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Using some plant extracts to control of mechanical injured, pest management, increasing productivity and storability of potato (*solanum tuberosum* l.).

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ABSTRACT

Two experiments were conducted in Baramoon Research Station, Dakahlia Governorate, Egypt during the growing summer seasons of 2014 and 2015 to determine the effect of some exogenous plant extracts to control mechanical injured, pest management, increasing productivity and storability of potato plants. Five locally available plants namely, neem, liquorice, turmeric, pomegranate and thyme were evaluated plus check treatment. Foliar spray with pomegranate peels or liquorice extracts (5%) led to significant increases in all vegetative growth parameters, total tuber and marketable yields and decreases in all physiological disorders and mechanical injures of potato plants. All the treatments were significantly reduced in population density of two spider mite, aphids and whitefly. The most effective treatments were turmeric, thyme and neem extracts for previous mentioned three insects, respectively, in terms of reduction percentage. Application of pomegranate or thyme extracts were significantly reduced percent of weight loss and decay, also excelled at increasing the content of dry matter and starch over the control and other treatments during storage at 4^{o}C. The control treatment or neem extract had significant reduction the content of total phenols and the activity of polyphenol oxidase enzyme.This study recommends using foliar application with pomegranate peels or licorice extracts to increase the productivity, quality and marketable yield and neem or thyme extracts as pesticides and pomegranate peels or thyme extracts to increase storability and reduce weight losses, at intervals of 15 days beginning from the first of March until the end of April.

INTRODUCTION

Potatoes are a major crop in Egypt and contribute immensely to human nutrition and food security (Karim *et al*., 2010). The total cultivated area of potatoes is about 200 thousand feddan, which produce about two million tons and about 85% of the production is consumed domestically.

The main summer crop, with imported seed tubers from European countries, is cultivated in 70,250 feddan which produced 726,385 tons of tubers with an average yield of 10.34 tons/feddan (FAO, 2013). Most of this crop, roughly 35 percent of annual production, is kept as seed for the fall planting. A small portion is exported to Arab countries. During their seasonal plantation, potato plants are subjected to numerous pathogens and insect pests which cause considerable loss in Egyptian quantitative and qualitative potato yield. The most important insect pests are spotted spider mite, *Tetranychus urticae*, the cotton aphid, *Aphis gossypii* and whitefly, *Bemisia tabaci* (Tang *et al*., 2002).

The Food and Agriculture Organization (FAO, 1981) reported that the estimated annual losses due to insect pests alone stands at about 15-20% during production and 18-20% during storage in summer plantation. The Federal Department of Agriculture (FDA) estimated that about 60% of the total food and fiber produced are lost to insect pests (Mohammed, 2002). A purely mechanical injury produced by the insect's stylets in process of sucking.

The world has become aware of environmental issue in recent years. Synthetic compounds are highly polluting, hazardous and much more costly. Synthetic chemical insecticides have proved very effective in the control of insect pests. However, problems associated with chemical insecticides, such as depletion of the ozone layer, health hazards, insect resistance, irregular supplies and cost have led to increased demand for alternatively safer, cheaper and more ecologically friendly methods in the control of these insects (Okunlola and Ofuya, 2013). Researchers are working in the field of natural products extensively as they are less hazardous, low cost and easily available. The dependency on the use of inorganic fertilizers as a source of plant nutrients by farmers and their high cost is further associated with land and soil degradation and environmental pollution (Phiri, 2010). Thus, there is continuous need to search for alternative safe natural sources of plant nutrients, natural growth regulators even for protecting against disease and insects. Plant hormones can be used to increase yield per unit area because they influence every phase of plant growth and development (Prosecus, 2006).

Liquorice (*Glycyrrhiza glabra* L., Family: Leguminosae) is a plant which grows in Egypt and some other countries of the world. Its roots possess some nutritive value and medicinal properties. So, widely are used as a cold beverage, and in preparing some pharmaceutical agents (Fenwick *et al*., 1990).The licorice extract contain more than 100 various compounds, some of which accumulated in large amounts, which most important of them are triterpene saponins (including glycyrrhizin) and phenolic compounds (Shabani *et al*., 2009). The yellow color of licorice is due to the flavonoid content of the plant, which includes liquiritin, isoliquiritin, and other compounds. The isoflavones glabridin and hispaglabridins A and B have significant antioxidant activity. In addition, licorice extract contain protein and amino acid (Asparagin), monosaccharide glucose, fructose, sucrose and maltose), lignins, tannins, starch, choline, phytosterols, different types of vitamins such as B1, B2, B3, B6, C, E, biotin, oleic acid, pantothenic acid, many mineral compounds (aluminum, calcium, iron, magnesium cobalt, zinc, phosphorus, sodium, silicone, potassium and stannous) and bitter principles (Rossi, 1999; Arystanova *et al*., 2001). Zuhair (2010) studied the effect of three concentrations of licorice root extract (0, 2 and 4 g l^{-1}) and used as a foliar spray on vegetative and flowering parameters of two strawberry varieties. The treatments with licorice extract (2 g l^{-1}) gave a significant increase in average leaf area and foliage dry weight, but (4 g l^{-1}) of liquorices caused a significant increase in total chlorophyll content. Qaraghouli and Jalal (2005) found that spraying apple with licorice and garlic extracts gave the highest value in yield and fruit quality. On the other hand, licorice extract improving all growth parameters. Hussein (2008) found that spraying date palm with licorice extract at 5 g l^{-1} increased the fruit quality.

Pomegranate peels (*Punica granatum* L., Family: Lythraceae) compounds, including flavonoids, anthocyanins and tannins, proathocyanidins and ascorbic acid are the main group of antioxidant phytochemicals with interesting properties due to their biological and free radical scavenging activities (Li *et al*., 2006; Elfalleh *et al*., 2011).

Turmeric (*Curcuma longa* L.) is an herbaceous perennial plant belonging to the Zingiberaceae family. Curcuma genus contains about 30 species. It originates from India and South East Asia and cultivated in the majority of tropical countries. It is obtained from the rhizome of *Curcuma longa*. It contains 2 to 9% curcuminiods which contains 60% curcumin, desmethoxycurcumin, monodemethoxycurcumin, bisdemethoxycurcumin, dihydrocurcumin and cyclocurcumin. Cucumins oxidation yield vanillin. Turmeric extract is rich in carbohydrates, (50% starch), arabinogalacton, potassium salt, essential oils and pigments. It is known for its anti- inflammatory, anti-oxidant and anti- microbial properties. Curcumin has a free radical scavenger activity namely hydroxyl radical that is responsible to protect DNA from damage and inhibit lipid peroxidation (Srimal, 1997). Mercy *et al*., (2014) found that the application of fruit peels powder and extract increased the growth of plants (rice, rye, mustard and fenugreek) and gave higher yields.

The neem tree (*Azadirachta indica* (A. Tuss.) Brandis, Family: Meliaceae) a source of several insecticidal alkaloids is a sub tropical tree native to the arid areas of Asia and Africa (Saha *et al*., 2006). Azadirachtin is the main pesticidal component of neem. Neem products are naturally available materials, cheaper, and also safe for beneficial organisms. It is distasteful and repells insects and may reduce the insect infestation (Sarode *et al*., 1995). It is necessary to determine the most effective dose of neem extract (both leaf and seed) for the control of mustard aphid. Information using different doses of neem extract for the control of mustard aphid in Bangladesh is scanty.

Thyme plant and its essential oil (*Thymus vulgaris* L., Family: Lamiaceae) is known to contain more than 40% of phenolic compositions (thymol and carvacrol), that have strong antiseptics effect. In addition to thymol, caffeic acid and than in existing in essential oil can effectively prevent growth of bacteria, fungus and viruses. The highest value of thymol exists in *Thymus vulgaris*. According to GC analysis, *Thymus captatus* contains carvacrol that researchers pointed to its anti microbial property and inhibition activity of the existence of these two compounds (Karimi and Rahemi, 2009). Many aromatic materials are against micro organism, insects and herbivorous animals (Harmmer and Carson, 1999).

Mechanical damage to potatoes occurs during the harvesting and the associated potato storage handling operations. Mechanical injury is an important factor contributing to reduced yields of marketable potatoes. The damaged areas serve as openings for rot organisms which can destroy potatoes in storage. The damaged potatoes have to be sorted out before sale. In appropriate agrotechnology may cause tuber deformation, greening, cracks, size reduction, hollow hearts, bruises, and other mechanical injuries (Nowacki, 2006). Mechanical injuries occurring at harvest are the main cause of tuber diseases during storage (Peters, 1996). In the field, potato tubers usually become infected through wounds (Kuźniewicz-Czerko *et al*. 1993).

Insect pests are also a major factor affecting the productivity of vegetables. Aphid is one of the most important pests worldwide causing considerable losses in several economically important crops such as cotton, apple, vine, bean, strawberry, papaya, potatoes, tomatoes and other vegetables, ornamental and medicinal plants (Miresmailli and Isman, 2006; Maciel *et al*., 2015). These massive losses underscore the need for a sustainable and environmentally friendly approach for addressing the situation. Aphids suck the host's sap and weaken the plant; sugary excretions favor black fungal growth on the leaves. Aphids traveling from plant to plant are efficient vectors of viral diseases.

Whitefly adheres firmly to the underside of the leaves and weakens plants by feeding on their juices. A black fungus that grows on the honeydew produced by the nymphs will cover the plant. Plant infestation by whiteflies is often the consequence of biological imbalance resulting from the intensive use of insecticides (Tang *et al*., 2002).

All mites have needle-like piercing-sucking mouthparts. Spider mites feed by penetrating the plant tissue with their mouthparts and are found primarily on the underside of the leaf. All spider mites spin fine strands of webbing on the host plant (Nyoike and Liburd, 2013).

Medicinal plants have received considerable attention as potential sources of alternative materials for use as insecticides and antifeedants. They contain a wide range of bioactive chemicals that are potentially suitable for use in integrated pest management (Pavela, 2004; Akendengue *et al*. 2005; Han *et al*. 2006; Javed *et al*. 2008).

The objective of this study was to study the effects of some plant extracts (thyme, liquorice, turmeric and pomegranate husk) as well as neem oil on the growth, yield performance, storability, mechanical injures and pest management of potatoes.

MATERIALS AND METHODS

Two field experiments were conducted in the Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt (+ 7m altitude, 30° 11⁻ latitude and 28° 26⁻ longitude), during summer seasons of 2014 and 2015, to study the effect of some plant extracts (neem, thyme, liquorice, turmeric and pomegranate peels) on the growth, productivity, storability, mechanical injures and some pest management of potatoes cv. Spunta (Agrico Co., the Netherlands). Seed tubers were planted on 15th of January in both seasons of study using half seed tubers (40: 50 g) "Elite E". Seed tubers were taken from Bahaira Governorate and kept under ambient temperature for 20 days until sprouting occurs. Plot area was 11.25 m^2; consisted of 3 ridges; 5 m long; 75 cm wide, and 25 cm apart. Nitrogen (ammonium nitrate 33.5% N), phosphorus (mono-superphosphate 15.5% P_2O_5) and potassium (potassium sulphate 48% K_2O) were applied in the rates of 150 + 75 + 96 kg fed^{-1}, respectively. Nitrogen fertilizer was added at three equal doses, i.e., the first after emergence, and then the second and third doses were applied with 2nd and 3rd irrigation. Moreover, calcium superphosphate was thoroughly mixed within the upper soil layer (0-25 cm) before planting. Potassium was added at two times, one half was added with the second addition of N-fertilizer, and the second half was added with the third doses of N-fertilizer. The other agricultural practices were carried out according to the recommendation of Ministry of Agriculture.

Some physical and chemical properties of the experimental soil at the depth of 0-30 cm were determined according to the standard procedures as described by Page (1982) (Table 1). The chemical analysis of the used compost was determined using standard methods described by AOAC (2000) (Table 2).

Table 1: Some physical and chemical properties of the experimental soil.

Some Physical properties	Values 1st season	Values 2nd season	Some Chemical Properties	Values 1st season	Values 2nd season
Sand (%)	26.2	27.2	pH value	8.0	7.9
Silt (%)	32.6	31.9	EC dSm^{-1}	0.9	0.8
Clay (%)	41.2	40.9	Total N (%)	0.03	0.04
			Available N (ppm)		
Texture class	clay-loam	clay-loam	NH_4-N	23.00	23.24
			NO_2-N	0.158	0.132
			NO_3-N	12.28	13.08
$CaCO_3$ (%)	3.4	3.5	Available P (ppm)	11.9	12.0
Organic matter (%)	1.4	1.6	Available K (ppm)	308	302

A complete randomized blocks design with three replicates was used. The experiment included 6 treatments, which were as follows:

1. Control (tap water)
2. Neem extract
3. Thyme extract
4. Liquorice extract
5. Turmeric extract
6. Pomegranate peels extract.

All treatments were sprayed at concentration of 5% once every 15 days started from 1st of March until the 30th of April (5 times).

The plant extracts

Plant materials (licorice root, pomegranate peels, turmeric rhizomes, fresh green neem leaf and full herb thyme) were obtained from the local market, washed with distillated water and dried in the shad. They were finely grinded to powder. Fifty grams of each plant material in powder form was homogenized by laboratory blender in 200 ml of methanol (96%) and distilled water (20:80 v/v) for 10 min, and then left dark glass bottles for 72 h for complete extraction. The extracts were filtered through thin cheesecloth sheets. The final extracts were collected separately in other dark glass bottles and exposed to 60 °C in water bath for 30 min for methanol evaporation. The collected extracts were then stored in a refrigerator at 5 °C until needed. Plant extracts was subjected to GC-MS analysis using a Gas Chromatograph (Singh *et al*., 2005).

Table 2: The main compounds identified in the methanol extract of tested plant extracts by using GC-MS.

Liquorice extract Compounds	Liquorice extract Concentration	Pomegranate peels extract Compounds	Pomegranate peels extract Concentration	Turmeric extract Compounds	Turmeric extract Concentration	Neem extract Compounds	Neem extract Concentration	Thyme extract Compounds	Thyme extract Concentration
Glycyrrhizin	14.5%	Total phenols	64.2 mgGAE/g	Curcumene	10.23%	Azadirachtin	4.5%	Thymol	30.0%
Liquiritin	0.51%	Flavonoids	1.4 mgGAE/g	Nitrogen	6.79%	Toluylaldehyde	21%	Carvacrol	3.10%
Kaempherol	32.95 ug/g	Caffeic acid	0.48 mg/g	Feruloylmethane	2.11%	Lineoleoyl chloride	26%	Camphor	0.82%
Cinnamic acid	31.22 ug/g	p-Coumaric	0.18 mg/g	Vanillin	0.15%	Methyl isoheptadecanoate	12%	Geraniol	0.64
Apignin	29.97 ug/g	Gallic acid	0.23 mg/g	Zingiberene	0.08%	--	--	α-terpineol	1.22%
Rutin	24.41 ug/g	Ellagic acid	12.56 ug/ml	Total phenols	11.24 mgGAE/g			Linalool	2.25%
p-Coumaric	21.67 ug/g	Potassium	6680 mg/kg	Niacin	2.3%			1,8-cineole	1.83%
Vanillin	20.43 ug/g	Calcium	729 mg/kg	Calcium	0.21%			p-Cymene	29.54%
Phenol	18.40 ug/g	Magnesium	525 mg/kg	Phosphorus	0.63%			Sabinene	4.18%
Benzoic acid	14.42 ug/g	Iron	18 mg/kg	--	--			limonene	0.62%

Data and measurements

Field experiment:

A random sample of three plants from each experimental plot was taken at 70 days after planting to estimate vegetative growth characters, i.e., plant height, shoot fresh weight and convert to shoot dry weights/plant and number of leaves per plant. At harvest time, 110 days after planting, the total tuber yield/feddan (ton) was recorded. Marketable yield/feddan was recorded using good shapes healthy tubers (30: 60 mm or more). Unmarketable yield was determined using off shape, rotten and less than 30 mm in diameter. Physiological disorders (greening, secondary growth and cracks) were assessed qualitatively at harvest; all tubers per a replicate were recorded and converted into percent attributed to total tuber yield. The mechanical injures expressed as rupture, bruising and crushing during harvest, curing and transport to cold storage were recorded according to the methods described by Food and Agriculture Organization (1981).

Procedures of evaluation:

Twenty five leaves of each replicate randomly selected from 25 plants were picked up and put in paper bags then transferred to laboratory. The samples were collected before spraying and after 3, 5, 7, 10 and 14 days of spraying. The numbers of *T. urticae,* the cotton aphid *A. gossypii* and the sweet potato whitefly, *B. tabaci* were counted by the aid of a binocular stereomicroscope.

Storage behavior:

Potato tubers were harvested from the field on 5 May 2014 and 2015 and cured for 15 days at 25±5^{o} C under rice straw. The same treatments, replications and experimental design in the farm were repeated in the Laboratory. Healthy potato tubers, uniformly (of 40-80 mm in diameter and 150-250 g), sorted by medium and large grade (30 tubers; ca 6 kg per treatment), were stored in net plastic bags with 3 replications. The treatments were stored on May 20th for five months at 4^{o} C and 95% RH in refrigerator.

Storage characters:

Ten potato tubers were randomly chosen in each treatment, each tuber of this treatment marked and weighted at the beginning and at the end of storage, the damaged tubers were excluded, the average weight (gm/tuber) at the beginning and the end. Weight loss and decay at the beginning and the end of storage (150 DAS) were determined. Percentage of tuber dry matter (calculated by drying 100 grams of fresh tubers in oven at 70^{o} C tills a constant weight). Starch content was determined in tubers according to the method described by AOAC (2000).Total phenol was determined at 150 DAS according to the methods described by and Du *et al*. (2009). Enzyme analysis of polyphenol oxidase in fresh tubers was determined using standard methods described by Yamazaki and Piette (1963).

Statistical analysis

Data were analyzed using analysis of variance technique and the differences between individual pairs of treatment means were compared using Duncan Multiple Range Test at 5% according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Vegetative growth:

Foliar spraying of potato plants Spunta cv. with pomegranate peels or liquorice extracts had significant effects on plant length, foliage fresh and dry weights and number of leaves, followed by thyme and neem extracts in both seasons of study (Table 3). These results agree with Shafeek *et al*. (2015), who reported an increase in plant height, leaf area and number of leaves on onion plant by foliar spraying with licorice and seaweed extract.

This may be due to that licorice contains more than 100 various compounds, some of them accumulated in large amounts, most important of them are triterpene saponins (including glycyrrhizin), phenolic compounds, mevalonic acid, amino acid (asparagin), polysaccharide (glucose, fructose, sucrose, maltose) lignins ,vitamins such as B1, B2, B3, B6, C and E, Biotin, folic acid and pantothenic acid which play an important role in improving the growth of the plants (Rossi, 1999; Arystanova *et al*., 2001). Glycyrrhizic acid is first synthesized from mevalonic acid which has similar effect to GA_3 in reducing complex compounds to simple ones utilized by plants to build new proteins necessary for growth (Babilie *et al*., 2015). In addition, magnesium (main element in liquorice) plays a role in increasing foliage growth, cell division, and biological plant activities (Moses *et al*., 2002). Mercy *et al*. (2014) found that the application of fruit peels powder and extract increased the growth of plants (rice, rye, mustard and fenugreek) and gave the higher yields.

Table 3: Effect of plant extracts on some vegetative growth characters of potato plants in 2014 and 2015 seasons.

Treatments	Plant length (cm)		Foliage F.W. /plant (g)		Foliage D.W. /plant (g)		No. leaves/plant	
	2014	2015	2014	2015	2014	2015	2014	2015
1. Control (tap water)	41.00 c	46.33 a	290.51 c	300.63 d	34.78 d	34.10 d	20.3 b	30.0 ab
2. Neem extract	45.00 ab	44.00 ab	300.65 c	320.08 bcd	36.18 cd	38.36 bc	25.6 ab	26.3 bcd
3. Liquorice extract	45.33 ab	45.00 a	322.18 ab	342.50 a	40.58 ab	42.18 a	28.3 a	28.3 abc
4. Turmeric extract	42.33 bc	42.67 ab	320.62 b	326.18 abc	40.02 ab	40.33 abc	20.0 b	25.6 cd
5. Pomegranate peels extract	47.67 a	46.67 a	340.50 a	338.32 ab	42.50 a	41.80 ab	30.3 a	32.3 a
6. Thyme extract	43.67 bc	40.33 b	310.28 bc	310.64 cd	38.26 bc	36.76 cd	24.6 ab	22.0 d

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Total tuber yield, marketable and unmarketable yield:

Total tuber yield, marketable and unmarketable yields were significantly affected by all treatment in both seasons (Table 4). Foliar spraying with the extracts had a positive effect on total tuber and marketable yields compared to neem treatment or control (Table 4). Highest tuber yield (14.580 and 14.286 ton fed^{-1}, in both seasons, respectively) was obtained under the treatment received pomegranate peels extract. The second treatment regarding the increase in tuber yield (14.460 and 14.210 ton fed^{-1}) was liquorice without significant differences between 1st and 2nd treatments, respectively. The percentage increases over the control (tap water) reached to 13.37, 11.61 % and 12.44, 11.02 % for both superiority treatments, in both seasons, respectively. On the other hand, the lowest tuber yield (12.860 and 12.800 ton fed^{-1}) was recorded under the check treatment, in both seasons.

Regarding, the marketable tuber yield (Table 4), it took the same direction of total tuber yield as previously mentioned. Science, total yield increases were due to primarily the increase in tuber size in larger and medium grades (marketable) and decreased the small grades (unmarketable). In this respect, the treatment of pomegranate peels and liquorice extracts decreased significantly unmarketable yield in both seasons.

Liquorice and pomegranate peels extracts are rich in amino acids, vitamins and growth stimulating photo-hormones that increases the activity of apical meristem tissue resulting in cell division and elongation (Elfalleh *et al*., 2011; Adeyela *et al*., 2013). The above findings agreed with those reported by Nasser *et al*., (2014), they found that spraying fenugreek plants with licorice extract led to more absorption of nutrients from the soil, which accelerated growth and increased their production. The tannin-rich ellagitannins and phenolic acids (Table 1) of *Punica granatum* peels have antibacterial activity (Supayang *et al*., 2005)

Table 4: Effect of plant extracts on total yield, marketable and unmarketable of potato tubers in 2014 and 2015 seasons.

Treatments:	Total tuber yield (Ton/fed.)		Marketable yield (Ton/fed.)		Unmarketable yield (Ton/fed.)	
	2014	2015	2014	2015	2014	2015
1. Control (tap water)	12.860 d	12.800 d	12.000 d	11.880 c	0.860 a	0.920 a
2. Neem extract	12.920 d	12.880 cd	12.120 d	12.000 b	0.800 a	0.880 a
3. Liquorice extract	14.460 ab	14.210 a	13.960 a	13.610 a	0.500 d	0.600 cd
4. Turmeric extract	13.410 c	13.330 b	12.730 c	12.680 b	0.680 b	0.650 bc
5. Pomegranate peels extract	14.580 a	14.286 a	14.180 a	13.766 a	0.400 e	0.520 d
6. Thyme extract	14.120 b	13.185 bc	13.540 b	12.485 c	0.580 c	0.700 b

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Physiological disorders:

There were slightly significant differences in physiological disorders of potato tuber parameters, in both seasons (Table 5). Application of pomegranate peels extract significantly decreased secondary growth (0.480 and 0.620 kg $plot^{-1}$, in both season, respectively) and cracks (0.000 kg $plot^{-1}$, 1^s^t season), in comparison with other treatments. Turmeric extract also had a significant decrease in secondary growth in 1st season only. However, there were no significant differences among all tested treatments on tuber greening or cracks in 2nd season of this study. The positive influence of these materials may be due pomegranate peels extract content of glycyrrhizic acid that has antioxidant effects, antimicrobial effects, inhibits aflatoxin B2 DNA binding, and neurotrophic effects (Yamasaki *et al*., 1991). As a result of climate changes in recent times and that led to the high temperatures, which could cause stresses developing plants in the summer season lead to the develop of physiological disorders (Jovovic *et al*., 2016). The addition of extracts such as pomegranate peels which contains the anti-oxidant rich in glycyrrhizic acid reduces free radicals (O_2^-, $OH^\cdot$ and $ROO^\cdot$) and other harmful compounds, thereby reducing the physiological disorders (Akpinar-Bayizit *et al*., 2016). Oxidative stress generated by free radicals can disturb DNA, proteins and lipids. Antioxidants inhibit or restrain the oxidation of molecules in the cells and are considered to confer positive effects against physiological disorders.

Table 5: Effect of plant extracts on physiological disorders of potato tubers in 2014 and 2015 seasons.

Treatments:	Greening (Kg/plot)		Secondary growth (Kg/plot)		Cracks (Kg/plot)	
	2014	2015	2014	2015	2014	2015
1. Control (tap water)	0.580 ab	0.570 a	1.100 a	1.200 a	0.470 ab	0.530 a
2. Neem extract	0.490 b	0.450 a	0.900 a	1.150 a	0.610 a	0.600 a
3. Liquorice extract	0.250 b	0.310 a	1.000 a	0.950 abc	0.000 c	0.540 a
4. Turmeric extract	1.000 a	0.340 a	0.450 b	1.050 ab	0.250 b	0.335 a
5. Pomegranate peels extract	0.520 b	0.580 a	0.480 b	0.620 c	0.000 c	0.300 a
6. Thyme extract	0.410 b	0.620 a	0.590 b	0.680 bc	0.450 ab	0.450 a

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Mechanical injures:

Control treatment had a significant effect on all mechanical injures parameters (rupture, bruising and crushing as percent), in both season (Table 6). Pomegranate peels and liquorice had a significant reduction in all the attributes under study, followed by neem and thyme extract (Table 6). The skin of a mature tuber is normally an effective barrier against most potentially invading bacteria, fungi and pests causing rotting of the tissues. Any rupture of this barrier caused by damage or injury to the skin will provide an entry point for infection and will also stimulate physiological deterioration and dehydration. There are different degrees of mechanical damage, from small bruises to deep cuts and they may be sustained at any stage, from pre-harvest operations, through harvesting and subsequent handling operations when the product is graded, packed and transported for market or, simply, even carried to the farmer's house. Serious mechanical injury, which may result in the product being rejected during grading, is a direct loss. Damage to the tuber skin that is not immediately obvious can lead to physiological deterioration and allow the entry of pathogens or insects. The insect injuries that occur during growth and harvest could lead to mechanical damage, which weakens the ability of the tubers during handling, curing, and storage especially in the summer season, where the temperature raises (Nowacki, 2006; Maciel *et al*., 2015). The management of pests in crops to obtain better yield is paramount for food security (Javed *et al*. 2008). The use of integrated pest management, which including plant extracts can reduce the presence of the insects (Tables 7: 9), which in turn lead to reduce mechanical damage (Han *et al*. 2006; Javed *et al*. 2008).

Table 6: Effect of plant extracts on mechanical injures of potato tubers in 2014 and 2015 seasons.

Treatments:	Rupture* (%)		Bruising (%)		Crushing (%)	
	2014	2015	2014	2015	2014	2015
1. Control (tap water)	2.18 a	3.29 a	10.33 a	14.50 a	13.33 a	12.67 a
2. Neem extract	0.72 b	0.98 c	3.83 c	5.17 cd	5.17 c	5.67 c
3. Liquorice extract	0.62 b	0.81 c	3.33 c	3.33 d	4.00 c	4.33 d
4. Turmeric extract	1.95 a	2.94 ab	8.33 b	9.00 b	10.83 b	8.33 b
5. Pomegranate peels extract	0.51 b	0.78 c	3.00 c	3.67 d	3.33 c	3.67 d
6. Thyme extract	1.27 ab	1.25 b	5.33 bc	6.33 c	4.67 c	5.00 cd

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.
***Stage affected of rupture: harvesting; bruising: harvest, transport and storage; crushing: transport and storage**

Efficacy of tested plant extracts against the two spotted spider mite, *Tetranychus urticae*:

Statistically analysis showed that, there were significant differences in *T. urticae* population on potato between treated and untreated after spraying. Data in Table (7) show that the most effective plant extract of the experiment was turmeric extract, which caused 68.634 and 70.298 % mean of reduction during 2014 and 2015 seasons, respectively, while the lowest effect were obtained with . Liquorice extracts causing, 30.11 and 29.45 % reduction percentages in the first & the second seasons, respectively. The efficacy of the tested plant extracts could be arranged according to the general mean of reduction percentage of the two seasons in a descending order as follows: turmeric extract, thyme extract, neem oil, pomegranate peels extract and liquorice extract with average reduction percentages of 69.47, 51.05, 42.90, 42.48 and 29.45%, respectively. The thyme extract (rich in the phenols thymol and carvacrol) and *Origanum majorama* (rich in terpinen-4-ol) (Table 1) were the most toxic (Regnault Roger *et al*., 1993). In a more evaluated the fumigant toxicity of 28 essential oils and 10 of their major constituents against four different species of stored product coleopterans. Most interestingly, there was little overlap among the insect species with respect to the most toxic oils and constituents, indicating that while these substances are generally active against a broad spectrum of pests, interspecies toxicity of individual oils and compounds is highly idiosyncratic. Sarac and Tunc (1995), investigated the fumigant action off our essential oils to three species of stored product pests, reached the same conclusion.

Table 7: Efficacy of the plant extracts against the two spotted spider mite, *Tetranychus urticae* on potato plants during 2014 and 2015 seasons.

Treatments:	Reduction Percentage after spraying (2014)					Mean	Reduction Percentage after spraying (2015)					Mean	General mean of reduction % of two seasons
	3 days	5 days	7 days	10 days	14 days		3 days	5 days	7 days	10 days	14 days		
1. Neem extract	60.28^{bc}	54.73^{cd}	37.82^{c}	33.71^{c}	26.87^{bc}	42.68^{c}	63.05^{b}	52.92^{c}	45.03^{bc}	31.87^{cd}	22.75^{bc}	43.12^{c}	42.90^{bc}
2. Liquorice extract	63.26^{b}	65.72^{b}	46.26^{bc}	40.52^{b}	32.69^{b}	49.69^{b}	66.82^{ab}	68.62^{ab}	55.92 ^{b}	41.07^{b}	29.64^{b}	52.41^{b}	51.05^{b}
3. Turmeric extract	47.52^{d}	39.51^{d}	26.03^{d}	20.67^{d}	16.82^{cd}	30.11^{d}	45.73^{d}	35.03^{d}	29.04^{d}	18.36^{d}	15.82^{c}	28.80^{c}	29.45^{d}
4. Pomegranate peels extract	70.35^{a}	78.52^{a}	85.21^{a}	65.37^{a}	43.72^{a}	68.63 ^{a}	73.83^{a}	77.42^{a}	82.92^{a}	69.41^{a}	47.91^{a}	70.30^{a}	69.47^{a}
5. Thyme extract	50.71^{c}	62.81^{c}	47.72^{b}	30.02^{cd}	22.62^{c}	42.78^{bc}	53.95^{c}	58.03^{b}	44.83^{c}	36.08^{c}	18.03^{cd}	42.18^{bc}	42.48^{c}

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Efficacy of tested plant extracts against the cotton aphid, *Aphis gossypii*:

Data in Table (8) show that both thyme and neem extracts recorded the highest effect where causing, 59.98 & 45.78 and 66.94 & 68.65% reduction in population density *A. gossypii* adults on potato than check, in 2014 and 2015 seasons, respectively. On the other hand, liquorice and pomegranate peels extracts showed the lowest effect. They recorded, 29.99 & 26.69 and 31.61 & 34.80 % reduction percentages in population density of *A. gossypii* adults than check, in the two seasons, respectively. Neem extract, is an exciting option for integrated pest management programs, since such plant derived insecticides have various benefits, including selectivity, greater safety for non-target organisms, and compatibility with biological control organisms (Tang *et al*., 2002). The primary active ingredient of most neem-based pesticides is azadiractin (Table 1), a liminoid compound, which has multiple biological activities on more than 400 insect species including aphids from several orders (Schmutterer and Singh, 1995). Besides azadirachtin, there are other active components in some formulations. Azadirachtin-based compounds obviously have insecticidal, feeding deterrent, repellent, antioviposition, and physiological properties. They have an effect on some important physiological processes in insect such as are survival, longevity, molting and reproduction (Mordue and Nisbet, 2000).

Table 8: Efficacy of the plant extracts against the cotton aphid, *Aphis gossypii* on potato plants during 2014 and 2015 seasons.

Treatments:	Reduction Percentage after spraying (2014)					Mean	Reduction Percentage after spraying (2015)					Mean	General mean of reduction % of two seasons
	3 days	5 days	7 days	10 days	14 days		3 days	5 days	7 days	10 days	14 days		
1. Neem extract	66.18^{b}	73.81^{b}	56.02^{b}	21.83^{c}	11.05^{cd}	45.78^{ab}	73.83^{b}	84.02^{a}	68.82^{b}	60.92^{a}	55.68^{a}	68.65^{a}	57.22^{ab}
2. Liquorice extract	70.37^{a}	84.77^{a}	68.62^{a}	45.99^{a}	30.12^{a}	59.98^{a}	77.91^{a}	83.86^{ab}	74.29^{a}	58.02^{ab}	40.62^{b}	66.94^{ab}	63.45^{a}
3. Turmeric extract	40.92^{d}	47.81^{cd}	30.90^{d}	18.43^{cd}	11.92^{c}	29.99^{c}	40.84^{de}	43.03^{d}	33.05^{c}	25.70^{cd}	15.42^{d}	31.61^{d}	30.80^{c}
4. Pomegranate peels extract	68.16^{ab}	50.91^{c}	46.19^{c}	36.05^{b}	19.62^{b}	44.19^{b}	60.72^{c}	65.07^{b}	70.27^{ab}	55.82^{b}	36.07^{c}	57.59^{b}	50.89^{b}
5. Thyme extract	50.81^{c}	36.16^{d}	20.72^{e}	15.02^{d}	10.73^{d}	26.69^{cd}	48.08^{d}	50.63^{c}	33.85^{cd}	29.04^{c}	12.42^{e}	34.80^{c}	30.75^{cd}

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Efficacy of tested plant extracts against the whitefly, *Bemisia tabaci*:

Concerning the efficacy of tested plant extract against *B. tabaci* adult on potato plants (Table 9), statistically, there were significant differences between treatments and check after spraying. The most effective compound of the experiment was neem oil, which caused 66.79 and 67.71 % mean reduction percentages during 2014 and 2015 seasons, respectively. While the lowest effect was obtained with pomegranate husk extract causing, 33.43 and 30.75 % reduction in population density compared with control, during the two seasons, respectively. The efficacy of the tested plant extracts could be arranged according to the general mean of reduction percentage of the two seasons in a descending order as follows: neem oil, thyme extract, turmeric extract, liquorice extract and pomegranate husk extract with average reduction percentages of 58.45, 67.25, 34.84, 29.68 and 28.18 %, respectively. The findings of the present study are almost similar to the findings of several authors. Saxena (1989) reported that Azadirachtin the main pesticidal component of neem extracts specially neem seed extract possessed feeding deterrent, repellent, toxic, and growth disruption properties against numerous pest species.

Table 9: Efficacy of the plant extracts against whitefly, *Bemisia tabaci* on potato plants during 2014 and 2015 seasons.

Treatments:	Reduction Percentage after spraying (2014)					Mean	Reduction Percentage after spraying (2015)					Mean	General mean of reduction % of two seasons
	3 days	5 days	7 days	10 days	14 days		3 days	5 days	7 days	10 days	14 days		
1. Neem extract	88.82^{a}	76.28^{a}	68.02^{a}	55.92^{a}	44.9^{a}	66.79^{a}	85.52^{a}	74.23^{b}	70.12^{a}	63.06^{a}	45.62^{a}	67.71^{a}	67.25^{a}
2. Liquorice extract	79.15^{b}	67.11^{b}	53.01^{b}	42,71^{b}	16.43^{b}	53.93^{b}	76.03^{b}	82.17^{a}	64.28^{b}	55.73^{ab}	36.62^{b}	62.96^{b}	58.45^{b}
3. Turmeric extract	39.40^{d}	44.82^{d}	35.02^{cd}	26.17^{c}	14.92^{c}	32.06^{cd}	40.72^{cd}	37.18^{d}	28.02^{cd}	18.64^{d}	11.87^{d}	27.28^{d}	29.68^{d}
4. Pomegranate peels extract	50.62^{c}	46.91^{cd}	35.16^{c}	19.42^{d}	07.53^{d}	31.93^{c}	45.92^{c}	55.82^{c}	38.87^{c}	30.72^{c}	17.38^{c}	37.74^{c}	34.84^{c}
5. Thyme extract	45.03^{cd}	47.14^{c}	38.92^{bc}	25.07^{cd}	11.03^{cd}	33.43^{d}	28.67^{d}	32.98^{e}	27.82^{d}	18.55^{de}	06.54^{e}	22.91^{e}	28.18^{de}

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Storage behavior:

Deterioration following the harvesting of potato fresh tubers and the consequent losses are caused by: mechanical damage, physiological changes within the plant, infection by decay organisms and pest infestation. The losses caused by these processes may occur throughout all stages of the food system, from crop maturity through harvesting, transport and storage (FAO, 1981).

Weight loss and Decay:

Data in Figures 1and 2 show the effect of foliar spraying of Spunta plants with extracts on storability. Results indicate that all plant extract treatments and stored at 4 ^{o}C gave the lowest values of weight loss and decay compared with the control at the end of storage. A decrease in weight loss and decay were seen in tubers stored at 4ºC and treated with pomegranate peels extract (1.25 and1.24 %) or thyme extract (1.19 and1.35 %) for both traits (average of two seasons). The plant extracts (pomegranate peels and thyme) contain basic compounds such as volatile and fixed oils. The inhibitory activity of plant extracts is due to the presence of several constituents such as antioxidant and monoterpene, mainly, total phenols 64, flavonoids 1.4 mg GAE /g D.W, thymol 30 %, carvacrol 3.10% and p-cymene 29.54 %. Davies (1990) indicated that basic constituents (monoterpenes and antioxidants) trended to slow down the activity of carbohydrates and protein breakdown associated enzymatic systems as well as respiration and energy metabolism enzyme.

Dry matter and Starch:

All the foliar of plant extracts gave higher bioconstituent during the term storage of Spunta tubers; compared with those of untreated tubers in average the two seasons (Figs. 3 and 4). Pomegranate peels extract applied to Spunta plants gave the highest significant dry matter and starch content in the tubers. These constituents preserved stored tubers, keeping the internal biochemical enzymatic activities in minimum levels. The pomegranate peels constitutes more than 40% of the fruit and is a valuable source of antioxidants (Nasr *et al*., 1996) Polyphenol from pomegranate are associated with a number of health benefits including a role as, antioxidant, antimicrobial agent, anti-inflammatory agent, anti-proliferative agent, lipase inhibitor, and inhibitor for α-glycosidase (maltase or glucoinvertase) (Akhtar *et al*., 2015). Indeed, pomegranate peels antioxidant is being examined as natural ingredients for food processing and preservation (Tanveer *et al*., 2015).

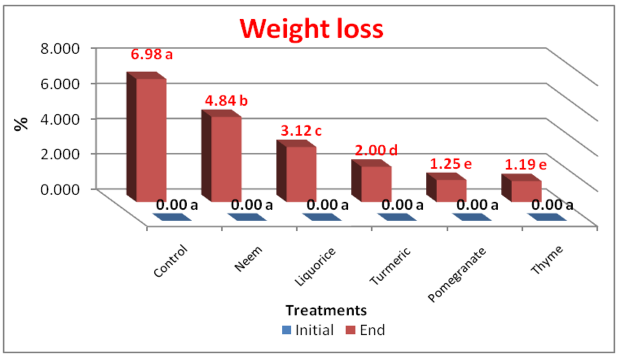

Fig. 1: Weight loss as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

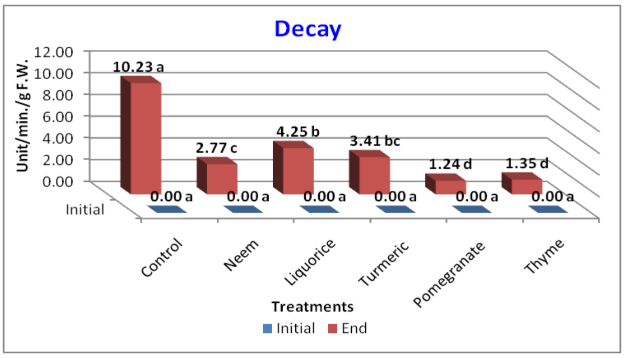

Fig. 2: Decay as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

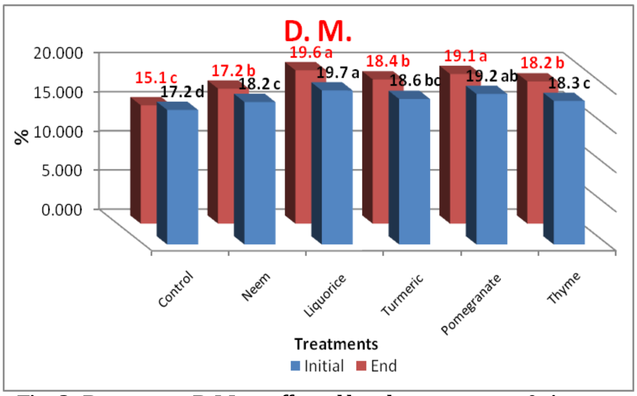

Fig. 3: Dry matter D.M. as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

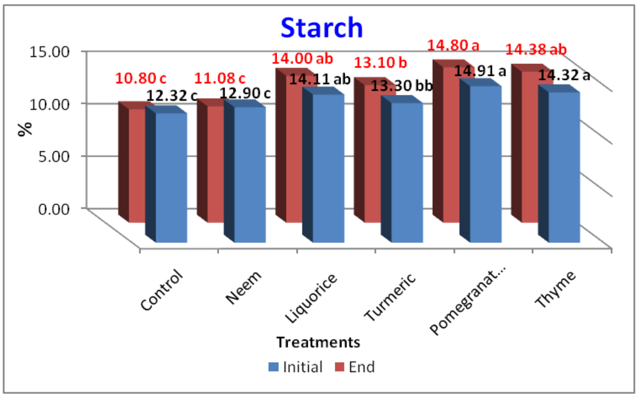

Fig. 4: Starch as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

Total phenols and Polyphenol oxidase (PPO):

Phenolic compounds are the most abundant antioxidants in potatoes, and their levels in tubers are affected by growing (Reyes *et al*., 2004) and post-harvest storage conditions (Rosenthal and Jansky, 2008). Phenolic compounds have been widely studied (Lachman *et al*., 2005), and potato falls into a category of moderate to high total phenolic content (TPC). Although chlorogenic acid is the main phenolic acid in potato, caffeic acid, gallic acid, protocatechuic acid and quercetin are other major phenolic compounds in potato tubers (Külen *et al*., 2013).

Total phenol and PPO are physiological parameter reflecting the health condition of plant. Data of physiological profile of potato tubers as affected by the tested treatments are presented in Figures 5 and 6. The total phenol and PPO were significantly induced in the tubers of control plants even in the end of storage, compared with other treatments. Neem extracts came in the second rank, in this respect. The interaction of phenolic compounds and polyphenol oxidase (PPO) that are activated in case of control treatment due to the oxidative stress occurred in the field.

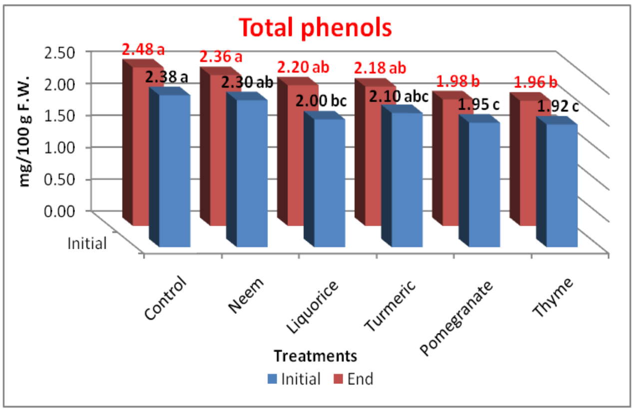

Fig. 5: Total phenols as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

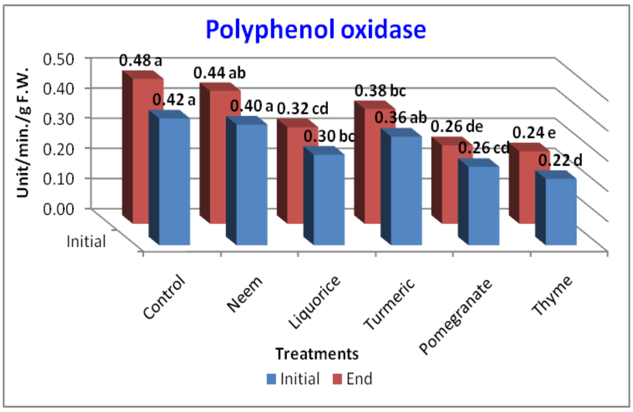

Fig. 6: Polyphenol oxidase as affected by plant extracts at 0 times (initial) and 120 days after storage (end) (4 °C).

Although high phenolic compound activities are associated with high potential of stresses (Külen *et al*., 2013), they also have positive benefits such as enhancing the antioxidant capacity of plant tissue, mainly related to its role of eliminating reactive oxygen species (ROS) and free radicals (Akpinar-Bayizit *et al*., 2016). Many polyphenols, especially phenolic acids, are directly involved in the response of plants to different types of stress. These chemicals contribute to healing by lignifications of damaged areas, and possess antimicrobial properties by increasing concentrations after pathogen infection. On the other hand, most of plant extracts have strong antioxidant materials, so the tubers resulting from the treatment of those extracts, the content of their phenols are decreased (Figs 5 and 6; Reyes *et al*., 2005).

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استخدام بعض المستخلصات النباتية في التحكم في الأضرار الميكانيكية ومقاومة الآفات الحشرية وزيادة الإنتاجية والقدرة التخزينية في البطاطس.

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أجريت تجربتان بحثيتان في مزرعة بحوث البساتين بالمنصورة – محافظة الدقهلية في الموسميين الصيفيين المتعاقبين ٢٠١٤ و ٢٠١٥م بهدف دراسة استجابة محصول البطاطس (صنف اسبونتا) للرش الورقي ببعض المستخلصات النباتية بتركيز ٥% (عدد مرات الرش ٥ مرات) والتي تشمل: النيم، عرق السوس، الكركم، قشر الرمان والزعتر بالإضافة إلي المعاملة الكنترول وتأثير ذلك علي النمو والمحصول وجودة الدرنات والعيوب الفسيولوجية والأضرار الميكانيكية التي تحدث عقب الحصاد والتداول، وزيادة القدرة التخزينية للدرنات وتقليل نسبة الفاقد. كما يهدف البحث أيضا إلي مقاومة بعض الآفات الحشرية الهامة والتي تصيب محصول البطاطس في العروة الصيفية.أدي الرش الورقي باستخدام مستخلصات قشر الرمان أو عرق السوس إلي حدوث زيادة معنوية في معظم القياسات الخضرية وصفات المحصول الكلي والمحصول القابل للتسويق وخفض نسبة العيوب الفسيولوجية والأضرار الميكانيكية التي تحدث للدرنات عقب الحصاد. كما أظهرت معاملات الرش الورقي بالمستخلصات النباتية خفض كثافة الآفات الحشرية من العنكبوت الأحمر، المن والذبابة البيضاء. كانت أكثر المعاملات تأثيرا هي مستخلصات الكركم، الزعتر والنيم في نسبة الخفض لثلاثة أنواع من الآفات السابقة. أدي استخدام معاملة الرش الورقي بمستخلص الرمان أو الزعتر قبل الحصاد إلي زيادة القدرة التخزينية للدرنات وتقليل نسبة الفاقد في الوزن ونسبة التالف، وكذلك زيادة محتوي الدرنات من المادة الجافة ونسبة النشا مقارنة بالكنترول وباقي المعاملات عند التخزين على ٤ درجة مئوي. أظهرت معاملة الكنترول وممستخلص النيم تفوقا معنويا في زيادة نسبة الفينولات الكلية ونشاط إنزيم البولي فينول أوكسيديز.توصي هذه الدراسة باستخدام الرش الورقي بمستخلص قشر الرمان أو عرق السوس لزيادة الإنتاجية والجودة والمحصول القابل للتسويق ومستخلص النيم أو الزعتر لمقاومة الآفات الحشرية ومستخلص قشر الرمان أو الزعتر لزيادة القدرة التخزينية وتقليل نسبة الفاقد، بفاصل ١٥ يوم بداية من الأول من مارس حتى نهاية إبريل.