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Effect of organic mulch, potassium silicate and postharvest treatments on productivity, quality attributes and storage life of cauliflower

Manal M. H. Gad EL-Moula[1], S.M. Abou-Elwafa[2] and A.A. Farag[1]

[1]*Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Dokki, Giza, Egypt.*
[2]*Department of Postharvest and Handling of Vegetable Crops. Horticulture Research Institute. Agricultural Research Center, Giza, Egypt. .E-mail: salehaboelwafa@yahoo.com*

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ABSTRACT

This study was conducted during two successive seasons (2014 -2015 and 2015- 2016) on cauliflower *(Brassica oleraceae var. botrytis* L.), to study the effect of organic mulching, potassium silicate and postharvest treatments (wrapping and exposure to light), during storage at 0 ºC, plus two days shelf life conditions at 10ºC to simulate market display. The highest significant cauliflower yield was obtained using 2% foliar spraying potassium silicate combined with 1% foliar spraying potassium silicate, while the lowest yield was obtained in case of 0% foliar spraying potassium silicate combined with bare soil treatment. Chemical analysis of cauliflower leaves at harvest revealed that the percentage of N, P and K increased significantly with increasing foliar spraying potassium silicate rates. Organic mulch treatment increased N, P and K percentages significantly in comparison with bare soil treatment (M1). The obtained results showed that exposure to light during shelf life with packed film of low density polyethylene (LDPE) 15 µm thicknesses gave the lowest weight loss during storage periods. As well, maintained quality attributes TSS, ascorbic acid , reduced browning enzyme activity (PPO) and extended storage life for 24 days at 0 ºC, plus two days at shelf life with good appearance compared with PVC film and unwrapped.

Keywords: : Cauliflower, organic mulch, foliar spraying potassium silicate rate, Packaging film, Light, Quality attributes, Storage life and PPO

Introduction

Cauliflower is one of several vegetables in the species *Brassica oleracea*, family Brassicaceae. It is an annual plant that reproduces by seeds. The edible part, i.e. curd is a 'prefloral fleshy apical meristem', is white in color and may be enclosed by inner leaves before its exposure. Typically, only the head (the white curd) of aborted floral meristems is eaten, while the stalk and surrounding thick, green leaves are used in vegetable broth or discarded. Its name is from Latin caulis (cabbage) and flower, an acknowledgment of its unusual place among a family of food plants, which normally produces only leafy greens for eating. *Brassica oleracea* also includes cabbage, Brussels sprouts, kale, broccoli, and collard greens, though they are of different cultivar groups (Bulletin of the agriculture statistics 2011) Cauliflower is an important vegetable worldwide. It has a huge market demand and economic importance. Commercial cultivation of cauliflowers can give you a lot of profit. The edible portion of cauliflower in the site curd like mass composed of a close aggregation of abortive flower developed on thick bunches of the inflorescence. This edible portion is called Curd, It's rich in various minerals which improve the bone density and benefit to patients cancer and heart and Cauliflower is rich in vitamin C (Cebula *et al.,* 2006). Also, it is high in fiber but low in calories (Schreiner *et al.,* 2007). Intemperate climates, their supply is limited to a few months of the year. In order to provide year-round availability, various storage conditions improving shelf-life and processing are used (Ahmed and Ali, 2013). Cauliflower is a cool season crop, tolerating temperature as low as 4 ºC and as high as 38 ºC. However, optimum temperature varies between20ºCand25ºCinSeptember-Octoberand5ºCto10ºCinDecember-January according to (Kumar *et al*., 2005). Cauliflower (*Brassica oleraceae*var. *botrytis L.*) is a vegetable crop grown for its white curds. It is a cool season crop that demands high levels of nitrogen to maximize yields. Statistics from the (Bulletin of the agriculture

Corresponding Author: Manal M. H. Gad EL-Moula, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Dokki, Giza, Egypt.
E-mail: manalhosny8@yahoo.com

2011) reported that, in Egypt cauliflower is well known and commonly consumed since, the amount of cultivated aria reached 8970 fedan and the annual production was 11317 ton in year 2011.The mulch determines its energy-radiating behavior and its influence on the microclimate around the plant. Organic mulches dominate in the commercial vegetable production over the world. Mulches promote a relatively large net radiation at the soil surface, increase soil heat flux and as a consequence, both minimum and maximum soil temperatures are increased (Lamont. 1993). Row covers are a flexible transparent covering, which is installed over plants to reduce water needs and increase air temperature around the crop. Furthermore, their usage has been associated with increased plant growth, higher yields and earliness of harvest. Application of mulch to cultivated soil increases soil organic carbon (SOC) concentrations (Blanco and Lal 2007).As potassium is highly mobile in the plant, the first symptoms appear on older leaves. This isbecause upon the onset of K deficiency, the plant K moves from older to younger leaves. The sequence in the development of deficiency symptoms is almost the same in all plants, although different plants may exhibit different symptoms. In all cases, symptoms start from the distal part (tip) of the leaf. The base of the leaf usually remains dark green (Abu-hussien *et al*., 2001). Use of foliar feeding during growth and development can improve the nutrient balance of crops, which, in turn, leads to in-creased yield and quality (Kolota and Osińska 2001). Potassium (K), which is necessary for efficient plant growth and development, exists predominantly as a free or absorptive bound cation (Abbas *et al*., 2011; Very and Sentenac 2003). Potassium is one of the essential elements in plant nutrition. It intensifies the synthesis of carbohydrates, catalyzes the activity of some enzymes promotes the synthesis and accumulation of thiamin and riboflavin and is essential for the activity of guard cells (Pettigrew, 2008). Foliar fertilization is a method of crop feeding that involves applying a solution of micro- and macronutrients to the leaves, which allows rapid uptake regardless of soil conditions (Nasiri *et al*., 2010). It helps in the transport of water and nutrients through the xylem, influencing various biochemical and physiological parameters like photosynthesis, respiration, protein synthesis, cell extension, and wall thickness and stability (Abbas *et al*., 2011).

The main postharvest problems of fresh cauliflower are yellowing of the leaves, sharp increase in bitter test (Hodges *et al.,* 2006), browning of the curd, floret opening, hardness loss and undesirable odour development, which decrease shelf-life and affect consumer buying behavior (Licciardello *et al.,* 2013; Zhan *et al.,* 2014). Since cauliflower deteriorates very quickly soon after harvest, it should be stored immediately after they are harvested, the ideal conditions for storing cauliflower are 3-4 weeks under common commercial storage conditions at 0°C and 90- 95% relative humidity (Hodges *et al*., 2006). on the other hand, storage period can be extended with wrapping , cauliflower curds individual packed in high density polyethylene bags (20 µm) with perforation (6 holes/bag) can be stored up to 21 days at 0 ± 1°C and 90–95% RH. With maximum retention of white colour of curd, minimum spoilage, weight and firmness loss and good sensory quality attributes (Dhall *et al.,* 2010), LDPE film should be a good substitute for PVC in wrapping cauliflower heads, mainly for shipment to those countries where the use of PVC in horticultural products is currently forbidden. Wrapping the product in a frequently used to reduce water loss , retain firmness and decrease wilting but this practice often promotes decay, possibly due to increased free-water in the package and on the surface of the cauliflower (Artes and Martinez, 1999). polyethylene bags and wrapping by polyvinyl chloride (PVC) stretch film on the visual quality of some Cole fruits during storage, it was noticed from one of the experiments done on cauliflower that curds packed in perforated polyethylene bags and stored at 0 ˚C significantly improved to great extent the appearance of curds that stored for more than 4 weeks (Ekman and Golding, 2006). cauliflower curds wrapped by polypropylene and polyvinyl chloride (5 micron) Kept more sugars than the unwrapped ones during storage at 0˚C (Schonhof *et al.,* 2004 and Simon and dominyo 2008). Cauliflower curds packed in individual HDPE bags could retain white colour, good sensory quality, firm and fresh curds with least loss in weight, texture and minimum spoilage up to 21 days during cold storage (Dhall *et al.,* 2010). cauliflower curds packed in high density polyethylene perforated bags (6 holes / bags) and stored up to 21 days under the Conditions of 4º C and90- 95% Rh resulted in high reductions in the weight losses in comparison with those of control non – packed ones (Simon *et al.,* 2008). Light plays an important role in browning enzyme activity, total phenol (Zhan, *et al*., 2014) also maintaining sensory quality and prevents loss of ascorbic acid in fresh cauliflower and extend shelf life (Noichida *et al*., 2007; Susana *et al.,* 2007).

The aim of this study was to evaluate the effect of different applied rates of foliar spraying potassium silicate , organic mulch (rice straw) and postharvest treatments (wrapping and exposure to light) during storage (at 0 ºC), shelf life on yield, productivity, quality attributes and storability of cauliflower plants of cauliflower.

Materials and Methods

Two experiments, field and storage, were conducted during the winter seasons of 2014-2015 and 2015-2016. To study the effect of organic mulches, foliar application of potassium silicate and postharvest treatments (wrapping and exposure to light) on productivity, quality and storability of Cauliflower *(Brassica oleraceae var. botrytis*L.).

The field experiment: was conducted at the Central Laboratory for Agricultural Climate (CLAC), Dokki, Giza, Egypt, during the two successive winter seasons of 2014-2015 and 2015-2016, to study the effect of two mulch treatments:
M1=Bear soil
M2=Organic mulch (rice straw)

Three different concentration of foliar spraying potassium silicate:
0% (P1) = Foliar spraying potassium silicate
1% (P2) = Foliar spraying potassium silicate
2 % (P3) = Foliar spraying potassium silicate

The interactions, on vegetative growth, yield and quality of Cauliflower. cv. Amshiry. Organic mulch (6 cm thickness) was used as soil mulch for the tested crop. Seeds of Cauliflower (*Brassica oleraceae* var. botrytis L. cv. Amshiry) were sown in foam trays (209 eyes) filled with mixture of peatmoss: vermiculite (1:1 volume) on 15th.of September (the recommended transplant production media for protected cultivation). Seedbed was well prepared watered early in the morning with sprinkler till germination. Trays were kept under net–house conditions. Seedlings of healthy cauliflower cv. Amshiry were transplanted, on one side of the ridges at a distance of 50 cm, on October 18th, 2014 and October 15th, 2015 for the first and second seasons, respectively. Later in the field in clay soil at the Central Laboratory for Agricultural Climate (CLAC) farm. Physical and chemical analysis of soil samples were followed according to Chapman and Pratt (1978) and illustrated in Table (1).

Table 1: The physical and chemical properties of the soil.

Particle size distribution		OM (%)	0.35
Sand	15	**Cations and anions (meq / l)**	
Silt	35	Ca	6.0
Clay	50	Mg	3.0
Texture	clay	Na	20.1
PH (1:2:3)	8.2	K	1.2
EC (dS / m)	2.4	Cl	13.0
$CaCo_3$ (%)	16.0	HCO_3	2.6

Climatic data, maximum (T. max. oC) and minimum (T. min. oC) air temperature and relative humidity (RH%) were recorded under greenhouse conditions by the meteorological station of CLAC during both growing. seasons and data are shown in Table (2).

Table 2: Average maximum and minimum air temperature and relative humidity under greenhouse condition during growing seasons

	First season (2014-2015)			Second season (2015-2016)		
Month	T. max. ºC	T. min ºC	RH (%)	T. max. ºC	T. min ºC	RH (%)
Oct.	26.6	24	58.8	28.1	23.4	53.9
Nov.	25.7	13.9	65.0	25.7	16.4	65.9
Dec.	23.3	10.9	67.9	20.6	10.7	68.2
Jan.	21.4	8.9	72.0	19.9	8.2	57.8
Feb.	22.6	10.4	67.4	20.9	9.0	56.4
Mar.	25.4	13.2	55.2	25.0	13.2	56.1

The area of the experimental plot was 17.5 m^2 consisted of two rows, each raw was 25 m length and 0.7 m width, the plant distance was 0.5 m apart on one side. Rows were directly irrigated by drip irrigation system. The harvesting period was from February 15th to March 5th in the seasons of 2015 and 2016, respectively. At the harvesting stage, ten leaves were obtained from five cauliflower plants that were selected from the middle row of each plot. Nutrient contents (N, P and K) were evaluated in the indicated leaves. The three foliar spraying potassium silicate (P1, P2) and P3) were sprayed in three equal parts after 2, 4, and 6 weeks from transplanting date. The recommended amount of mineral fertilizers was added according to Ministry of Agriculture and Land Reclamation recommendations (2013) as follow:

228 kg ammonium sulphate (20.5% N), 50 Kg potassium sulphate (48% k_2O) and 145 Kg calcium superphosphate (15.5 % P_2O_5).

The experiment was conducted in a Splitplot design with four replicates. Three plants were chosen at random from every plot after seven weeks from each transplanting date to study the following parameters. The plants were directly sent to the laboratory. The following data were recorded:-

Vegetative growth:

- Plant height: plant height was measured from the meddle point of the crown till the highest point of the leaves.
- Number of leaves per plant
- Leaf fresh weight per plant
- Leaf dry weight per plant
- Stem length: After removing all leaves, stem length was measured.
- Stem diameter: The average stem diameter, at 5 cm from soil surface the measure was estimated by caliper.

Mineral content in Cauliflower leaves.

The percentages of nitrogen, phosphorus and potassium in the acid digested samples of dry leaves of Cauliflower at 45 days after transplanting were determined using (Chapman. 1978).

- Nitrogen content (N): Nitrogen was determined by the modified micro Kjeldahmethod.
- Phosphorus content (P): phosphorus was determined colorimetrically by NH4- Metavanidate method.
- Potassium content (K): potassium was estimated flame-photometrically
- Total heads yield of every treatment.

The harvesting periods were from February 15thand from March 5th during both seasons of 2015 and 2016, respectively. At harvesting stage, ten leaves were obtained from five cauliflower plants that were selected from the middle row of each plot.

Field experimental Design and Statistical Analysis

Split plot design with four replicates was used. Potassium silicate rate arranged in the main-plots and mulch treatments were distributed randomly in the sub-plots. Data were statistically analyzed using statistical analysis system using MSTATC computer package programmer. The means that significant were separated using Duncan's New Multiple Range Test (DNMRT) at $P \leq 0.05$. **(Duncan 1955).**

Storage experiment

It was designed to study the effect of exposure to light and wrapping films on storability, quality attributes and extend shelf life during storage at cold temperature 0 ◦C and RH 95% and held on shelf life conditions at 10◦C to simulate the super market display with exposure to light and dark in the two seasons .It had been selected the best treatment of cauliflower (*Brassica oleracia var. botrytis*), which obtained from the previous field experiment after The heads were harvested at optimum mature stage ,compact and color white to creamy white, harvesting was done with great care to prevent bruising to the highly sensitive turgid curds in March month. Immediately after harvesting, the heads were transported to laboratory Department of handling of vegetables, Horticulture Research Institute, Agriculture Research Center, Giza Governorate, then sorted and selected for uniform size, appearance and freedom from defects, with removed the outer leaves of curds exception 2–3 leaves per curd as in commercial practice, then placed in two types of wrapping (Low Density Polyethylene 15 µm thickness LDPE (2holds/bag) 30 × 35 cm, sealed hermetically and Polyvinylchloride film 11 µm thicknesses (PVC) and placed inside carton boxes (40 cm x30 cm x15 cm).Eighteen replicates for each examination, heads of cauliflower stored at 0 ºC and 90– 95% RH, for 24 days in dark. After the cool storage period, heads were held for 2 days at shelf life conditions at 10◦C to simulate super market display after divided to two groups with light exposure and dark during shelf life. The light was Fluorescent bulb 120 cm Light color white snowy light intensity 2450 Leumen. Samples of 3 replicates were taken randomly, every 6 days at 0 ºC plus two days at shelf life (10 ºC) to simulate market display to determine:

Physical analysis:

- The visual quality was determined according to the scale of scoring system 9: Excellent, 7: good, 5: fair, 3: poor and 1: unsalable (Kader *et al.,* 1973). which depends on morphological defects such as shriveling, loss of compactness and presence of physiological and pathological defects
- Weight loss: weight of each sample of the three replication of each treatment was recorded after harvest and each 6 days at 0ºC plus two days at 10 ºC during 24 days of storage. Cumulative weight losses were expressed as percentage loss of original weight (Czaikoski *et al.,* 2012).
- Total soluble solids (TSS) percent: It was measured in the juice samples by using PR- 101 Digital Refractometer (A.O.A.C., 1990).

Ratio between oxygen and carbon dioxide (Head space):

This ratio was determined using a Checkmate model 9900 for O_2 and the gas analyser (PBI-Dansensor, Ringsted, Denmark) for Co_2 a syringe where by applying samples were taken automatically for determination.

Chemical analysis:

Ascorbic acid content (mg/100g FW):

- Ascorbic acid: Ascorbic acid content in the curd was detemined as mg/100g fresh weight using 2.6 dicholorophenol indophenol method (A.O.A.C., 1980).
- Polyphenol Oxidase Activity (PPO) was extracted by homogenizing treated or untreated vegetable samples with 1.5-fold their weight sodium phosphate buffer (0.1 M, pH 6.5) containing 30 mM sodium ascorbate and 0.4 M sucrose at 25 ºC. The crude extraction was filtered and refrigerated till used within 24 h. Optimum pH was determined at various pH (4–8) in 0.1 M sodium phosphate buffer and catechol as a substrate. Catechol (3 mL, 80.0 mM) dissolved in the phosphate buffer was mixed with 1.0 mL of enzyme extract. All of the enzymatic reactions were kept at the optimum condition (substrate saturation, pH 6.5 and 25 °C). The increase in absorbance of 0.01 per min. at 410 nm at the specified condition was defined as one unit of PPO activity. The results were expressed as the activity percentage of the respective zero experiment (Dogan *et al.,* 2002).

Statistical Analysis:

The experiment was factorial with 2 factors in complete randomized design (CRD) with 3 replicates. Comparison between means were evaluated by Duncan's Multiple Range Test at 5% level of significance. The statistical analysis was performed according to Snedecor and Cochran, (1982).

Results and Discussion

First experience

Soil Temperature

The average soil temperature, at 15 cm soil depth, for each treatment, during the two seasonsof2014/2015 and 2015/2016, are shown in Figs. (1and 2). During the crop cycle, the highest soil temperature was obtained under conditions of the organic mulch (M1). During the same period, soil temperature under bare soil (M1) was lower than under organic mulch (M2) by 1-2°C. The obtained results were in agreement with those obtained by Moursy *et al*. 2015 who observed that the straw mulch affected soil temperature to make it higher during the colder seasons and lower during the warmer seasons when compared with the bare soil.

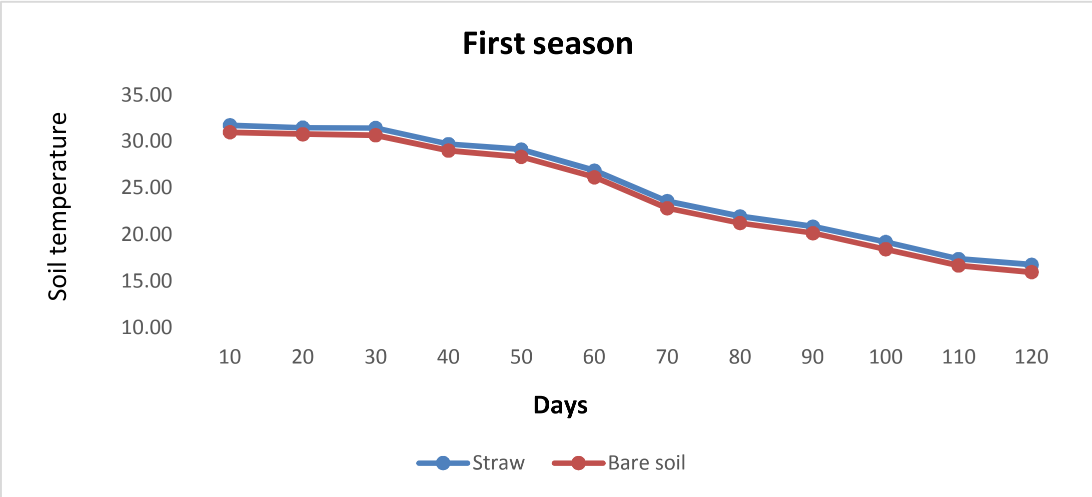

Fig. 1: The average mean soil temperature straw rise mulch and bare soil starting from eighteen of October 2014 to the Half of February 2015.

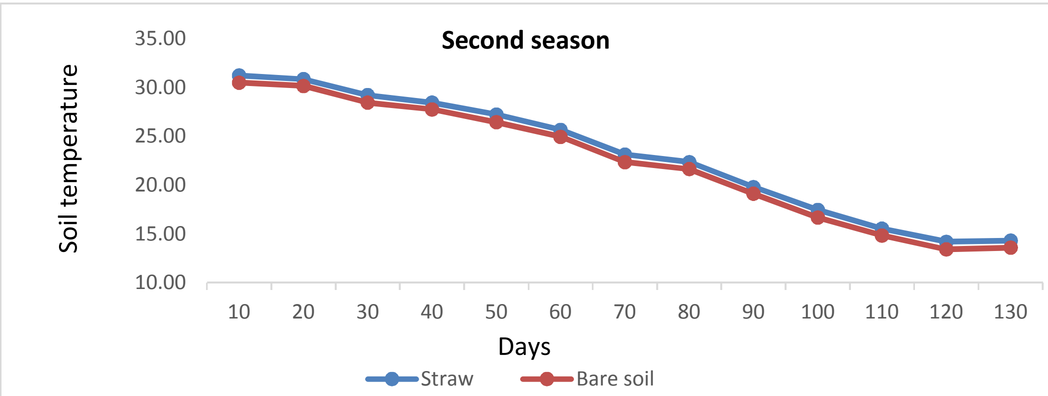

Fig. 2: The average mean soil temperature straw rise mulch and bare soil starting from half of October 2015 to the five of March2016.

Vegetative Characteristics

The obtained results in Table (3) revealed that mulch and foliar spraying potassium silicate applications significantly affected cauliflower vegetative characteristics (plant height, number of leaves, total leaf fresh and dry weight and stem diameter) during the two growing seasons. The highest potassium silicate rate of (P3) produced the highest vegetative characteristics; while (P2) treatment came in the second order followed by that of (P1) which produced the lowest values, with significant differences among treatments. Regarding the mulch treatments, data indicated that mulch resulted in the highest vegetative characteristics followed by bare soil, with significant difference between them. The lowest values were obtained in case of control treatment (P1M1).The interaction between foliar spraying potassium silicate rate and mulch treatments was significant for vegetative characteristics during the two growing seasons.

The highest values were obtained in cauliflower plants grown using (P3) combined with (M2) treatment followed by those provided with (P2) combined with (M2).The lowest vegetative growth was obtained from plants provided with (P1) treatment along with (M1).

Results showed that vegetative growth of Cauliflower plants expressed as plant height, leaves number, stem diameter as well as fresh weight and dry weight of leaves and total plant were statistically influenced by potassium fertilization. Linear relationship was obtained between the above mentioned characteristics and the increased potassium levels up to its highest level. The highest vegetative growth was obtained by the addition of the high K level. Cell extension in leaves is closely related to their K level (Abou-Hussein, 2005).

There searcher opined that mulching contributed positively to higher soil temperature and consequently improving growth and yield (Moursy *et al.*, 2015).

Table 3: Effect of mulch and foliar spraying potassium silicate on vegetative Characteristics of cauliflower during the studied two seasons of 2014/2015 and 2015/2016

	2014/2015				**2015/2016**			
Treatment (A)	**Foliar spraying potassium silicate**			**Maen (B)**	**Foliar spraying potassium silicate**			**Maen (B)**
	P1	**P2**	**P3**		**P1**	**P2**	**P3**	
	Plant height (cm)							
M1	54 d	64c	64.5 c	63.3 b	57.75 d	64.5c	65c	65.25 b
M2	71.5 b	74.25a	81.75a	73.3 a	73.5b	74.5b	84a	74.5a
Mean(A)	59c	69.375b	76.625a		61.37 c	69.5b	78.75a	
	No. leaves/plant							
M1	9.5 f	11.75e	13.25d	13.66b	13	15	17	16.16b
M2	14.75	18.25	20.25	15.58a	18.5	18.75	21.25	18.3a
Mean	10.62c	14 b	19.25a		14c	17.87b	19.87a	
	Fresh weight of leaves (kg/plant)							
M1	1.16c	1.36b	1.44a	1.43 b	1.23 e	1.43d	1.52c	1.66a
M2	1.54e	1.68 d	1.8 d	1.56a	1.66b	1.7 b	1.90a	1.48 b
Mean(A)	1.26c	1.49b	1.74a		1.33 c	1.59 b	1.80a	
	Dry weight of leaves (g/plant)							
M1	174.75e	204.5d	217cd	214.5a	183.5e	215d	228c	222.16a
M2	226.5	251.75	270	233.66b	248.5b	255 b	284.25a	249.25b
Mean(A)	189.62c	221.75b	260.87a		199.25 c	238.25 b	269.625 a	
	Stem diameter (cm)							
M1	5.15 d	5.27cd	5.33bcd	5.47 a	5.16c	5.55b	5.62b	5.781a
M2	5.41bc	5.51ab	5.63a	5.3b	5.69b	5.83a	5.95a	5.49b
Mean(A)	5.21b	5.42a	5.52a		5.35c	5.72b	5.82a	

P1= 0% Foliar spraying potassium silicate M1= Bare soil
P2= 1% Foliar spraying potassium silicate M2= Organic mulch (rice straw)
P3= 2% Foliar spraying potassium silicate

Yield

Application of (P3) in cauliflower increased the total yield (ton/feddan), curd weight per plant and curd diameter compared to the other foliar spraying potassium silicate treatments during the two tested seasons (Table 4). The (P2) application rate came in the second order without significant differenceswith(P3).Useoffoliarfeedingduringgrowthanddevelopmentcanimprovethenutrient balance of crops, which, in turn, leads to increased yield and quality (Van der Meulen *et al.*, 2006) reported that K (140mgKkg soil) treatment significantly increased the yield of broccoli but only under conventional management compared with other treatments.

Regarding the effect of organic mulch treatments, data recorded the highest values of yield in the two studied seasons (Table 3). The lowest yield was obtained by bare soil treatment with significant differences with other treatments. Organic mulch modified root zone temperature, which has been shown to have an important role in plant growth and yield. (Kosterna, 2014) mentioned that organic mulch increased yield and improved crop growth of many vegetable crops.

Referring to the interaction effect between foliar spraying potassium silicate rate and organic mulch, data indicated that increasing foliar spraying potassium silicate rate (P3), led to the increase in cauliflower yield under organic mulch; however, decreasing foliar spraying potassium silicate rate than (P2) led to significant difference in cauliflower yield. The highest yield was obtained in cauliflower plants in treatment (P3M2) followed by (P2M2).The lowest yield was obtained in plants in treatment (P1M1). Singh and Akhilesh (2000) found that the highest net head weight of broccoli plants were obtained when K at 50 kg/ha were applied compared with k at 0 or 25 kg/ha. Other investigators reported enhancing quality of broccoli heads by NPK applications (Abou EL-Magd *et al*., 2006). And organic mulch gave higher yield and heavier fruit than the bare soil, which could be explained in the light of beneficial effects of organic mulch, which enables retention of soil moisture and prevents soil temperature (Moursy *et al*., 2015).

Table 4: Effect of mulch and foliar spraying potassium silicate on yield characteristics of cauliflower in the two studied seasons of 2014/2015 and 2015/2016

	2015				**2016**			
Treatment (A)	**Foliar spraying potassium silicate**			**Mean (B)**	**Foliar spraying potassium silicate**			**Mean (B)**
	P1	**P2**	**P3**		**P1**	**P2**	**P3**	
	Curd weight (kg/plant)							
M1	1.18d	1.26c	1.27c	1.27b	1.22e	1.31d	1.32d	1.31 b
M2	1.35b	1.36b	1.44a	1.35a	1.41c	1.47b	1.52 a	1.43a
Mean(A)	1.22 c	1.31b	1.40a		1.27c	1.39b	1.46a	
	Curd diameter (cm)							
M1	20.87e	23.55d	24.47c	23.83 b	22.35	25.025	25.625	27.32a
M2	26.02b	26.15b	28.47a	26.01a	27.05	27.175	29.775	25.00 b
Mean(A)	22.21c	25.25b	27.31a		23.68	26.4	28.41	
	Total yield (ton/feddan)							
M1	8.55c	8.98c	9.07c	10.12 a	8.825d	9.7 c	9.725 c	11.13 a
M2	10.07b	10.35b	11.22a	9.29 b	10.72b	11.52a	12.18 a	9.75 b
Mean(A)	8.81c	9.52b	10.78a		9.26 c	10.62b	11.45a	

P1= 0% Foliar spraying potassium silicate M1= Bare soil
P2= 1% Foliar spraying potassium silicate M2= Organic mulch (rice straw)
P3= 2% Foliar spraying potassium silicate

Nutrient Content

The obtained results in Table (5) showed that the foliar spraying potassium silicate rate and mulch treatments significantly affected the uptake of N, P and K by cauliflower plants during the two studied growing seasons. The highest N, P and K percentages in the cauliflower leaves were obtained with (P3) treatment followed by (P2),while the lowest N, P and K contents were obtained with(P1) treatment.

Mulch treatments significantly affected the N, P and K percentages. The organic mulch (M2) resulted in the highest average values in cauliflower plants followed by that of bare soil. The lowest N, P and K percentages were obtained in case ofcontrol treatment (M1) during the two studied seasons. This result agreed with Cakmak (2005) who mentioned that potassium (K) is an essential plant mineral element (nutrient) having a significant influence on increasing many human-health related quality compounds in different fruits and vegetables. (Pradeepkumar *et al*., 2002) came to similar results. They recorded these increases might be due to the increased absorption of N, P and K resulting by the interactions of these elements. These results were due to that these elements encourage the absorption of each other within soil solution by plant roots. Guo Xi Sheng *et al.* (2007) found that K application could increase K content of cauliflower, P content inside leaves while reducing the N content in all tissues.

Table 5: Effect of mulch and foliar spraying potassium silicate on cauliflower leaves elemental content of N, P and K in the two studied seasons of 2014/2015 and 2015/2016

	2015				2016			
Treatment (A)	**Foliar spraying potassium silicate**			**Mean (B)**	**Foliar spraying potassium silicate**			**Mean (B)**
	P1	**P2**	**P3**		**P1**	**P2**	**P3**	
	% N							
M1	2.87c	3.18bc	3.20bc	3.34a	2.76c	3.01c	3.45bc	3.32b
M2	3.95ab	3.99ab	4.5 a	3.89b	3.75bc	4.22ab	4.92a	4.05a
Mean(A)	3.03 c	3.6 b	4.22a		2.88b	3.84a	4.33a	
	% P							
M1	0.43c	0.45bc	0.48bc	0.47a	0.4d	0.41c	0.45c	0.43 b
M2	0.49bc	0.51ab	0.55a	0.50a	0.47b	0.48 a	0.53a	0.48a
Mean(A)	0.44c	0.49b	0.53a		0.42c	0.45b	0.50a	
	% K							
M1	2.94c	3.41 b	3.75ab	3.56a	2.59d	3.02c	3.58b	3.36a
M2	3.76ab	3.98a	4.13a	3.76 a	3.73 b	3.91 ab	4.1 a	3.61b
Mean(A)	3.17c	3.76b	4.06a		2.81 c	3.65b	4.00a	

P1= 0% Foliar spraying potassium silicate   M1= Bare soil
P2= 1% Foliar spraying potassium silicate   M2= Organic mulch (rice straw)
P3= 2% Foliar spraying potassium silicate

Second Experience:-

Physical analysis:-

Visual Quality:

The results presented in Table (6) indicated that the effect of exposure to light and wrapping on visual quality of cauliflower curds during storage at 0 ºC, 90 – 95% RH and held for 2 days at shelf life conditions at 10◦C. In general, there were significant differences between all treatments in visual quality of cauliflower curds for both seasons. The visual quality decreased progressively with the extend of cold storage periods (Ekman and Golding, 2006,). Concerning the effect of packaging on visual quality during cold storage and shelf life condition, Data indicated that the cauliflower curds packed LDPE film maintaining visual quality for 24 days at0 ºC plus two days at 10◦C compared with wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons. These results were in agreement with those reported by Dhall *et al.* (2010); Deell, (2003). Which might be due to decrease in the respiration rate in cauliflower as reported by Romo-Parada *et al.*, (1989); Menjura and villamizar, (2004).Regarding the effect of exposure to light and dark on visual quality of cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions. The obtained results exhibited that exposed to light cauliflower maintaining on quality with good appearance for 24 days at0 ºC plus two days at 10◦C compared with cauliflower cards kept in the dark, which might be due to exposure to light maintained the gaseous exchange between plant tissue and the atmosphere inside the packages for longer periods than in samples kept in darkness (Susana *et al*., 2007). The effect of interaction between the exposure to light and wrapping on visual quality of cauliflower curd during storage at 0 and held for 2 days at shelf life conditions at 10◦C data indicated that that light exposed cauliflower curds and packed in bag LDPE film cauliflower obtained good general appearance during examination periods compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons. Which might be due to exposure to light stimulated the respiratory activity so that the composition of the atmosphere inside the packages (Olarte *et al.*, 2009).

Table 6: Effect of exposure to light and wrapping on visual quality (score) of cauliflower curd during storage at 0˚C plus 2 days on shelf life conditions in 2015/2016 and 2016/2017 seasons.

Treatments		2015-2016			2016-2017		
		Light	Dark	Mean	Light	Dark	Mean
Starting	LDPE	9.00a	9.00a	9.00A	9.00a	9.00a	9.00A
	PVC	9.00a	9.00a	9.00A	9.00a	9.00a	9.00A
	Control	9.00a	9.00a	9.00A	9.00a	9.00a	9.00A
	Mean	9.00A	9.00A		9.00A	9.00A	
6+2 days	LDPE	9.00a	7.67ab	8.33A	9.00a	8.33ab	8.67A
	PVC	7.67ab	7.67ab	7.33AB	7.00bc	7.00bc	7.00B
	Control	6.33b	6.33b	6.33B	6.33c	6.33c	6.33B
	Mean	7.67A	7.00A		7.44A	7.22A	
12+2 days	LDPE	9.00a	7.00b	8.00A	9.00a	7.00b	8.00A
	PVC	7.00b	5.67bc	6.33B	7.00b	5.67b	6.33B
	Control	4.33c	4.33c	4.33C	3.67c	3.67c	3.67C
	Mean	6.78A	5.67B		6.55A	5.44B	
18+2 days	LDPE	8.33a	5.00b	6.67A	8.33a	5.00b	6.67A
	PVC	5.00b	3.00bc	4.00B	5.00b	3.00bc	4.00B
	Control	2.33c	2.33c	2.33C	2.33c	2.33c	2.33C
	Mean	5.22A	3.44B		5.22A	3.44B	
24+2 days	LDPE	7.00a	5.00b	6.00A	7.00a	3.67bc	5.33A
	PVC	4.33b	2.33c	3.33B	4.33b	2.33bc	3.33B
	Control	1.00c	1.00c	1.00C	1.67c	1.67c	1.67C
	Mean	4.11A	2.78B		4.33A	2.56B	

Means followed by different letters are significantly different at P≤ 0.5 level; Duncan's multiple range test.
Visual quality was determined using the following rating score system: Excellent=9,Good=7, Fair=5, Poor=3 and Unusable =1

Weight loss %

The obtained results in Table (7) show the effect of exposure to light and wrapping on weight loss percentage of cauliflower curds during storage at 0 ºC, 90 – 95% RH plus 2 days at shelf life conditions at 10◦C. In general, there were significant differences between treatments in cauliflower curds during storage periods in weight loss for both seasons. It is clear that a continuous gradual loss in weight existed with the extend of storage periods in both seasons. The effect of packaging in weight loss percentage, the results demonstrated that cauliflower curds packed LDPE film obtained the lowest in weight loss compared with wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons, it was 3.35%, 3.62 % after 24 days at ºC plus two days at 10 ºC in LDPE while was 5.20%, 5.47% in PVC film and 18.01%, 18.24% in control respectively in both seasons. Similar results were also observed in cauliflower by Artes and Martinez, (1999); Dhall *et al.* (2010). The lower weight loss of cauliflower curds packed in LDPE film may be attributed to the reduction in weight loss to creation of micro-atmosphere in the package which reduced the transpiration losses and respiration rate (Dhall *et al.*, 2010). Concerning the effect of exposure to light and dark on weight loss percentage of cauliflower curds during storage at 0 ºC plus 2 days at shelf life conditions. Data indicated that exposed to light cauliflower curds recorded the lowest weight loss compared with kept in the dark during storage periods in both seasons, similar results were obtained by other workers (Kasim and Rezzan, 2017). Regarding the effect of interaction between the exposure to light and wrapping on weight loss percentage of cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions at 10◦C. Data indicated that light exposed cauliflower curds and packed in bag LDPE film cauliflower curd gave the lowest weight loss compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons. Which might be due to the reducing the O2 concentration and increasing CO_2 concentration had a significant influence on reducing eight losses during storage of cauliflowers (Romo-Parada *et al.*, 1989).

Table 7: Effect of exposure to light and wrapping on weight loss% of Cauliflower curd during storage at 0◦C Plus 2days on shelf life conditions in 2015/2016 and 2016/2017 seasons.

Treatments		2015-2016			2016-2017		
		Light	Dark	Mean	Light	Dark	Mean
6+2 days	LDPE	0.53d	0.71d	0.63C	0.53d	1.60c	0.92C
	PVC	1.38c	1.71b	1.55B	1.30c	2.30b	1.95B
	Control	8.47a	8.41a	8.44A	8.67a	8.47a	8.57A
	Mean	3.47B	3.61A		3.60B	4.02A	
12+2 days	LDPE	1.10d	1.45d	1.28C	0.92d	1.98c	1.45C
	PVC	1.93c	2.39b	2.16B	1.87c	2.93b	2.40B
	Control	10.73a	1069a	10.71A	11.03a	10.86a	10.95A
	Mean	4.59B	4.84A		4.61B	5.26A	
18+2 days	LDPE	1.91e	2.38d	2.15C	2.05e	2.52d	2.28C
	PVC	2.76c	3.12b	2.94B	2.83c	3.28b	3.06B
	Control	14.77a	14.71a	14.74A	14.93a	14.88a	14.91A
	Mean	6.48B	6.74A		6.60B	6.89A	
24+2 days	LDPE	3.10e	3.61c	3.35C	3.40e	3.83d	3.62C
	PVC	5.00c	5.40b	5.20B	5.28c	5.67b	5.47B
	Control	18.03a	17.98a	18.01A	18.27a	18.21a	18.24A
	Mean	8.71B	8.99A		8.98B	9.24A	

Means followed by different letters are significantly different at P≤ 0.5 level; Duncan's multiple range test.

Total soluble solids content

Data Presented in Table (8) include the effect of exposure to light and wrappers on TSS of cauliflower curd during storage at 0 ºC, 90 – 95% RH plus 2 days at shelf life conditions at 10◦C in 2015and 2016seasons.

Table 8: Effect of exposure to light and wrapping on TSS °Brix of cauliflower curd during storage at 0◦C plus 2 days on shelf life conditions in 2015/2016 and 2016/2017 seasons.

Treatments		2015-2016			2016-2017		
		Light	Dark	Mean	Light	Dark	Mean
Starting	LDPE	7.75a	7.75a	7.75A	7.60a	7.60a	7.60A
	PVC	7.75a	7.75a	7.75A	7.60a	7.60a	7.60A
	Control	7.75a	7.75a	7.75A	7.60a	7.60a	7.60A
	Mean	7.75A	7.75A		7.60A	7.60A	
6+2 days	LDPE	7.63a	7.00c	7.32A	7.30a	6.67c	6.98A
	PVC	7.27b	6.80c	7.03B	6.97b	6.43d	6.70B
	Control	6.53d	6.50d	6.52C	6.17e	6.13e	6.15C
	Mean	7.14A	6.77B		6.81A	6.41B	
12+2 days	LDPE	7.43a	6.57c	7.00A	7.03a	6.10c	6.57A
	PVC	7.07b	6.40c	6.73B	6.63b	6.03c	6.33B
	Control	5.97d	6.07d	6.02C	5.67d	5.67d	5.62C
	Mean	6.82A	6.34B		6.44A	5.90B	
18+2 days	LDPE	7.23a	6.13c	6.68A	7.03a	6.10c	6.57A
	PVC	6.83b	5.83d	6.33B	6.63b	6.03c	6.33B
	Control	5.53e	5.50e	5.52C	5.67d	5.57d	5.62C
	Mean	6.53A	5.82B		6.44A	5.90B	
24+2 days	LDPE	6.83a	5.67c	6.25A	7.27a	6.17c	6.72A
	PVC	6.40b	5.20d	5.80B	6.87b	5.87d	6.37B
	Control	4.57e	4.47e	4.52C	5.33e	5.50e	5.52C
	Mean	5.93A	5.11B		6.56A	5.84B	

Means followed by different letters are significantly different at P≤ 0.5 level; Duncan's multiple range test.

In general, there were significant differences between treatments in cauliflower curds during storage periods of TSS for both seasons, the effect of wrapping on T.S.S. The results exhibited that packed in bag LDPE film cauliflower curds retained more to total soluble solids content than Polyvinylchloride film (PVC) and unwrapped during examination periods for both seasons. Similar results were also observed in cauliflower by Artes and Martinez, (1999); Raja *et al.* (2011). Regarding the effect of exposure to light and dark on TSS of cauliflower curds during storage at 0 ºC plus 2 days at shelf life conditions. The exposed to light cauliflower curds retained more to total soluble solids content than comparatively with the cauliflower curd kept in dark for both seasons. The higher TSS content in light stored was supposed to be attributed to the higher soluble sugar content as sugars are generally considered to be the main contributors of TSS in fresh fruits and vegetables besides of organic acid, vitamins and mineral (Zhan *et al.,* 2014). The effect of interaction between the exposure to light and wrapping on T.S.S of cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions at 10◦C. Data indicated that light exposed cauliflower curds and packed in bag LDPE film maintaining total soluble solids content during examination periods compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons (Zhan *et al.,* 2013).

Ratio of oxygen and carbon dioxide (Head space):

The Data represented in Fig. (3 & 4) Include the effect of exposure to light and wrapping on ratio of oxygen and carbon dioxide (head space) of cauliflower curds during storage at 0 ºC, 90 – 95% RH plus 2 days at shelf life conditions at 10◦C. in light and dark. It is clear, as a general trend, that the levels of oxygen decreased meanwhile those of carbon dioxide increased around the wrapped curds comparing the wrapped and unwrapped curds. The results exhibited that LDPE film gave higher CO_2concentration than cauliflower curds wrapping by polyvinyl chloride (PVC) stretch film for both seasons. the packaging treatment of LDPE with exposure to light registered higher CO_2% compared with the cauliflower curds kept in polyvinyl chloride (PVC) stretch film and unwrapped for both seasons. Similar results were also observed in cauliflower by Artes and Martinez, (1999); Raja *et al.* (2011) The effect of interaction between the exposure to light and wrapping on ratio of oxygen and carbon dioxide (head space) during storage at 0 ºC and held for 2 days at shelf life conditions at 10◦C, exposure to light with packaging of LDPE gave the higher percentage of CO_2 during storage periods compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons (Susana *et al*., 2007; Olarte *et al*., 2009; Kasim and Rezzan 2017).

Chemical Analysis.

Ascorbic acid content

The effect of exposure to light and wrappers on content of ascorbic acid in cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions at 10◦C in 2015and 2016seasons are shown in Table (9) the exposure to light and dark of cauliflower curds exhibited a general trend of decrease in this content of ascorbic acid during examination periods at 0 ºC, plus 2 days at shelf life conditions at 10◦C in two seasons. The exposed to light cauliflower curds were retain more ascorbic acid content during storage periods comparatively with the cauliflower curd kept in dark for both seasons. Similar results were also observed in cauliflower and other works by (Zhan *et al*. , 2014; Noichind *et al.,* 2007; Lester, *et al*., 2010; Xiaoe *et al.,* 2014). Concerning the effect wrapping on ascorbic acid content during storage periods at 0 ºC plus 2 days at shelf life conditions at 10◦C, Data revealed that cauliflower curds packed in bag LDPE film kept the higher content of the ascorbic acid content during examination periods comparatively with the cauliflower curds wrapping by polyvinyl chloride (PVC) stretch film and unwrapping, Similar results were also observed in cauliflower by Lee and Kader, (2000) ; Albrecht *et al.,* (1990); Pramanik *et al*., (2006) Which might be due to reduced metabolic active and modified atmosphere created within the Package (Berrang *et al*., 1990).

Ratio of oxygen and carbon dioxide (Head space):

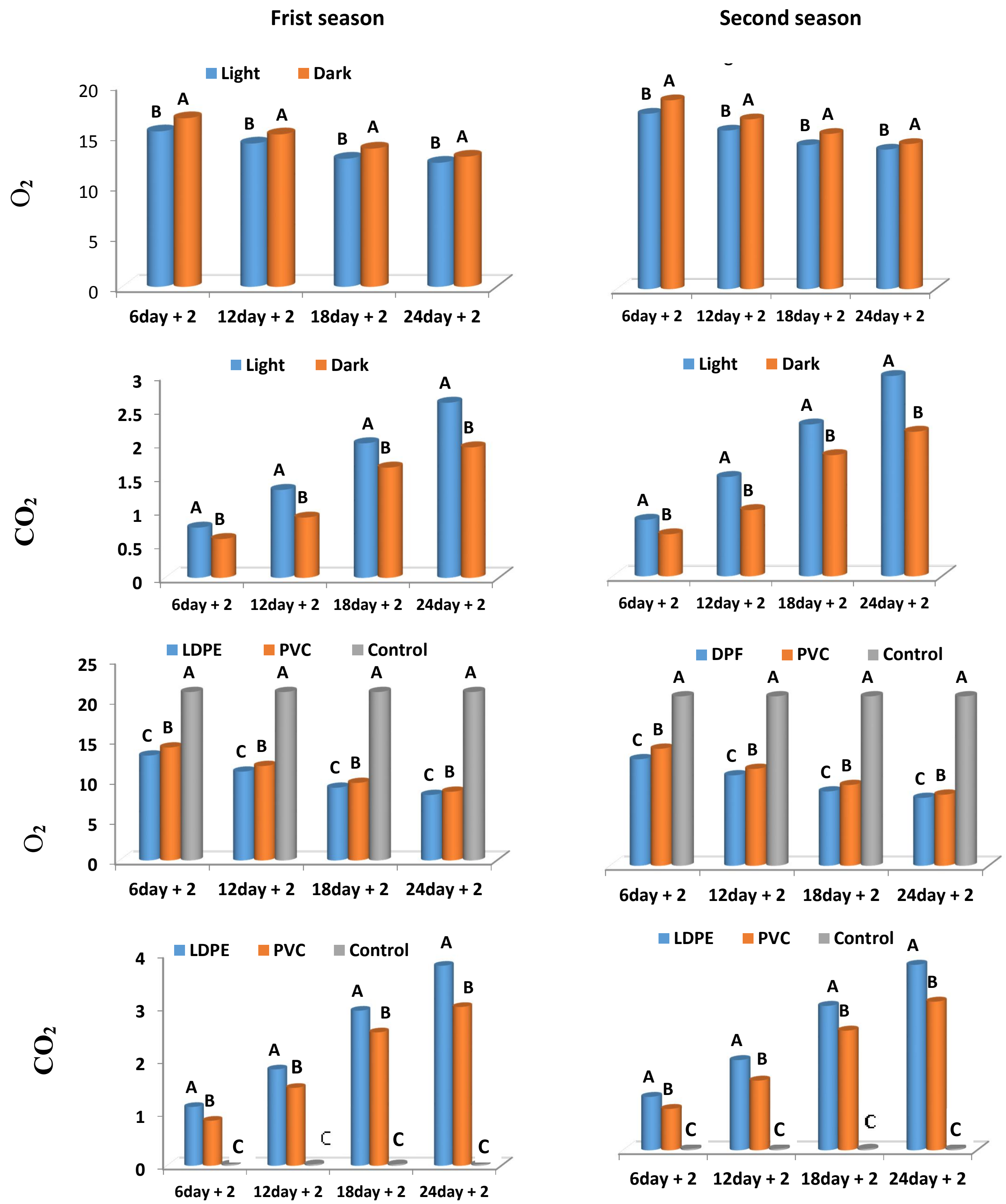

Fig. 3: Effect of exposure to light and wrapping on ratio of oxygen and carbon dioxide (head space) of cauliflower curds during storage at 0 ºC, 90 – 95% RH plus 2 days at shelf life conditions at 10◦C in 2015 and 2016 seasons.

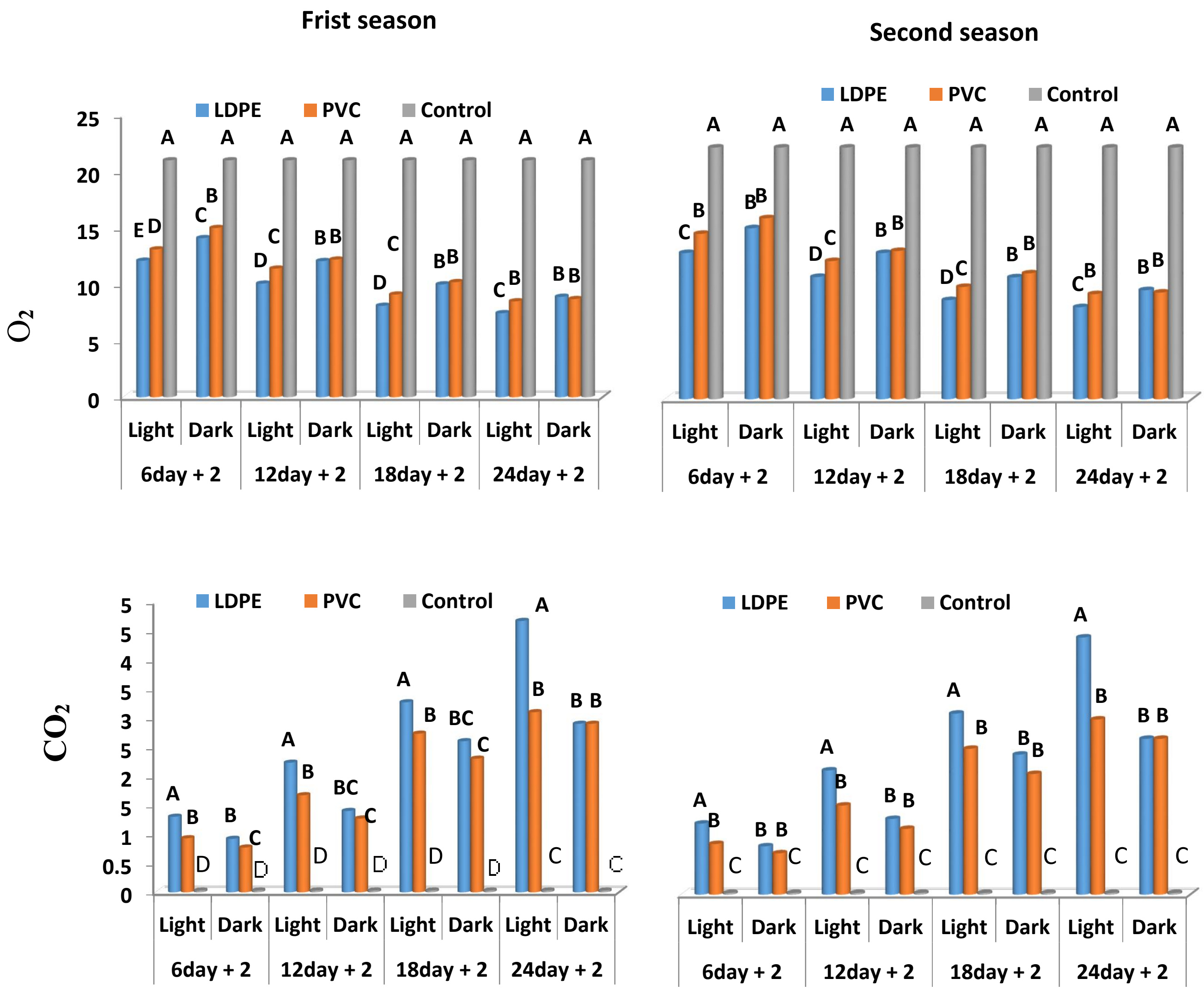

Fig. 4: Effect of interaction between exposure to light and wrapping on ratio of oxygen and carbon dioxide (head space) of cauliflower curds during storage at 0 °C, 90 – 95% RH plus 2 days at shelf life conditions at 10◦C in 2015 and 2016 seasons.

Table 9: Effect of exposure to light and wrapping on ascorbic acid content (mg/100gFW) of cauliflower curd during storage at 0◦C Plus 2days on shelf life conditions in 2015/2016 and 2016/2017 seasons.

Treatments		2015-2016			2016-2017		
		Light	Dark	Mean	Light	Dark	Mean
Starting	LDPE	63.00a	63.00a	63.00A	61.00a	61.00a	61.00A
	PVC	63.00a	63.00a	63.00A	61.00a	61.00a	61.00A
	Control	63.00a	63.00a	63.00A	61.00a	61.00a	61.00A
	Mean	63.00A	63.00A		61.00A	61.00A	
6+2days	LDPE	60.00a	53.33c	56.67A	59.00a	52.33c	55.67A
	PVC	57.00b	50.33d	53.67B	55.67b	51.00cd	53.33B
	Control	48.00de	47.33e	47.67C	49.33d	49.67d	49.50C
	Mean	55.00A	50.33B		54.67A	51.00B	
12+2days	LDPE	53.00a	43.33c	48.17A	51.00a	43.67bc	47.33A
	PVC	47.00b	41.67cd	44.33B	46.67b	40.67cd	43.67B
	Control	40.00d	39.00d	39.50C	39.00d	38.00d	38.50C
	Mean	46.67A	41.33B		45.56A	40.78B	
18+2days	LDPE	43.00a	39.bc	41.00A	39.67a	34.33c	37.17A
	PVC	40.33b	36.67c	38.50B	37.33b	32.67c	35.00B
	Control	34.d	32.00d	33.00C	30.00d	29.67d	29.83C
	Mean	39.11A	35.89B		35.67A	32.33B	
24+2days	LDPE	37.00a	31.00b	34.00A	32.20a	26.00c	29.10A
	PVC	32.67b	26.67c	29.67B	28.73b	23.33d	26.03B
	Control	21.00d	21.67d	21.33C	21.00d	20.97d	20.98C
	Mean	30.22A	26.44B		27.31A	23.43B	

Means followed by different letters are significantly different at P≤ 0.5 level; Duncan's multiple range test.

Regarding the effect of interaction between the exposure to light and wrappers on ascorbic acid content of cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions at 10◦C. Data indicated that light exposed cauliflower curds and packed in bag LDPE film kept the higher content of the ascorbic acid content during storage periods compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons.

Polyphenol oxidase activity:

The results presented in Table (10) indicated that the effect of exposure to light and wrapping on PPO of cauliflower curd during storage at 0 ºC and held for 2 days at shelf life conditions at 10◦C in 2015 and 2016seasons. In general, there were significant differences between treatments in cauliflower curds during examination periods in PPO for both seasons. It is clear that a continuous gradual trend of increase in the activity of this enzyme PPO with the extending storage life. The results exhibited that cauliflower curds packed in LDPE film gave lower polyphenol oxidase active than wrapping (PVC) and unwrapped in both seasons. This might be due to reduce the oxygen level, increase the carbon dioxide and low respirations rate within the package (Kader and Saltveit, 2003).

Concerning the effect of exposure to light on Polyphenol oxidase activity (PPO) the results shown that. The exposed to light cauliflower curds, gave lower polyphenol oxidase active compared with the cauliflower curds kept in dark in both seasons similar results were also observed in cauliflower by (Zhan *et al*., 2014). The effect of interaction between the exposure to light and wrapping on Polyphenol oxidase activity (PPO) of cauliflower curd during storage at 0 ºC plus 2 days at shelf life conditions at 10◦C. data indicated that light exposed cauliflower curds and packed in bag LDPE film a gave lower polyphenol oxidase active during storage periods compared with the cauliflower curds kept in dark and wrapping by polyvinyl chloride (PVC) stretch film and unwrapped for both seasons.

Table 10: Effect of exposure to light and wrapping on polyphenol oxidase activity (%) of cauliflower curd during storage at 0◦C Plus 2days on shelf life conditions in 2015/2016 and 2016/2017 seasons.

Treatments		2015-2016				2016-2017		
		Light	Dark	Mean		Light	Dark	Mean
6+2days	LDPE	0.021c	0.034b	0.028C		0.023a	0.039c	0.031C
	PVC	0.031b	0.051a	0.041B.		0.030d	0.046b	0.038B
	Control	0.048a	0.048a	0.048A		0.056a	0.055a	0.055A
	Mean	0.033B	0.045A			0.036B	0.046A	
12+2days	LDPE	0.031d	0.074b	0.053C		0.031e	0.053d	0.047C
	PVC	0.062c	0.081b	0.072B		0.063c	0.082b	0.068B
	Control	0.091a	0.092a	0.091A		0.093a	0.092a	0.093A
	Mean	0.016B	0.082A			0.059B	0.079A	
18+2days	LDPE	0.069e	0.088c	0.079C		0.052d	0.087bc	0.070C
	PVC	0.082d	0.095b	0.089B		0.085c	0.10b	0.093B
	Control	0.094b	0.099a	0.097A		0.12a	0.12a	0.12A
	Mean	0.081B	0.094A			0.086B	0.11A	
24+2days	LDPE	0.084d	0.11c	0.095C		0.082D	0.11C	0.093C
	PVC	0.11c	0.14b	0.13B		0.097C	0.12B	0.11B
	Control	0.16a	0.17a	0.16A		0.16A	0.16A	0.16A
	Mean	0.12B	0.14A			0.11B	0.13A	

Means followed by different letters are significantly different at P≤ 0.5 level; Duncan's multiple range test.

Conclusion

The present investigation revealed that, mulch can improve plant growth and yield of cauliflower compared with bare soil. Increase in the rate of potassium silicate foliar spraying is recommended for larger and heavy cauliflower curds under field conditions. Use of 2% foliar spraying potassium silicate with organic mulch is recommended for increasing the yield. Improving the management of K fertilizer for field crops can improve an essential plant mineral element (nutrient) and saving farmers money. Cauliflower curds packed in LDPE bags and exposed to light gave the lowest in weight loss during storage periods. As well, maintained quality attributes (TSS, ascorbic acid,) and reduced browning enzyme activity PPO and extended storage life for 24 days at 0 ºC, plus two days at shelf life with good appearance compared with PVC film and unwrapped.

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