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The Effects of Various Types of Press Wheels Mounted on Pneumatic Precise Drilling Machine on the Quality Criteria of Black Carrot

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Abstract: Black carrots are consumed as fresh vegetables in Turkey and are preferred in the form of fermented beverages in large quantities. Black carrots are cultivated in different regions of Turkey. The black carrot is cultivated heavily in the Eregli region. In this region, the highest yields for black carrots are obtained by planting on the ridge at narrow interval range with triplet drilling. In this study, the effects of front and rear stainless steel press wheel (BT_1), front and rear rubber press wheel (BT_2) and front and rear rubber press wheel and triple narrow intermediate rubber wheels (BT_3) on black carrot quality criteria in field conditions were investigated. According to results, yield, single carrot mass, diameter and length varied between, 15.11 and 41.61 t ha^{-1}, 76.96 and 226.43 g, 33.61 and 53.14 mm, and 193.65 and 237.33 mm respectively. It was found that total phenolic varied between 349.80 and 745.37 mg gallic acid equivalent $(100\ ml)^{-1}$ and the antioxidant activity value, determined by DPPH, varied between 26.71% and 54.80%.

Keywords: Press wheel, plant distribution on the row, yield, black carrot, quality criteria

1. INTRODUCTION

The carrot (*Daucus carota*) is a perennial plant from the *Umbelliferae* family. In Turkey, carrots are produced to a large extent in the Central Anatolia and Konya regions. Black carrots are an important agricultural product and source of income for Turkey, specifically in the Eregli District. It is estimated 40 000 to 50 000 decares of production are made in the area and according to the production area by years, approximately 100 000 to 150 000 tons of products have been manufactured. Although the fresh consumption of black carrots in our country is low, it is nevertheless preferred as a fermented beverage in high quantities.

Considering the production history of black carrots in the region until 2008, exports of black carrots were primarily as a raw material, and since then exports as a concentrate (i.e. as a fermented drink) have gained greater momentum. In production, approximately 80% is concentrated, while 20% is used in the turnip industry. The turnip juice obtained from the black carrot is a fermented product with many appealing properties [1]. One of the most important

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properties of turnip juice is the lactic acid content. Aside from the sour taste encountered in turnip juice, lactic acid is known also to be a digestive facilitator, refresher, pH regulator of the digestive system, and provides other more beneficial properties to the body in order to utilize more minerals [2].

Black carrots are a potential source of anthocyanin pigment with high antioxidant activity. Its composition is characterized by its high anthocyanin content (1750 mg kg^{-1}) and special quality parameters [3]. Anthocyanins are best known as natural food dyes that provide the bright red color in some foods such as blueberries and pomegranates, and moreover are considered an important alternative to synthetic dyes in the dyeing of many foods [4 and 5]. Fruit colored with black carrot juice provides significant benefits against chronic diseases due to the high anthocyanin content. In vascular diseases for instance, particularly arterial thickening, cancer, diabetes and disorders of nerve degeneration and in certain eye diseases, it has been shown to be especially therapeutic [6 and 7]. The pigment of the anthocyanin in black carrots is acylated with p-coumaric, ferulic, p-hydroxybenzoic acid and sinapic acids and thus more resistance to hydration, light and food pH. The black carrot extract gives an excellent strawberry red brilliance at acidic pH values. Fruit juice is used for coloring, softness, protection, glazing, and in pastries; as such, an e-number is not required in food labels because it is a natural additive [8]. Black carrot concentrate is also used as natural fabric dye. Synthetic fabric dyes is expected to be prohibited in the coming years and thus the use of natural dyes such as that from black carrots will be more important.

In recent years, narrow row spacing vacuum pneumatic precision sowing machines have begun to be used in the region. The pressure wheels used in these machines are flat sheet or flat tire. These machines also have pressure wheels with triple narrow tires in the middle. By planting two or three rows of carrots instead of a single row of seeds, agricultural products with high quality market value can be obtained. It has been reported that the seed quality can increase due to the uniformity of the habitat area within the narrow row spacing [9]. For this reason, it was aimed to determine the effects of press wheels on plant distribution uniformity, yield, and carrot quality in black carrot cultivation with a pneumatic sensitive vegetable sowing machine.

2. MATERIAL and METHODS

The research was carried out in the village of Kuzukuyusu, located in the Eregli District of Turkey, and according to the trial design of the divided parcels, three repetitions were conducted. In the experiments, a local ancient carrot genotype known with its common name “Eregli variety” (*Daucus carota* L.) was used. The seeds were uncoated, with a thousand seed weight of about 1.65 g and 88% germination rate as determined in the laboratory.

The sowing was done in three rows in the back and 7.5 cm between rows (Figure 1). In the experiments, the seeds were made at the same planting depth in all applications. The schematic view of the pneumatic precision vegetable seeding machine is given in Figure 2. The feed rate of the sowing machine was chosen to be 0.75 m s^{-1}.

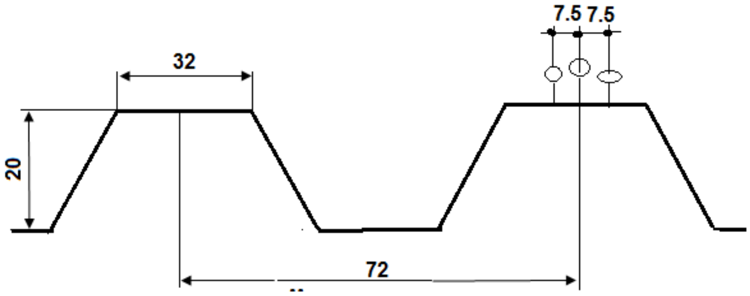


Figure 1. Measurements of the back ridge (Measurements cm)

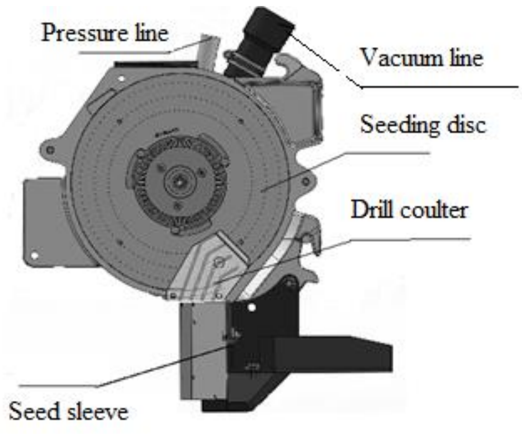


Figure 2. Schematic view of the sowing unit

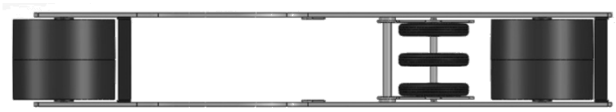
The research was conducted on three different rows with varying sowing distances (Z_1=2.38, Z_2=4.65 and Z_3=6.78 cm) and on three different rollers. These pressure wheels consisted of a front and rear pressure tire (BT_1), a front and rear pressure sheet (BT_2), and a front and rear pressure tire with a triple narrow tire (BT_3) in the middle (i.e. Figures 3, 4 and 5, respectively). Each parcel is arranged to have a length of 50 m and a width of 2.8 m.

Material	: Tire
Diameter	: 250 mm
Width	: 200 mm
Mass	: 72.9 N

Figure 3. Front and rear pressure tire (BT_1)

Material	: Sheet
Diameter	: 217 mm
Width	: 200 mm
Mass	: 59.7 N

Figure 4. Front and rear pressure sheet (BT_2)



Narrow wheel

Material	: Tire
Diameter	: 180 mm
Width	: 30 mm
Mass	:10.6 N
Number	: 3 pieces

Figure 5. Front and rear pressurized tire and pressure spring adjustable medium triple narrow tire (BT_3)

The clay content in the experimental field was determined to be 22.90%, with a silt content of 7.50%, and a sand content 69.90%. The soil texture class was categorized as Sandy-clay-loamy. Soils had a low organic matter content (1.45%) and aggregate stability value (5.90%). The soil was considered to be a very high calcareous soil, with lime content as 37.49% $CaCO_3$ and a pH value of 8.27, denoting a middle grade alkaline class.

Sowing was carried out from the end of April to mid-November 2015. Meteorological data from April to November covering these vegetation periods are given in Table 1. The seed bed was prepared in mid-February and plowed at the end of March 2015. Using a centrifugal distributor, a DAP fertilizer rate of 40 kg da^{-1} was distributed in late April 2015. The seed bed was prepared by using horizontal rototill in late April and sowing ridges were formed with a ridge making machine (Table 2). The harvesting was carried out in mid-November 2015 and the experimental parcels were irrigation was supplied 23 times to, with 1 904 mm water given in total.

Table 1. Monthly meteorological data from the black carrot growing season [10].

Months (2015)	Average Monthly Maximum Temperature (^{0}C)	Average Monthly Minimum Temperature (^{0}C)	Monthly Average Temperature (^{0}C)	Monthly Average Rainfall (mm)
April	16.0	3.1	11.3	32.4
May	24.0	9.3	17.8	45.0
June	26.3	12.6	19.9	73.8
July	31.8	15.0	26.6	0.2
August	32.6	17.0	27.3	9.6
September	31.4	13.6	24.3	0.0
October	21.9	9.4	16.7	49.2
November	15.6	1.0	8.6	0.0

Table 2. Agricultural operations applied to the experimental plots in 2015 production

Dates	**Agricultural practices**
16.02. 2015	Seed bed preparation
30.03.2015	Plowing
23.04.2015	Centrifugal fertilizer distribution (DAP with 40 kg da^{-1} fertilizer norm)
25.04.2015	Preparation of seed bed with horizontal rototil
26.04.2015	Sowing preparation of ridges
26.04.2015	Sowing operation
21.05.2015	Inter-row hoeing
28.05.2015	Weed treatment (Linourin 150 g da^{-1})
04.06.2015	Sprinkler irrigation with 15 kg da^{-1} fertilizer UREA
17.06.2015	Fertile intermediate diameter (15 kg da^{-1} fertilizer UREA)
24.06.2015	Addition of humic acid with sprinkler irrigation 2 kg da^{-1}
29.06.2015	Removal of weeds
05.07.2015	Ammonium nitrate fertilizer application at 10 kg da^{-1} with sprinkler irrigation
14.07.2015	Ammonium nitrate fertilizer application at 10 kg da^{-1} with sprinkler irrigation
22.07.2015	Ammonium nitrate fertilizer application at 10 kg da^{-1} with sprinkler irrigation
25.07.2015	Inter-row hoeing
08.08.2015	Remove bolting plants
16.09.2015	Remove bolting plants
18.11.2015	Harvesting

Spacing measurements on row were performed on a 10 m length of row on randomly selected three rows of each plot 30 days after the seeding date and plant spacing was measured with a steel rule. Variation coefficient for on-row plant distribution was calculated by using the following equation.

$$VC=\sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}\cdot\frac{100}{\bar{x}}$$

x : Average planting spacing on-row (cm)
$\bar{x}$: Measured planting spacing on-row (cm)
n : Number of measured planting spacing on-row
VC : Variation coefficient (%)

In yield measurements, five carrot samples of approximately 1.4 m in length were removed, cleaned and weighed from each plot. Black carrots were evaluated according to the extra class, based on the carrot boiling standard specified in TS 1193. Larger diameters of extruded carrots should be between 25 and 45 mm in diameter and masses between 50 and 200 g [11]. The method recommended by [12] for the determination of total phenolic materials of the samples taken from the field was used. This method is based on the fact that the phenolic compounds form a blue complex by reducing the phosphololybdic-phosphotungstic solution of the Folin-Ciocalteu solution and that this blue color is measured colorimetrically [13]. The results are given as Gallic acid equivalent (GAE). Antioxidant activity was determined by the DPPH (1,1-diphenyl-2-picrylhydrazyl) method [14].

It was analyzed by the Shapiro-Wilk test to determine whether the data showed a normal distribution. Variance analysis was performed using the MINITAB 16 program. LSD analysis was performed on the properties with variance at 1% and at least 5% significance level among the applications. These analyzes and calculations were made in the MSTAT-C package software.

3. RESULTS

Plant distribution uniformity and yield values for the 2015 black carrot growing season are given in Table 3. As it is shown in the table, under field conditions, the average rate of increase of plant per distance over the designated row was obtained. The lowest average was determined for the BT_2 press at 2.86 while the highest at 3.42 was obtained in the BT_1 press wheel. When the coefficient of variation was evaluated, the average coefficient of variation obtained at three distances was BT_1 with 97.85%, BT_2 with 87.07% and BT_2 with 86.88%. Yield values changed between 15.11 t ha^{-1} and 46.82 t ha^{-1}. The maximum yield value was shown to be with the BT_2 pressure wheel with an average of 30.70 t ha^{-1}, followed by the BT_3 pressure wheel (i.e. 30.62 t ha^{-1}) and the BT_1 pressure wheel with 30.07 t ha^{-1}. A variance analysis on yield values, indicated there was no statistically significant relationship between pressure wheels (F = 0.30). When the distance (F = 11.82) was examined, the yield value of 36.33_a t ha^{-1} was obtained at the Z_1 planting distance, 30.14_{ab} t ha^{-1} at the planting distance Z_2 and 22.91_c t ha^{-1} at the planting distance Z_3. Differences between the positions above and below were statistically significant at 1% level (LSD = 7.985), but no difference can be drawn between the Z_1 and Z_2 planting distances.

However, a significant interaction was found between pressure wheel and row distance (F=3.78) and the highest yield values were obtained at the Z_1 sowing of the pressure wheels. The average yield of agricultural enterprises in the region varies between 2 and 5 t da^{-1}. When an evaluation is made in this respect, it can be said that the regional average yields are achieved outside the Z_3 planting distance.

The mass, diameter and height values obtained after measurement of the black carrots taken from the parcels are given in Table 4. As a result of the analysis of variance applied to the mass, diameter and height values of black carrots, the pressure wheel was not found statistically significant, but the distance between row spacing and interaction pressure wheel by the distance between the row spacing was statistically significant. When the mass values of black carrots were examined, results showed there was a change between 76.96 g and 226.43 g. When the above distances were examined, it was found that the highest mass value was obtained at a distance of Z_3 with 178.97 g (Table 5). However, when the interaction was examined, the highest mass value (226.43 g) was obtained in the parameter of BT_3Z_3.

Table 3. Plant distribution smoothness and yield values on row in black carrot cultivation

Pressure Wheel	Row over theoretical distance (cm)	Average Row Spacing (cm)	The coefficient of variation (%)	Yield (t ha^{-1})
	2.38	11.44	113.25	41.61_{a}
BT_1	4.65	14.35	102.03	33.48_{abc}
	6.78	16.05	78.28	15.11_{d}
	2.38	8.67	84.36	31.95_{abc}
BT_2	4.65	12.49	91.25	30.61_{bc}
	6.78	15.24	85.59	29.56_{bc}
	2.38	7.58	86.40	35.44_{ab}
BT_3	4.65	13.56	91.08	26.34_{bc}
	6.78	21.05	83.16	24.07_{cd}
				LSD ($p<0.05$)=10.050

Table 4. Mass, diameter and height values of black carrots and applied LSD test

Pressure Wheel	Distance over the row	Mass (g)	Diameter (mm)	Height (mm)
	Z_1	76.96_{d}	33.61_{c}	208.63_{bcd}
BT_1	Z_2	142.59_{b}	41.05_{b}	209.25_{bcd}
	Z_3	152.60_{b}	43.40_{b}	213.82_{bc}
	Z_1	83.39_{d}	35.30_{c}	193.65_{d}
BT_2	Z_2	134.98_{bc}	42.79_{b}	216.63_{bc}
	Z_3	157.88_{b}	44.63_{b}	224.45_{ab}
	Z_1	81.11_{d}	33.74_{c}	201.85_{cd}
BT_3	Z_2	99.47_{cd}	41.33_{b}	216.03_{bc}
	Z_3	226.43_{a}	53.14_{a}	237.33_{a}
		LSD ($p<0.01$)=1.851	LSD ($p<0.05$)=5.598	LSD ($p<0.05$)=10.030

Table 5. LSD test applied to the mass, diameter and height values obtained from averages over distance

Distance over Row	Average Mass (g)	Average Diameter (mm)	Average Height (mm)
Z_1	80.49_{c}	34.21_{c}	201.38_{c}
Z_2	125.68_{b}	41.72_{b}	213.97_{b}
Z_3	178.97_{a}	47.06_{b}	225.20_{a}
	LSD ($p<0.01$)=1.068	LSD ($p<0.01$)=4.428	LSD ($p<0.01$)=10.03

When the diameter measurement values of black carrots were examined, it showed there was a change between 33.61 mm and 53.14 mm. When the sowing distances were examined, results showed that the highest mass value was obtained at Z_3 (47.06 mm) and at Z_2 planting distance (41.72 mm) and there was no statistical difference between them. When the spacing interaction with the pressure wheel was examined, the highest diameter value was found for BT_3Z_3 (53.14 mm).

The height values of black carrots varied between 193.65 mm and 237.33 mm. Results showed that at the planting distance Z_3 the highest height average of 225.20 mm was obtained, however when the distance between the pressure wheel and the row is measured, results showed that BT_2Z_3 (224.45 mm) and BT_3Z_3 (237.33 mm) had the highest values. In a study about yellow carrots it was reported that the maximum length value for Nantura F1 was 18.00 cm and 17.74

cm for Bertan F1 in mid-October of 1999. Furthermore, for the Asubeni F1 variety the highest mass average was 117.7 g and the lowest length value was 13.72 [15]. In this respect, our values correspond with those of the literature.

Carrots with large diameters entering the extra classifications, and classified according to the carrot boiling standard determined in TS 1193 (i.e. one of the quality criteria of black carrot), must have a diameter ranging between 25-45 mm and a mass value between 50-200 g. Hence, large diameter and mass interval values for our black carrot samples were set according to these standards, and the percentage ratios of the small and large ones from the limit value are given in Table 6.

Table 6. Distribution of diameter and mass values

Pressure Wheel	Row Spacing	Carrot diameter distribution (%)			Carrot weight distribution (%)		
		<24.99	25- 45	>45.01	<49.99	50- 200	>200.01
BT_1	Z_1	24.42	61.30	14.29	37.28	59.25	3.47
	Z_2	6.67	45.48	47.85	16.23	56.68	27.09
	Z_3	0.00	24.81	75.19	1.75	42.60	55.64
BT_2	Z_1	26.16	56.46	17.38	39.14	52.15	8.52
	Z_2	7.88	47.02	45.10	15.93	54.36	29.71
	Z_3	14.94	45.54	39.52	20.98	56.70	22.32
BT_3	Z_1	13.89	70.54	15.58	36.37	59.17	4.46
	Z_2	5.50	52.97	41.53	13.33	65.75	20.92
	Z_3	7.65	51.54	41.82	20.66	56.04	23.30

When the distribution of carrot diameters was examined in terms of pressure wheels, it was determined that the distribution between 25-45 mm diameters varied between 24.81% and 70.54% and the distribution of diameters <24.99 mm varied between 0 and 26.16%. The distribution of carrot diameters > 45.01 changed between 14.29% and 75.19%. Variance analysis for the diameter range 25-45 mm showed a statistical significance for the parameters of pressure wheel ($F = 6.75$) and row distance ($F = 16.00$). When the pressure-only averages were examined, it is clear that in the BT_2 and BT_3 press wheel, when considering the distances between the rows, the maximum values of the distances between 25-45 mm were obtained at the Z_1 sowing distance (Table 7).

Table 7. LSD test applied to average of 25-45 mm diameter ranges

Pressure Wheel Average	Average Row Spacing
BT_1 43.86_b	Z_1 62.76_a
BT_2 49.67_{ab}	Z_2 48.49_b
BT_3 58.34_a	Z_3 40.63_b
LSD (p<0.01)=11.42	LSD (p<0.01)=11.42

Results of measurements of mass values in the study, found the change of rates of carrot fractions with masses of 50-200 g were between 52.84% and 60.32%. It was determined that the mass of carrots lighter than 49.99 g is between 18.42% and 25.35% and the mass of carrots weightier than 200 g is between 16.22% and 28.73%. Analysis of variance applied to carrot fractions with masses between 50 and 200 g did not reveal a statistically significant relationship between pressure wheel ($F = 1.30$), row distance ($F = 1.13$) and pressure wheel and row spacing interactions ($F = 0.96$).

It can be said that the carrot diameter and mass values were generally evaluated, but the distance of the row had a significant impact. It is evident that the proportion of carrots with diameters <24.99 mm and between 25-45 mm in diameter decreases while the ratio of those with diameters >45.01mm increases. In general, it can be said that similar relations are also seen in the diameter range values of 25-45 mm.

The moisture, brix, total phenolic material and antioxidant activity values of the harvested black carrots are given in Table 8. The obtained moisture values ranged from 83.54% to 88.11% and the brixs values ranged from 9.87% to 11.57%. Total phenolic values of black carrots ranged from 349.80 to 745.37 mg GAE (100 ml) $^{-1}$. The highest total amount of phenolic material was obtained in the BT_2 press wheel [505.68 mg GAE (100 ml) $^{-1}$] and Z_2 planting distance [619 mg GAE (100 ml) $^{-1}$] based on the distance averages over the printing press averages. Antioxidant activity values ranged from 28.71% to 69.48%. The highest antioxidant activity values were found in the BT_2 press wheel (45.50%) and at the Z_2 planting distance (55.66%) when the average of the pressurized and row spacing were examined. In studies using black carrots, the antioxidant effect value of the black carrot concentrate was found to be 10.98% in unpasteurized black carrot juice [16], 187.8 in the amount of phenolic substance in the Antonina variety and 492 89 mg GAE (100 g) $^{-1}$ in the Purple Haze variety [17]. Reports also stated that the antioxidant effect of black carrot concentrate was 89.71% [18]. The reported high antioxidant value may be due to the different antioxidant contents of black carrot varieties. The results obtained generally correspond to the data obtained in the investigations.

Table 8. Phenolic substance and antioxidant activity values

Pressure Wheel	Row Spacing	Moisture (%)	Brixs (%)	Total Phenolic Matter [mg GAE (100 ml) $^{-1}$]	Antioxidant Activity (%) DPPH
	Z_1	85.22	11.57	388.43	28.71
BT_1	Z_2	83.54	11.27	745.37	54.80
	Z_3	88.11	10.33	349.80	30.01
	Z_1	83.63	10.37	510.47	40.30
BT_2	Z_2	85.18	9.87	633.30	69.48
	Z_3	85.03	10.67	373.26	26.71
	Z_1	83.61	11.37	507.01	41.81
BT_3	Z_2	85.91	11.00	478.00	42.70
	Z_3	84.21	11.00	490.67	42.21

4. DISCUSSION

Black carrot farming in the Eregli Region uses seeds that are of a local population. In addition, these seeds are not classified according to quality class. Therefore, the planting quality is deteriorating. According to the results of the experiment, planting should be done on small rows at planting distances in order to obtain the desired plant density in the sowing of black carrots. Field tests suggested to plant with pressure wheels (BT_2), which are front and rear press wheels, due to the lowest increase in the row, the lowest variation coefficient value and the highest average yield values. In terms of quality criteria, total phenolic substance and antioxidant activity values containing mass values between 50 and 200 g, determined Z_2 should be planted at the planting site.

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Conflict of Interests

Authors declare that there is no conflict of interests.

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