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PERFORMANCE OF PNEUMATIC PRECISION SEED DRILL IN BLACK CARROT SOWING

Mustafa Nevzat Ornek[1], Ali Yavuz Seflek[2] and Haydar Haciseferogullari[2,*]

[1]Department of Computer Engineering, Faculty of Technology, Selcuk University, 42031, Konya, Turkey;
[2]Department of Agricultural Machineries and Technologies Engineering, Faculty of Agriculture, Selcuk University, 42031 Konya, Turkey.
***Corresponding author's e-mail: hhsefer@selcuk.edu.tr**

In this study, non-pelleted black carrot seeds were planted over the ridges under field conditions. Planting was performed over three narrow spacing rows with a vacuum-type pneumatic single-seed planter. Planter forward speeds were arranged as 0.42, 0.84 and 1.25 m s^{-1} and on-row seed spacing was arranged as 2.34, 4.65 and 6.87 cm. Experimental plots were observed during the initial month after planting. Mean germination times, germination rate index, field emergences, on-row plant distribution patterns and number of plants per unit area were evaluated. Variation coefficients indicating the on-row plant regularity were between 62.86 and 86.42%, mean germination rates between 15.98 and 23.07 days, germination rate index values between 0.321and1.502 per meter, field emergence rates between 34.26 and 69.70% and number of plants between 37.66 and 70.66 plant m^{-2}.

Keywords: Black carrot seed, ridge planting, on-row plant distribution, germination rate index, field emergence rates.

INTRODUCTION

Carrot (*Daucus carota)* is a biannual plant of Umbelliferae family. Roots of black carrot are consumed as vegetable. It has multipartite leaves and small, white and tight umbrella-shaped flowers. Carrot is widely cultivated in Central Anatolia Region and especially in Konya province of Turkey. In black carrot production on the other hand, Ereğli town of Konya has the first place in Turkey. There is a recent increase in black carrot production fields of the region. Although reliable data is not available, it was reported that black carrot traders of the region contracted about 150 -160 thousand tons of produce. Such contracted amounts correspond about 40 thousand decares of production sites.

Black carrots contain various healthy ingredients such as sugar, vitamin A and creatine. Chemical composition of black carrot is provided in Table 1. It was also stated in a research that black carrots have about 26.40 mg. 100 ml^{-1} ascorbic acid in their chemical composition (Kirca, 2004).

Table 1. Some analytical characteristics of black carrots (Gunes, 2008).

Analytical characteristics	Amount
Dry matter (g kg^{-1})	110.54
Total sugar (g kg^{-1})	68.3
pH	6.04
Total acidity (g kg^{-1})	0.23
Ash (g kg^{-1})	8.68
Anthocyanin (mg kg^{-1})	1440.3

Since black carrot has high anthocyanin content and easily processed into carrot juice concentrate, it is commonly used as anthocyanin source. Anthocyanins are the most popular commercial natural pigments. They provide the carmine color to foods and they are the best known natural food dyes. Therefore, they are commonly used as an alternative of synthetic food dyes (Giusti and Wrolstad, 2003). Anthocyanins were proved to have therapeutic effects on vascular diseases and some eye diseases (Kong *et al*., 2003). There are also several anthocyanin-containing pharmaceutical products in markets.

Fermented black carrot juice has an appetizing characteristic (Canbas and Deryaoglu, 1993). It has high lactic acid content. Besides providing a sour flavor to carrot juice, lactic acid also has digestive and refreshing effects, adjust the pH of digestive system and allows the body to benefit more from some minerals (Miisoglu, 2004). Black carrot is also a good source of ascorbic acid. Ascorbic acid contents of carrots vary between 4 mg. 100g^{-1} (Favell, 1998).

Seeding norm is relatively small in planting small vegetables and oil crop seeds. Therefore, it is hard to provide equal living space. Such seeds are also highly expensive. Since sowing norms are arranged at about a few times higher than the required values, cost of production is increasing. Thus, high-performance planters should be used for such a small seeds.

When the on-row seeding spacing is blow 5 cm, a distinctive decrease was observed in sowing performance of single-seed planters. Rather than single seed planters, regular row planters with slot-type driller are preferred in narrow row spacing sowings just to reduce the cost of planting (Griepentrog,

1994). There are limited studies in Turkey about the performance of seed throwing pulleys in alfalfa and sesame seeding (Yildirim and Turgut, 2007), pelleted or non-pelleted canola seeding (Ertugrul, 2010) and carrot seeding (Onal and Ertugrul, 2011).

Various planting methods and tools are employed in black carrot planting implementations of the region. Among them, ridge-sowing row planters with sprocket reels are commonly used in carrot seeding. Recently, vacuum-type precise pneumatic ridge planters are started to be used in narrow row spacing seeding. Therefore, in this study, non-pelleted black carrot seeding was performed by using a locally produced vacuum-type precise pneumatic planter able to seed three narrow-space rows under field conditions and planter performance was evaluated.

MATERIALS AND METHODS

The present study was conducted in Kuzukuyusu Village of Ereğli with intensive black carrot culture during the year 2012. Experimental fields were plowed with moldboard plows. Cultivator, rototiller and ridge-forming machines were used to prepare seed beds. Experiments were conducted in randomized block design with three replications over 3 x 50 m plots. Experimental fields has loamy texture (L) with slightly alkaline (pH = 8.44) and un-saline soils. Potassium content of experimental soils was sufficient, phosphorus levels were insufficient and lime contents were relatively high. Soil sieve analysis results of seed bed are provided in Table 2 and technical specifications for pneumatic single-seed planter are provided in Table 3.

Table 2. Seed bed sieve analysis results.

Sieve diameter (mm)	Dry aggregate (%)
0.42<	28.10
0.42- 0.84	3.70
0.84- 2.0	7.30
2.0- 6.4	5.80
6.4- 12.7	40.60
12.7>	14.60

Table 3. Technical specifications for pneumatic single-seed planter.

Number of unit	4
Length	2500 mm
Width	1650 mm
Height	1450 mm
Weight	525 kg
Track width	1410 mm
Diameter of front and rear pressure wheels	220 mm
Width of front and rear pressure wheels	175 mm
Type of front and rear pressure wheels	Stainless steel

Schematic view of vacuum-type pneumatic single-seed planter able to sow narrow-space three rows of a ridge at a time are presented in Figures 1, 2 and 3. Hollow seeder plate of the planter has a diameter of 235 mm and thickness of 0.25 mm. Hollow diameter is 0.5 mm and there are three rows of hollows over the plate each of with 96 hollows. From the outer circle to inner one, diameters of hollow circles are ordered as 210, 185 and 155 mm. Although the linear velocity of hollows over there lines are different, they provide the same on-row seed spacing. Complying with three-rows sowing technique, vacuum chamber is separated into three galleries. Seeds are attached to hollows on seeding plate in three rows through the negative pressure and single-out apparatus ensures that each hollow has a single seed. Then, seeds are dropped into seeding foot with three galleries through seed sleeves with the shot down of vacuum pressure and pressurized air. Experiments were implemented at 30 mbar vacuum pressure and 10 mbar air pressure.

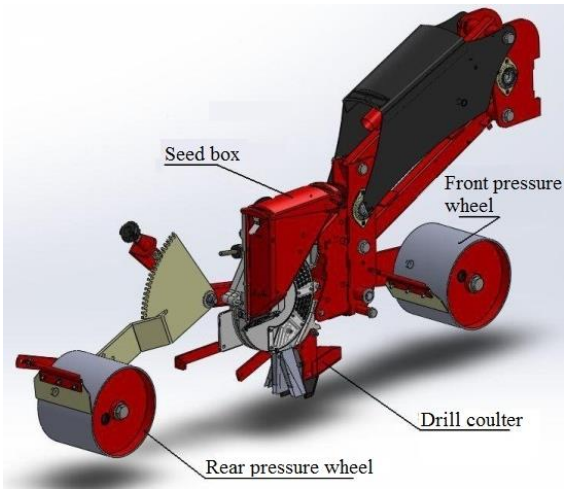

Figure 1. Schematic view of a seeding unit

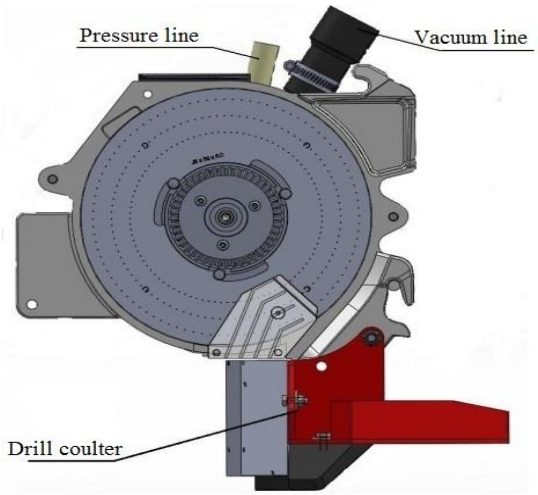

Figure 2. Front view of seeding unit

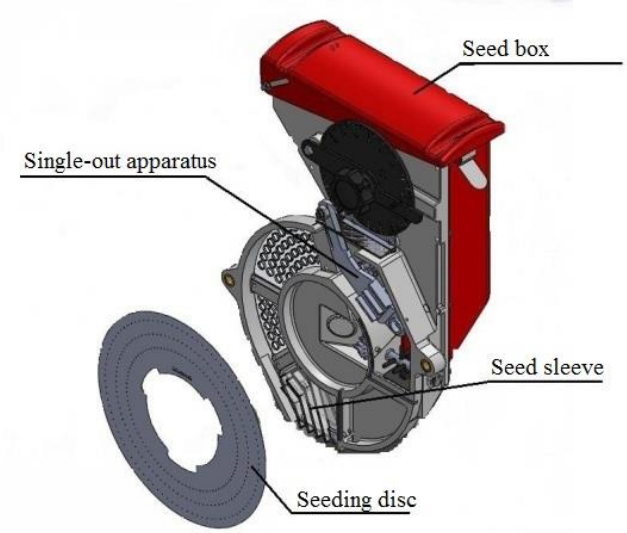

Figure 3. Rear view of seeding unit

Seeder plate receives the strokes from the right wheel of the machine (Fig. 4). The stroke taken from the wheel is transferred to gear box through Z_1 and Z_2 sprockets. There are two sprocket groups in gear box. The shaft indicated with A has 6 sprockets with 16, 17, 18, 19, 20 and 21 jogs and the other shaft indicated with B has 5 sprockets with 11, 13, 17, 21 and 24 jogs. The stroke out of the gear box is then transferred to main stroke shaft through Z_5 and Z_6 sprockets and distributed to each seeding unit through Z_7 or Z_8 sprockets. On-row seed spacing is adjusted with these sprocket groups. The stroke to seeder disk is provided through Z_9, Z_{10} and Z_{11} sprockets over the seeding unit. On-row seeding spacing of the machine is also adjusted by changing the number hollows over the seeding plate. Dimensions of a seeding ridge are presented in Figure 5.

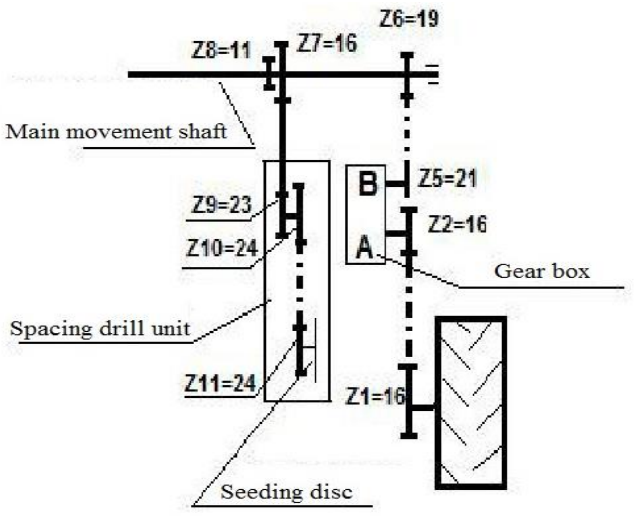

Figure 4. Stroke transfer scheme

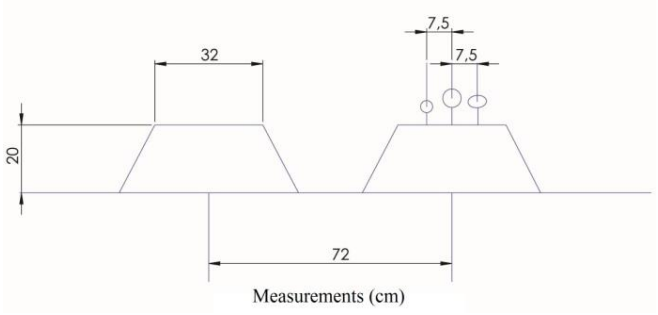

Figure 5. Cross-section of a sowing ridge

The non-pelleted black carrot seeds with 1.64 g thousand-seed weight and 91% laboratory germination rate were used to test the performance of the planter. Seeding was performed on 24th of March 2012 and 4 sprinkler irrigations were carried out until the last emergences on 24th of April. Average seeding depth of the experiments was 1.25 cm. Meteorological data for the period from the seeding to last emergences are provided in Table 4 (Turkish State Meteorological Service).
Soil penetration resistances were measured over the tracks of pressure wheels before and after the seeding at different forward speeds. A cone with 1 cm^2 base area and 30° top angle was used in these measurements. A mechanical penetrometer (Eijkelkamp) was used to measure the soil penetration resistance at 0-30 cm soil profile in MPa.

Table 4. Meteorological data for research period.

Temperature (°C)	
Max.	21.6
Min.	6.9
Average	14.8
Average soil temperature at 5 cm depth (°C)	19.1
Total precipitation (mm)	5.10

From each plot, five soil samples were taken from 0-10 cm soil profile into stainless steel cylinders with 5 cm diameter and 100 cm^3 volume. Wet samples were weighed in laboratory, dried at 105°C for 24 hours. Dried samples were placed into a desiccator, cooled there and weighed to determine dry weights. Then, gravimetric moisture content and unit weights were calculated by using these measurements (Black *et al*., 1965).
To determine the forward speeds of single-seed planter, range rods were placed over the field with 50 m spacing and the planter was driven between those rods at proper gear level and engine speeds. The time elapsed to take 50 m was measured three times with a chronometer. Then, forward speeds were determined by dividing the distance with the time measured to take the relevant distance. Experimental forward speeds were taken as 0.42, 0.85 and 1.25 m s^{-1}.
To determine on-row plant regularity, 10 m long ropes were extended over randomly selected three rows of each plot 30 days after the seeding date and plant spacing was measured

with a steel rule. Measurements were recorded and used to draw seeding regularity histograms). 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 (%)

To evaluate the sowing apparatus of single-seed planter, relative ratios of (0.5 – 1.5) Z plant spacing among the total plant spacing were evaluated. On-row plant spacing of (0.5 – 1.5) Z is assumed to be an acceptable plant spacing. The relative ratios of plant spacing of below 0.5 Z, between (0.5-1.5) Z and above 1.5 Z were determined by classification of plant spacing measured over the experimental plots (Schrodl, 1992). It is required for modern single-seed planters that relative plant spacing ratio of (0.5-1.5) Z interval should not be less than 80% and the ratios of plant spacing of below 0.5 Z and above 1.5 Z should be less than 10% (Irla, 1983; Haciseferogullari, 2005).

In each experimental plot, randomly selected 1 m strips over five rows were observed for 30 days in three replications and sprouts were counted at certain time intervals. Sprout counts were then used to determine mean germination date, germination rate index and field emergence values by using the following equations. The number of seed planted by single-seed planter over 1 m strip was determined by the number of seeds put by the planter over 1 m long section of an adhesive carton at the same on-row spacing and forward speeds.

$$MET=\frac{N_1.D_1+N_2.D_2+\ldots+N_n.D_n}{N_1+N_2+\ldots+N_n}$$

$$GRI=\frac{\text{Number of germinated seed in 1 m}}{MET}$$

$$FE=\frac{\text{Number of germinated seed in 1 m}}{\text{Number of seed planted in 1 m}}$$

N : Number of germinated seed in each counting
D : Number of days from seeding corresponding to N
MET : Mean germination time (day)
GRI : Germination rate index values [number $(m.day)^{-1}$]
FE : Field emergence rates (%)

To determine the number of plant per decare, number of plants over randomly selected 1.4 m strips of each plot was counted in three replications. Following the homogeneity test for field emergence values (Bartlett test), the values were then subjected to variance analysis. The values of variation coefficient, indicating on-row plant regularity, mean germination time, germination rate index, field emergence levels and number of plants per decare were also subjected to variance analysis and LSD test are realized by using MINITAB computer based program.

RESULTS

Average moisture content of soil samples taken from 10 cm soil depth of experimental plots before the experiments was found 11.12% and average unit weight was 1.26 g cm^{-3}. Penetration resistance values measured over planter pressure tracks of different sections after the planting are presented in Figure 6. The penetration resistance values at 30 cm soil profile were below 2 MPa.

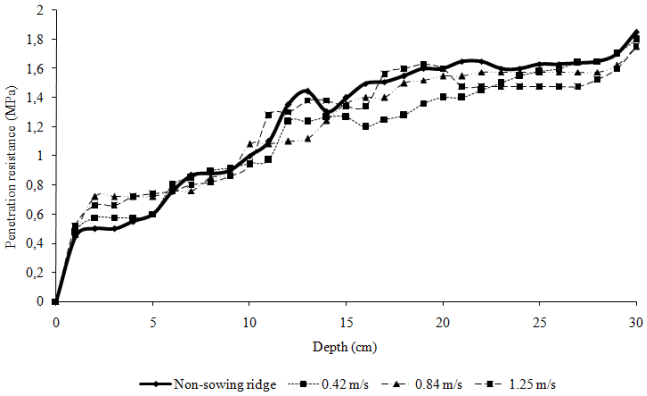

Figure 6. Penetration resistance values over sowing ridges.

Plant distribution histograms obtained by using vacuum-type pneumatic single-seed three-row black carrot planter at narrow row spacing are presented in Figure 7 and the evaluations of field measurements are provided in Table 5. Irregularities were observed in orthogonal patterns of on-row plant distribution histograms at different on-row plant spacing and forwards speeds.

Table 5. Experimental results obtained from vacuum-type pneumatic single-seed three-row non-pelleted black carrot seed planter at narrow row spacing.

		On-row plant distribution				
Seeding spacing Z (mm)	**Forward speed (m s^{-1})**	**$\bar{x}$ (mm)**	**VC (%)**	**<0.5 Z (%)**	**(0.5-1.5) Z (%)**	**>1.5 Z (%)**
22.36	0.42	61.29	73.34	1.83	30.49	67.68
	0.84	54.53	82.47	1.59	36.17	62.23
	1.25	66.81	85.86	0.98	28.78	70.24
46.50	0.42	74.99	71.26	9.25	46.24	44.51
	0.84	62.32	69.88	3.69	66.82	29.49
	1.25	95.61	86.42	4.29	42.95	52.76
68.70	0.42	66.19	84.35	22.03	66.10	11.86
	0.84	63.05	73.75	25.42	57.63	16.95
	1.25	73.76	62.85	18.64	61.02	20.34

Variation coefficients indicating the regularity of on-row plant distributions varied between 62.85 – 86.42%. Based on variation analysis over these coefficients, on-row plant

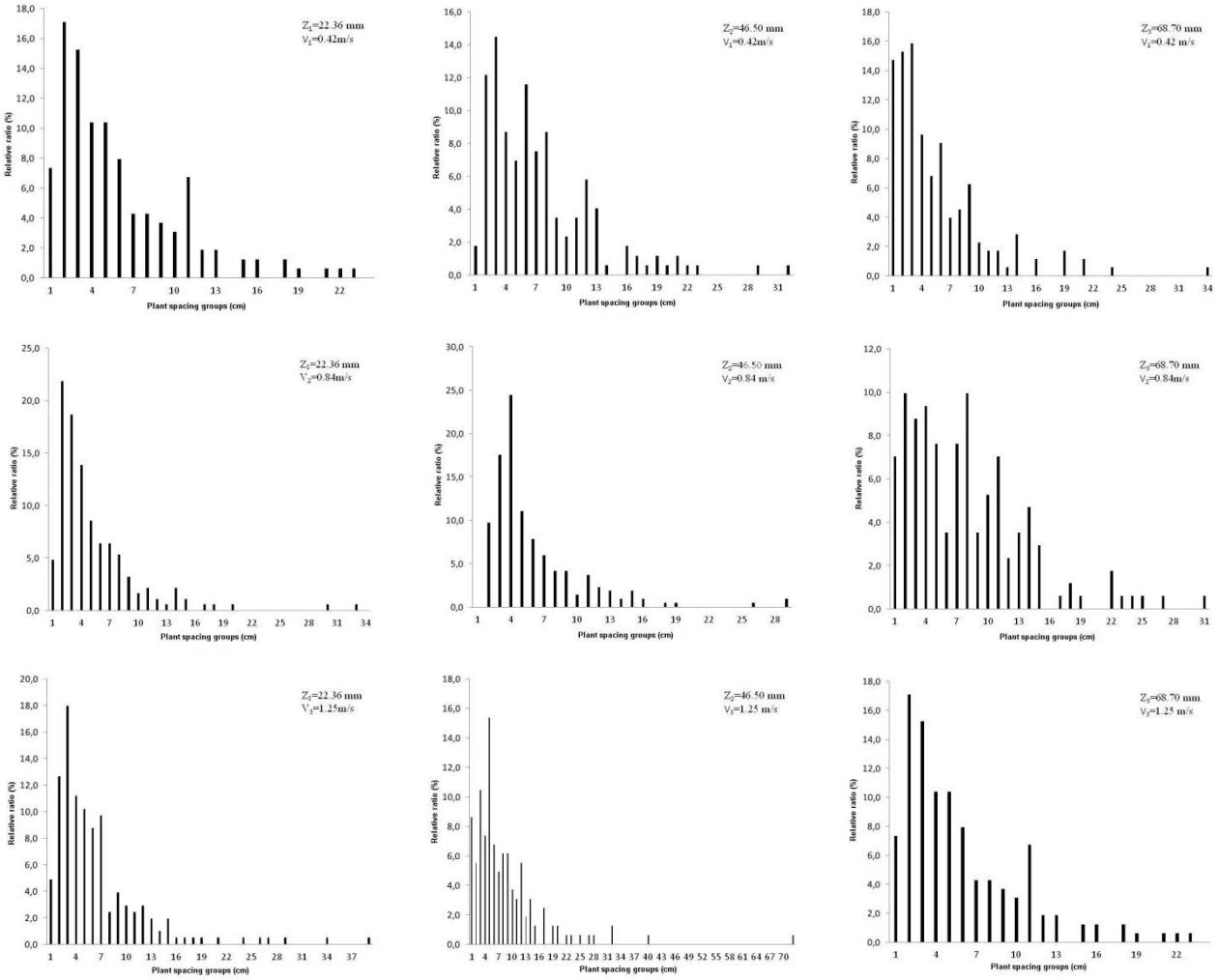

Figure 7. Plant distribution histograms of vacuum-type pneumatic single-seed three-rows black carrot planter at narrow row spacing and different forward speeds.

spacing (F=3.07), forward speeds (F=0.20) and spacing x speed interaction (F=1.45) were all found to be insignificant. High variation coefficients and insignificant differences among selected parameters were mainly due to non-attachment of seeds over the hollows of seeding plate since thousand-seed weights of black carrots were very low, seed shapes were significantly irregular and seeds were not sufficiently clean. Also decrease in seed attachments with increasing linear speeds of seeding plate increased on-row plant spacing and consequently increased the relative ratios of >1.5 Z plant spacing.

Mean germination times varied between 15.98 - 23.07 days (Table 6). Based on variance analysis over mean germination times, on-row spacing (F=0.35), forward speeds (F=0.49) and spacing x speed interaction (F=2.40) were also found to be insignificant. Indifferences in sowing depths and penetration resistances may also result in insignificant differences among germination times.

Germination rate index values varied between 0.321 - 1.502 [number (m day)$^{-1}$] (Table 7). Variance analysis on germination rate index values revealed significant differences in on-row spacing (F=18.19). On the other hand, differences in forward speeds (F=1.40) and spacing x speed interaction (F=1.44) were found to be insignificant. According to LSD test on on-row spacing, germination rate index at 22.36 mm on-row spacing were significantly higher than the values obtained at 46.50 and 68.70 mm on-row spacing. Such a difference may come from the higher number of seeds put per unit length at 22.36 mm spacing.

Field emergence rates varied between 34.26 - 69.70% (Table 8). Variance analysis over transformed field emergence values also yielded insignificant relationships with regard to on-row spacing (F=0.40), forward speeds (F=0.78)

Table 6. Mean germination times obtained from vacuum-type pneumatic single-seed three-rows non-pelleted black carrot seed planter at narrow row spacing (day).

		Mean germination time (day)								
Seeding spacing Z (mm)		**22.36**			**46.50**			**68.70**		
Forward speed (m s^{-1})		**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**
Blocks	I	16.25	18.37	20.82	19.50	18.58	18.51	19.22	15.98	18.88
	II	16.55	23.07	20.44	18.03	16.77	21.38	22.65	18.08	16.02
	III	20.32	16.30	19.65	15.09	19.63	18.56	20.13	17.00	17.61
	Mean	17.71	19.25	20.30	17.54	18.33	19.48	20.67	17.02	17.50

Table 7. Germination rate index values obtained from vacuum-type pneumatic single-seed three-row non-pelleted black carrot seed planter at narrow row spacing [number (m. day)$^{-1}$].

		Germination rate index values [number (m.day)$^{-1}$]								
Seeding spacing Z (mm)		**22.36**			**46.50**			**68.70**		
Forward speed (m s^{-1})		**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**
Blocks	I	1.004	1.215	0.912	0.410	0.673	0.460	0.468	0.469	0.424
	II	1.502	0.698	0.613	0.623	0.651	0.398	0.503	0.472	0.508
	III	1.016	1.379	0.721	0.794	0.673	0.862	0.321	0.471	0.571
	Mean	0.906	1.365	0.749	0.609	0.665	0.573	0.431	0.471	0.501
LSD (p<0.01)=0.2658			1.0067_a			0.6160_b			0.4674_b	

Table 8. Field emergence rates obtained from vacuum-type pneumatic single-seed three-row non-pelleted black carrot seed planter at narrow row spacing (%).

		Field emergence rates (%)								
Seeding spacing Z (mm)		**22.36**			**46.50**			**68.70**		
Forward speed (m s^{-1})		**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**
Blocks	I	42.47	62.03	49.99	40.25	62.50	40.15	60.00	49.98	53.33
	II	69.44	41.66	34.26	55.75	54.35	42.50	73.34	59.96	49.95
	III	57.40	62.03	37.97	59.75	30.65	69.70	40.15	53.33	56.67
	Mean	56.47	55.24	40.74	51.92	49.17	50.78	57.83	54.42	53.42

Table 9. Number of plant per m^2 obtained from vacuum-type pneumatic single-seed three-row non-pelleted black carrot seed planter at narrow row spacing.

		Number of plant per m^2									
Seeding spacing Z (mm)		**22.36**			**46.50**			**68.70**			
Forward speed (m s^{-1})		**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**	**0.42**	**0.84**	**1.25**	Mean speeds
Blocks	I	70.66	64.67	57.00	46.00	63.67	38.00	45.00	41.67	39.00	$V_1=54.11_a$
	II	61.67	60.00	61.00	57.00	49.00	41.00	41.00	43.00	37.66	$V_2=53.59_a$
	III	60.33	69.00	57.33	61.67	53.67	46.00	43.66	37.66	41.67	$\underline{V_3=46.52_b}$
	Mean	64.22	64.56	58.44	54.89	55.45	41.67	43.22	40.77	39.44	LSD (p<0.01)=6.327
LSD (p<0.01)=6.327			62.41a			50.67b			41.15c		

and spacing x speed interaction (F=0.45). Such insignificant relationships were mainly due to low germination rate indexes.

Number of plant per m^2 varied between 37.66 - 70.66 plants (Table 9). With regard to number of plants per m^2, on-row spacing (F=43.74) and forward speeds were found to be significant. However, spacing x speed interaction (F=1.44) was found to be insignificant. LSD test over on-row spacing revealed significant differences among all spacing with regard to number of plant per m^2. Such a case may be resulted from different number of seeds thrown over per unit area. LSD test on forward speeds revealed smaller number of plants per unit area for 1.25 m s^{-1} than the other forward speeds. It may be due to increase in disc linear speed.

DISCUSSION

Black carrot seeds have linters. The linters are broken away from seeds during planting by the effect of mixer. These linters plugs up the seed planter disc 0.5 mm diameter holes and prevent the seeds from flowing in a singulated manner required for planting. In this study, it was observed that

several holes having missing seeds because of linters that plugs up the planter disc holes. Because of that, the variation coefficients that determine the seed distribution homogeneity on rows were high and accordingly, it was found that plant spacing on row was measured higher than 1.5 Z. In all treatments, 0.5 – 1.5 Z range were found lower than 80%.

The transmission rate decrease when the plant spacing on rows are high. Accordingly, perimeter velocity of disc decreases. In this case, the number of seeds that stuck in the holes on planter disc increased. As a result, the germination increase on the rows and the variation coefficients tends to decrease.

In this study, no significant difference between mean germination times was examined. This is because that the front and rear press wheels were manufactured from steel and the wheels press the soil surface.

There was no statistically significant difference between germination rate indexes. It was caused because all the seeds were planted at the same depth under same pressure of pressure wheel. Generally small granular seed beds are required to increase germination rate. Accordingly, it is necessary to use vertical shaft rotary tiller.

In this region, the desired plant population is between 60-90 plants per m^2 for carrot cultivation. As a result of study, plant population values ranged between 60-90 plants per m^2 obtained for smaller plant spacing on row. It was also found that when the pneumatic precision drill machine forward speed increases, plant population per m^2 decreases. So it is advised to avoid high speed and higher plant spacing on rows, not more than 5 cm.

Conclusion: In the region, the farmers sow their own black carrot seeds that are kept from previous production year; however, there is need for classification of the black carrot seeds depending on quality. The desired sowing quality was not provided due to unsuitable seeds conditions (non-eliminated linters from the seeds) that were not well cleaned and classified. There is big demand on entering different black carrot varieties to the market. The press wheel doesn't provide enough pressure to the seed bed at higher forward speed. So that the seeds should be planted at lower pneumatic precision drill machine forward speed and the plant spacing in rows should be decreased for quality black carrot production.

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