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Effect of Different Mulching Colors and Tunnel Coverings on Plant Growth, Yield and Post-harvest Quality of Green Bean

Noha G. Abd El-Rahman*, S. M. Abou El-Wafa, A. A. Farag* and M. A. M. Heggi***

**Central Laboratory for Agricultural Climate, Agricultural Research Centre and ** Vegetable Handling, Postharvest Research Section, horticultural Research Institute, Agriculture Research Center, Cairo, Egypt.*

THIS investigation was conducted during the two successive seasons of 2015 and 2016 on green bean cv. Paulista to study the effect of different mulching colors and tunneling on the vegetative growth, yield, productivity, pod quality as well as storability and quality attributes during storage at 5 ºC, plus two days at shelf life temperature (10 ºC), to simulate the market display. The obtained results showed that transparent and black mulching gave the highest number of leaves, plant height, pod diameter, pod length, pod weight, and NPK contents in the leaves. The result also indicated that using tunnel under unheated greenhouse led to increases in the vegetative growth and productivity. Results also indicated that black mulching with non-perforated film gave the lowest weight loss of green bean pods followed by transparent mulching with non-perforated film during the storage periods. Black mulching with non-polypropylene film maintained quality attributes (TSS, ascorbic acid and total chlorophyll contents) and extended the storage life for 15 days at 5 ºC plus two days at the shelf life with a good visual quality. Tunnels and transparent treatments in the greenhouse (540 m^2) gave the highest return amount (5006.7 L.E.) and the highest rate of return on invested pound in season (75 % of pound). This led to increases in the efficiency of production unit and the income of farm and thus raising farm livelihood.

Keywords: *Phaseolus vulgaris*, Packaging, Polypropylene film, Productivity, Visual quality, Ascorbic acid, Chlorophyll, Tunnel, Economic efficiency.

Introduction

Green bean **(***Phaseolus vulgaris* L**.)** is one of the most important vegetable crops belonging to the legume family grown in Egypt for local consumption as well as exportation. Green bean pods provide good sources of protein, calcium, vitamins, and amino acids (Ibrahim et al., 2012). The cultivated area of green bean in Egypt considered 2.4% of total world cultivated area of green bean, producing about 3.5% of total global production of bean (FAO, 2004). The optimum temperature range for bean growth is 16-30 °C, while seeds would not germinate or might be decayed at temperature below 10 °C (Elhag and Hussein, 2014).

The major restrictive factor for the conventional greenhouse cultivation is the high cost of heating during winters. Thus, the profit can be improved in unheated greenhouses by passive heating methods such as mulching, low tunnel and thermal curtains. The low-tunnels, established during the initial plant development stage in the greenhouse, are the structures which increase temperature to 1-2 ºC and enable plant growing during the critical development period (Arin and Ankara, 2001).

Modified microclimate under low tunnels can raise soil and air temperatures during the winter season. In general, low tunnels allow shortwave solar radiation to transmit through during the day, while the plastic material slows the long wave radiation from the surface at night. Additional control over the interior microclimate is possible by changing the color of the cover tunnel materials (Snyder and Melo-Abreu, 2005).

Corresponding author: dr.nohagaber@yahoo.com
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Low tunnels can modify crop microclimate by raising temperature and promote earlier plant growth compared to without use tunnel (Hochmuth et al., 2009). Using beds covered with black plastic mulch together with low tunnels, soil temperatures can be increased, weeds can be controlled, water can be conserved, and fertilizer application is optimized (Schrader, 2000).

Black plastic alters the plant's growing environment by generating warmer soil temperatures and holding more soil moisture compared to the bare soil. Previous studies reported that using black plastic instead of the bare soil have recorded better yields and earlier harvests (Dodds et al., 2003 and Hanna et al., 2003)

Green beans are categorized as a highly perishable vegetable and quickly deteriorate if not given proper temperature management (Kader, 1995). Packing of vegetables in polymeric films creates modified atmospheric conditions around the product inside the package allowing lower degree of control of gases and can interplay with physiological processes of commodity resulting in reduced rate of respiration, extended shelf life, lower physiological weight loss, reduced decay and maintained colour (nath et al., 2010, Ubhi et al., 2014, Chitravathi et al., 2015 and Soltani et al., 2016). Packaging film gave minimum weight loss, highest fruit firmness, and highest retention of chlorophyll and ascorbic acid content (Mahajan et al., 2012). Storage crops in a modified atmosphere conditions can preserve quality and extend product shelf life, by slowing biochemical deteriorative reactions and slowing the growth of spoilage organisms (Coles et al., 2003). Micro perforated films allow the rapid development of proper CO2 and O2 concentrations in the package headspace to extend shelf life (Lucera et al., 2011 and Kartal et al., 2012). A combination of temperature storage and packaging has a very good preservation effect on the quality such as TSS, weight loss and total chlorophyll (Sahoo and Kulkarni, 1999, Sánchez-Mata et al., 2003 and Kinyuru et al., 2011). Shrink film proved a quite effective in prolonging the shelf-life for 7 and 10 days under super market conditions and ordinary market conditions, respectively, as against 5 and 2 days only in the case of unpacked control fruits (Mahajan et al., 2016)

The objectives of the present study were to investigate the effect of different mulching colors and covering green bean plants with low tunnel on the plant growth, yield and pod quality, as well as to study the effects of packaging on pod quality and pod chemical composition and visual quality during the refrigerated storage, and shelf life of green bean pods.

Materials and Methods

Two experiments were conducted during the winter seasons of 2015 and 2016; each season started on the first of January and ended on the last of April. *Field experiment*

The experiment was conducted at the Central Laboratory for Agricultural Climate (CLAC), Dokki site, Agricultural Research Center (ARC), Giza, Egypt, in clay soil under single span plastic house (9 m width and 30 m length) to investigate the effect of different types of mulching (transparent and black) and bare soil as control and transience cover and without cover. The tunnel height was 120 cm over the soil, its thickness was 40 u and its wide was 2.4 m. The tunnel was directly used during the first month from sowing date.

Green bean cv. Paulista seeds were sown in the greenhouse on 4th and 6th of January during the first and second seasons, respectively. The experimental trial was conducted in unheated single span plastic house using drip irrigation system. Emitter discharge rate was 4 L/hr, and the distance between emitters was 0.3 m. Each dripper has two plants. The green bean seeds were placed in double rows. The final plant spacing was 30 cm within the row, 60 cm between rows and 70 cm between the beds.

Soil temperature readings were recorded using a thermometer (HI93510 model) inserted at 10-15 cm depth in the soil. The readings were taken in the morning at 8 AM and in the afternoon at 15 PM, Climate data: maximum and minimum air temperature and soil temperature were recorded daily from the weather station which putted in the greenhouse

Samples of nine plants from each treatment were taken from three replicates. The area of the experimental plot was 30 m^2. Samples were taken to determine the growth parameters after 90 days of planting as follows: plant height and number of leaves per plant. Fiber percentage in the pods was measured. Total yield was measured and pod characteristics were determined as following: pod diameter, length and weight.

Mineral analyses of green bean leaves (N, P and K) were estimated at the harvest stage. Nine samples of green bean leaves from each treatment were dried at 70 °C in air forced oven for 48 h. Dried leaves were digested in H_2SO_4 according to the method described by A.O.A.C (2000), and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer as described by Chapman and Pratt (1961).

Storage experiment

The storage experiment was designed to study the effect of different mulching colors, tunnel and wrapping films on storability and quality attributes of green bean pods during storage at 5 °C and held on the shelf life conditions at 10°C to simulate the super market conditions in the two seasons of 2015 and 2016. Green bean pods, which obtained from the previous field experiment, were harvested at the proper stage of marketing (bright green, tender fleshy with small immature seed) on 28th and 30th of March in the first and second season, respectively. The pods were immediately transported after the harvest to the Laboratory of the Vegetable Handling, Postharvest Research Section, Horticultural Research Institute (HRI), Agriculture Research Center, Giza, Egypt and sorted to exclude those with obvious defects in size, color and appearance. The pods were selected for uniformity of color, size and freedom from defects. Selected green bean pods had been placed in two packages (perforated polypropylene film 30 µm thickness and non-perforated) 15 × 18 cm, sealed hermetically and each treatment was approximately 250 g. Eighteen replicates for each packaging material for each examination were prepared and placed inside carton boxes (40 cm x 30 cm x 12.5 cm). Green bean pods of all treatments were stored at 5 ºC and 90-95% RH, for 15 days. After the storage period green bean pods were held for 2 days at the shelf life conditions at 10 ºC to simulate super market conditions. Samples of 3 replicates were randomly taken and examined after harvest and each five days at 5 ºC plus two days at 10 ºC for the following properties:

*Weight loss***:** weight of each sample, with three replications from each treatment, was recorded after harvest and every five days at 5 ºC, plus two days at 10 ºC, during the 17 days of storage. Cumulative weight losses were expressed as a percentage loss from the initial weight (Czaikoski et al., 2012).

Total soluble solids (TSS): It was measured in the juice samples using PR-101 digital refractometer.

Visual quality: Evaluations of visual quality parameters, i.e. surface color, browning severity, shriveling, pitting, rusty spots and discoloration of green bean pods during the storage were subjectively determined using a 9-1 visual rating scale, where 9 = excellent, 7 =good, 5 =fair, 3 = poor, and 1=unsalable as described by Martinéz et al. (1995).

Ascorbic acid content: It was determined in 5 g of grated pod tissue which was mixed in mortar with 5 ml metaphosphor acid (20%) and titrated with 2,6 - chroroindophenol solution (0.01) according to Matisek *et al.* (1992).

Total chlorophyll content: One gram of grated pod tissues with the addition of 20 ml of 80% acetone. Centrifuged at 5000 rpm for 5 min and the supernatant was transferred to a 100 ml volumetric flask. The residue was grind with 20 ml of 80% acetone, centrifuged and transferred the supernatant to the same volumetric flask, then collected in the volumetric flask and volume was made to 100 ml with 80% acetone. Chlorophyll pigment was extracted in 80% acetone and absorption at 663 nm and 645 nm were read in the spectrophotometer. Using the absorption coefficients, the amount of chlorophyll was calculated (A.O.A.C., 2000).

Experimental design and statistical analysis

The field experiment was a spilt plot design with three replicates, while the storage experiment was factorial with 3 factors in a complete randomized design (CRD) with 3 replicates. Comparisons between means were compared by Duncan's Multiple Range Test at 5% level of significance. The statistical analysis was performed according to Sendecor and Cochran (1982).

Indicators of productivity and economic efficiency

The indicators of productivity and economic efficiency were used to differentiate between the treatments and choose the best treatment that minimizes costs or maximizes the return. The indicators include productivity, costs, and rate of return on invested pound in each season. The application of the results from this experiment, in the case of growing green bean pod, was done on an area of the greenhouse (540 m^2) using data published by the Economic Sector of the Egyptian Ministry of Agriculture.

The indicators of productivity and economic efficiency were determined by calculating average data for the two years (2015 and 2016) including quantity of production, productivity, total costs without use of treatments and total costs after treatments use (fixed and variable, cost treatments/ two years) for the two seasons. These indicators were calculated as follows: revenue (yield * price), return= (revenue - total costs), productivity /m^2 and rate of return on invested pound in the season = Return/Total Costs * 100.

Results and Discussion

Field experiment

Data in Fig. 1 showed that covering green bean with a low tunnel under unheated greenhouse increased maximum and minimum air temperature by 2-2.5 ºC compared to un-covering conditions. These findings are similar to those of Tarara (2009) who found that polyethylene plastic covering led to increases in the maximum temperatures compared to without covering, since the polyethylene permits the short wave (ultraviolet) to transmit via the cover material to increase temperature under low tunnel but, not allow the thermal long wave (infrared) to transmit easily from the polyethylene layer and then temperature under low tunnel become higher than those outside (El-Nemr, 2006).

Fig. 2 showed that tunnel treatment also increased soil temperature by 1.4 ºC, more than without tunnel treatment, while mulching treatment increased soil temperature by 2.6 ºC at 15 cm depth under mulch more than un-mulched treatment. Tunnel and mulch treatments together increased soil temperature by around 3.5 ºC more than un-mulched soil without tunnel.

Soil temperature under mulch treatment was higher than control due to the fact that the plastic conserve the soil temperature compared to unmatched soil (Kwambe et al., 2015). The use of transparent or black plastic mulch is preferred during the winter growing season due to retaining the heat at night in comparison with un-mulched soil (Kar and Kumar, 2007).

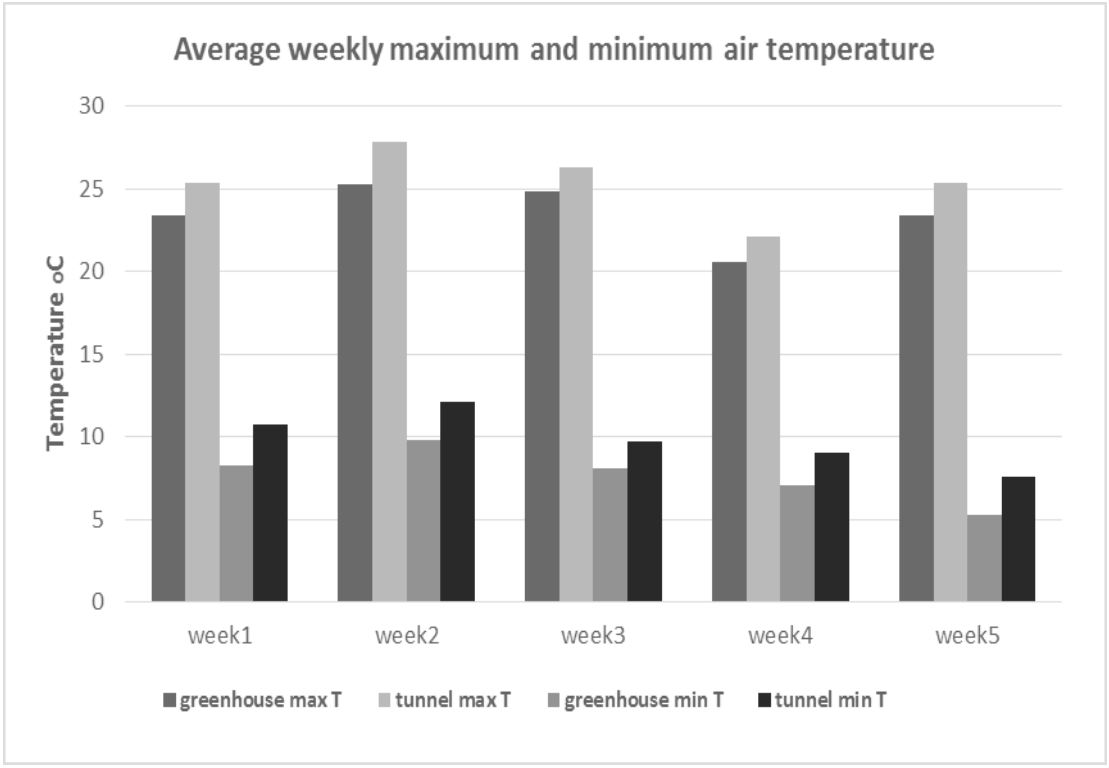


Fig. 1. Average maximum and minimum temperature under different treatments during five weeks in 2015 and 2016 seasons.

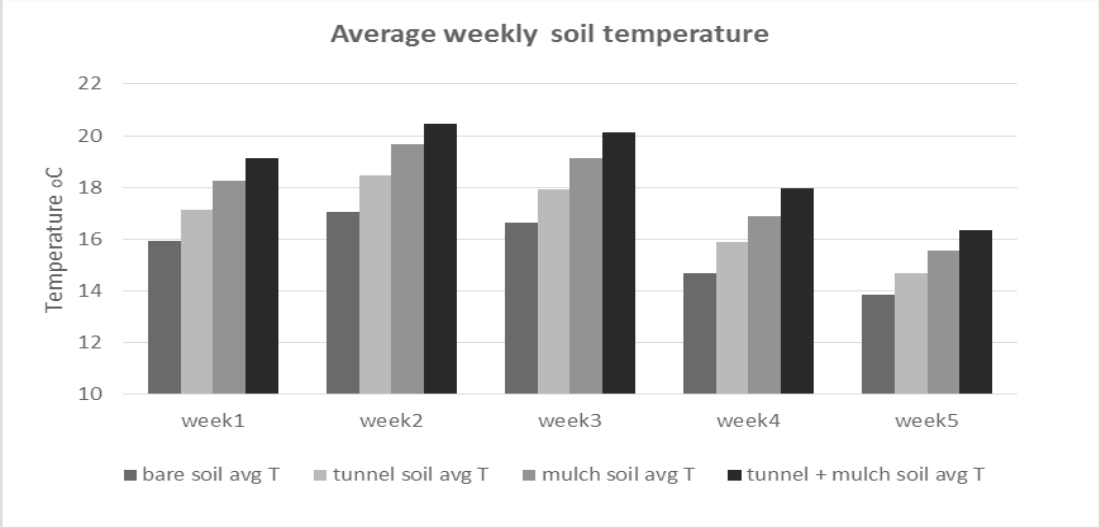


Fig. 2. Average soil temperature under different treatments during five weeks in 2015 and 2016 seasons.

Data in Table 1 showed that transparent and black mulch treatments gave higher number of leaves per plant and plant height than un-mulched soil in both tested seasons. On the contrary, mulching did not affect pod fiber percentage in both seasons. Data also showed that tunnel treatment significantly increased number of leaves in both seasons. No significant differences were found among tunnel treatment and control treatment concerning plant height and pod fiber percentage.

The interaction between mulching color and tunnel treatments resulted in a significant increment in number of leaves compared to other combined treatments. Insignificant difference was found between transparent and black mulching with tunnel or control treatments for plant height. The lowest plant height obtained with bare soil without using tunnels. This was probably because of trapped moisture under the plastic mulch. The warmth provided the root zone with favorable temperatures for nutrient absorption. In the plastic mulch, there was probably less nutrient volatilization thus most of the time the available nutrients were used for vegetative growth by the plant Tarara (2009). These findings are similar to Kwambe et al. (2015) who reported that soil temperature under black polythene and clear polythene plastic mulch had a higher soil temperature than bare soil due to the fact that plastic retained the heat. Data also showed that bare soil treatments gave the highest fiber percentage values, while all other treatments gave the lowest fiber percentage without significant differences between them. The second season showed the same trend.

TABLE 1. Effect of mulching color and tunnels on number of leaves, plant height and pod fiber percentage in 2015 and 2016 seasons.

Treatments	2015 season				2016 season			
	M1	M2	M3	Mean	M1	M2	M3	Means
Number of leaves/plant								
T1	24.83 a	24.5 a	14.83 c	21.38 A’	26.31 a	25.96 a	15.73 c	22.66 A’
T2	18.66 b	18.83 b	10.16 d	15.88 B’	19.8 b	19.96 b	10.87 d	16.87 B’
Mean	21.74 A	21.66 A	12.49 B		23.05 A	22.96 A	13.25 B	
Plant height (cm)								
T1	46.66 a	45.66 a	39.26 b	43.86 A’	49.93 a	48.86 a	42.01 b	46.93 A’
T2	48.33 a	47.33 a	31.33 c	42.33 A’	51.71 a	50.64 a	33.52 c	45.29 A’
Means	47.50 A	46.50 A	35.30 B		50.82 A	49.75 A	37.77 B	
Pod Fibers (%)								
T1	8.15 b	8.15 b	8.68 a	8.33 A’	8.33 a	8.33 a	8.33 a	8.91 A’
T2	8.12 b	8.16 b	8.73 a	8.34 A’	8.34 a	8.34 a	8.34 a	8.92 A’
Means	8.14 B	8.16 B	8.70 A		8.33 A	8.33 A	8.33 A	

M1= Black mulch, M2= Transparent mulch, M3= Control (Unmulched soil), T1= Tunnel, T2= Without tunnel.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($P \leq 0.05$) for mulching color treatments, tunnel treatments and interaction, respectively.
Means within each group followed by the same letter are not significantly different according to Duncan’s multiple range test.

The effect of mulching color and tunnel on pod diameter, length, weight and yield per plant is presented in Table 2. Soil mulching led to increases in the above-mentioned data compared with the un-mulched soil in both growing seasons. However, no significant differences were found between transparent and black mulching.

As for the tunnel effect on pod diameter, there were no significant differences among treatments in both seasons. However, tunnel treatment gave higher pod length, weight and yield than the control treatment.

Concerning to the interaction between both factors, transparent and black mulching with tunnel and control gave higher values for pod diameter, length, weight and yield than the control in both growing seasons.

Tunnels can mitigate these temperature variations thus resulting in early germination, higher yields, and more quality fruits. Early uniform germination is a key to produce high fruit quality. These results were supported by those of Hochmuth et al. (2009) and Farag et al. (2010), who showed that increased cucumber growth and yield by polyethylene mulch is a consequence of enhanced root growth and nutrient uptake early in the season. Tunnel covering with polyethylene plastic increased air temperature during the vegetative growth led to an increase the biological process and increase plant growth rate (Farag et al., 2010).

TABLE 2. Effect of mulching color and tunnels on pod diameter, length weight and yield/plant in 2015 and 2016 seasons.

Treatments	2015 season				2016 season			
	M1	M2	M3	Mean	M1	M2	M3	Mean
Pod diameter (cm)								
T1	0.43 a	0.40 a	0.40 a	0.41 A’	0.45 a	0.42 a	0.42 a	0.43 A’
T2	0.40 a	0.40 a	0.30 b	0.36 A’	0.42 a	0.42 a	0.32 b	0.38 A’
Mean	0.41 A	0.40 A	0.35 B		0.43 A	0.42 A	0.37 B	
Pod length (cm)								
T1	11.23 a	11.20 a	10.13 b	10.85 A’	11.93 a	11.90 a	10.73 b	11.52 A’
T2	11.16 a	11.20 a	7.86 c	10.07 B’	11.86 a	11.90 a	8.36 c	10.71 B’
Mean	11.20 A	11.20 A	9.00 B		11.90 A	11.90 A	9.55 B	
Pod weight (g)								
T1	3.86 a	3.90 a	3.83 a	3.86 A’	4.02 a	4.05 a	3.99 a	4.02 A’
T2	3.80 a	3.86 a	3.13 b	3.60 B’	3.95 a	4.02 a	3.25 b	3.74 B’
Mean	3.83 A	3.88 A	3.48 B		3.98 A	4.04 A	3.62 B	
Yield (g/plant)								
T1	193.67 a	193.33 a	118.67 c	168.56 A’	209.00 a	209.00 a	128.33 c	182.11 A’
T2	139.33 b	140.67 b	70.00 d	116.67 B’	150.33 b	152.00 b	75.00 d	125.78 B’
Mean	166.50 A	167.00 A	94.33 B		179.67 A	180.50 A	101.67 B	

M1= Black mulch, M2= Transparent mulch, M3= Control (Unmulched soil), T1= Tunnel, T2= Without tunnel.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($P \leq 0.05$) for mulching color treatments, tunnel treatments and interaction, respectively.
Means within each group followed by the same letter are not significantly different according to Duncan’s multiple range test.

Data in Table 3 illustrated the effect of mulching color and tunnels on nitrogen, phosphorus and potassium in the leaves. In both seasons, data showed that transparent and black mulch gave higher N, P, and K percentages than the bare soil.

On the other hand, tunnel treatment gave higher N and K contents than the control treatment. There were no significant differences between transparent and black mulch on N, P, and K percentages in green bean leaves.

In both seasons, transparent and black mulching combined with tunnel increased N contents in leaves than control treatment. On the other hand, data showed that no significant differences among all treatments concerning P and K contents in leaves.

The higher N absorption may be due to the increase in soil temperature and moisture, caused by the plastic mulch that led to higher vegetative growth. Lower temperature may have negative influence on N absorption especially during winter season. An increase in soil temperature may increase the nutrient levels in plants. As the temperature rises, phosphorus tends to diminish and nitrogen and potassium tend to increase, as well as the growth of the aerial part of the plant (Pedersena et al., 2004).

TABLE 3. Effect of mulching color and tunnel on nitrogen, phosphorus and potassium in leaves in 2015 and 2016 seasons.

2016 season				2015 season				Treatments
Mean	M3	M2	M1	Mean	M3	M2	M1	
				N %				
2.83 A'	2.61 c	2.95 a	2.93 a	2.67 A'	2.64 c	2.78 a	2.77 a	T1
2.66 B'	2.40 d	2.79 b	2.80 b	2.51 B'	2.27 d	2.63 b	2.64 b	T2
	2.51 B	2.87 A	2.87 A		2.36 B	2.71 A	2.70 A	Mean
				P %				
0.51 A'	0.40 b	0.55 a	0.57 a	0.48 A'	0.38 b	0.52 a	0.54 a	T1
0.49 A'	0.39 b	0.55 a	0.54 a	0.46 A'	0.37 b	0.52 a	0.51 a	T2
	0.39 B	0.55 A	0.55 A		0.37 B	0.52 A	0.52 A	Mean
				K %				
2.58 A'	2.40 b	2.68 a	2.67 a	2.49 A'	2.31 b	2.58 a	2.57 a	T1
2.53 B'	2.34 b	2.62 a	2.63 a	2.43 B'	2.25 b	2.52 a	2.53 a	T2
	2.37 B	2.65 A	2.65 A		2.28 B	2.55 A	2.55 A	Mean

M1= Black mulch, M2= Transparent mulch, M3= Control (Unmulched soil), T1= Tunnel, T2= Without tunnel.
Capital letters, capital letters with apostrophe and small letters for the significant difference ($P \leq 0.05$) for mulching color treatments, tunnel treatments and interaction, respectively.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

Storage experiment

Weight loss

Data in Fig. 3 represented the effect of mulch treatments, tunnel and packaging film on weight loss of green bean pods, during the storage (at 5 ºC, 90 – 95% RH) and held for 2 days at the shelf life conditions (10 ºC), for 2015 and 2016 seasons. In general, there were significant differences among all treatments in the weight loss of green bean pods in for both seasons. Weight loss percentage was increased with prolongation of storage periods. Similar results were obtained by other workers (Sahoo and Kulkarni, 1999, Kinyuru et al., 2011 and Mahajan et al., 2016). The increase in weight loss during the storage periods may be due to higher moisture loss and increased respiration (Wilss et al., 1998 and Homin and Woo 1999).

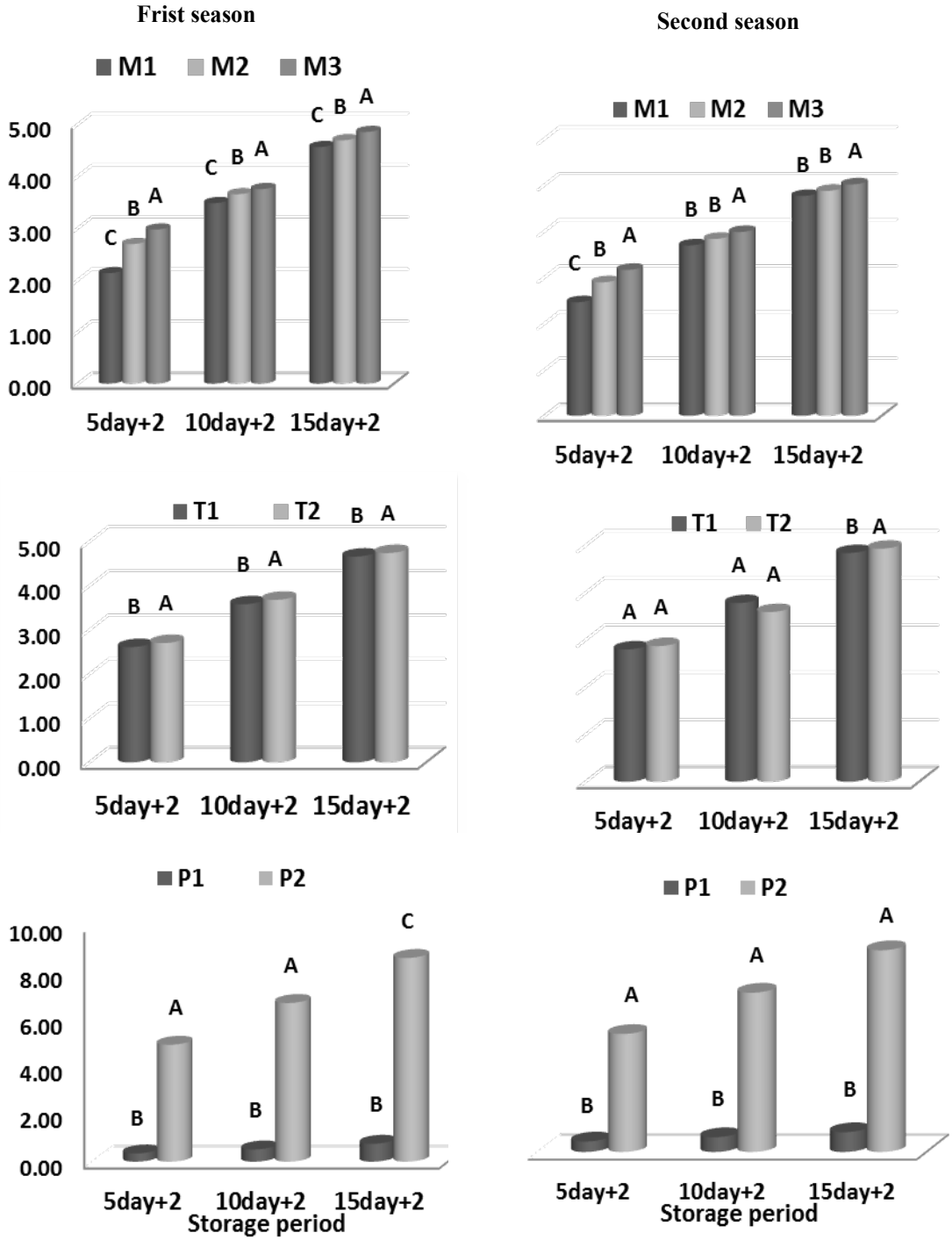
Concerning the effect of mulch treatments, data indicated that black mulch gave the lowest weight loss followed by transparent mulch compared to the bare soil (control) in both seasons during the storage periods. This may be due to the trapped moisture under the plastic mulch and the warmness which provided the root zone with favorable temperatures for nutrient absorption and a less nutrient volatilization thus most of the time the available nutrients were used for vegetative growth by the plant which increases crop yields, marketable yield and leads to more efficient use of soil nutrients (Ban et al., 2009, Mamkagh, 2009, Tarara, 2009, Berihun, 2011, Bhatt et al., 2011, Hatami et al., 2012, and Kwambe et al., 2015).

In relation to the effect of tunnel on weight loss during the storage periods, data revealed that tunnel gave the lowest weight loss compared to the control treatment in both seasons. As shown in Fig. 4, the green bean pods packed in non-perforated polypropylene film registered the lowest values of weight loss in both seasons, and this may be attributed to the positive role in preventing dehydration by creating a saturated micro atmosphere around the green bean pods **(**González-Aguilar et al., 1999). Data presented in fig. 4 exhibited that interaction between mulching, tunnel and packaging on weight loss during storage periods for 15 days at 5 ºC, 90 – 95% RH and held for 2 days at shelf life conditions (10◦C). Data showed that green bean pods produced from black mulching and tunnels and packaging with non-polypropylene gave the lowest percentage of weight loss during the storage period compared with other treatments.

Regarding to the interaction between mulching, tunnel and wrapping on weight loss during storage periods for 15 days (at 5 ºC, 90 – 95% RH) and held for 2 days at shelf life conditions (10◦C), data in Table 4 indicated that pods produced from black mulching and tunnels and wrapped with non-polypropylene gave the lowest percentage of weight loss during the storage period compared with other treatments. The reduction in weight loss in green bean pods packed with polypropylene film is attributed to the inhibition of respiratory rate inside the film (Ben-Yehoshua, 2003 and Rao et al., 2011).

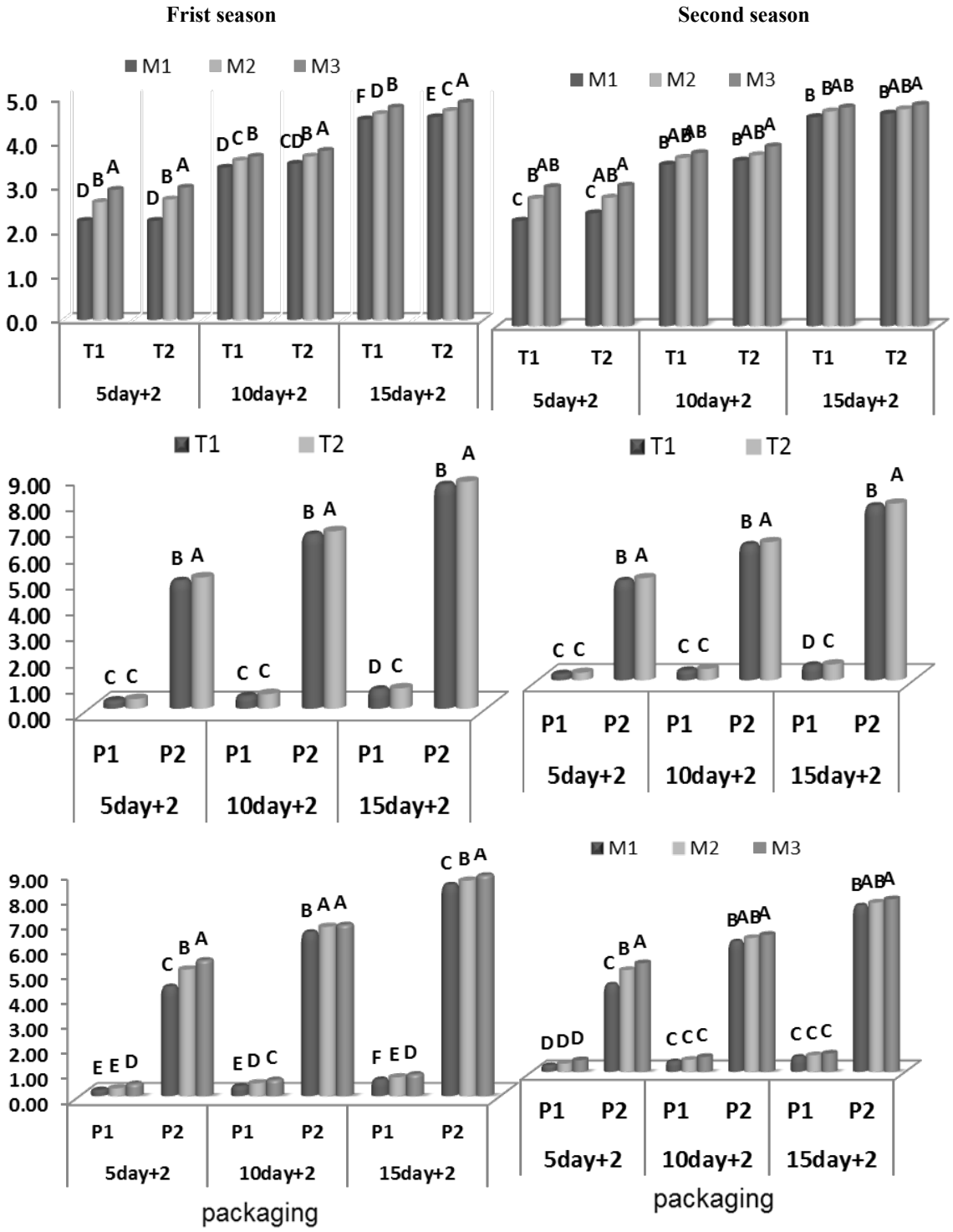
Total soluble solids

Data presented in Tables 5 and 6 showed the effect of mulch treatments, tunnel, and packaging film on total soluble solids in green bean pods during cold storage at 5 ºC and followed by 2 days at shelf



M1= Black mulch, M2= Transparent mulch, M3= Control (un-mulched soil), T1= Tunnel, T2= Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

Fig. 3. Effect of the main effects of mulching color, tunnels and packaging on weight loss of green bean pods during the storage period at 5 ºC plus two days at the shelf life in 2015 and 2016 seasons.



M1= Black mulch, M2= Transparent mulch, M3= Control (un-mulched soil), T1= Tunnel, T2= Without tunnel, P1= Non-polypropylene, P2= Polypropylene.

Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

Fig. 4. Effect of the second-order interactions between mulching color, tunnels and packaging on weight loss% of green bean pods during the storage period at 5 °C plus two days at the shelf life in 2015 and 2016 seasons.

TABLE 4. Effect of the third-interaction of mulching color, tunnels and packaging on weight loss of green bean pods during the storage period at 5 °C plus two days at the shelf life in 2015 and 2016 seasons.

Treatments		Weight loss (%)					
		5 days (5 °C) + 2 days (10 °C)		10 days (5 °C) + 2 days (10 °C)		15 days (5 °C) + 2 days (10 °C)	
		P1	P2	P1	P2	P1	P2
2015 season							
M1	**T1**	0.22g	4.25d	0.37h	6.51d	0.65j	8.41f
	T2	0.27g	4.51c	0.44gh	6.61cd	0.68j	8.50e
M2	**T1**	0.29g	5.03b	0.48f-h	6.73bc	i0.74	8.57d
	T2	0.33eg	5.11b	0.55e-g	6.83ab	0.76i	8.68c
M3	**T1**	0.46ef	5.41a	0.61ef	6.77bc	0.83h	8.76b
	T2	0.52e	5.48a	0.69e	6.95a	0.90g	8.92a
2016 season							
M1	**T1**	0.33c	4.43b	0.52c	6.78b	0.76c	8.68b
	T2	0.37c	4.73b	0.58c	6.89ab	0.81c	8.78b
M2	**T1**	0.39c	5.36a	0.61c	6.98ab	0.85c	8.84ab
	T2	0.47c	5.34B	0.66c	7.06ab	0.88c	8.92ab
M3	**T1**	0.59c	5.69a	0.75c	7.06ab	0.94c	8.94ab
	T2	0.63c	5.71a	0.80c	7.32a	0.98c	9.17a

M1= Black mulch, M2= Transparent mulch, M3= Control (Unmulched soil), T1= Tunnel, T2= Without tunnel.
Means followed by the same letter are not significantly different according to Duncan's multiple range test.

life conditions at 10◦C. Total soluble solids in green bean pods decreased with prolongation of storage periods. Similar results were obtained by Guo et al. (2008) and Kinyuru et al. (2011) who revealed that the decreased in total soluble solids could be due to the respiration consumption, then metabolism of the beans. Also observation showed an increase in TSS after 5 days from the storage which might be due to moisture loss (Nunes et al., 2004).

Concerning the effect of packaging on TSS during the cold storage and shelf life condition, data indicated that green bean pods packed in non-perforated polypropylene film maintained the highest TSS compared to the perforated polypropylene film in the two studied seasons. These results were in agreement with those reported by Kinyuru et al. (2011).

Regarding the effect of mulch treatments on TSS content, data indicated that the black mulch gave the highest TSS contents compared to the transparent mulch and bare soil in the two tested seasons. The obtained results are, generally, in accordance with those reported by Ali and Radwan (2008) and Franquera (2015).

As for the effect of tunnels on TSS contents, data showed that there was no significant difference between tunnels and uncovered (control) in both seasons.

As for the interaction between mulching color, tunnel and wrapping on TSS contents during the storage periods, data in Table 6 indicated that there were significant differences among different treatments.

Concerning the effect of the black mulch treatment with packaging data indicated that non-polypropylene film gave the highest TSS contents compared to the control in both seasons, and this could be due to creates modified atmospheric conditions around the produce inside the package and extended shelf (Kinyuru et al., 2011).

Visual quality

Data in Fig. 5 and 6 showed the effect of mulch treatments, tunnels, and packaging film on visual quality in green bean pods during the cold storage at 5 ºC and plus 2 days at shelf life conditions at 10 ºC. In general, there were significant differences between all treatments compared to the control. Visual quality of green bean pods, during both seasons, was decreased with prolongation of storage periods. Similar results were obtained by shehata et al. (2010).

Concerning the effect of packaging on visual quality during the cold storage and shelf life condition, data indicated that the green bean pods packed in non-perforated polypropylene film

TABLE 5. Effect of the main effects of mulching color, tunnels and packaging and their second-order interactions on total soluble solids of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

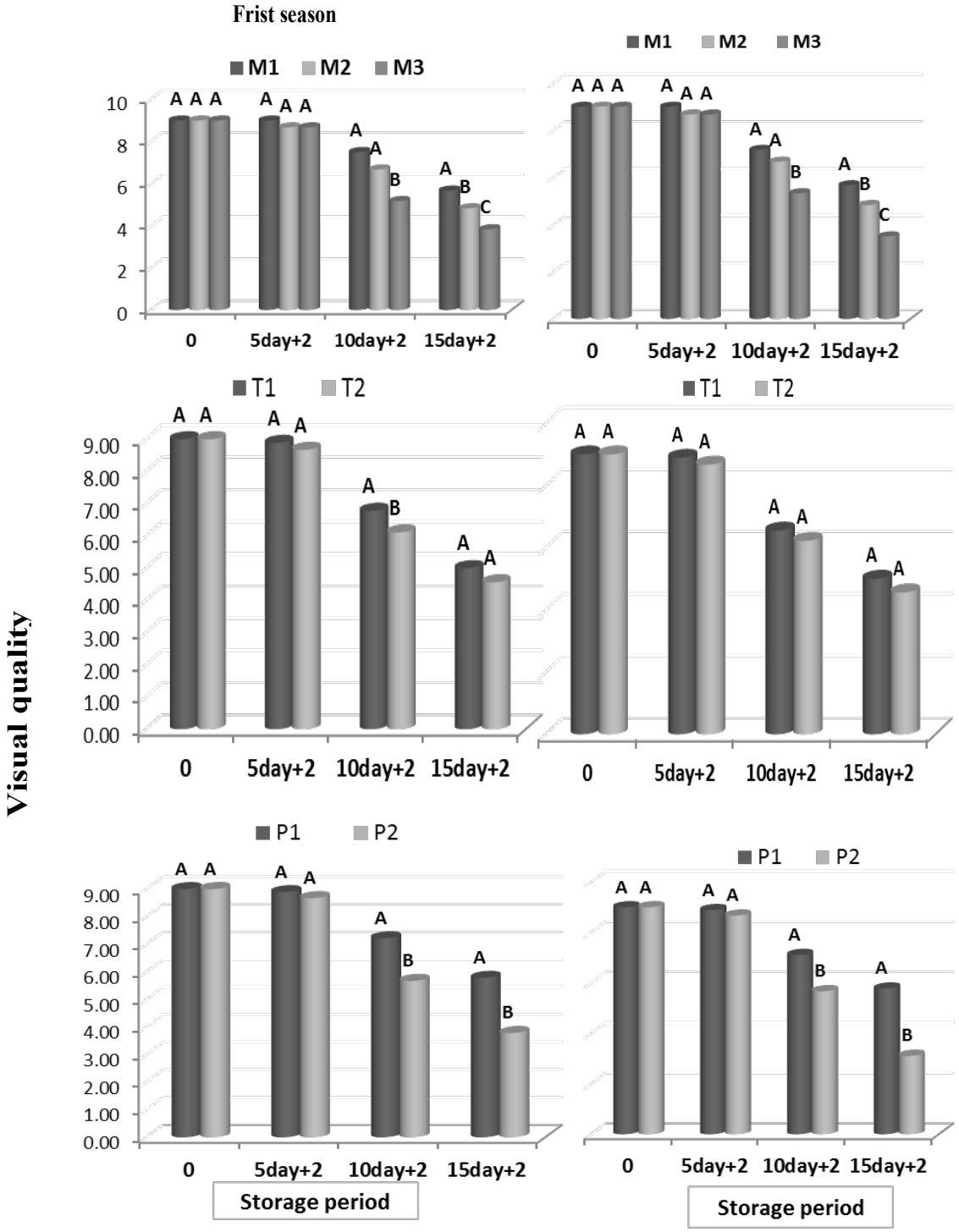
Treatments		Total soluble solids (%)							
		0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)	0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)
		2015 season				2016 season			
M	M1	5.28A	5.68A	4.50A	2.78A	5.18A	5.59A	4.33A	2.80A
	M2	4.87B	5.39B	4.10B	2.17B	4.65B	5.43AB	4.10A	2.16B
	M3	4.64B	5.18B	3.63C	1.96C	4.48B	5.25B	3.36B	1.96B
P	P1	5301A	5.49A	4.08A	2.61A	4.93A	5.56A	3.95A	2.60A
	P2	4.86A	5.34A	4.08A	1.99B	4.61B	5.28B	3.91A	2.01B
T	T1	4.91A	5.42A	4.09A	2.41A	4.73A	5.48A	3.94A	2.43A
	T2	4.96A	5.41A	4.06A	2.19B	4.81A	5.37A	3.92A	2.18B
M x P	M1 x P1	5.43A	5.70A	4.60A	3.20A	5.25A	5.63A	4.42A	3.28A
	M1 x P2	5.13B	5.67AB	4.40AB	2.35B	5.10A	5.50A	4.25A	2.32B
	M2 x P1	4.97BC	5.72A	4.05C	2.33B	4.98AB	5.68A	4.17A	2.27B
	M2 x P2	4.77BC	5.07C	4.15BC	2.00C	4.32C	5.17A	4.02A	2.05BC
	M3 x P1	4.62C	5.05C	3.58D	2.30BC	4.55BC	5.32A	3.37B	2.25B
	M3 x P2	4.67C	5.30BC	3.68D	1.62D	4.42C	5.18A	3.45B	1.67C
M x T	M1 x T1	5.33A	5.63AB	4.57A	3.05A	5.18A	5.63A	4.32A	3.07A
	M1 x T2	5.32AB	5.73A	4.43AB	2.50B	5.17A	5.55A	4.35A	2.35B
	M2 x T1	4.92A-C	5.45A-C	4.12BC	2.17C	4.63B	5.48A	4.08A	2.18C
	M2 x T2	4.82BC	5.33BC	4.08C	2.17C	4.67B	5.37A	4.10A	2.13C
	M3 x T1	4.57C	5.18C	3.60D	2.02C	4.38B	5.32A	3.42B	2.05C
	M3 x T2	4.72C	5.17C	3.67D	1.90C	4.58B	5.18A	3.30B	1.87C
T x P	T1 x P1	5.01A	5.43A	4.09A	2.17A	4.81AB	5.59A	3.94A	2.72A
	T1 x P2	4.80A	5.41A	4.10A	2.11B	4.67B	5.37A	3.93A	2.14B
	T2 x P1	5.00A	5.54A	4.07A	2.51A	5.04A	5.53A	3.88A	2.48A
	T2 x P2	4.91A	5.28A	4.06A	1.87C	4.57B	5.20A	3.92A	1.88B

M1= Black mulch, M2= Transparent mulch, M3= Control (un mulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

TABLE 6. Effect of the third interaction of mulching color, tunnels and packaging on total soluble solids content (%) of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Total soluble solids (%)							
		0 day		5 days (5 °C) + 2 days (10 °C)		10 days (5 °C) + 2 days (10 °C)		15 days (5 °C) + 2 days (10 °C)	
		P1	P2	P1	P2	P1	P2	P1	P2
		2015 season							
M1	T1	5.47a	5.20a-c	5.53a-d	5.73ab	4.80a	4.33a-c	3.43a	2.67bc
	T2	5.40ab	5.07a-c	5.87a	5.60a-c	4.40ab	4.47ab	2.87ab	2.03de
M2	T1	4.93a-c	4.70bc	5.83a	5.07cd	4.10bc	4.13bc	2.33cd	2.00de
	T2	5.00a-c	4.83a-c	5.60a-c	5.07cd	4.00b-d	4.16bc	2.33cd	2.00de
M3	T1	4.63c	4.50c	4.93d	5.43a-d	3.37e	3.83c-e	2.37cd	1.67e
	T2	4.60c	4.83a-c	5.17b-d	5.17b-d	3.80c-e	3.53de	2.23cd	1.57e
		2016 season							
M1	T1	5.13ab	5.23ab	5.67a	5.60a	4.47a	4.17ab	3.57a	2.57bc
	T2	5.37a	4.97a-c	5.70a	5.40a	4.37a	4.33a	2.07c-e	2.07c-e
M2	T1	4.77a-d	4.50b-d	5.77a	5.20a	4.20ab	4.13a-c	2.30cd	2.07c-e
	T2	5.20ab	4.13d	5.60a	5.13a	4.13a-c	4.07a-d	2.23cd	2.03c-e
M3	T1	4.53b-d	4.23cd	5.33a	5.30a	3.17d	3.67a-d	2.30cd	1.80de
	T2	4.57a-d	4.60a-d	5.30a	5.07a	3.37b-d	3.23cd	2.20cd	1.53e

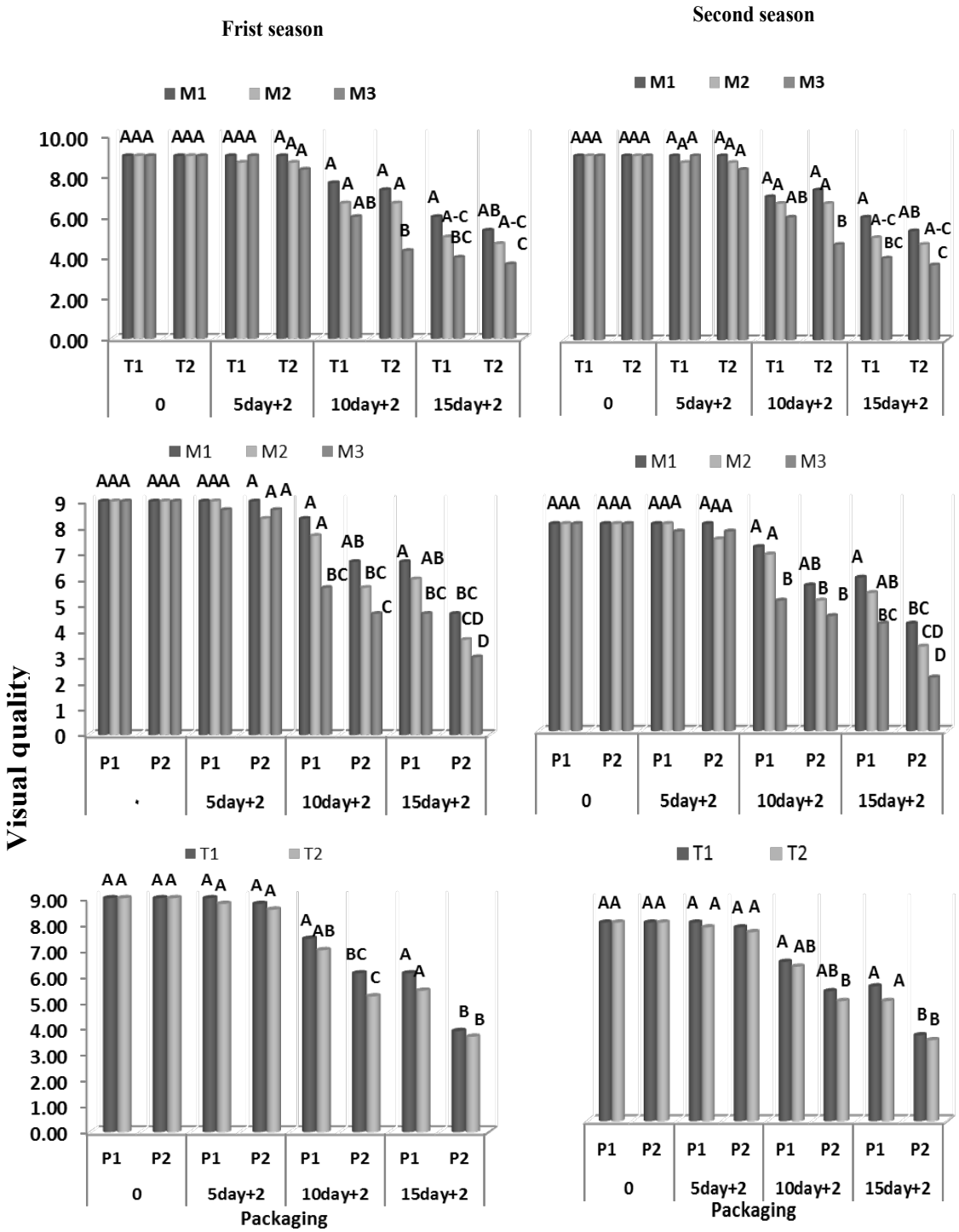
M1= Black mulch, M2= Transparent mulch, M3= Control (un mulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.



M1= Black mulch, M2= Transparent mulch, M3= Control (un-mulched soil), T1= Tunnel, T2= Without tunnel, P1= Non-polypropylene, P2= Polypropylene.

Means within each group followed by the same letter are not significantly different according to Duncan's multiple **range test.**

Fig. 5. Effect of the main effects of mulching color, tunnels and packaging on visual quality (score) of green bean pods during the storage period at 5 °C plus two days at the shelf life in 2015 and 2016 seasons.



M1= Black mulch, M2= Transparent mulch, M3= Control (un-mulched soil), T1= Tunnel, T2= Without tunnel, P1= Non-polypropylene, P2= Polypropylene.

Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

Fig.6. Effect of the second-order interactions between mulching color, tunnels and packaging on visual quality (score) of green bean pods during storage period at 5 °C plus two days at shelf life in 2015 and 2016 seasons

maintained the visual quality which might be due to its role in marinating colour and freshness due to creating modified atmosphere condition inside the package and decreasing respiration rate (mahajan et al., 2012).

As for the effect of mulching color on visual quality, data indicated that the black mulch gave the highest score during the storage periods compared to the white mulch and control in two seasons.

Concerning the effect of tunnel on the visual quality, data showed that there was no significant difference between tunnel and no-tunnel in both seasons.

Regarding to the interaction between mulching color, tunnel and wrapping on the visual quality during the storage periods, data in Table 7 showed that there were no significant differences among the different treatments in both seasons.

Ascorbic acid content

Data presented in Tables 8 and 9 showed the effect of mulching color, tunnels and packaging

TABLE 7. Effect of the third-order interaction of mulching color, tunnels and packaging on visual quality of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Visual quality score							
		0 day		5 days (5 °C) + 2 days (10 °C)		10 days (5 °C) + 2 days (10 °C)		15 days (5 °C) + 2 days (10 °C)	
		P1	P2	P1	P2	P1	P2	P1	P2
2015 season									
M1	**T1**	9.00a	9.00a	9.00a	9.00a	8.33a	7.00ab	7.00a	5.00a-d
	T2	9.00a	9.00a	9.00a	9.00a	8.33a	6.33a-c	6.33ab	4.33b-d
M2	**T1**	9.00a	9.00a	9.00a	8.33a	7.67ab	5.67a-c	6.33ab	3.67cd
	T2	9.00a	9.00a	9.00a	8.33a	7.67ab	5.67a-c	5.67a-c	3.67cd
M3	**T1**	9.00a	9.00a	9.00a	9.00a	6.33a-c	5.67a-c	5.00a-d	3.00d
	T2	9.00a	9.00a	8.33a	8.33a	5.00bc	3.67c	4.33b-d	3.00d
2016 season									
M1	**T1**	9.00a	9.00a	9.00a	9.00a	7.67ab	6.33a-c	7.00a	5.00a-d
	T2	9.00a	9.00a	9.00a	9.00a	8.33a	6.33a-c	6.33ab	4.33b-d
M2	**T1**	9.00a	9.00a	9.00a	8.33a	7.67ab	5.67a-c	6.33ab	3.67cd
	T2	9.00a	9.00a	9.00a	8.33a	7.67ab	5.67a-c	5.67a-c	3.67cd
M3	**T1**	9.00a	9.00a	9.00a	9.00a	6.33a-c	5.67a-c	5.00a-d	3.00d
	T2	9.00a	9.00a	8.33a	8.33a	5.00bc	4.33c	4.33b-d	3.00d

M1= Black mulch, M2= Transparent mulch, M3= Control (unmulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
The visual rating scale, where 9 = excellent, 7 =good, 5 =fair, 3 = poor, and 1=unsalable
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

on ascorbic acid content of green bean pods during the storage at 5 °C Plus 2 days at the shelf life condition. Data revealed that ascorbic acid content in green bean pods exhibited a gradual decrease with the storage periods. Similar results were observed in previous studies (mahajan et al., 2016). The decline in ascorbic acid contents in green bean pods during the cold storage at 5 ºC, 90 – 95% RH followed by 2 days at shelf life conditions at 10 °C might be due to conversion of ascorbic acid into dehydroascorbic acid (Lin et al., 1988). The green bean pods packed in non-perforated polypropylene film maintained the highest ascorbic acid contents compared to the perforated polypropylene film during the two seasons. These results are in agreement with those reported by Reddy et al. (2010) and Kinyuru et al. (2011).

Regarding the effect of mulching color on ascorbic acid contents, it was indicated that the black mulch gave the lowest decline in ascorbic

TABLE 8. Effect of the main effects of mulching color, tunnels and packaging and their second-order interactions on ascorbic acid content of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Ascorbic acid content (mg/100g FW)							
		0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)	0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)
		2015 season				2016 season			
M	M1	22.98A	21.55A	18.68A	16.92A	22.60A	20.20A	17.71A	17.09A
	M2	21.45B	20.22B	16.76B	15.71B	21.07B	18.97B	16.66B	16.10B
	M3	18.71C	17.63C	15.51C	13.23C	18.75C	17.22C	14.08C	13.46C
P	P1	21.09A	20.13A	18.07A	16.06A	20.73A	19.08A	16.87A	16.25A
	P2	21.01A	19.47B	16.57B	14.51B	20.88A	18.51B	15.43B	14.85B
T	T1	21.96A	20.42A	17.62A	15.66A	21.77A	19.23A	16.43A	15.78A
	T2	20.14B	19.18B	17.01B	14.91B	19.84B	18.36B	15.87B	15.32B
M x P	M1 x P1	23.23A	21.90A	19.60A	17.78A	22.42A	20.37A	18.77A	18.08A
	M1 x P2	22.73B	21.20B	17.77C	16.05B	22.78A	20.03A	16.65C	16.10BC
	M2 x P1	21.40C	20.40C	18.35B	16.25B	21.05B	19.38AB	17.13B	16.52B
	M2 x P2	21.50C	20.03C	17.17C	15.17C	21.08B	18.55BC	16.18C	15.68C
	M3 x P1	18.63D	18.08D	16.25D	14.15D	18.72C	17.50CD	14.70D	14.15D
	M3 x P2	18.78D	17.17E	14.77E	12.32E	18.77C	16.93D	13.47E	12.77E
M x T	M1 x T1	23.97A	20.07A	18.80A	17.45A	23.53A	20.40A	17.71A	17.13A
	M1 x T2	22.00C	21.03B	18.57A	16.38B	21.66B	20.00A	17.70A	17.05A
	M2 x T1	22.68B	21.32B	18.32A	16.32B	22.38AB	19.92A	17.43A	16.83A
	M2 x T2	20.22D	19.12C	17.20B	15.10C	19.76C	18.02B	15.88B	15.37B
	M3 x T1	19.22E	17.87D	15.75C	13.22D	19.39C	17.37B	14.15C	13.37C
	M3 x T2	18.20F	17.38D	15.28C	13.25D	18.11D	17.07B	14.02C	13.55C
T x P	T1 x P1	21.87A	20.77A	18.40A	16.51A	21.63A	19.54A	17.23A	16.56A
	T1 x P2	22.04A	20.07B	16.84C	14.81C	21.92A	18.91AB	15.63C	15.00C
	T2 x P1	20.31B	19.49C	17.73B	15.61B	19.85B	18.62BC	16.50B	15.94B
	T2 x P2	19.97C	18.87D	16.29D	14.21D	19.83B	18.10C	15.23C	14.70C

M1= Black mulch, M2= Transparent mulch, M3= Control (unmulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

TABLE 9. Effect of the third interaction of mulching color, tunnels and packaging on ascorbic acid content of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Ascorbic acid content (mg/100g FW)							
		0 day		5 days (5 °C) + 2 days (10 °C		10 days (5 °C) + 2 days (10 °C)		15 days (5 °C) + 2 days (10 °C)	
		P1	P2	P1	P2	P1	P2	P1	P2
		2015 season							
M1	T1	23.93a	24.00a	22.47a	21.67ab	19.90a	17.70b	18.40a	16.50bc
	T2	22.53b	21.47c	21.33b	20.73b	19.30a	17.83b	17.17b	15.60cd
M2	T1	22.60b	22.77b	21.40b	21.23b	19.03a	17.60b	17.10b	15.53cd
	T2	20.20d	20.23d	19.40c	18.83c	17.67b	16.73bc	15.40ce	14.80df
M3	T1	19.07e	19.37e	18.43cd	17.30e	16.27cd	15.23de	14.03f	12.40g
	T2	18.20f	180.20f	17.73de	17.03e	16.23cd	14.30e	14.27ef	12.23g
		2016 season							
M1	T1	23.20ab	23.87a	20.77a	20.03a	19.03a	16.40cd	18.47a	15.80de
	T2	21.63bc	21.63bc	19.97a	20.03a	18.50a	16.90bc	17.70ab	16.40 bd
M2	T1	22.26ab	22.49ab	20.70a	19.13ab	18.00ab	16.87bc	17.33ac	16.33ce
	T2	19.84cd	19.67cd	18.07bc	17.97bc	16.27cd	15.50de	15.70df	15.03eg
M3	T1	19.38d	19.40d	17.17c	17.57bc	14.67ef	13.63fg	13.87gh	12.87h
	T2	18.07d	18.15d	17.83bc	16.30c	14.73ef	13.30g	14.43fg	12.67h

M1= Black mulch, M2= Transparent mulch, M3= Control (unmulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

acid contents, followed by the transparent mulch when compared with the control. This might be due to that plastic mulch increased the amount of ascorbic acid in mulch treated plants compared to the control in the field experiment. Similar results were also reported by Panchal et al. (2001) and Ashrafuzzaman et al. (2011).

Concerning the effect of tunnel on ascorbic acid content, data showed that there were significant differences between tunnel and without tunnel during the storage periods in both seasons.

Regarding to the interaction between mulching, tunnels and packaging on ascorbic acid content during the 15 days the storage periods (5 ºC, 90 – 95% RH) that followed by 2 days at shelf life conditions (10◦C), data indicated that using the black mulch, tunnel and packaging with non–perforated polypropylene film gave the highest ascorbic acid contents compared with the other treatments during both seasons**.**

Total Chlorophyll

Data in Tables 10 and 11 clarified that the total chlorophyll content in green bean pods was decreased with increasing the storage periods irrespective of different package in both seasons. The decrement in total chlorophyll content might be due to chlorophyll degradation, by chlorophylls degrading enzyme activity which leads to senescence (gong, 2003).

In relation to the effect of packaging on total chlorophyll content, the green bean pods packed in non-perforated polypropylene film gave the lowest decline in total chlorophyll content compared to perforated polypropylene film in the two seasons and this might be due to respiration inhibiting and reducing deterioration of green color (kays et al., 2004).

Concerning the effect of mulching color, data indicated that the black mulch gave the lowest decline in total chlorophyll contents compared other treatment, and this which might be due to the role of mulch in enhancing plant growth and consequently increasing total chlorophyll contents of plants and produced pods. Similar result was also reported by Panchal et al. (2001) and Ashrafuzzaman et al. (2011).

Regarding the tunnel effect, it gave the highest

TABLE 10. Effect of the main effects of mulching color, tunnels and packaging and their second-order interactions on total chlorophyll content of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Total chlorophyll content (mg/100g FW)							
		0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)	0 day	5 days (5 °C) + 2 days (10 °C)	10 days (5 °C) + 2 days (10 °C)	15 days (5 °C) + 2 days (10 °C)
		2015 season				2016 season			
M	M1	110.40A	104.13A	101.31A	93.67A	106.08A	105.33A	98.09A	97.28A
	M2	109.41A	99.68B	95.448	87.96B	103.14B	102.87B	92.39B	91.46B
	M3	104.74B	94.93C	91.08C	81.84C	98.42C	98.07C	87.08C	86.16C
P	P1	108.73A	102.24A	98.67A	90.73A	105.09A	104.51A	95.38A	94.41A
	P2	107.63B	96.92B	93.22B	84.91B	100.00B	99.67B	89.66B	88.86B
T	T1	109.56A	101.24A	97.45A	89.68A	104.2A	103.39A	94.03A	93.00A
	T2	106.81B	97.92B	94.39B	85.97B	100.87B	100.39B	91.01B	90.27B
M x P	M1 x P1	110.82A	106.50A	104.15A	96.40A	108.57B	107.48A	100.63A	100.05A
	M1 x P2	109.98A	101.75B	98.47B	90.93B	103.60C	103.18C	95.55B	94.28A
	M2 x P1	109.20A	102.57B	98.35B	90.77B	105.85B	105.53B	95.15B	94.00B
	M2 x P2	109.62A	96.80C	92.53C	85.15C	100.43D	100.20D	89.63C	88.92C
	M3 x P1	106.18B	97.65C	93.50C	85.03C	100.87D	100.52D	98.07C	89.17C
	M3 x P2	103.30C	92.22D	88.65D	78.65D	95.97E	95.62E	90.37C	83.15D
M x T	M1 x T1	111.98A	105.72A	102.83A	95.40A	108.3A	107.33A	99.47A	98.53A
	M1 x T2	108.82B	102.23B	99.78B	91.93B	104.13B	103.33BC	96.72B	95.98B
	M2 x T1	110.75A	101.32A	97.22C	89.60C	104.22B	103.95B	93.70C	92.65C
	M2 x T2	108.07B	98.05C	93.67D	86.32D	102.07C	101.78D	91.08D	90.27D
	M3 x T1	105.95C	96.68D	92.42E	84.03E	100.42D	100.08D	88.92E	87.77E
	M3 x T2	103.53D	93.18E	89.73F	79.65F	96.42E	96.05E	85.23F	84.55F
T x P	T1 x P1	109.91A	103.86A	99.94A	92.48A	106.76A	106.18A	96.73A	95.58A
	T1 x P2	109.21A	98.62C	95.03C	86.88C	101.69C	101.40C	91.32C	90.42C
	T2 x P1	107.56B	100.62B	97.39B	88.99B	103.43B	102.82B	94.03B	93.23B
	T2 x P2	106.06C	95.22D	91.40D	82.94D	9831D	97.93D	87.99D	87.30D

M1= Black mulch, M2= Transparent mulch, M3= Control (unmulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.

Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

TABLE 11. Effect of the third interaction of mulching color, tunnels and packaging on total chlorophyll content of green beans pods during the storage at 5 °C plus 2 days at the shelf life condition during 2015 and 2016 seasons.

Treatments		Total chlorophyll content (mg/100g FW)							
		0 day		5 days (5 °C) + 2 days (10 °C		10 days (5 °C) + 2 days (10 °C)		15 days (5 °C) + 2 days (10 °C)	
		P1	P2	P1	P2	P1	P2	P1	P2
2015 season									
M1	**T1**	112.77a	111.20ab	107.80a	103.63b	105.47a	100.20c	98.43a	92.37bc
	T2	108.87bd	108.77bd	105.20b	99.87cd	102.83b	96.73d	94.37b	89.50ef
M2	**T1**	110.57ac	110.93ac	104.43b	98.20d	99.60c	94.83e	91.73c	87.47fg
	T2	107.83ce	108.80be	100.70c	95.40e	97.10d	90.23g	89.80de	82.83h
M3	**T1**	106.40de	105.50e	99.33cd	94.03e	94.77e	90.07g	87.28g	80.80h
	T2	105.97de	101.10f	95.97e	90.40f	92.23f	87.23h	82.80h	76.50i
2016 season									
M1	**T1**	110.13a	105.93bc	109.13a	105.53b	102.00a	96.93bc	101.27a	95.90b
	T2	107.00b	10127ef	105.83b	100.83de	99.27ab	94.17de	98.83a	93.13cd
M2	**T1**	107.30b	101.13ef	106.87ab	101.03de	96.00cd	91.40f	94.63bc	90.67d
	T2	104.40cd	99.73fg	104.20bc	99.37ef	94.30c-e	87.87gh	93.13cd	87.17ef
M3	**T1**	102.83de	98.00g	102.53cd	97.63f	92.20ef	85.63h	90.83d	84.70f
	T2	98.90fg	93.93h	98.50ef	93.60g	88.53g	81.93i	87.50e	81.60g

M1= Black mulch, M2= Transparent mulch, M3= Control (unmulched soil), T1= Tunnel, T2=Without tunnel, P1= Non-polypropylene, P2= Polypropylene.
Means within each group followed by the same letter are not significantly different according to Duncan's multiple range test.

percentage in total chlorophyll contents compared to un-tunneled (control).

Regarding the effect of the interaction between mulching color, tunnels and packaging, during cold storage and shelf life on total chlorophyll contents, there were significant differences between all treatments. The best treatment was black mulching, tunnels and packaging with non-perforated polypropylene film in both seasons.

Indicators of productivity and economic efficiency

Table 12 showed that tunnel and transparent treatments achieved the highest productivity and economic efficiency compared with the other treatments. The averages of indicators: productivity, return, and rate of return on invested pound in season are 2.42 kg/m^2, 5006.7 L.E. and 75%, respectively, followed by tunnel and black mulch, control and black mulch, control and Transparent mulch, and tunnel and bare soil, respectively where achieved averages indicators (productivity, return, and rate of return on invested pound in season), (2.41 kg/m^2 – 4679.7 L.E. and 67 %), (1.76 kg/m^2 – 2341.5 L.E. and 38 %), (1.60 kg/m^2 –1853.1 L.E. and 32 %) and (1.48 kg/m^2 –953.1 L.E. and 15 %), respectively. Control and bare soil treatments achieved loss of average of indicators productivity and economic efficiency (productivity, return, and Rate of return on invested pound in season) (0.87 kg/m^2, -1181.7 L.E., and -22%, respectively).

TABLE 12. Averages of productivity and economic efficiency indicators for cultivated green bean pod using experiment data in 2015 and 2016 seasons for greenhouses (540 m^2).

Treatments	2015 season			2016 season			Mean		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
Yield/plant (g)									
T1	194	193	119	209	209	128	201.5	201	123.5
T2	139	141	70	128	152	75	133.5	146.5	72.5
Yield/kg = 4000 plants * yield/plant									
T1	776	772	476	836	836	512	806	804	494
T2	556	564	280	512	608	300	534	586	290
Loss ratio of yield 10% = Yield/kg * 0.10									
T1	77.6	77.2	47.6	83.6	83.6	51.2	80.6	80.4	49.4
T2	55.6	56.4	28	51.2	60.8	30	53.4	58.6	29
†Cost of season consumption of fixed costs (L.E.) = The annual consumption costs/3									
T1		1166.7			1166.7			1166.7	
T2		1167.7			1167.7			1167.7	
Cost of treatments (L.E.)									
T1	1260	1560	810	1260	1560	810	1260	1560	810
T2	450	750	0	450	750	0	450	750	0
‡Variable costs (L.E.)									
T1		4000			4400			4200	
T2		4000			4400			4200	
Total costs (L.E.) = fixed costs + cost of treatments + variable costs									
T1	6426.7	6726.7	5976.7	6826.7	7126.7	6376.7	6626.7	6926.7	6176.7
T2	5616.7	5916.7	5166.7	6016.7	6316.7	5566.7	5816.7	6116.7	5366.7
Revenue (L.E.) = (Yield/kg - Loss ratio of yield 10%) * price per kg (15 and 17 L.E.)									
T1	10476	10422	6426	12790.8	12790.8	7833.6	11633.4	11606.4	7129.8
T2	7506	7614	3780	7833.6	9302.4	4590	7669.8	8458.2	4185
Return (L.E.) = revenue - total costs									
T1	4049.3	3695.3	449.3	5964.1	5664.1	1456.9	5006.7	4679.7	953.1
T2	1889.3	1697.3	-1386.7	1816.9	2985.7	-976.7	1853.1	2341.5	-1181.7
Productivity (kg/m^2) = 12 * (Yield/plant/1000)									
T1	2.33	2.32	1.43	2.51	2.51	1.54	2.42	2.41	1.48
T2	1.67	1.69	0.84	1.54	1.82	0.90	1.60	1.76	0.87
Rate of return on invested pound in theseason = return/total costs									
T1	0.63	0.55	0.08	0.87	0.79	0.23	0.75	0.67	0.15
T2	0.34	0.29	-0.27	0.30	0.47	-0.18	0.32	0.38	-0.22

M1= Black mulch, M2= Transparent mulch, M3= Control (un-mulched soil), T1= Tunnel, T2= Without tunnel
Bulletins -Agriculture directorates in governorates, Economic Affairs Sector, Egypt.
† The fixed costs of 540 m^2 area through the market with total amount of 27521.7 L.E. and the annual consumption costs calculated by dividing the cost item/lifetime component.
‡The variable costs for growing green bean pod were amount 4000 L.E., 4400 L.E for the two years of 2015 and 2016.

Conclusion

From the previous results, it could be concluded that the black mulch with non-perforated polypropylene film reduced the weight loss of green bean pods followed by the transparent mulch with non-perforated polypropylene film during the storage periods. As well, the black mulch with non-perforated polypropylene film maintained quality attributes (TSS, ascorbic acid and total chlorophyll contents) and extended the storage life for 15 days at 5 ºC plus two days at shelf life 10 ºC with a good appearance.

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تأثير إستخدام ألوان مختلفة من الملش والأنفاق على النمو والمحصول وجودة ما بعد الحصاد على الفاصوليا الخضراء

نهى جابر عبد الرحمن*، صالح محمد أبو الوفا**، أحمد عونى فرج* و محمد عبد المحسن حجى
*المعمل المركزى للمناخ الزراعى - مركز البحوث الزراعية و** قسم تداول الخضر- معهد بحوث البساتين - مركز البحوث الزراعية – القاهرة – مصر.

تم إجراء هذا البحث خلال الموسمين المتتالين (٢٠١٥ و ٢٠١٦) على الفاصوليا الخضراء، صنف بوليستا لدراسة تأثير ألوان مختلفة من الملش والأنفاق على النمو الخضري، المحصول، الإنتاجية، جودة القرن بالإضافة الى صفات التخزين والجودة خلال التخزين (في ٥ درجة مئوية)، بالإضافة إلى يومين من العمر على الرف (في ١٠ درجة مئوية)، لمحاكاة عرض السوق. وقد أظهرت النتائج ان معاملة الملش الشفاف والأسود قد أعطت أعلى عدد من الأوراق، إرتفاع النبات، قطر القرن، طول القرن، وزن القرن، أعلى محتوى من النيتروجين والفوسفور والبوتاسيوم فى الأوراق. وتشير النتائج أيضا ان إستخدام الأنفاق تحت الصوب غير المدفأة يؤدى إلى زيادة النمو الخضرى والإنتاجية. وتشير النتائج أيضا أن معاملة الملش الأسود مع الغشاء غير المثقب قد أعطت أقل فقد فى وزن قرون الفاصوليا الخضراء ويليها معاملة الملش الشفاف مع الفيلم غير المثقب أثناء فترات التخزين. وقد حافظت معاملة الملش الأسود مع الأغشية الخالية من البولي بروبلين على خصائص الجودة (المواد الصلبة الذائبة وحمض الأسكوربيك ومحتوى الكلوروفيل الكلي) كما أطالت فترة التخزين لمدة ١٥ يومًا عند درجة ٥ درجة مئوية بالإضافة إلى يومين في فترة حياة الرف وبجودة ظاهرية جيدة. أعطت معاملة الأنفاق مع الملش الشفاف في الصوبة (٥٤٠ م٢) أعلى عائد (٥٠٠٦,٧ جنية) وأعلى معدل عائد على الجنيه المستثمر في الموسم (٧٥٪ من الجنيه. وقد أدى ذلك إلى زيادة كفاءة وحدة الإنتاج ، وزيادة دخل المزرعة ، وبالتالي رفع مستوى معيشة المزارع.