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EFFECT OF PLANT SPACING AND HARVESTING DATE ON YIELD, QUALITY AND STORABILITY OF GREEN GARLIC

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ABSTRACT

The present experiment was carried out during three seasons of 2014/2015, 2015/2016 and 2016/2017 at El-Kassasien Research Station, Ismalia Governorate, Horticulture Research Institute, Egypt to examine the effect of plant spacing (7.5, 10 or 12.5 cm within the row) and harvesting dates (1st February, 15th February, 1st March or 15th March) on the vegetative growth, quality and yield of green garlic plants (*Allium sativum* L.) cv. Balady grown under sandy soil conditions and also, to study the effect of different types of packaging materials on the quality parameters of green garlic during storage at 0°C and 95% Relative Humidity (RH) for 20 days.

According to the field experiment, the results indicated that planting garlic cloves at 10 cm between plants significantly increased plant length, the number of leaves per plant, total chlorophyll reading, green bulbs dry matter percentage, total yield and exportable yield of green garlic. While, plant spacing at 12.5 cm increased leaf area per plant, green bulb diameter, green neck diameter and green bulbs weight of green garlic plants in 2014/2015 and 2015/2016 seasons. Harvesting green garlic plants on 15th March recorded the highest values of vegetative growth, quality and yield of green garlic plants. Whereas, the highest exportable green garlic yield was recorded with harvesting date on 1st March followed by harvesting on 15th February. Generally, the interaction between plant spacing at 10 cm and harvesting green garlic plants on 15th March was the most superior treatment for increasing the vegetative growth, green bulbs dry matter percent and total yield. Meanwhile, the interaction between plant space at 12.5 cm and harvesting green garlic plants on 15th March increased leaf area per plant, green bulb diameter, green neck diameter and green bulbs weight. Whereas, the interaction between plant space at 10 cm and harvesting green garlic plants on 1st March displayed the highest exportable green garlic yield followed by the same plant space and harvesting on 15th February during the first and second seasons. Regarding storage experiment, the results showed that, packing green garlic bulbs in polypropylene or polyethylene bags reduced weight loss % to less than 1% and displayed green garlic bulbs with fresh appearance and white color for 20 days at 0°C and 95% RH in the 2015/2016 and 2016/2017 seasons of storage.

Key words: *Green garlic, plant spacing, harvesting dates, vegetative growth, yield, storability.*

1. INTRODUCTION

Green garlic or fresh garlic is immature garlic with tender leaves, which is harvested before the bulb is fully formed and the stalks are still totally green. Green garlic is one of the most important crops in Egypt for both domestic and export markets. Planting garlic starting in the second half of September and extends until the end of October in some Egyptian areas due to variable climate factors. Moreover, the green garlic is exported during February and March (EL-Zohiri and Farag, 2015). The European markets require specific quality standards such as white crust bulbs and the diameter of the head should be greater than 5 cm. These standards are difficult to be achieved through agricultural processes used to produce dry garlic. The Governorate of Minya (El Adwa, Magaghah and Beni Mazar areas) is one of the

most important export areas of green garlic in Egypt . In February, farmers select large plants to prepare for export. This method is not allocated for growing green garlic for export and the risk is a large amount of these plants are rejected because it is not suitable for export as green garlic (Egyptian Ministry of Agriculture and Land Reclamation bulletin, 1999). Plant spacing and harvesting time are considered as important yield contributing factors for garlic production, which greatly influence the growth, yield and quality of green garlic crop (Kilgori *et al.,* 2007). According to Moravcevic *et al.* (2011), green garlic responds best to moderate stand densities 600,000 and 750,000 plants/ ha compared with other plant densities 300,000, 450,000 and 900,000 plants/ ha. At such densities (600,000 and 750,000 plants/ ha) garlic developes a powerful photosynthetic apparatus and the bulbs are large and uniform. Also, Youn *et al*. (2015) indicated that the marketable garlic ratio was the highest in planting density of 20 × 15 cm compared with planting densities of 20 × 20 and 20 × 10 cm. Plant spacing at 5 cm and 11 cm showed significant increase for leaf area, leaf length, plant height, bulb size, bulb fresh weight, bulb dry weight, the number of cloves bulb and garlic yield ha^{-1} as compared to other treatments, *i.e.,* 3, 7 and 9 cm spacing (Muneer *et al*., 2017).

Maturity stage at harvest was found to be the most important determinant of storage life and final fruit quality (Alam *et al*., 2006). Ibrahim (2008) stated that garlic scallion characters (plant length, white base length, green top length, base diameter, the number of leaves/ plant, plant fresh weight and yield/ m^2) increased with increasing plant age. In addition, Zedan (2011) worked on onion and indicated that the delayed harvesting date (156 days after planting) increased bulb weight, bulb length and the total yield ton/ hectare compared with other harvesting dates (114, 128 and 142 days after planting).

After harvesting, green garlic is a highly perishable crop due to its high moisture content, high respiration rate and short shelf life. The major causes of quality loss of green garlic are dehydration, bulb discoloration and decay (similar to green onions). Green garlic is usually packed in carton boxes or white net bags for export from Egypt to other countries. These packaging materials may decrease the shelf life of green garlic. Modified atmospheres are commonly used for storage and transportation of fruits and vegetables, and it result in passive effects between plant material and sealed packages such as polyethylene or polypropylene bags, which in turn create passive modified atmosphere to reduce respiration and transpiration rates, maintain quality and extend shelf life of the produce (Kader, 1986). The most suitable temperature for storage or shipping green garlic is 0 °C and 90-95% relative humidity (RH). Application of plastic bag packaging maintains freshness and shelf life of Chinese kale (Niyomlao *et al*., 2000). Also, Rahman *et al.* (2012) found that packing green chili pepper (*Capsicum annuum*) in polypropylene (PP) bags maintained moisture, reduced weight loss and prevented shrinkage.

The present study was an attempt to identify suitable planting space and harvesting date for successful production of green garlic under local conditions and to study the effect of different types of packaging materials on quality parameters of green garlic during storage at 0°C and 95% RH for 20 days.

2. MATERIALS AND METHODS

This experiment was carried out at El-Kassasien Research Station, Horticulture Research Institute, Ismalia Governorate during the winter seasons of 2014/2015, 2015/2016 and 2016/2017 to investigate the effect of plant spacing and harvesting date on the vegetative growth, yield, quality and storability of green garlic plants (*Allium sativum* L.) grown in sandy soil under drip irrigation system. The main physical and chemical properties of the used soil (Table 1) were determined according to Jackson (1967). This experiment included three-plant spacing (7.5, 10 or 12.5 cm) in combinations with four harvesting dates *i.e.,* 1st February (4.5 months from planting to harvest), 15th February (5 months from planting to harvest), 1st March (5.5 months from planting to harvest) or 15th March (6 months from planting to harvest). The experimental design was a split plot design with three replications, where plant spacing was randomly distributed in the main plot, while the harvesting dates were randomly assigned in the sub-plots. Each experimental plot included three drip lines 10 m length and 60 cm width with an area about 18 m^2.

Table (1): Physical and chemical analyses of the soil of garlic at (0-30 cm) depth before planting in 2014/2015 and 2015/2016 seasons.

Particle size distribution		
Seasons		
2014/2015	**Sand %**	96.5
	Silt%	1.7
	Clay%	1.8
	Soil texture	Sandy
	Organic matter%	0.03
2015/2016	**Sand %**	95.6
	Silt%	1.6
	Clay%	2.8
	Soil texture	Sandy
	Organic matter%	0.08
Chemical		
2014/2015	**N (ppm)**	5.4
	P (ppm)	5.5
	K (ppm)	52
	pH	8.1
2015/2016	**N (ppm)**	6.9
	P (ppm)	6.2
	K (ppm)	64
	pH	8.1

Garlic seeds (cloves) cv. Balady were obtained from Potato and Vegetatively Propagated Vegetables Department, Horticulture Research Institute, Agriculture Research Center, Egypt. Cloves (uniform in shape and size) were manually planted on both sides of the dripper line at the middle of September in the three seasons. Other agricultural practices were carried out according to the recommendations of Ministry of Agriculture for green garlic planting.

This work was divided into two experiments as follows:

2.1. Field experiment

This experiment was conducted during the winter seasons 2014/2015 and 2015/2016 to investigate the effect of plant space and harvesting date on the vegetative growth, bulb quality and yield of green garlic.

2.1.1. Data recorded

Harvesting was done after 4.5, 5, 5.5 or 6 months from planting to record the following data in each harvesting date:

2.1.1.1 Vegetative growth and quality of green garlic

A random sample of five plants from each experimental unit was taken from each harvesting date to investigate the following vegetative growth and quality of green garlic parameters: plant length, average number of leaves/ plant, total chlorophyll reading, leaf area/ plant, average green bulb diameter, average green neck diameter, average weight of green bulbs and dry matter percentage of green bulbs, where:

Chlorophyll was determined by using Minolta chlorophyll meter SPAD- 502 as SPAD units. SPAD unit = 10 mg/ 100g fresh weight of leaves (Netto *et al.*, 2005).

Average weight of green bulbs equal average bulbs weight with 10 cm neck (g).

Dry matter percentage: The bulbs with 10 cm neck were oven dried at 70 ^{0}C till constant weight and then the bulbs with 10 cm neck dry weight / bulbs with 10 cm neck fresh weight X 100 was recorded.

Yield of bulbs

At each harvesting date all plants from each plot were harvested to measure the total yield (ton/ fed.) and exportable green garlic yield (ton/ fed.), where: Exportable green garlic yield = total number of green garlic × average weight of green garlic per fed.

2.2. Storage experiment

2.2.1. Plant material and treatments

This experiment was carried out during the two successive seasons of 2015/2016 and 2016/2017 at the laboratory of Postharvest and Handling of Vegetable Crops Dept.

Green garlic cv. Balady plants obtained from plant space 10 cm and harvested on 1st March were selected because those plants gave the highest exportable green garlic yield and the greatest bulb diameter (greater than 5 cm) as these parameters are suitable for European markets. The plants were transported to the laboratory within 2 hours, and kept overnight at 0 °C and 95 % RH. The following morning, the green garlic plants were graded to select plants with 6 cm in diameter and the dried outer leaves surrounded the bulb were removed, stalks were cut to about 10 cm length with sharp knife and roots were also trimmed with a sharp scissors.

Six green garlic bulbs weighing about 250 g were packed together in polypropylene (PP), polyethylene (PE), white net bags or non-

packed (control) and put in cardboard boxes with the dimensions of (30×20×10 cm). Each cardboard box contained three bags as one replicate. Fifteen replications for each treatment were stored at 0 °C + 95% RH for 20 days. Eighteen bulbs from each treatment were taken at random of three replications and arranged in a complete randomized design. Samples were evaluated for the changes in the quality parameters at the beginning of storage and every 4 days during storage.

2.2.2. The following data were recorded

2.2.2.1. Weight loss percentage (estimated according to the following equation:

$$\text{Weight loss\%} = \frac{\text{Initial plant weight} - \text{plant weight at sampling date}}{\text{Initial plant weight}} \times 100$$

2.2.2.2. General appearance was determined according to the following score: 9 = excellent, 7 = good, 5 = fair, 3 = poor and 1 = unusable. This scale depends on morphological defects such as leaves wilting and leaves discoloration according to Kader *et al.* (1973).

2.2.2.3. The external surface color was measured using a color meter (Minolta, model CR200). Color changes were quantified in the lightness (L) and hue angle (h°). where: Lightness, ranging from 0(= black) to 100(= white) and high hue angle is defined as a color wheel with red-purple at an angle of 0°, yellow at 90°, bluish-green at 180° and blue at 270° (McGuire, 1992).

2.3. Statistical analysis

Data of field experiment were statistically analyzed as randomized split plot design, and storage experiment data were statistically analyzed as complete randomized design according to Snedecor and Cochran (1980), using MSTAT-Computer V4. The treatment means were compared by using LSD at 0.05 level of probability.

3. RESULTS AND DISCUSSION

3.1. Field experiment

3.1.1. Vegetative growth

3.1.1.1. Effect of plant space

Data presented in Table (2) showed clearly the effect of plant space on plant length,the number of leaves per plant, leaf area per plant and the total chlorophyll reading of green garlic plants grown under sandy soil conditions during 2014/2015 and 2015/2016 seasons. It was obvious that plant spacing had a significant effect on all the studied vegetative growth of green garlic plants except number of leaves per plant in the first season, the highest values of plant length, the number of leaves per plant and total chlorophyll reading were recorded when garlic cloves were planted at 10 cm between plant followed by plant space at 12.5 cm, while the least values were obtained with plant space at 7.5 cm. These effects of the above-mentioned treatments could be attributed to the fact that the optimum plant population ensure effective use of available cropland and avoid competition between plants on light, water and nutrient (Geremew *et al.,* 2010). In the same line, Moravcevic *et al*. (2011) indicated that green garlic responded best to moderate stand densities of 600,000 and 750,000 plants/ ha compared to other plant densities 300,000; 450,000 and 900,000 plants/ ha. Present results confirm the findings of Youn *et al.* (2015) and Muneer *et al.* (2017) on garlic.

Regarding leaf area, leaf area per plant increased by plant space at 12.5 cm, whereas plant space at 7.5 cm decreased this character. This result may be attributed to the fact that wider plant spacing showed less competitive for resource and as a result leaves developed to a larger size. This result was in conformity with the findings of Muneer *et al.* (2017) who worked on garlic and stated that the maximum leaf area (101.59 cm^2) was achieved with plant spacing of 11 cm, while the minimum leaf area (91.46 cm^2) was achieved from plant spacing of 3 cm.

3.1.1.2. Effect of harvesting date

Results in Table (2) showed the effect of harvesting dates on vegetative growth of green garlic plants. In general, delaying harvest date to 15^{th} March was the most favorable treatments for enhancing vegetative growth (plant length, the number of leaves per plant, leaf area per plant and the total chlorophyll reading) followed by harvest date on 1^{st} March then harvest date on 15^{th} February. On the contrary, the early harvesting (1^{st} February) recorded the least values in this respect. The promotion effect of delaying harvest on increasing the growth parameters of green garlic

Table (2): Effect of plant spacing, harvesting date and their interaction on the vegetative growth of green garlic plants during 2014/2015 and 2015/2016 seasons.

Treatments		2014/2015 season				2015/ 2016 season			
Plant spacing (cm)	Harvesting dates	Plant length (cm)	Leaves number/ plant	Leaf area (cm^2/plant)	Total chlo. * reading (SPAD)	Plant length (cm)	Leaves number/ plant	Leaf area (cm^2/plant)	Total chlo. * reading (SPAD)
7.5		84.7	10.5	178.1	65.6	88.5	11.1	211.5	67.3
10		96.3	11.2	212.5	72.3	108.5	12.2	230.7	74.9
12.5		92.4	10.8	229.9	68.6	102.1	11.5	247.5	71.4
LSD at 0.05%		**2.0**	**NS**	**28.0**	**1.8**	**16.9**	**0.6**	**6.0**	**1.6**
	1st Feb.	69.1	9.6	126.1	59.0	76.2	10.1	136.4	63.5
	15th Feb.	89.6	10.6	185.1	69.3	96.7	11.7	228.0	71.7
	1st March	100.3	11.1	222.6	72.3	111.3	12.1	250.1	73.7
	15th March	105.5	12.0	293.5	74.8	114.6	12.5	305.3	75.7
LSD at 0.05%		**1.4**	**0.6**	**10.0**	**1.6**	**14.3**	**0.4**	**9.4**	**1.3**
7.5	1st Feb.	63.3	9.3	114.0	55.0	69.3	9.6	126.7	58.0
	15th Feb.	83.6	10.3	153.6	66.3	97.6	11.3	207.6	69.0
	1st March	89.6	11.0	172.6	69.3	104.3	11.6	223.2	70.0
	15th March	102.3	11.3	272.4	72.0	110.3	12.0	288.8	72.3
10	1st Feb.	73.6	10.0	128.0	63.3	84.6	10.6	135.7	68.6
	15th Feb.	94.6	11.0	188.4	73.0	114.0	12.3	230.6	75.3
	1st March	107.7	11.3	236.7	75.3	116.7	12.6	252.0	76.6
	15th March	109.3	12.6	296.9	77.6	118.7	13.3	304.8	79.0
12.5	1st Feb.	70.3	9.6	136.4	58.6	74.6	10.0	146.8	64.0
	15th Feb.	90.6	10.6	213.3	68.6	106.0	11.6	245.9	71.0
	1st March	103.7	11.0	258.5	72.3	113.0	12.0	275.2	74.6
	15th March	105.0	12.0	311.4	75.0	115.0	12.3	322.3	76.0
LSD at 0.05%		**2.4**	**1.1**	**17.4**	**2.8**	**3.2**	**0.8**	**16.4**	**2.3**

*** Chlo.: chlorophyll reading in SPAD units, SPAD = 10 mg/ 100 g fresh weight of leaves.**

plants may be attributed to the fact that delaying harvest led to increasing accumulation of photosynthesis outputs, which in turn led to increasing the vegetative growth. These results are in accordance with those obtained by Ibrahim (2008) who stated that garlic scallion characters (plant length and the number of leaves/ plant) increased with increasing plant age.

3.1.1.3. Effect of the interaction between plant space and harvesting date

Data obtained in Table (2) showed that the interaction between plant space at 10 cm and harvesting green garlic plants on 15th March significantly increased all the studied vegetative growth followed by the interaction between plant space at 10 cm and harvesting green garlic plants on 1st March without significant differences between them in most cases, while leaf area increased with plant space at 12.5 cm and harvesting green garlic plants on 15th March. On the other hand, the lowest values in this respect were recorded with the interaction between plant space at 7.5 cm and harvesting date on 1st February. These results were true in both seasons of study.

3.1.2. Quality and yield

3.1.2.1. Effect of plant space

Results in Tables (3 and 4) showed the effect of plant space on the quality and yield of green garlic plants expressed as green bulb diameter, green neck diameter, green bulbs weight, green bulbs dry matter, and total yield and exportable green garlic yield, in both seasons. The wider plant space (12.5 cm) let to the highest values of green bulb diameter, neck diameter and green bulbs weight followed by the medium plant spacing (10 cm), whereas green bulbs dry matter percentage, total yield and the exportable yield of green garlic increased with the plant space at 10 cm followed by plant space at 12.5 cm. On the contrary, the lowest plant space (7.5 cm) gave the lowest values for all characters. The positive increased in bulb

Table (3): Effect of plant space, harvesting date and their interaction on the quality characters of green garlic plants during 2014/2015 and 2015/2016 seasons.

Treatments		2014/2015 season				2015/ 2016 season			
Plant spacing (cm)	**Harvesting dates**	**Green blub diameter (cm)**	**Green neck diameter (cm)**	**Weight of green bulbs**	**Green bulbs dry matter (%)**	**Green blub diameter (cm)**	**Green neck diameter (cm)**	**Weight of green bulbs**	**Green bulbs dry matter (%)**
7.5		4.91	1.49	28.7	15.6	4.58	1.64	33.4	15.0
10		5.41	1.89	33.0	17.9	5.25	2.02	38.4	17.3
12.5		6.25	2.10	37.4	17.0	5.58	2.27	41.8	16.5
LSD at 0.05%		**0.18**	**0.11**	**2.5**	**0.4**	**0.55**	**0.12**	**2.4**	**0.4**
	1st Feb.	3.77	1.24	16.0	14.5	3.44	1.41	18.7	12.0
	15th Feb.	5.11	1.74	23.3	14.9	4.66	1.86	25.9	15.5
	1st March	6.00	2.10	33.9	17.8	5.66	2.30	41.8	16.9
	15th March	7.22	2.23	59.0	20.1	6.77	2.40	64.9	20.7
LSD at 0.05%		**0.81**	**0.10**	**2.4**	**0.5**	**0.71**	**0.10**	**1.8**	**0.5**
7.5	1st Feb.	3.00	1.16	13.3	13.3	2.66	1.33	17.4	9.5
	15th Feb.	5.00	1.46	18.3	14.1	4.33	1.53	20.3	15.0
	1st March	5.33	1.63	29.8	16.5	5.33	1.80	36.9	16.4
	15th March	6.33	1.70	53.6	18.7	6.00	1.90	58.9	19.1
10	1st Feb.	4.00	1.20	16.2	15.6	3.66	1.40	18.4	13.7
	15th Feb.	4.66	1.66	23.7	15.8	4.66	1.86	27.3	16.0
	1st March	5.66	2.23	34.0	18.8	5.66	2.43	42.8	17.5
	15th March	7.33	2.46	58.3	21.3	7.00	2.56	65.1	22.2
12.5	1st Feb.	4.33	1.36	18.6	14.6	4.00	1.50	20.5	12.8
	15th Feb.	5.66	2.10	27.9	14.9	5.00	2.20	30.3	15.6
	1st March	7.00	2.43	37.9	18.2	6.00	2.66	45.7	17.0
	15th March	8.00	2.53	65.1	20.5	7.33	2.73	70.8	20.8
LSD at 0.05%		**1.42**	**0.17**	**4.3**	**0.9**	**1.23**	**0.18**	**3.2**	**1.0**

yield at medium plant space might be attributed to the increase in plant population. According to our findings in this study, it could be concluded that the total yield per unit area depended not only on the performance of individual plants but also on the number of plants. Present results confirm the findings of Youn *et al*. (2015) and Muneer *et al.* (2017) on garlic.

3.1.2.2. Effect of harvesting date

Data presented in Tables (3 and 4) showed the effect of harvesting date on the yield and quality of green garlic plants in 2014/2015 and 2015/2016 seasons. It is obvious from the data that, harvesting date reflected a significant effect on yield and quality of green garlic plants expressed as green bulb diameter, green neck diameter, green bulbs weight, green bulbs dry matter %, total yield and exportable green garlic yield.

In general, delaying harvest date (15th March) was the most favorable treatments for enhancing yield and quality parameters, while the early harvesting (1st February) recorded the least values in this respect during the first and second seasons. Concerning the exportable green garlic yield, the highest values were obtained with harvesting date on 1st March followed by harvesting dates on 15th March or 15th February without significant differences between the two dates.

The promotion effect of delaying harvest on increasing quality and yield parameters of green garlic plants may be attributed to the fact that delaying harvest led to increasing accumulation of photosynthesis outputs which in turn enhancing plant growth rate which exert direct effect on the yield and its components. Our results are in agreement with Zedan (2011), who mentioned that the total yield of onion was increased with the

Table (4): Effect of plant space, harvesting date and their interaction on the yield of green garlic plants during 2014/2015 and 2015/2016 seasons.

Treatments		2014/2015 season		2015/2016 season	
Plant spacing (cm)	**Harvesting dates**	**Total yield (ton/ fed.)**	**Exportable green garlic yield (ton/ fed.)**	**Total yield (ton/ fed.)**	**Exportable green garlic yield (ton/ fed.)**
7.5		5.565	3.021	5.996	2.900
10		7.360	4.653	6.801	4.643
12.5		6.288	3.271	6.190	3.549
LSD at 0.05%		**0.391**	**0.501**	**0.260**	**0.189**
	1st Feb.	4.058	1.689	4.458	1.444
	15th Feb.	5.170	3.990	5.170	4.268
	1st March	6.957	5.070	7.227	4.966
	15th March	9.434	3.844	8.460	4.112
LSD at 0.05%		**0.258**	**0.190**	**0.230**	**0.195**
7.5	1st Feb.	3.217	1.301	4.358	0.864
	15th Feb.	4.340	3.575	4.536	3.281
	1st March	5.982	4.111	6.922	3.184
	15th March	8.725	3.096	8.170	4.271
10	1st Feb.	5.006	2.363	4.796	2.246
	15th Feb.	6.199	4.831	5.629	5.305
	1st March	8.151	6.510	7.688	6.509
	15th March	10.090	4.909	9.091	4.513
12.5	1st Feb.	3.952	1.403	4.221	1.221
	15th Feb.	4.973	3.565	5.347	4.218
	1st March	6.739	4.588	7.074	5.204
	15th March	9.491	3.526	8.121	3.552
LSD at 0.05%		**0.447**	**0.330**	**0.398**	**0.338**

delay harvesting date (156 days after planting) compared with other harvesting dates (114, 128 and 142 days after planting).

3.1.2.3. Effect of interaction between plant space and harvesting date

The results listed in Tables (3 and 4) indicated that the interaction between the two studied factors had a significant effect on all measured parameters of green garlic expressed as green bulb diameter, green neck diameter, green bulbs weight, green bulbs dry matter, total yield and exportable green garlic yield in both seasons. Generally, the interaction between plant space at 12.5 cm and harvesting green garlic plants on 15th March significantly increased green bulb diameter, green neck diameter and green bulbs weight followed by the interaction between plant space at 10 cm and harvesting green garlic plants on 15th March. It is clear from the same data that the maximum green bulbs dry matter % and the total yield of green garlic plants were obtained by the interaction between plant space at 10 cm and harvesting green garlic plants on 15th March. In this regard, Lana (2012) reported that the root yield of carrot increased with later harvest (100 days after sowing) at each density level (16.6, 12.5 and 10 cm between lines) compared with the other harvesting (80 or 90 days after sowing).

In respect to exportable green garlic yield per fed. data presented in Table (4) showed that the interaction between plant spacing at 10 cm and harvesting green garlic plants on 1st March effectively increased the exportable green garlic yield, followed by the interaction between the same planting space and harvesting green garlic plants on 15th February which produced acceptable yield of the exportable green garlic with high marketable quality parameters of the exportable green garlic. These results were true in the two seasons. On the other hand, the least values in this respect were recorded by the interaction between plant space at 7.5 cm and harvesting date on 1st February.

3.2. The storage experiment

3.2.1. Weight loss percentage

Data in Table (5) showed that weight loss percentage of green garlic bulbs increased considerably and consistently with the prolongation of storage period. This weight loss may be attributed to respiration and other senescence related metabolic processes during storage **(**Watada and Qi, 1999). However, packing fresh garlic bulbs in polypropylene (PP) or polyethylene (PE) showed a significant lower decrease in weight loss % during storage, without any significant difference between them in the second and third seasons. Such result, are in agreement with those of Rahman *et al.* (2012) on green chili pepper. On the other hand, the highest value of weight loss was observed in the control and followed by net packages. The interaction between the treatments and the storage periods was significant and revealed that both PP or PE packages significantly displayed weight loss % of green garlic bulbs less than 1% during all the storage periods for 20 days at 0 ºC and 95 % RH.

3.2.2. General appearance

General appearance (GA) included morphological defects occur in green garlic bulbs during storage such as wilting, bulb discoloration and decay. As shown in Table (5), GA of green garlic bulbs declined as the storage period extended. This decrement might be due to plant wilting and bulb discoloration. Regarding treatments, GA of green garlic bulbs packed in PP or PE packages displayed much better appearance than net package and the control. These results might be due to the role of plastic bag packaging in maintaining quality, retarding senescence and extending shelf life of vegetables. Similar findings were observed by Niyomlao *et al*. (2000) in Chinese kale. The interaction between treatments and storage periods showed significant effect. So, PP or PE packages rated excellent look during all storage periods, *i.e.,* 20 days at 0ºC and 95% RH.

In contrast, both net and control treatments dropped to fair and poor levels, respectively, after 16 days of storage, and exhibited wilt and yellowish look without any signs of decay.

3.2.3. Bulb skin color

As presented in Table (6), a significant decrease was noted in our studied treatments regarding lightness (L) and hue angle (hº) as the storage period prolonged. Such results were supported by Vazquez-Barrios *et al.,* (2006) on garlic. The decrement in L values might be correlated with water loss which negatively affected the luminosity of fresh garlic bulbs. Meanwhile, the decreasing in hue angle may be attributed to yellowish and reddish tones associated with senescence. Concerning storage materials, the same table showed that the PP or PP bags exhibited brighter fresh garlic bulbs as compared with the net and control bags, which presented dull and yellowish color during 2015/2016 and 2016/2017 seasons without noticeable differences between them. The interaction between treatments and storage period was significant and indicated that either PP or PE bags effectively conserved the green garlic bulbs with white and light color for 20 days storage at 0 °C and 95% RH.

Conclusion

The results obtained in this investigation suggest that planting garlic cloves in the middle of September at 10 cm plant space and harvesting green garlic on 15th February is recommended when the objective is to achieve early exportation (the market demand and price are high). Whereas, harvesting green garlic on 1st March with the same plant space (10 cm) is suggested for higher production (short period for exportation) under sandy soil conditions and drip irrigation system. It is also recommended to use polypropylene (PP) or polyethylene (PE) bags as packing materials for green garlic bulbs to display good appearance and increase the shelf life for 20 days storage at 0 °C and 95 % Relative Humidity (RH).

Table (5): Effect of some packaging materials on weight loss % and visual appearance of green garlic during storage period in 2015/2016 and 2016/2017 seasons.

Treatments (T)	Weight loss %													
	2015/2016 season							2016/2017 season						
	Storage period in days (S)													
	0	4	8	12	16	20	Mean	0	4	8	12	16	20	Mean
Control	-	3.25	6.37	7.49	11.03	11.36	7.90	-	3.65	6.68	6.80	10.57	11.28	7.80
White net bags	-	2.45	5.47	5.88	6.92	10.15	6.18	-	2.61	4.83	5.78	6.11	10.96	6.06
PP bags	-	0.22	0.31	0.53	0.71	0.74	0.50	-	0.15	0.34	0.59	0.60	0.62	0.46
PE bags	-	0.23	0.41	0.61	0.66	0.83	0.55	-	0.16	0.39	0.63	0.83	0.86	0.58
Mean	-	1.54	3.14	3.63	4.83	5.77		-	1.64	3.09	3.45	4.53	5.93	
LSD at 0.05 level		T = 0.33	S = 0.39	T × S =0.78					T = 0.65	S = 0.29	T×S =0.58			
	Visual appearance score*													
Control	9.00	9.00	7.33	4.67	3.67	3.00	6.11	9.00	9.00	7.00	5.00.33	4.00	3.33	6.22
White net bags	9.00	9.00	9.00	6.67	5.00	4.33	7.17	9.00	9.00	9.00	7.00	5.67	5.00	7.44
PP bags	9.00	9.00	9.00	9.00	9.00	8.67	8.94	9.00	9.00	9.00	9.00	9.00	9.00	9.00
PE bags	9.00	9.00	9.00	9.00	9.00	8.33	8.89	9.00	9.00	9.00	9.00	9.00	9.00	9.00
Mean	9.00	9.00	8.58	7.33	6.67	6.08		9.00	9.00	8.50	7.50	6.92	6.58	
LSD at 0.05 level		T = 0.27	S = 0.25	T × S =0.50					T = 0.34	S = 0.25	T × S = 0.51			

***Score: 9= Excellent, 7= Good, 5= Fair, and 3= Poor T= packaging material PP=polypropylene PE= polyethylene**

Table (6): Effect of some packaging materials on L value and hue angle of green garlic during storage period in 2015/2016 and 2016/2017 seasons.

Treatments (T)	L value													
	2015/2016 season							2016/2017 season						
	Storage period in days (S)													
	0	4	8	12	16	20	Mean	0	4	8	12	16	20	Mean
Control	81.68	81.15	80.60	77.73	77.38	76.38	79.15	81.34	80.55	79.86	78.03	76.50	75.50	78.63
White net bags	81.68	81.31	81.13	79.40	77.63	76.80	79.66	81.34	80.82	80.77	78.59	76.77	76.07	79.06
PP bags	81.68	81.50	81.45	81.02	80.31	79.05	80.84	81.34	81.16	80.70	80.45	79.88	79.30	80.47
PE bags	81.68	81.21	81.21	80.36	78.77	77.49	80.12	81.34	80.71	80.54	80.32	79.54	78.17	80.10
Mean	81.68	81.29	81.10	79.63	78.52	77.43		81.34	80.81	80.47	79.35	78.17	77.26	
LSD at 0.05 level	**T = 0.44 S = 0.52 T × S =1.04**							**T = 0.69 S = 0.50 T×S =1.00**						
	Hue angle													
Control	94.32	92.67	92.43	91.96	87.88	87.55	91.14	94.37	93.20	92.93	92.49	89.57	88.57	91.86
White net bags	94.32	93.38	92.72	92.38	88.88	88.55	91.70	94.37	93.79	93.64	93.30	92.93	89.57	92.93
PP bags	94.32	94.29	93.97	93.95	93.76	92.43	93.79	94.37	93.94	93.71	93.70	93.24	92.64	93.60
PE bags	94.32	93.88	93.64	93.64	93.45	91.49	93.40	94.37	93.71	93.56	93.42	92.50	90.79	93.06
Mean	94.32	93.55	93.19	92.98	90.99	90.01		94.37	93.66	93.46	93.23	92.06	90.39	
LSD at 0.05 level	**T = 0.38 S = 0.66 T × S =1.32**							**T = 0.62 S = 0.81 T × S = 1.62**						

T= packaging material PP=polypropylene PE= polyethylene

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تأثير مسافة الزراعة وميعاد الحصاد على المحصول والجودة والقدرة التخزينية للثوم الأخضر

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ملخص

أجريت هذه الدراسة خلال الموسم الشتوى لثلاث أعوام 2014-2015 و2015-2016 و2016-2017 م فى مزرعة التجارب البحثيه بمحطة بحوث البساتين بالقصاصين، مركز البحوث الزراعية، محافظة الإسماعيلية – مصر لدراسة تأثير مسافات الزراعة بين النباتات (7.5 او 10 او 12.5سم) ومواعيد الحصاد (أول فبراير أو منتصف فبراير أو أول مارس أو منتصف مارس) على صفات النمو الخضرى والجوده والمحصول"الصنف بلدى" لنباتات الثوم الأخضر(*Allium sativum* L.) المنزرعة تحت ظروف الأراضى الرملية والرى بالتنقيط. وأيضا لدراسة تأثير أنواع مختلفة من مواد التعبئة والتغليف على صفات الجودة للثوم الأخضر أثناء التخزين عند درجة حرارة الصفر المئوى ورطوبه نسبيه 95٪ لمدة 20 يوماً.

أوضحت النتائج المتحصل عليها بالنسبة لتجربة الحقل أن زراعة فصوص الثوم على مسافة 10سم بين النباتات أدت إلى حدوث زيادة معنوية فى طول النبات وعدد الأوراق للنبات وقراءة الكلورفيل الكلى ونسبة المادة الجافة للثوم الأخضر والمحصول الكلى والمحصول الأخضر القابل للتصدير. بينما زودت الزراعة على مسافة 12.5 سم المساحة الورقية وقطر الرأس وقطر العنق ووزن الثوم الأخضر فى موسمى الزراعة 2014/2015 و2015/2016. سجل ميعاد الحصاد فى 15 مارس أعلى القيم بالنسبة لصفات النمو الخضرى والجودة والمحصول الكلى لنباتات الثوم الأخضرمقارنة بباقى مواعيد الحصاد. اما بالنسبه لمحصول الثوم الأخضر القابل للتصدير ، سجلت أفضل النتائج عند الحصاد فى ميعاد 15 مارس ويلية الحصاد فى أول فبراير. عموما اعطى التفاعل بين معاملة الزراعة على مسافة 10سم وميعاد الحصاد فى 15 مارس أفضل القيم بالنسبة لصفات النمو الخضرى ونسبة المادة الجافة والمحصول الكلى ، فى حين أدت الزراعة على مسافة 12.5 سم والحصاد فى 15 مارس لزيادة المساحة الورقية للنبات وقطر الرأس وقطر العنق والوزن الطازج للثوم الأخضر. بينما اظهرت الزراعة على مسافة 10 سم بين النباتات وحصاد في أول مارس اعلى قيمة لمحصول الثوم الأخضر الصالح للتصدير يلية معاملة نفس مسافة الزراعة بين النباتات مع الحصاد فى 15 فبراير خلال الموسم الاول والثانى من الزراعة. بالنسبه لتجربة التخزين فقد أظهرت النتائج أن تعبئة الثوم الأخضر فى أكياس من البولى بروبلين أو البولى ايثلين أدت إلى حدوث إنخفاض معنوي فى النسبه المئويه للفقد فى الوزن لأقل من 1% وإحتفاظ النباتات بمظهر طازج ولون أبيض لمدة 20 يوم من التخزين على صفر م°، و95 % رطوبه نسبيه خلال موسمى التخزين 2015/2016 و2016/ 2017 م.

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