of flowering and fruiting stages.

Table (1): Some morphological characteristics of mulched sweet pepper with the onset of reproductive stage at 50 days after transplanting.

Character-istics / Treatment		Season 2005				Season 2006			
		No. of branches /plant	No. of leaves /plant	Leaf area (cm^2) /plant	Leaves dry weight (g/plant)	No. of branches /plant	No. of leaves /plant	Leaf area (cm^2) /plant	Leaves dry weight (g/plant)
Bare soil		8.1	58.1	415.5	5.2	10.7	54.7	461.8	4.9
Black		13.5	64.3	468.3	5.7	15.7	70.6	583.3	6.3
Red over black		28.5	99.0	847.7	8.9	30.4	112.5	1225.8	10.1
Red		32.8	102.8	917.2	10.0	29.3	107.3	970.2	9.6
LSD	**5%**	**6.3**	**14.3**	**170.8**	**1.7**	**7.2**	**16.3**	**184.7**	**2.0**
	1%	**8.5**	**19.6**	**236.2**	**2.2**	**9.7**	**20.7**	**254.6**	**2.3**

Here, the obvious effects of red mulch are including not only significant increases of photosynthates creation but also an alteration of their partitioning and allocation. Confirming our present results are those of moreover, as shown in Table (2) red or red over black mlches obviously increased the content of chlorophylls (a & b) and their accessories carotenoid pigments as well, either when compared with the bare soil or black mulch. In agreement with our results are Oguchi *et al.* (2003) who reported that in *Chenopodium album* chlorophyll content in high irradiated leaves was the highest comparing with low irradiated ones or these subjected to high light after low one. Again, here, it seems that enhancement of photosynthetic pigments creation maximized dry matter production and accumulation confirming with no double-the high ability of the

red mulch to increase not only the rate of photosynthesis (by increasing the photosynthetic area Table, 1) but also, by rising the efficiency of photosynthesis process itself.

Of the other studies are being in harmony with our results are Adams (1977), Fortnum *et al.* (1997) and El-Desouky *et al.* (2005a) who reported that tomato plants grown with red mulch resulted in increase of leaf area and dry weight of leaves and branches compared with black mulch or other colors. Leaf area and chlorophyll content in strawberry were also increased by red mulch when compared with other colors (Wang *et al.*, 1998). Also, Flores and Ibarra (1998) found that in sweet pepper, red mulch gave the greatest of stem diameter; yet, blue mulch exhibited the highest of plant height.

Table (2): Photosynthetic pigments content in leaves of sweet pepper from the onset of reproductive stage at 5o days after transplanting (mg/g fresh weight).

Characteristics / Treatment	Season 2005				Season 2006			
	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Carotonoids	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Carotonoids
Bare soil	0.59	0.44	1.03	0.40	0.52	0.46	0.99	0.41
Black	0.61	0.52	1.31	0.48	0.70	0.56	1.26	0.51
Red over black	0.78	0.61	1.39	0.54	0.79	0.60	1.38	0.58
Red	0.79	0.61	1.41	0.60	0.77	0.59	1.36	0.55

Recently, Kreslavski *et al.* (2005) reported that far red light reversed all effects of red light upon wheat seedlings, i.e., increased chlorophyll accumulation and accelerated both coleoptile and first leaf elongation. In this respect, vigorous growth of pepper plants grown over red mulch could be attributed to the following facts: (1) providing the common known benefits for mulch (minimizing water consumption, weeds control and keeping fruit clean); moreover, changing mulch color to the red one could keep those benefits, while also evocates a growth and yield-enhancing morphogenic light singal to the growing plants (Kasperbauer and Hunt, 1998 and Kasperbauer, 2000). (2) physiologically, light (including the red one) affects metabolism directly through photosynthesis and growth and development, indirectly (Casal, 2000; Neff *et al.*, 2000 and Yang *et al.*, 2001).

2- Flowering and fruiting:

As shown in Table (3) flowers, early and total fruit numbers/plant were increased by using the red mulch either alone or over the black one to reach the high level of significance when compared with bare soil or the black mulch. The same trend was also existed with fruit setting percentage. Also, it could be noticed that the above mentioned results were nearly the same in the two seasons under study. The only exception was that significant increase of early fruit number of plants cultivated over the mulch when compared with the bare soil number during 2005 and 2006 seasons.

It is of interest to note that, increase of early fruits number with red mulch treatment is being of great economic value because that not only enables producers to market their fruits with high prices but also it is possible to worth them from the high coasts of production under green houses or tunnels. On the other hand, in the two seasons the economical final yield, i.e., the weight of total picked fruits-in the two mulch colors (i.e., red and black) increased this fruit weight to reach the high level of significance. Although, increase of this weight in the case of red mulch was nearly double that of black one.

Table (3): Flowering and fruiting of sweet pepper (*Capsicum annum* cv. Baladi) grown under mulch treatment

Characteristics / Treatments		Season 2005					Season 2006				
		Number per plant			Fruit set. (%)	Fruit yield (kg/ plant)	Number per plant			Fruit set. (%)	Fruit yield (kg/ plant)
		Flowers	Early fruits	Total fruits			Flowers	Early fruits	Total fruits		
Bare soil		77	4.0	25.7	33.4	0.68	80.4	4.6	27.4	34.1	0.73
Black		82	9.4	28.3	34.5	1.31	86.5	8.6	30.5	35.3	1.42
Red over black		109	23.3	50.4	46.2	2.34	113.6	22.8	57.3	50.4	2.53
Red		115	22.2	52.7	45.9	2.45	110.5	24.6	55.3	50.1	2.49
LSD	5%	**10.17**	**4.22**	**6.40**	**2.84**	**0.28**	**11.63**	**5.11**	**7.32**	**3.01**	**0.31**
	1%	**15.42**	**5.77**	**11.90**	**3.70**	**0.69**	**14.86**	**6.62**	**13.17**	**4.12**	**0.42**

Regarding the above mentioned data, we could conclude that, the vigorous growth obtained (Table, 1) and the high photosynthetic pigments content (Table, 2) were extended to reverse upon flowering (including earliness and reduction of their abscission) and fruiting of sweet pepper growing over red mulch (Table, 3). That means that a large amount of photosynthates are being directed towards the formed fruits. In this respect, the alteration of R/FR ratio has been reported to affected photosynthates partitioning and allocation (Kraepiel and Miginiac, 1997). Also, of interest not only increases number of formed flowers with red mulch treatment but also the earliness of flowers appearance. There are several hypothesis, concepts and theories about the role of phytochrome (the photoreceptor of red and far red light) in the mechanism of plant transition to the generative development. Also, Chory *et al.* (1996), Chory and Li (1997), Duchovskis (2004), El-Desouky *et al.* (2005b) and Samuloliene *et al.* (2005) suggested that the ratio of phytohormones in plants exposed to the light has substantial influence on flowering initiation especially increase of gibberellins and auxins and the reduction of abscisic acid.

3- Fruit quality:

a) Some bioconstituents:

Data in Table (4) clearly indicate that each of red and black coloured mulch when used each alone or together increased vitamin C content, total soluble solids (TSS) and titratable acidity percentages when compared with the bare soil as control. These findings are of great economic value because the shelf time of such fruits will increased and that is confirmed by Wang *et al.* (1998).

Table (4): Effect of much treatments on vitamin C (vit. C), total soluble solids (T.S.S.) and titratable acidity (Tritart acid) in sweet fruits.

Characteristics / Treatments	Season 2005			Season 2006		
	Vit. C (mg/g) F.W.	T.S.S. (%)	Titrat. Acid %	Vit. C (mg/g) F.W.	T.S.S. (%)	Titrat. Acid %
Bare soil	115.5	4.1	0.37	112.4	4.0	0.38
Black	121.6	4.2	0.41	124.7	4.0	0.47
Red over black	134.6	5.2	0.46	130.3	4.9	0.47
Red	133.8	5.5	0.51	132.7	5.36	0.51

As for the amino acids content, it could be noticed that the red over black mulch film gave the highest content of the essential amino acids determined, i.e., methionine, threonine, valine, isoleucine, leucine, tyrosine, phenylalanine and lysine. Meanwhile, the red mulch film ranked the second in this respect, yet, the lowest content of these amino acids was existed in case of basre soil.

On the other hand, as regards the non-essential amino acids, it could be seen that nearly were behaved as in case of essential ones. Despite it was in some cases alternatively positions of superiority between black film and bare soil and between red over black film and the red one.

In this respect, the increment effect of red mulch film either used over black alone strictly would define the form of created proteins. That it means the strict role of red light through amino acids biosynthesis (Table 5).

In general, if that is the case, therby, priced fruits with maximized quality and nutritional value is being gained and the main target of the present study to be performed.

b) Nutrients elements:

As shown in Table (6), total nitrogen content was slightly increased in mulch treatment either red or black one when compared with the bare soil. Meanwhile, for carbon an opposite trend was existed, since it was slightly higher in case of bare soil comparing with mulch treatment.

Concerning crude protein content it was also obviously increased in mulch treatments when compared with bare soil. But increase was moreless than the red one either when used alone or over the black mulch (Table, 6).

Otherwise (as shown in Table 7) red over black treatment ranked the first in case of Mn, Zn and Mo, yet black mulch showed only the highest amount of Fe in the fruits that reached 58% more than the control. Meanwhile, aluminum (Al), boron (B), calcium (Ca), copper (Cu), magnesium (Mg), phosphorus (P) and sulphur (S) were considerably increased with mulch treatment to reached its maximum with the red one followed by red over black and black one in the last order, yet bare soil showed lowest content. These results are being more evident when calculated as a percentage of control, e.g. in case of red mulh percentages of increases were 90, 70, 25, 56, 28, 31 and 29%, more than contol (bare soil) for Al, B, Ca, Cu, Mg, P and S, respectively.

Table (5): Effect of mulch treatment on amino acids content of sweet pepper fruits during 2006 season (on dry matter basis)

Treatments / Amino acid	Bare soil		Black		Red over black		Red	
	(g/16 g N)	%	(g/16 g N)	%	(g/16 g N)	%	(g/16 g N)	%
Cystine	1.05	0.31	1.22	0.34	1.25	0.39	1.32	0.40
Methionine*	1.28	0.37	1.32	0.37	1.28	0.40	1.26	0.38
Aspartic acid	10.47	3.04	11.06	3.07	10.92	3.37	10.95	3.30
Threonine*	3.94	1.14	4.05	1.12	4.00	1.23	3.94	1.19
Serine	3.54	1.03	3.60	1.00	3.57	1.10	3.51	1.06
Glutamic acid	10.08	2.93	10.43	2.89	10.22	3.15	10.08	3.04
Proline	13.57	3.94	10.73	2.98	9.58	2.95	9.18	2.76
Glycin	4.72	1.37	4.92	1.37	4.78	1.47	4.79	1.44
Alanine	5.29	1.54	5.54	1.51	5.34	1.65	5.27	1.59
Valine*	5.87	1.71	6.07	1.69	5.76	1.77	5.70	1.72
Isoleucine*	12.01	3.49	10.15	2.82	8.31	2.56	7.71	2.32
Leucine*	7.58	2.20	7.95	2.21	7.70	2.37	7.71	2.32
Tyrosine*	2.05	0.60	2.65	0.73	2.56	0.79	2.58	0.78
Phenylalanine*	4.95	1.44	5.16	1.43	4.90	1.51	4.93	1.48
Histidine	1.65	0.48	1.73	0.43	1.74	0.54	1.66	0.50
Lysine*	4.19	1.22	4.37	1.21	4.37	1.35	4.22	1.27
Arginine	5.51	1.60	5.70	1.58	5.41	1.67	5.32	1.60
Nitrogen		4.65		4.44		4.93		4.82

* essential amino acids

Table (6): Effect of mulch treatment on some bioconstituents content in sweet pepper fruits, 2006 season.

Characteristics / Treatments	Total N (%)	% to bare soil	Crude protein (%)	% to bare soil	Carbon (%)	% to bare soil
Bare soil	4.64	100	29.00	100	39.11	100
Black	5.02	107	31.38	108	38.13	0.98
Red over black	4.70	101	29.37	102	37.54	0.97
Red	5.05	108	31.56	110	37.48	0.97

Otherwise (as shown in Tables 7 and 8) red over black treatment ranked the first in case of Mn, Zn and Mo, yet black mulch showed only the highest amount of Fe in the fruits that reached 58% more than the control. Meanwhile, boron (B), calcium (Ca), copper (Cu), magnesium (Mg), phosphorus (P) and sulphur (S) were considerably increased with mulch treatment to reached its maximum with the red one followed by red over black and black one in the last order, yet bare soil showed lowest content. These results are being more evident when calculated as a percentage of control, e.g. in case of red mulch percentages of increases were 70, 25, 56, 28, 31 and 90%, more than contol (bare soil) for B, Ca, Cu, Mg, P and S, respectively.

For interpreting the above mentioned results, from our view stimulation of mineral absorption and content under mulch treatment could be of great value not only for maximizing yield and improving quality but also it could be determine whether or not to use fertilizer, and if so, of what type and quantity it should be. Also, that it may guide us for using mulch system especially in the organic farming. That, it could provide sufficient supply of nutrients from different organic resources those are being used. Thereby, large yield with good quality could be reversed up on net satisfied gain for producers and minimizing prices for consumers.

Table (7): Effect of mulch treatment on the amount of macro-nutrient elements (g/kg DM) in sweet fruits (Season, 2006).

Treatments	Mg		P		S		Ca	
	g/kg	% of cont.	g/kg	% of cont.	g/kg	% of cont.	mg/kg	% of cont.
Bare soil	9.273	100	3.192	100	0.1698	100	16.416	100
Black	11.050	121	3.451	108	0.2999	176	19.065	116
Red over black	11.632	126	3.602	112	0.3013	177	18.921	115
Red	11.875	128	4.183	131	0.3215	190	20.448	125

Table (8): Effect of mulch treatment on the amount of micro-nutrient elements (mg/kg DM) in sweet fruits (Season, 2006).

Treatments	Zn		Mn		Mo		B		Cu		Fe	
	mg/kg	% of cont.	mg/kg	% of cont.	mg/kg	% of cont.	mg/kg	% of cont.	mg/kg	% of cont.	mg/kg	% of cont.
Bare soil	27.6	100	65	100	16.416	100	27.6	100	17.2	100	220	100
Black	30.9	112	77	120	19.065	116	30.9	112	21.6	129	348	155
Red over black	32.7	118	82	126	11.892	115	32.7	118	25.4	147	344	156
Red	45.1	170	79	123	20.448	125	45.1	170	26.9	156	345	157

In this respect, Marschner (1995) reviewed that environmental factors such as temperature, soil moisture and irradiation (considerably were achieved in mulch treatment) influence both the availability and uptake of nutrients by the roots and the shoot growth rate. Also, El-Desuky *et al.* (2005c) attributed the significant increase of tomato and pepper yielded fruits over mulch treatment to those acute alteration in the phytohormones profile and the histological feature in mulched plants as well as repartitioning and allocation of photosynthates. In general, according to our knowledge and reviews we have researched, increasing the uptake of measured nutrient elements by mulch treatments it may considered pioneer findings in this respect.

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تأثير الأغطية البلاستيكية الملونة على التشكل الضوئى وإنتاجية الفلفل الحلو

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للضوء الأحمر دور هام فى التشكل الضوئى الظاهرى وبالتالى نمو وتطور وإنتاجية النبات. لذلك أجريت هذه الدراسة بهدف استجابة نبات الفلفل الحلو لتأثير الأغطية البلاستيكية الملونة (السوداء – الحمراء) مع نظام الرى بالتنقيط بمحطة بحوث الخضر التابعة لقسم البساتين – كلية الزراعة بمشتهر – جامعة بنها خلال موسمى ٢٠٠٥، ٢٠٠٦م.

وتم دراسة بعض القياسات الخضرية وهى عدد الأفرع ومساحة الأوراق والوزن الجاف للأوراق للنبات وكذلك التزهير والإثمار وجودة الثمار ومكوناتها من البروتين والأحماض الأمينية وبعض العناصر الأخرى وذلك خلال موسمى الزراعة، ومن النتائج المتحصل عليها:

- كانت أعلى زيادة معنوية فى عدد الأفرع ومساحة الأوراق وكذلك صبغات البناء الضوئى فى النباتات التى نمت فوق الأغطية البلاستيكية الحمراء.
- وأدى استخدام هذه الأغطية الحمراء إلى التبكير فى الإزهار والإثمار مما أدى إلى زيادة المحصول المبكر والكلى للثمار وكذلك تحسين صفات جودة الثمار وزيادة محتواها من الأحماض الأمينية الضرورية وبعض العناصر الغذائية مقارنة بالنباتات التى نمت فوق الأغطية البلاستيكية السوداء أو المعاملة بدون أغطية.

ومن النتائج السابقة فإن هذه الدراسة توصى باستخدام الأغطية البلاستيكية الحمراء فى إنتاج الفلفل والنباتات الإقتصادية الأخرى بدلا من الأغطية السوداء. وبالإضافة إلى ذلك فإن الدراسة أيضا تؤكد الحاجة إلى المزيد من الدراسات حول ميكانيكية استدعاء التزهير وتكوين أكثر من ثمرة على نفس العقدة وكذلك زيادة عدد الأفرع المتكونة