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Impact of some Agronomical Practices on Carrot Productivity and Nutritional Value

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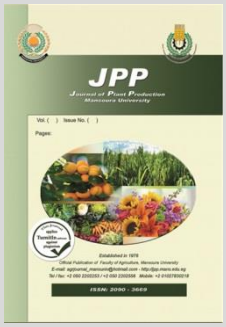

ABSTRACT

Experiments were conducted during the two winter seasons of 2018 and 2019 to investigate the response of two carrot cultivars (Chantenay and Nantes) to pre-and post-emergence linuron applications and different agronomic methods (broadcasting and drilling on raised rows and broadcasting in beds). The effect of factors on the vegetative growth and accumulation of nutrient compounds has been assessed. Pre emergence linuron treatment substantially increased the yield, dry matter and root physical characters (root length and weight, root and core diameter) compared to post emergence treatment. Chantenay accumulated more phenolics and antioxidants than Nantes, which was 14.73-16.59%, 7.64-8.15% and 12.37-15.66% greater ($p < 0.05$) than Cahantenay in carotenoids, total and reducing sugars in 2018 and 2019, respectively. In order to raise the productivity of feddan, broadcasting on raised rows (140 plant/ m^2) was correlated with higher yield and the sweet and darker root of carrot. Carrots were strongly influenced by linuron addition times in terms of yield or phytochemical status. Phenolic compounds and antioxidant strength were cultivar-dependent and Chantenay was the richest overall.

Keywords: Carrot; Linuron; yield; phenolic compounds; carotenoids

INTRODUCTION

Carrot (*Daucus carota* L.) is a member of the family Umbelliferae and occupies the top of the ten most common vegetables (Kharsan *et al*., 2019). Nowadays the most widely grown varieties have an orange root and have been formed from earlier yellow variants (Singh *et al*., 2018). China is the largest producer with a yield value of ≥18 million tons. Carrots are very popular vegetables in Egypt that producing 266248 Tons from 9009 hectare as recorded in the latest statistics of Food and Agriculture Organization (FAOSTATA, 2018). Carrots are valuable for their taste, good digestibility, and high levels of carotene, pro-vitamin A, and fibers in addition to appreciable quantities of thiamine and riboflavin (Kharsan *et al*., 2019). The favored sweet taste of carrots referred to sugar contents such as glucose, fructose and starch which are the main types of carbohydrates (Que *et al*., 2019). In addition, carrot is a vegetable rich in antioxidants both lipophylic (carotenoids) and hydrophilic (phenolics) compounds that vary considerably among carrot cultivars and varieties (Leja *et al*., 2013). Therefore, carrots have been used as a potent antioxidant to combat certain types of cancer, especially lung cancer (Simon and Goldman, 2007; Singh *et al*., 2018).

Carrot as a root crop is sensitive to soil quality, and in particular, to soil compression (Kęsik and Konopiński, 1993). It is also very sensitive to weed competition due to slow germination and faster growing weeds (Luo *et al*., 2004, Swanton *et al*., 2010, Gruszecki *et al*., 2015). The presence of weeds is considered to be one of the biotic factors responsible for reducing both quantity and quality of the roots. Decreased root production is possible up to 100% due to lack of proper control (Freitas *et al*., 2009, Swanton *et al*., 2010, Correia and Carvalho, 2017). Weeds can serve as hosts for pests, diseases and nematodes, thus weed control is one of the focal cost constrains affecting carrot production (Boydston *et al*., 2008).

Linuron has been the utmost commonly used carrot herbicide for carrot crop for several years (Swanton *et al.* 2010; Correia and Carvalho, 2017). Linuron (3-(3,4-Dichlorophenyl)-1-methoxy -1-methylurea) is a synthetic urea herbicide used to combat annual and perennial broadleaf and grassy weeds at crop and non-crop sites. It is used as a pre- and post- emergent herbicide and works by inhibiting photosynthesis in target weed plants, causing them to lose color, wilt, then die. Post-emergency sprayed linuron was recommended by Correia and Carvalho (2017) for growing carrots, regardless of cultivar, product dosage and plant development. Crop yields treated with herbicides reflected their weed control efficiencies (Pacanoski *et al*., 2014).

Plant spacing also affects the growth, development and yield of carrots (Kharsan *et al*., 2019). In the case of closer spacing or higher plant density, competition among individual plants increases for essential growth factors which do not get their normal size (Norman *et al*., 1992). Root size, root weight and yield of carrot can be modified through refinements in the growing system especially population density (Lana, 2012). Similarly, at wider spacing, yield of individual plants will more, but yield per feddan may decline due to low plant density (Kharsan *et al*., 2019).

The objective of our research is to estimate the optimum planting method and the linuron application time as key factors affecting the carrot growth and yield of two cultivars in carrot production. Since the effect of these

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factors on total phenols and antioxidants content is still unknown, this study aims to assess the impact of these variables on the quality of the produced carrot.

MATERIALS AND METHODS

Experimental design

Two field experiments were conducted at the Agricultural Experimental and Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt (28.7666° N, 29.2321° E) during the two winter seasons of 2018 and 2019. Seeds were sown in the two seasons on 3th November. The experiment included three factors (two carrot cultivars, three planting methods and two herbicide application times). The experiment was arranged as split split plot design with three replicates, where the two carrot cultivars were allocated to the main plots, the three planting methods were randomly arranged in the sub main plots and the two herbicide application times were randomly distributed in the sub sub plots. Each area of the plot was 12 m^2.

The carrot cultivars used were Chantenay (agent: MECCA Trade Co., France) and Nantes (Seminis Co., France). The herbicide used was Ultra Afalon (Linuron 45% Sc), Akko B.V., Netherlands. It was added at a dosage of 500 ml per Acre. The herbicide was applied as a pre-emergence (4 days after seed sowing) or as a post-emergence (at 2-3 true leaf level).

Planting methods

The experiment included the following three planting methods:

1- Broadcasting on the raised rows (140 plant/m^2)

The plot consisted of 6 ridges; each 4 m in length and 0.5 m in width. The seeds were broadcasted on the top of the ridge.

2- Drilling on the raised rows (80 plant/m^2)

The plot consisted of 6 ridges, the same dimension as the previous one. The seeds were sown in rows at a distance of 10 cm from the top of the ridge.

3- Broadcasting in beds (180 plant/m^2)

The seeds were spread in beds. The plot consisted of 3 flat beds; each 4 m in length and 1m in width. All recommended agricultural practices were followed as commonly used in the commercial production of carrot.

Data recorded

After 5 months of planting (April), yields from all plots were collected and weighed to assess the carrot response to the planting methods and the applied herbicide. Also, ten plants were taken randomly from each plot to evaluate the following characters:

A-Vegetative growth parameters:

- Plant length and Plant fresh weight

B-Yield traits:

- Total yield /fed.
- Average root weight
- Root length
- Root diameter
- Core diameter
- Root dry matter
- Firmness
- TSS

D-Chemical constituents and quality:

- **Reducing and total sugars**: Reducing sugars were determined by Miller (1959), while, the total sugars were determined by Ludwig and Rochester (1956).
- **Carotenoids**: it was estimated by Lee and Castle (2001)
- **Total phenolic compounds**: It was estimated by Folin-Ciocalteu method (Aryal *et al.*, 2019).
- **Estimation of the radical scavenging activity (DPPH) and** *antioxidant activity* by Yan-Hwa *et al*. (2000). Antioxidant activity percentage was calculated by the following equation:

$$\% \textbf{\textit{Antioxidant activity}} = \frac{\textbf{\textit{A control}} - \textbf{\textit{A sample}}}{\textbf{\textit{A control}}} \; \boldsymbol{x\,100}$$

Statistical analysis

Data collected from the two seasons were subjected to the statistical analysis according to Gomez and Gomez (1984) and the least significant difference test (LSD) at 5% level of probability was used to verify the significant difference between treatments.

RESULTS AND DISCUSSION

Results

Vegetative growth

The effect of herbicide cultivars, planting method and application time as well as the interaction among them is present in Table 1.

Regarding cultivars, the length of the plant (in both seasons) and the plant fresh weight (in the first season) of Chantenay were significantly greater than those of 'Nantes.

With regard to planting methods, the carrot plants planted with broadcasting in beds were the tallest followed by those planted in rows with seed drilling then those planted broadcasting on raised rows in both seasons. The opposite was true of the plant weight. Plants collected from seed drilling on raised rows (in the first season) and those planted in the second season by broadcasting on raised rows were the biggest. Meanwhile, in both seasons the plants sown broadcasting in beds were the smallest.

Concerning the interaction between cultivars and planting methods, the plants of Chantenay or Nantes obtained from the seed broadcasting in beds were the tallest followed by those planted from the seed drills in rows, followed by the third planting system. Vice versa was observed in the fresh weight of Chantenay in both seasons and Nantes in the second season. With the exception of Nantes in 2018, the plants planted by drilling on rows had the highest fresh weight followed by those collected from the seeds broadcasting on rows compared to broadcasting in beds.

As shown in this Table, there were no significant differences between pre- and post-emergence of linuron treatments on plant length in the two seasons and plant weight in the second season. Pre emergence treatment resulted in a substantial increase in plant fresh weight in the first season relative to post-emergence treatment.

The interaction between carrot cultivars and herbicide application time on the vegetative growth was significant. In 'Chantenay', there were no significant differences between the two times of the herbicide application concerning plant length in both seasons and plant weight in the second season , but pre herbicide application was significantly higher in 2018 than post herbicide application in plant weight. In 'Nantes' plants treated with post emergence herbicide were taller than those treated with pre herbicide in the first season. The vice versa was noticed in the second season, but there were no significant differences between both herbicide applications in plant weight.

Table 1. Effect of cultivars, planting methods, herbicide application time and their interactions on the vegetative growth of carrot

Carrot cultivar	Planting method	Herbicide application time	Plant length (cm)		Plant weight (g)	
			2018	2019	2018	2019
Chantenay			35.56	37.56	54.50	53.08
Nantes			32.20	34.96	45.26	51.36
		LSD at 0.05	2.33	1.39	3.71	NS
	Broadcasting on raised row		30.67	34.91	51.29	57.65
	Drilling on raised row		34.13	35.84	53.93	53.86
	Broadcasting in beds		36.83	38.03	44.42	45.15
		LSD at 0.05	1.59	1.79	2.56	2.08
	Broadcasting on raised row		31.15	35.91	58.46	61.15
Chantenay	Drilling on raised row		36.21	37.46	57.79	55.14
	Broadcasting in beds		39.32	39.32	47.25	42.95
	Broadcasting on raised row		30.19	33.92	44.13	54.16
Nantes	Drilling on raised row		32.06	34.22	50.07	52.58
	Broadcasting in beds		34.34	36.75	41.59	47.35
		LSD at 0.05	2.25	2.53	3.62	2.94
		Pre emergence	33.47	37.18	52.92	52.95
		Post emergence	34.28	35.35	46.83	51.49
		LSD at 0.05	NS	NS	3.84	NS
Chantenay		Pre emergence	36.49	37.91	59.02	53.01
		Post emergence	34.63	37.21	49.97	53.14
Nantes		Pre emergence	30.45	36.44	46.83	52.89
		Post emergence	33.94	33.48	43.69	49.84
		LSD at 0.05	3.29	1.96	5.25	NS
	Broadcasting on raised row	Pre emergence	30.01	36.20	58.13	60.94
		Post emergence	31.34	33.63	44.46	54.37
	Drilling on raised row	Pre emergence	34.75	36.43	52.91	53.78
		Post emergence	33.52	35.25	54.95	53.94
	Broadcasting in beds	Pre emergence	35.67	38.9	47.74	44.13
		Post emergence	37.99	37.17	41.10	46.16
		LSD at 0.05	2.25	2.53	3.62	2.94
	Broadcasting on raised row	Pre emergence	30.66	37.38	69.40	62.48
		Post emergence	31.65	34.45	47.51	59.81
Chantenay	Drilling on raised row	Pre emergence	38.76	37.81	58.15	58.24
		Post emergence	33.66	37.10	57.44	52.04
	Broadcasting in beds	Pre emergence	40.07	38.55	49.52	38.32
		Post emergence	38.57	40.08	44.97	47.57
	Broadcasting on raised row	Pre emergence	29.35	35.03	46.85	59.40
		Post emergence	31.02	32.8	41.40	48.92
Nantes	Drilling on raised row	Pre emergence	30.75	35.05	47.67	49.31
		Post emergence	33.37	33.4	52.46	55.85
	Broadcasting in beds	Pre emergence	31.27	39.25	45.95	49.94
		Post emergence	37.41	34.25	37.22	44.74
LSD at 0.05			3.18	3.58	5.12	4.15

Regarding the interaction between planting methods and herbicide application, plants obtained from seed broadcasting in beds and treated with post emergence Linuron in the first season showed a higher plant length value than those treated with pre emergence Linuron. On the contrary, plants produced from broadcasting on raised rows and treated with pre-emergence Linuron in the second season were taller than those treated with post emergence Linuron. Plants planted with broadcasting on raised rows (in both seasons) or with broadcasting in beds (in the first season) and treated with pre-emergence herbicide had greater plant fresh weight than those treated with post emergence herbicide.

The impact of the interaction between linuron application time, planting methods and carrot cultivars on the vegetative growth was significant. The tallest plants were observed in Chantenay cultivar pre emergence treated with herbicide, that sown by drilling on rows or broadcasting in beds in 2018. In the 2019 season, the Nantes pre emergence treated plant sown in beds, was significantly higher than the other planting methods. No major impact on plant height when any method of planting was applied in the second season. On the other hand, the tallest plants were collected from Chantenay and Nantes cultivars sown in beds after post emergence herbicide treatment. When the cultivar Chantenay was sown by broadcasting on raised rows and treated with pre emergence linuron, it displayed the highest values of the plant fresh weight.

Yield

Concerning the effect of the studied cultivars on root weight and yield, Chantenay cultivar showed significantly greater yield in the first season and root weight in both seasons as compared with Nantes in both seasons.

The effect of planting methods on yield was significant, where the highest carrot yields were obtained from plants sown on raised rows followed by those sown by drilling on rows, while the lowest yield was gained by broadcasting sowing in flat beds. The same trend was noticed with root weight, but there were no significant differences between the plants planted by broadcasting and those planted by drilling on rows.

With regard to the interaction between the planting methods and the carrot variety, Chantenay sown by broadcasting in raised rows has registered the highest yield in both seasons. During the second season, by planting by the second method (drilling on rows), Chantenay had the greatest root weight. During the same season, Nantes which was sown by drilling in rows, produced a significant yield, but when sown by broadcasting on raised rows it showed a significant increase in carrot root weight. There

were no differences between these two methods concerning the yield and root weight in the first season.

As illustrated in Table 2, pre-emergence linuron-treated plants was greater in roots weight and substantially higher in yields than post-emergence treated plants.

Table 2. Effect of cultivars, planting methods, herbicide application time and their interactions on the yield of carrot

Carrot cultivar	Planting method	Herbicide application time	Yield (ton/fed)		Root weight (g)	
			2018	2019	2018	2019
Chantenay			9454	10220	98.12	102.40
Nantes			8833	9998	89.45	97.04
		LSD at 0.05	303.4	238	2.97	4.46
	Broadcasting on raised row		10990	11240	98.57	110.30
	Drilling on raised row		10210	10650	94.69	109.90
	Broadcasting in beds		6234	8440	88.10	78.97
		LSD at 0.05	637.6	530.5	7.11	5.54
	Broadcasting on raised row		11810	11970	101.40	111.10
Chantenay	Drilling on raised row		10000	9637	93.82	123.80
	Broadcasting in beds		6549	9044	99.11	72.33
	Broadcasting on raised row		10160	10500	95.72	109.50
Nantes	Drilling on raised row		10420	11660	95.55	96.04
	Broadcasting in beds		5919	7835	77.09	85.62
		LSD at 0.05	901.7	750.3	10.06	7.83
		Pre emergence	11070	10520	107.90	100.90
		Post emergence	7214	9695	79.65	98.53
		LSD at 0.05	666.6	272.6	6.94	NS
Chantenay		Pre emergence	11150	10690	116.80	104.30
		Post emergence	7761	9750	79.39	100.50
Nantes		Pre emergence	11000	10350	99.01	97.57
		Post emergence	6668	9641	79.90	96.51
		LSD at 0.05	429.1	336.5	4.20	6.31
	Broadcasting on raised row	Pre emergence	13470	11250	116.70	116.50
		Post emergence	8505	11220	80.43	104.00
	Drilling on raised row	Pre emergence	11920	11100	108.60	110.90
		Post emergence	8505	10200	80.79	109.00
	Broadcasting in beds	Pre emergence	7836	9207	98.48	75.32
		Post emergence	4633	7673	77.72	82.63
		LSD at 0.05	901.7	750.3	10.06	7.83
	Broadcasting on raised row	Pre emergence	14280	12510	131.30	117.30
		Post emergence	9345	11440	71.55	104.80
Chantenay	Drilling on raised row	Pre emergence	10710	10370	111.00	130.90
		Post emergence	9293	8905	76.61	116.80
	Broadcasting in beds	Pre emergence	8453	9184	108.20	64.64
		Post emergence	4646	8905	90.01	80.02
	Broadcasting on raised row	Pre emergence	12650	9998	102.10	115.70
		Post emergence	7665	11000	89.31	103.20
Nantes	Drilling on raised row	Pre emergence	13130	11830	106.10	90.96
		Post emergence	7718	11490	84.96	101.10
	Broadcasting in beds	Pre emergence	7219	9230	88.75	85.99
		Post emergence	4620	6440	65.43	85.24
LSD at 0.05			1275	1061	14.23	11.07

The effect of the interaction between carrot cultivars and herbicide application time on yield was significant. Pre herbicide application surpassed the yield in both seasons and root weight in the first season as compared with post herbicide application within both cultivars.

The effect of interaction between planting methods and herbicide application on yield and root weight was significant. Plants sprayed with pre emergence herbicide had a higher yield (in both seasons) and root weight (in the first season) than those sprayed with post emergence herbicide . These results were true within any planting methods. Plants sown with broadcasting on raised rows and treated with pre-emergence Linuron recorded larger root weight than those treated with post emergence Linuron in the second season.

With regard to the interaction among herbicide application, planting methods and carrot cultivars, Chantenay broadcast on raised row and treated with pre-emergence herbicide and Nantes sown drilling on rows and treated with pre herbicide emergence in both seasons and the latest with post emergence treated herbicide in the second season recorded the highest carrot yield. On the contrary, broadcasting in beds and post emergence treatment with linuron resulted in the lowest yield of both cultivars in both seasons. The highest root weight was obtained by Chantenay which was treated with pre-emergence herbicide and sown on raised rows in the first season and sown by drilling on rows in the second season; and the lowest weight was recorded by treatment with post-emergence by both planting methods. Indeed, in 2019, Nantes cultivar with pre-emergence of herbicide and sown by broadcasting in beds or drill in raised rows had the lowest root weight values without any major differences.

Physical characters of carrot roots

Roots of "Chantenay" had significantly larger root diameter and core diameter (in both seasons) than those of "Nantes", but there were no noticeable differences between the two cultivars in root length in both seasons.

Concerning planting methods, carrot root length was not significantly influenced by any planting method in the first season. The maximum root length in the second season and diameter in both seasons were obtained by seed broadcasting on rows followed by seed drilling on rows then by broadcasting in beds, with no significant differences in root diameter between the latter two planting

methods. The highest core diameter in both seasons was recorded when the plants were sown by drill in rows, followed by planted by spreading in rows and broadcasting in beds in ascending order.

The interaction effect between cultivars and planting system on the physical characters of carrot roots was significant. "Chantenay" or "Nantes" grown by broadcasting on raised rows showed significant increase in root length in the second season compared to the other growing methods. In term of root diameter, there were no noticeable differences among planting methods of "Chantenay" in the first season and Nantes' in the second season. Also, there were no significant differences in core diameter among planting methods of each cultivar except for the second season; "Chantenay" grown by drilling on rows had the maximum core diameter.

Data concerning effect of herbicide addition time, is presented in Tables 3. The root length (in the two seasons), root diameter and core diameter (in the first season) were significantly higher in pre-emergence treated plants as compared with post-emergence ones.

Table 3. Effect of cultivars, planting methods, herbicide application time and their interactions on the physical characters of carrot root

Carrot cultivar	Planting method	Herbicide application time	Root length (cm)		Root diameter (cm)		Core diameter (cm)	
			2018	2019	2018	2019	2018	2019
Chantenay			18.23	17.23	4.10	3.92	1.93	1.76
Nantes			18.79	17.18	3.41	3.50	1.66	1.50
		LSD at 0.05	NS	NS	0.13	0.42	NS	0.09
	Broadcasting on raised row		18.74	18.23	3.85	3.84	1.80	1.66
	Drilling on raised row		18.72	17.11	3.77	3.79	1.88	1.80
	Broadcasting in beds		18.06	16.28	3.64	3.49	1.70	1.43
		LSD at 0.05	0.78	0.50	0.15	0.25	0.12	0.10
	Broadcasting on raised row		18.30	18.17	4.13	4.08	1.93	1.76
Chantenay	Drilling on raised row		18.44	17.35	4.11	4.07	2.00	2.06
	Broadcasting in beds		17.94	16.17	4.05	3.61	1.86	1.47
	Broadcasting on raised row		19.18	18.30	3.56	3.61	1.67	1.55
Nantes	Drilling on raised row		19.01	16.88	3.43	3.52	1.77	1.55
	Broadcasting in beds		18.18	16.38	3.23	3.38	1.55	1.39
		LSD at 0.05	1.12	0.71	0.22	0.36	0.17	0.22
		Pre emergence	18.94	17.63	3.97	3.73	1.95	1.64
		Post emergence	18.07	16.78	3.53	3.69	1.64	1.62
		LSD at 0.05	0.44	0.36	0.25	NS	0.17	NS
Chantenay		Pre emergence	18.97	17.94	4.33	3.97	2.01	1.72
		Post emergence	17.49	16.52	3.86	3.87	1.85	1.81
Nantes		Pre emergence	18.92	17.32	3.61	3.49	1.89	1.57
		Post emergence	18.66	17.05	3.2	3.51	1.43	1.43
		LSD at 0.05	1.01	0.75	0.19	NS	0.11	0.12
	Broadcasting on raised row	Pre emergence	19.25	19.16	4.08	3.93	1.97	1.70
		Post emergence	18.24	17.31	3.62	3.76	1.63	1.62
	Drilling on raised row	Pre emergence	18.87	17.18	3.96	3.83	1.98	1.79
		Post emergence	18.58	17.04	3.58	3.75	1.78	1.82
	Broadcasting in beds	Pre emergence	18.72	16.56	3.88	3.43	1.89	1.45
		Post emergence	17.40	16.00	3.40	3.56	1.52	1.42
		LSD at 0.05	1.12	0.71	0.22	0.36	0.17	0.22
	Broadcasting on raised row	Pre emergence	19.01	18.75	4.33	4.20	1.99	1.75
		Post emergence	17.60	17.59	3.93	3.96	1.87	1.77
Chantenay	Drilling on raised row	Pre emergence	19.07	17.97	4.35	4.11	2.07	1.91
		Post emergence	17.80	16.74	3.87	4.03	1.92	2.21
	Broadcasting in beds	Pre emergence	18.82	17.11	4.31	3.59	1.96	1.51
		Post emergence	17.06	15.24	3.79	3.63	1.76	1.44
	Broadcasting on raised row	Pre emergence	19.49	19.56	3.82	3.65	1.95	1.64
		Post emergence	18.88	17.03	3.31	3.56	1.39	1.46
Nantes	Drilling on raised row	Pre emergence	18.66	16.40	3.57	3.56	1.90	1.67
		Post emergence	19.35	17.35	3.28	3.48	1.63	1.44
	Broadcasting in beds	Pre emergence	18.61	16.00	3.45	3.27	1.82	1.39
		Post emergence	17.75	16.76	3.01	3.49	1.27	1.40
LSD at 0.05			1.56	1.00	0.31	0.50	0.24	0.31

Regarding the interaction between carrot cultivars and herbicide application time, Chantenay sprayed with pre herbicide application was significantly higher in root length in both seasons as well as root diameter and core diameter in the first season than post herbicide application. Meanwhile, in 'Nantes', there were no significant differences between the both herbicide applications in root length in both seasons and root diameter in the second season. The root diameter and core diameter of 'Nantes' were bigger in plants treated with pre emergence herbicide than those treated with post emergence herbicide in the first season and both seasons, respectively.

Concerning the interaction between planting methods and herbicide application, plants obtained from seed broadcasting in beds (in the first season) and broadcasting on raised rows (in the second season) and

treated with pre emergence herbicide produced longer root than those treated with post emergence herbicide. Plants sprayed with pre emergence herbicide in the first season had a larger root diameter and root core than those sprayed with post mergence herbicide, regardless of planting methods, while in the second season there were no significant differences between herbicide applications.

With regard to effect of the three variables, the longest root length was achieved by Chantenay or Nantes sown with any planting methods and treated with pre emergence of herbicide compared to Chantenay grown broadcasting in beds with post emergence linuron in the first season. In 2019, both cultivars had significant (p<0.05) long root when sown broadcasting on rows and treated with pre emergence of herbicide. The greatest root diameter was achieved by Chantenay treated with pre emergence of herbicide regardless the planting method during the first season relative to post emergence. The same trend was observed with Nantes sown by broadcasting or drilling on rows. Core diameter of carrot displayed different trend where no significant differences were recorded between the planting methods of spreading and drilling on rows regardless the cultivar in the first season, but they are higher than the broadcasting in beds. The highest significant value (p<0.05) was observed in the second season in Chantenay sown with drilling on rows.

Dry matter, firmness and TSS of carrot root

There were no noticeable differences between carrot cultivars or herbicide application times with respect to firmness or TSS in both seasons, and dry mater in the first season (Table 4).

Concerning the planting methods, the highest values of dry matter (in both seasons) as well as TSS and firmness (in the first season) were recorded using drilling on rows and broadcasting on rows, compared to broadcasting in beds.

The interaction between cultivars and planting methods showed no significant effect on TSS. The highest value of firmness was recoded in 'Chantenay' sown drilling on rows in the first season, but there were no significant differences among planting methods regardless of cultivars in the second season. The highest dry matter recoded in 'Chantenay' grown drilling on rows followed by broadcasting on raised rows then broadcasting in beds, but there were no significant differences between broadcasting on raised rows and drilling on rows in the second season. Concerning Nantes cultivar, there were no significant differences among different planting methods in the first season, while in second season, the maximum dry matter recoded in plants sown drilling on rows and the minimum dry matter recoded in those sown with broadcasting in beds.

Table 4. Effect of cultivars, planting methods, herbicide application time and their interactions on the dry matter, firmness and TSS of carrot root.

Carrot cultivar	Planting method	Herbicide application time	Dry matter(%)		Firmness (Kg/f)		TSS (%)	
			2018	2019	2018	2019	2018	2019
Chantenay			11.92	11.94	4.17	4.09	9.02	9.07
Nantes			12.1	12.24	3.77	3.71	8.88	9.38
		LSD at 0.05	NS	0.24	NS	NS	NS	NS
	Broadcasting on raised row		11.99	12.22	3.93	3.92	9.06	9.36
	Drilling on raised row		12.41	12.44	4.36	4.11	9.11	9.35
	Broadcasting in beds		11.64	11.60	3.62	3.68	8.69	8.96
		LSD at 0.05	0.42	0.32	0.51	NS	0.39	0.41
	Broadcasting on raised row		11.90	12.19	4.03	3.98	9.04	9.14
Chantenay	Drilling on raised row		12.57	12.06	4.76	4.44	9.25	9.26
	Broadcasting in beds		11.29	11.55	3.72	3.86	8.75	8.81
	Broadcasting on raised row		12.08	12.24	3.84	3.85	9.07	9.58
Nantes	Drilling on raised row		12.24	12.82	3.96	3.78	8.96	9.43
	Broadcasting in beds		11.99	11.66	3.51	3.51	8.62	9.12
		LSD at 0.05	0.60	0.46	0.72	0.61	0.55	0.58
		Pre emergence	12.10	12.38	3.85	3.86	9.05	9.22
		Post emergence	11.92	11.80	4.09	3.95	8.85	9.23
		LSD at 0.05	NS	0.52	NS	NS	NS	NS
Chantenay		Pre emergence	12.13	12.12	4.05	3.96	9.43	9.31
		Post emergence	11.71	11.75	4.28	4.23	8.60	8.82
Nantes		Pre emergence	12.08	12.63	3.64	3.76	8.67	9.12
		Post emergence	12.13	11.85	3.90	3.67	9.10	9.63
		LSD at 0.05	0.33	0.34	NS	NS	0.55	0.54
	Broadcasting on raised row	Pre emergence	11.99	12.63	3.86	3.82	9.20	9.43
		Post emergence	11.99	11.80	4.01	4.01	8.92	9.29
	Drilling on raised row	Pre emergence	12.47	12.82	4.17	4.12	9.16	9.26
		Post emergence	12.34	12.06	4.55	4.11	9.06	9.43
	Broadcasting in beds	Pre emergence	11.85	11.68	3.51	3.64	8.79	8.97
		Post emergence	11.43	11.53	3.72	3.73	8.59	8.96
		LSD at 0.05	0.60	0.46	0.72	NS	0.55	0.23
	Broadcasting on raised row	Pre emergence	11.63	12.20	3.99	3.89	9.61	9.52
		Post emergence	12.18	12.17	4.07	4.07	8.47	8.75
Chantenay	Drilling on raised row	Pre emergence	12.73	12.21	4.48	4.28	9.61	9.39
		Post emergence	12.41	11.92	5.04	4.60	8.89	9.14
	Broadcasting in beds	Pre emergence	12.04	11.96	3.70	3.70	9.06	9.04
		Post emergence	10.53	11.14	3.74	4.02	8.45	8.58
	Broadcasting on raised row	Pre emergence	12.35	13.05	3.73	3.76	8.78	9.33
		Post emergence	11.80	11.44	3.95	3.95	9.36	9.83
Nantes	Drilling on raised row	Pre emergence	12.22	13.43	3.86	3.95	8.70	9.13
		Post emergence	12.27	12.20	4.06	3.61	9.22	9.72
	Broadcasting in beds	Pre emergence	11.66	11.40	3.32	3.58	8.52	8.91
		Post emergence	12.33	11.91	3.71	3.44	8.72	9.33
LSD at 0.05			0.84	0.65	0.35	0.86	0.78	0.83

Concerning the interaction between carrot cultivars and herbicide application time, there were considerable differences in dry matter and TSS, although there was no significant impact on firmness. Dry matter (in both seasons) and TSS (in the first season) were slightly higher in Chantenay plants treated with pre emergence herbicide than those treated with post emergence herbicide. Meanwhile, Nantes plants treated with pre emergence herbicide had higher dry matter (in the second season) than those treated with post emergence herbicide. In contrast, there were no significant differences in TSS within both herbicide applications

The effect of interaction between planting methods and herbicide application on firmness and TSS was not significant. Plant sown with broadcasting on raised rows or drilling on raised rows and treated with pre-emergence Linuron showed a higher dry matter value than those treated with post emergence Linuron in the second season, while in the first season there were no noticeable differences between time of herbicide application.

As shown in Table (4), the highest dry matter recorded in Chantenay grown by drilling on rows followed by broadcasting on rows then in beds, but there were no significant differences between the planting methods in Nantes in 2018. Although drilling in rows during the second season maximizes the dry matter content of Nantes. Chantenay sown by drilling on rows was much harder as it recorded the highest firmness value in the first season. In 2019, there were no significant variation (p<0.05) among the planting methods applied for growing this cultivar. Interaction between planting methods and carrot varieties did not reveal any influence on TSS.

Regarding the effect of the three factors, dry matter was higher in both seasons in Chantenay sown by drilling on rows or broadcasting in beds and in Nantes sown by broadcasting or by drilling on rows that treated with herbicide pre-emergence. The same results were obtained by Chantenay sown by broadcasting on rows or drilled on rows and Nantes cultivar sown by drilling on rows or spread in beds after post emergence treatment compared to the third planting method. In terms of firmness, the highest values were registered by Chantenay treated with pre or post emergence linuron and Nantes treated just after post emergence of herbicide when they were sown by drilling on rows. In 2019, planting methods of broadcasting or drilling on rows resulted in significant high firmness values in both cultivars after linuron pre-emergence. No effect of the planting method on Chantenay plants post-emergence (p<0.05). Again Chantenay had the highest TSS percentage (9.06-9.61%) than Nantes in the first season when it was sown by any planting methods and handled with linuron pre emergence. Following the application of post-emergence linuron, Nantes contained more TSS particularly, when it was sown by broadcasting or drilling in rows in 2018.

Chemical composition of carrot roots

Total and reducing sugars and carotenoids

As shown in Table 5, the highest carotenoids, total and reducing sugars levels were significantly accumulated in Nantes cultivar and plants planting by broadcasting on raised rows as observed in the two seasons

Interaction between cultivars and planting method demonstrated that, Chantenay grown broadcasting on raised rows contained the highest carotenoids and reducing sugars content in both seasons, but those grown drilling on rows contained the highest total sugars in 2019. Meanwhile, Nantes produced by broadcasting on raised rows recorded substantially higher total and reducing sugars than the other planting methodologies. The same cultivar recorded the highest carotenoids when it was grown by drilling in rows. Again, broadcasting in beds recorded the lowest values of total and reducing sugars and carotenoids regardless of the variety.

As shown in Table 5, post emergence herbicide significantly exceeded (p<0.05) pre-emergence in carotenoids and reducing sugars, while the total sugars did not change by different herbicide application times during both seasons.

Concerning the interaction between cultivars and herbicide application, post emergence application significantly exceeded pre emergence application in reducing (in both seasons) and total sugars content (in first season), irrespective of cultivars. Chantenay plants sprayed with post emergence herbicide had significantly higher carotenoids content than those sprayed with pre emergence herbicide, while in Nantes there were no significant differences in carotenoids content between the two herbicide applications.

Plants obtained from seed broadcasting on raised rows or broadcasting in beds and treated with post emergence Linuron showed a higher carotenoids content as compared with those treated with pre-emergence Linuron. Meanwhile, plants obtained from seed drilling on raised rows and treated with pre-emergence Linuron showed a higher carotenoids content as compared with those treated with post mergence Linuron in both seasons.

Plants obtained from seed drilling on raised rows (in the second season) or broadcasting in beds (in both seasons) and sprayed with pre-emergence Linuron showed a higher total sugars value than those treated with post-emergence Linuron, while plants obtained from plants planted with broadcasting on raised rows and treated with post mergence Linuron had a higher total sugars value than those treated with pre-emergence Linuron in both seasons. Post emergence herbicide recoded a higher reducing sugars than pre-emergence herbicide within any planting methods.

Table (5) also showed the interaction between the herbicide addition time, planting methods and carrot cultivars. The highest score of carotenoid content was obtained by Chantenay when planted in raised rows and sprayed with linuron after leaves emergence. The highest scores of total sugars were recorded after treatment with post emergence herbicide in Nantes broadcasted on rows in both seasons and in Chantenay grown by broadcasting or drilling on rows in the second season. The highest score of reducing sugars was recoded in 'Nantus' grown with broadcasting or drilling on raised rows and sprayed with post emergence herbicide in both seasons.

Generally, the broadcasting in beds and pre-emergence treatment have contributed to a drop in the carotene, total and reducing sugars content in both cultivars to the lowest values.

Table 5. Effect of cultivars, planting methods, herbicide application time and their interactions on root content of carotenoids, total sugar and reducing sugar

Carrot cultivar	Planting method	Herbicide application time	Carotenoids (µg/g DW)		Total sugar (mg/g DW)		Reducing sugar (mg/g DW)	
			2018	2019	2018	2019	2018	2019
Chantenay			14.32	13.96	144.8	145.2	56.63	56.88
Nantes			16.43	16.59	156.6	156.3	63.64	65.79
		LSD at 0.05	0.63	0.54	0.62	1.30	1.91	1.92
	Broadcasting on raised row		20.01	20.19	165.1	164.3	63.56	64.64
	Drilling on raised row		15.56	15.66	159.8	160.8	60.401	62.08
	Broadcasting in beds		10.57	9.98	127.2	127.2	56.45	57.28
		LSD at 0.05	0.41	0.48	1.29	1.61	1.50	2.15
	Broadcasting on raised row		22.64	22.42	163.7	163.2	59.68	59.89
Chantenay	Drilling on raised row		11.76	11.55	163.6	165.7	57.28	58.65
	Broadcasting in beds		8.57	7.91	107.0	106.6	52.94	52.11
	Broadcasting on raised row		17.38	17.95	166.6	165.4	67.43	69.38
Nantes	Drilling on raised row		19.35	19.77	156.0	155.8	63.53	65.52
	Broadcasting in beds		12.57	12.04	147.3	147.8	59.97	62.46
		LSD at 0.05	0.57	0.68	0.57	2.28	2.12	3.05
		Pre emergence	14.44	14.13	149.9	149.9	53.72	56.11
		Post emergence	16.32	16.43	151.50	151.6	66.55	66.56
		LSD at 0.05	0.19	0.75	NS	NS	4.70	0.88
Chantenay		Pre emergence	12.40	11.65	143.8	144.3	49.75	51.38
		Post emergence	16.25	16.27	145.8	146.1	63.51	62.39
Nantes		Pre emergence	16.47	16.601	156.0	155.5	57.69	60.84
		Post emergence	16.40	16.58	157.3	157.1	69.59	70.73
		LSD at 0.05	0.88	0.77	0.88	1.84	2.7	2.71
	Broadcasting on raised row	Pre emergence	17.18	16.96	159.5	157.7	56.59	58.76
		Post emergence	22.84	23.41	170.8	170.8	70.52	70.51
	Drilling on raised row	Pre emergence	16.46	16.07	160.3	162.2	56.86	59.76
		Post emergence	14.66	15.26	159.4	159.4	63.95	64.41
	Broadcasting in beds	Pre emergence	9.67	9.34	129.8	129.8	47.71	49.81
		Post emergence	11.47	10.61	124.5	124.6	65.19	64.75
		LSD at 0.05	0.57	0.68	1.82	2.28	2.12	3.05
	Broadcasting on raised row	Pre emergence	16.79	15.77	158.7	157.0	49.58	51.33
		Post emergence	28.48	29.06	168.7	169.3	69.78	68.45
Chantenay	Drilling on raised row	Pre emergence	12.99	11.85	158.5	162.4	59.83	61.69
		Post emergence	10.53	11.26	168.7	169.0	54.74	55.62
	Broadcasting in beds	Pre emergence	7.42	7.33	114.2	113.5	39.85	41.12
		Post emergence	9.72	8.49	99.9	99.8	66.03	63.09
	Broadcasting on raised row	Pre emergence	17.57	18.15	160.3	158.5	63.61	66.20
		Post emergence	17.20	17.76	172.9	172.2	71.26	72.57
Nantes	Drilling on raised row	Pre emergence	19.93	20.29	162.1	161.9	53.90	57.83
		Post emergence	18.78	19.25	150.0	149.7	73.16	73.20
	Broadcasting in beds	Pre emergence	11.92	11.35	145.5	146.1	55.58	58.50
		Post emergence	13.21	12.73	149.1	149.5	64.36	66.41
LSD at 0.05			0.81	0.97	2.58	3.22	3.00	4.31

Phenolic compounds and antioxidant activity

Chantenay showed a higher level of phenolic compounds (in both seasons) and antioxidant activity (in the second season) than Nantes.

Plants sown broadcasting in beds reported the highest value of phenolic compounds, but those grown by drilling on rows showed the highest value of antioxidant activity.

The planting method had major impact on phenolics and antioxidant activity of the cultivars. As such, plants grown by broadcasting in beds contained the highest phenolic compounds in both seasons, regardless of cultivars. Chantenay drilled on rows or Nantes broadcasted on raised rows showed the highest antioxidant strength.

Concerning effect of herbicide time application, post emergence herbicide treatment resulted in higher levels of phenolic compounds and antioxidant activity compared to pre emergence herbicide treatment in both season (Table 6).

Chantenay treated with linuron as a post emergence demonstrated higher values of phenolic compounds than those treated with linuron as a pre emergence, while in Nantes, there were no noticeable differences phenolic compounds between the two herbicide applications. Nantes treated with post emergence application recorded higher value of antioxidant activity than those treated with pre emergence application, while in Chantenay, there were no noticeable differences in the antioxidant activity between the two herbicide applications.

Phenolic compounds of plants sown with broadcasting in beds and sprayed with post emergence Linuron was higher than those sprayed with pre-emergence Linuron. Antioxidant activity recoded a higher value in post emergence herbicide than pre-emergence herbicide, regardless planting metods.

With regard to the three factors impact, Chantenay treated with post-emergence herbicide and grown in beds had the highest phenolics (10.57 mg/g), but this planting method significantly lowered the antioxidant power in that cultivar. Post-emergence and row-broadcasting substantially increased the antioxidants to the maximum extent in Nantes followed by the drilling method. Irrespective the herbicide add-on time, drilling in rows was much better for Chantenay and spreading on rows for Nantes to maximize the antioxidant activity.

Table 6. Effect of cultivars, planting methods, herbicide application time and their interactions on root content of phenolic compounds and antioxidant

Carrot cultivar	Planting method	Herbicide application time	Phenolic compounds (mg/g DW) 2018	Phenolic compounds (mg/g DW) 2019	Antioxidant activity (%) 2018	Antioxidant activity (%) 2019
Chantenay			7.98	7.89	47.87	48.56
Nantes			6.33	6.50	46.99	46.57
		LSD at 0.05	0.28	0.47	NS	1.17
	Broadcasting on raised row		6.48	6.43	51.50	51.24
	Drilling on raised row		6.79	6.90	52.27	53.12
	Broadcasting in beds		8.20	8.25	38.52	38.33
		LSD at 0.05	0.44	0.38	1.82	1.51
	Broadcasting on raised row		7.26	7.13	46.63	46.99
Chantenay	Drilling on raised row		7.66	7.75	55.21	56.81
	Broadcasting in beds		9.03	8.79	41.78	41.89
	Broadcasting on raised row		5.71	5.74	56.37	55.50
Nantes	Drilling on raised row		5.91	6.05	49.34	49.43
	Broadcasting in beds		7.38	7.70	35.27	34.77
		LSD at 0.05	0.62	0.54	2.58	2.13
		Pre emergence	6.63	6.61	41.92	41.13
		Post emergence	7.69	7.78	52.94	54.00
		LSD at 0.05	0.54	0.50	3.47	3.69
Chantenay		Pre emergence	6.98	6.83	47.76	47.95
		Post emergence	8.98	8.95	47.98	49.18
Nantes		Pre emergence	6.27	6.38	36.09	34.30
		Post emergence	6.39	6.61	57.90	58.83
		LSD at 0.05	0.40	0.67	2.32	2.28
	Broadcasting on raised row	Pre emergence	6.25	6.16	47.69	46.46
		Post emergence	6.72	6.70	55.31	56.03
	Drilling on raised row	Pre emergence	6.64	6.83	45.14	43.83
		Post emergence	6.93	6.97	59.40	62.42
	Broadcasting in beds	Pre emergence	6.99	6.82	32.95	33.10
		Post emergence	9.42	9.68	44.10	43.56
		LSD at 0.05	0.62	0.54	2.58	2.13
	Broadcasting on raised row	Pre emergence	6.40	6.29	47.85	48.60
		Post emergence	8.12	7.97	45.40	45.38
Chantenay	Drilling on raised row	Pre emergence	7.05	7.11	51.65	50.57
		Post emergence	8.27	8.40	58.76	63.05
	Broadcasting in beds	Pre emergence	7.50	7.10	43.78	44.67
		Post emergence	10.57	10.49	39.77	39.10
	Broadcasting on raised row	Pre emergence	6.10	6.04	47.52	44.31
		Post emergence	5.31	5.43	65.22	66.68
Nantes	Drilling on raised row	Pre emergence	6.23	6.56	38.62	37.08
		Post emergence	5.60	5.53	60.05	61.79
	Broadcasting in beds	Pre emergence	6.48	6.54	22.12	21.52
		Post emergence	8.27	8.87	48.42	48.02
LSD at 0.05			0.88	0.76	3.64	3.02

Disscussion

1. Effect of cultivars, planting methods and time of linuron application on physical characters and yield of carrots plants.

There were significant differences between the two used cultivars in the most traits. In this regard, 'Chantenay' significantly exceeded 'Nantes' in the yield and in the most physical characters (length of the plant, root weight, root diameter, core diameter (in both seasons) as well as the plant fresh weight (in the first season). On the other hand, there were no noticeable differences between the two cultivars in plant fresh weight root length, root firmness and TSS in both seasons. These differences in the yield and physical characters of the carrot cultivars are attributed to the genetic variations between the two cultivars. Similarly, Lana (2012) found differences in the root weight between cultivars. Also, Correia and Carvalho (2017) found significant differences in root length among Brazilian carrot cultivars.

Plant fresh weight and root dry matter were significantly affected in one season, where plant fresh weight was greater in 'Chanteney' in the first season, and root dry matter (%) was higher in 'Nanats' in the second season. Zarzecka, *et al.* (2017) found that the dry matter it was affected by weather conditions.

With regard to planting methods, sowing carrot seeds broadcasting on raised row led to producing the heaviest plants (in the second season) (Table 1) that had the heaviest root fresh weight (Table 2), and largest roots, as a diameter and length (Table 3). The increase in root parameters led to producing the highest yield (Table 2). On the contrary, sowing carrot seeds broadcasting in beds showed significantly the reverse trend. (Tables 1, 2 and 3). These results may be attributed to the available areas between plants in each planting method, where the areas were the largest in seeds drilling (80 plant/m^2), and the smallest in seed broadcasting in beds (180 plant/m^2). These findings are consistent with Appiah, *et al*. (2017) who found that the smaller the distances between plants, the greater the competition between them for nutrients, water and air. Wider spacing plots recorded significantly increase in plant fresh weight and root weight and dimensions due to lack of competition among plants on those plots. These results are in agreements with Lana (2012), Appiah, *et al.* (2017) and Kharsan, *et al.* (2019) who found that the widest space between plants causes

significantly greater root diameter and longer roots. Kabir *et al.* (2013) explained that these plants absorbed more nutrients and had higher rate of photosynthesis than other plants. For this reason, these plants had large vegetative growth resulted in increased root length.

The wide spaces between plants that were found due to sowing carrot seeds broadcasting on raised row led also to larger roots and, as a result, higher yield.

Drilling seeds on raised row gave the highest values of core diameter, roots dry matter (%), TSS (%) and firmness followed by seeds broadcasting on raised row without significant differences between them, whereas seeds broadcasting in beds showed significantly the lowest values (Table 4). Kabir *et al. (2013*) showed that the maximum root dry weight was found at the larger space and the minimum was found at the narrower spacing, because spacing causes more consumption of dry mater of root than less density grown of carrot.

The present study indicated that generally pre-emergence treatment resulted in a significant increase in plant fresh weight (in the first season), greater roots weight (by 35.47% and 2.4% in 2018 and 2019, respectively) and substantially a higher yields (by 53.45% and 8.5% in 2018 and 2019, respectively) relative to post-emergence treatment (Table 1 and 2). The root length (in the two seasons), root diameter and core diameter (in the first season) were also higher in pre emergence treatment than those in post emergence application (Table 3). These findings may be related to improved weed control efficiency due to pre-emergence use of linuron compared to post emergence addition. Similar results were reported by Bell *et al.* (2000) who found that post emergent linuron treatment offered slightly poorer weed control than pre-emergent treatment and Van Heemst (1985) stated that weeds cause loss of carrot yields mainly by decreasing carrot root size due to direct competition for space, and water as well as growing nutrients.

There were no noticeable differences between carrot cultivars or herbicide application times with respect to firmness or TSS in both seasons, and dry mater in the first season (Table 4). Zarzecka, *et al.* (2017) found that the dry matter was not influenced by weed control methods such as herbicide application, but it was affected by weather conditions.

Effect of cultivars, planting methods and time of linuron application on chemical root quality.

The chemical root quality studied in the present work was total and reducing sugars, carotenoids, phenolic compounds and antioxidant activity. Chemical root quality is a very important character for human health. About 60% of the total carotene content in carrot is β-carotene (Bozalan and Karadeniz, 2011).

As shown in Table 5, roots of Nantes cultivar had higher contents of carotenoids (16.43, 16.59 µg/g), total (156.6,156.3 mg/g) and reducing sugars (63.64,65.79 mg/g). This result is in agreement with many researchers who have reported significant differences in carotene content among carrot varieties (Alasalvar *et al.*, 2001; Metzger *et al.*, 2008)

The maximum values of carotenoids were recorded in the planting method of broadcasting on raised rows (20.01, 20.19 µg/g) in 2018 and 2019, respectively and post-emergency treated plants (16.32, 16.43 µg/g), versus the other two planting methods and pre-emergence herbicide application. Seljasen and coauthors (2013) found that carrot content of carotene was higher with a low plant population than with a high plant population. These results are due to the fact that carotenoids act as photoprotive compounds in the photosynthetic system and low plant density causes an increase in UV radiation to the plants, thus leads to increase the carotene content of carrots.

On the other side, total sugars (glucose + fructose + sucrose) are important characteristics that decide the suitability of cultivar for direct consumption as well as the production of frozen packages, salads, pasteurized products (tinned food), as carrots containing more than 1% of these compounds have a sweet taste (Lee *et al.*, 2011). A higher total and reducing sugars levels were significantly accumulated in Nantes cultivar.

In the present investigation, post emergence herbicide significantly exceeded (p<0.05) pre-emergence in reducing sugars, while the total sugars did not change by different herbicide application times during both seasons. Meanwhile, the highest total and reducing sugars levels were significantly accumulated in plants planting by broadcasting on raised rows as observed in the two seasons.

Polyphenols are secondary metabolites that are essential in plants because they perform functions in response to stress conditions (Merino *et al.*, 2020). DPPH-free radical scavenging is an indicator of non-enzymatic antioxidant activity. Higher levels of DPPH activity were associated with increased tolerance to various negative environmental stimuli (Bozalan and Karadeniz, 2011)

Chantenay showed a higher level of phenolic compounds (7.98 and 7.89 µg/g in both seasons) and antioxidant activity (48.56% in the second season) than Nantes. These results are in accordance with the results of Alasalvar *et al.* (2001) and Leja *et al.* (2013) who recorded significant differences among some carrot cultivars in both attributes.

Plants sown broadcasting in beds reported the highest value of phenolic compounds, but those grown by drilling on rows showed the highest value of antioxidant activity. Kałużewicz *et al.* (2017) found that the content of the detected phenolic increased with an increase in plant density. According to Ghasemzadeh *et al.* (2010), the phenolic content of shaded plants can be affected due to the low temperatures under these conditions. Likewise, Machado *et al.* (2013) stated that the light-dependent induction of phenylpropanoid biosynthesis may have occurred in spinach of high planting density, giving the highest value of total phenol content and lowest antioxidants. Many investigators (D'Souza and Devaraj, 2010; Karimi *et al.*, 2013**)** stated that, the total phenolic content improved marginally as abiotic stress (e. g. light conditions, salinity, etc.) increased.

During both seasons of the study, post emergence herbicide treatment resulted in higher levels of phenolic compounds and antioxidant activity compared to pre emergence herbicide treatment (Table 6). Post-emergency herbicide caused stress in crops by negatively affecting photosynthesis, the opening and closing of stomata, and increasing vulnerability to fungi attacks and/or altering

physiological and metabolic functions (Das and Mondal, 2014). Thus, plant metabolism is changed by the application of herbicide and induces changes in fluorescence emission that are appeared in leaves before any other visible effect (Barbagallo *et al*., 2003). Reduced crop growth and yield can be influenced by a decline in photosynthesis (Ali and Honermeier, 2016); however, this stress can diminish the biomass production, alter the quantity of the secondary plant metabolites (Olivoto *et al.*, 2016); and increase the polyphenol content of the tissues (De Abreu and Mazzafera, 2005). Although, Merino *et al.* (2020) stated that the total polyphenol content did not change duo to the herbicide application regardless the effect on the quinoa yield.

CONCLUSION

From an economic point of view, the pre-emergency application of linuron is a recommended method than the post- emergency for obtaining the greatest yield of carrot crop with maximum physical carrot root measurements. However, the post-emergency method is better suited for achieving the maximum nutritional value, particularly antioxidants, and a darker orange color. Broadcasting in rows (140 plant/m^2) is the best method of carrot planting followed by drilling on rows (80 plant/m^2), while broadcasting in beds (180 plant/m^2)is the worst. Chantey was superior to Nantes in vegetative growth, yield, yield component, phenolic compounds and antioxidant power. In contrast, Nantes was the sweetest and contained more carotenoids and dry matter.

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تأثير بعض الممارسات الزراعية على إنتاجية الجزر و القيمة الغذائية

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تمت دراسة صنفين من أصناف الجزر (شانتاى- نانتس) خلال موسمى شتاء 2008 - 2009 لمعاملة اللينورون قبل وبعد الأنبات ، و لمختلف الطرق الزراعية (نثر و سر على الخطوط - نثر فى حوض) ، و تمت دراسة تأثير هذه العوامل على النمو الخضرى و تراكم القيمة الغذائية ، وقد أدت معاملة اللينورون قبل الأنبات إلى حدوث زيادة جوهرية فى المحصول والمادة الجافة و الصفات الطبيعية (طول الجذر ووزنه ، وقطر الكور والجذر) مقارنة بمعاملة اللينورون بعد الأنبات ، وتراكمت المواد الفينولية و مضادات الأكسدة فى شانتاى مقارنة بنانتس ، والتى زادت فيه الكاروتينات والسكريات الكلية والمختزلة بنسبة 14,73- 16,59 % ، 7,64 – 15.,8 % ، 12,37- 15,66 % عن الصنف شانتى فى عامى 2018 و 2019 على التوالى ، وبالنسبة إلى إنتاجية الفدان ، أدى النثر على الخطوط (140 نبات/متر^2) إلى زيادة فى المحصول ، وأن تصبح الجذور أكثر داكنة وأعلى حلاوة ، وقد تأثر الجزر تأثير كبير بوقت أضافة اللينورون من حيث المحصول والقيمة الغذائية ، و ارتبطت المواد الفينولية ومضادات الأكسدة بقوة بالصنف ، وكان الصنف شانتاى الأغنى بشكل عام.