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Determination of Effects the Different Holes Position in the Vacuum Discs of Pneumatic Precision Vegetable Planters on Emergence and Uniform Plant Distribution in Black Carrot Production

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HIGHLIGHTS

- Pneumatic precision planter using for vegetable seeds should be focused on subject to improve planting quality.
- Searching solution of the problems encountered in the precise planting of vegetable seeds.
- Significant both researchers and producers in terms of field emergence rate and seed placement.

Abstract

The objective of this study was to determine the seed releasing characteristics of seed metering discs used in the precision seeding of black carrot seeds. High precision vegetable seeder was tested in the field conditions using black carrot seeds in Kuzukuyu village of Ereğli-Konya in 2018. Three different seed metering discs that have holes in three different circle positions were used in the experiments. These applications referred to seeding techniques, ST_1, ST_2 and ST_3. The seed metering discs with three trajectories, each diameter was 210, 185, and 155 mm respectively. Each trajectory on vacuum plate using in ST_1 had equal number of holes (96 holes), while P_1 and P_2 hole positions had same number of holes in ST_2 ve ST_3, however, 25% and 50% decrease in the number of holes in the P_3 (bottom hole position), respectively. The downforce on the press wheel was kept constant throughout all trials. In these three different seeding techniques, the planting performance of the machine under field conditions was evaluated and the coefficient of variation values expressing the seed distribution uniformity, mean of the emergence rates were determined. According to the results, the mean of emergence rates and coefficient variation values were determined as %59.86 ve %76.84, %68.91 ve %75.31, %66.26 ve %72.48for ST_1, ST_2 ve ST_3, respectively. Given hole positions (planting rows), emergence rates and CV values were obtained %59.71 ve %81.94 for P_1, %62.69 ve %74.49 for P_2 and %72.60 ve %68.20 for P_3.

Keywords: Precision vegetable seeder; vacuum plate; black carrot seed; emergence rate; coefficient variation of plant distribution uniformity

1. Introduction

Currently the most widely used machine for precision seeding of small seeds is vacuum type. The capture of seeding by vacuum plate in seed metering unit of vacuum seeder should be performed precisely without doubling or missing. Habitat quality of the seed; seed bed preparation before sowing depends on variables

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such as seeder features. seed quality and ground speed. It is clear that the cost of seed. which is one of the most important inputs in vegetable production. can only be reduced by using a minimum number of seed. This is only possible by using advanced single seed sowing machines that provide the seed to be fed into the soil according to the agrotechnical demands. In the cultivation process carried out in this way. providing an equal amount of living space to the seed is one of the important advantages. The seed releasing characteristics of a seed meter units affect the seeding quality and metering unit design. In the literature there are a few published studies on vegetable seeders. One of these was conducted by Bracy et al. (1999). using the cabbage seed in Gaspardo brand vacuum type pneumatic precision seeder with 10 holes at 2.4 km h^{-1} forward speed and using a planter plate with a hole diameter of 1.0 mm. at six different seed spacing (38, 77, 114, 153, 229 and 284 mm) conducted laboratory tests. In the results of these experiments the miss indexes for 38, 77, 114-, 153-, 229- and 284-mm seed spacing were 60%, 35%, 38%, 26%, 32% and 18% respectively. As they obtained multiple indexes 19%, 24%, 12%, 7%, 10% and 10% and quality of feed indexes determined 21%, 41%, 49%, 68%, 58% and 73%. The other study conducted by Karayel and Özmerzi (2001) on the sowing of melon and cucumber seeds with a vacuum-based single seed planter under laboratory conditions at four different forward speeds (0.5, 1.0, 1.5 and 2.0 m s^{-1}) and three different seed spacing. They determined the forward speed and the seed spacing on the row statistically affect the sowing quality and that the best sowing quality for both seeds was achieved at 1.0 and 1.5 m s^{-1} forward speeds and 64 cm sowing distance. Additionally, Parish and Bracy (2003) tested the standard machine situation on the sticky belt test stand with seed orientation applications by using a guiding plate between the Gaspardo brand vacuum type precision vegetable planter and leaving the seed from the planter disc to the furrow and adding a tubular apparatus they call the seed tube. The acceptable seed spacing rates for cabbage. onion and mustard seeds at 76, 76 and 51 mm in-row planting distances, respectively, were 59.8%, 58.7% and 76.3% for cabbage, onion and mustard seeds, respectively and 48.2% for seed path application. They obtained 56.3% and 66.0% and 40.6%, 48.3% and 45.1% in seed tube application and reported that seed guiding plate and seed tube applications did not have a positive effect on the distribution uniformity. All of these studies were conducted in the sticky belt test stand. There is no study on these planters capable of sowing vegetable seeds in field conditions. The aim of this study is to determine by comparing the seed distribution uniformity criteria in the changes in the number of holes at different linear velocity of different hole positions on vacuum plate in field experiments. The objective of this study was the comparison of the seed distribution uniformity criteria in order to seed releasing from the disc with changes in the number of holes as a result of the change in linear velocities at different hole positions.

2. Materials and Methods

2.1. Precision planter and system components

Four-row pneumatic vegetable seeder with a chain-sprocket (gearbox) transmission system operating based on the vacuum principle was used within the scope of this study. Technical properties of the high precision vegetable planter (Şakalak Inc.) used in the experiments were given in Table 1. This planter equipped with four row unit was provided by project of TUBITAK (Project number was 115O111).

Figure 1. View of pneumatic precision vegetable seeder

During the planting operations, Hattat brand A78 model tractor was used and 210/95 R28 and 210/95 R44 sized front and rear rubber wheels with narrow track width were used in accordance with the tire tread spacing.

Table 1. Technical properties of the precision planter

Technical properties		
Number of row unit	4	
Width	1650 mm	
Height	1450 mm	
Length	2500 mm	
The min. row unit spacing	260 mm	
The width of runner opener	150 mm (75+75)	
The volume of seed hopper	4 x 2 L	
Mass	650 kg	
PTO speed	540 min^{-1}	
The properties of closing wheels	**Front and back closing wheels**	**Narrow closing wheels**
Material	Tyre	Tyre
Diameter	250 mm	180 mm
Width of closing wheels	200 mm	30 mm
The mass of closing wheels	72.9 N	10.6 N

2.2. Vacuum-type precision metering unit

In the experiments. a vacuum-type precision metering unit with triplet vacuum plate was used and with a ground-driven wheel with 0.65 m diameter that transfers the motion to vacuum plate with a combination of gears was used.

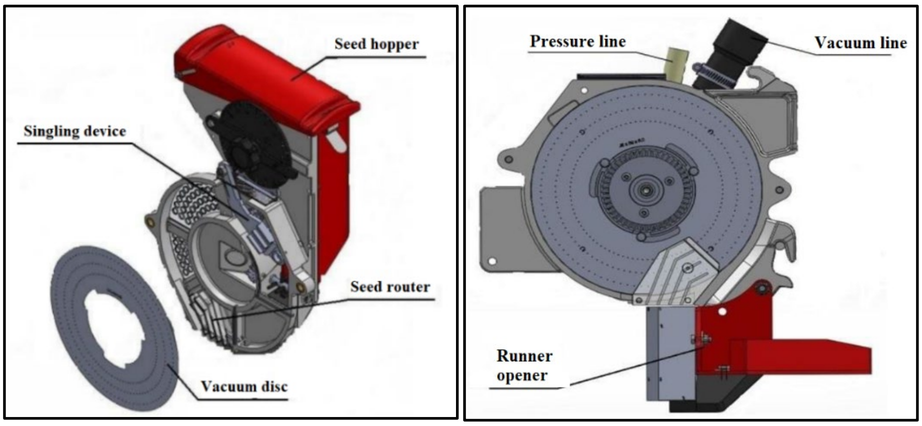


Figure 2. Seed metering unit

2.3. Vacuum plate used in the experiments

Seeds are released from the vacuum disc, and then pass through the seed router (Fig. 3) and finally, they are delivered in to the three different seed slides of runner opener (Fig. 4). The holes were drilled in three different trajectory such as P_1, P_2 and P_3 (which are on the orbit of 0.210, 0.185 and 0.155 mm, respectively) diameters. In first seeding technique (ST_1), the vacuum plate for P_1, P_2 and P_3 had 96 holes, while both ST_2 and ST_3 had the same number of holes (96) on P_1 and P_2 positions. However, it was found on P_3 position that 72 holes for ST_2 and 48 holes for ST_3. The negative pressure applied in vacuum line was 30 mbar and the positive pressure (pushing seeds to the furrow) in pressure line was 10 mbar.

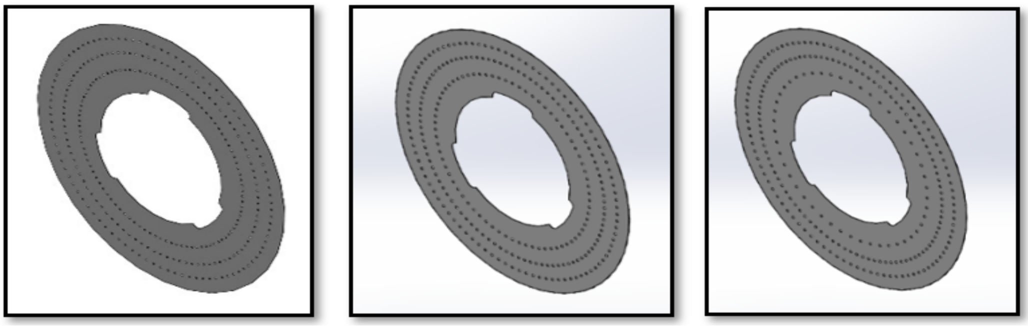


Figure 3. Disc plates used in field trials

2.4. Runner opener used in trials

The seed slide followed by the seeds release from different hole positions through the seed router (Fig. 2) on the runner opener was shown in Fig. 4. Runner opener has three different seed slides (P_1, P_2 and P_3) and angle between slides was 36°.

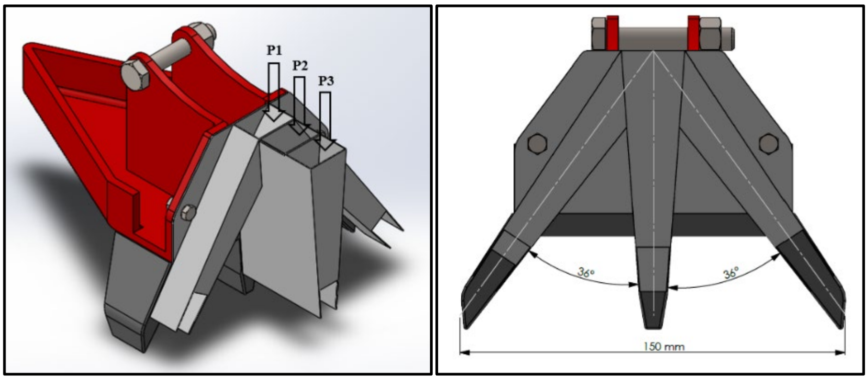


Figure 4. Runner opener and seed trajectories (P_1, P_2 and P_3)

2.5. Field description and layout

Field trials were conducted on 6 da sized loamy-sand soil at Ereğli-Konya in Turkey in 2018. Field coordinates were 37°41'51.683" N and 33°57'21.575" E (Fig. 5, no. 1). In the experiments, high precision vegetable planter was operated at the suggestion of producer optimum ground speed 0.48 m s^{-1} using black carrot seeds.

Target spacing in planting on ridge rows were adjusted for Z_1 (30.1 mm), Z_2 (47.3 mm) and Z_3 (66.5 mm). Decrease number of holes in the smallest orbit of vacuum plate, target spacing value of mid rows (P_3) in ST_2 and ST_3 increased in rate of 25% and %50 respectively.

Figure 5. Location of experiment field

The soil structure of the field, clay content was determined to be 12%. with a silt content of 1.60% and a sand content 86.40%. The soil texture was classified as Sandy-clay-loamy. In addition to these, properties of soil, pH, EC and mineral values at 30 cm soil depth where the root development of the black carrot takes place were shown in Table 2.

Table 2. Soil properties at root development area

Parameters	Units	Value
pH	-	8.45
EC	($\mu S\ cm^{-1}$)	315
Organic substance	%	0.78
Lime ($CaCO_3$)	%	40.32
Clay	%	12.00
Silt	%	1.60
Sand	%	86.40
NH_4-N	mg kg^{-1}	20.66
NO_3-N	mg kg^{-1}	31.32
P	mg kg^{-1}	23.43
K	mg kg^{-1}	362
Ca	mg kg^{-1}	3947
Mg	mg kg^{-1}	403
Na	mg kg^{-1}	378
Fe	mg kg^{-1}	1.42
Zn	mg kg^{-1}	1.67
Mn	mg kg^{-1}	8.01
Cu	mg kg-1	1.21

Ereğli local population black carrot seeds were used in the trials. These seeds have only been sift through a sieve and not calibrated. The thousand grain mass of uncoated black carrot seeds was determined as 1.65 g and the laboratory germination percentage was determined as 90%.

The average daily, minimum and maximum temperature values were determined as 20.6ºC, 13.6ºC and 28.5 ºC, respectively, after planting date of black carrot (16.05.2018) to the date of final emergence (16.06.2018). The average, minimum and maximum soil temperature values at 5 cm soil depth were occurred as 21 ºC, 13.8 ºC and 28.6 ºC, and there was a total of 34.8 mm of precipitation during the emergence period (TSMS, 2018).

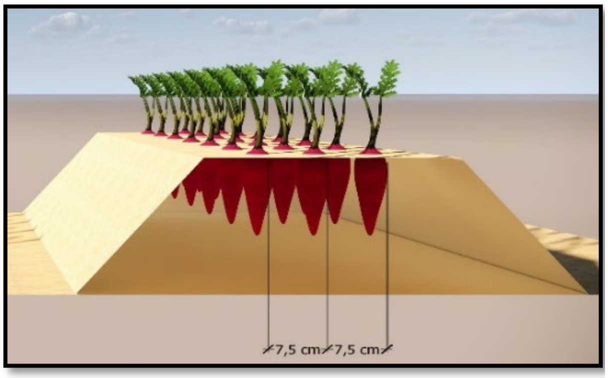
The agricultural operations were applied to the experimental plots and the amount of water given during emergence were given in Table 3. DAP fertilizer at 40 kg da^{-1} fertilizer norm was distributed on the field surface with a centrifugal fertilizer in each plots and the seed bed was prepared with rotary cultivators with vertical axes. Planting ridges were created with a pneumatic precision vegetable planter before planting (Figure 6).

Table 3. Agricultural operations and irrigation applied on experimental field

Date	Agricultural operation
20.02.2018	Tillage with chisel
23.04.2018	Tillage with mouldboard plough
03.05.2018	Seed bed preparation with rotary cultivators with vertical axes
13.05.2018	Centrifugal fertilizer spreading machine (DAP at 40 kg da^{-1} fertilizer norm)
14.05.2018	Rotary cultivators with vertical axes (after rain)
15.05.2018	Preparation of planting ridges
16.05.2018	Planting using pneumatic precision vegetable planter
19.05.2018	1^{st} irrigation using sprinkler (80 mm)
21.05.2018	2^{nd} irrigation using sprinkler (32 mm)
25.05.2018	3^{rd} irrigation using sprinkler (32 mm)
05.06.2018	4^{th} irrigation using sprinkler (48 mm)
10.06.2018	5^{th} irrigation using sprinkler (48 mm)

Split plot in randomized complete block design with three replicates. Dimensions of plots were 75 m in length and 2.8 m (210 m^2) in width. Measurements of plant spacing, were collected from 5 m sample strips determined on the row. Analysis of variance was performed to field emergence rates and coefficient of variation values which express the uniformity of plant distribution using the MINITAB 16 program.

LSD analysis was performed using the MSTAT-C package program on features with a 1% and at least 5% significance level variance between applications (Düzgüneş ve ark., 1983). Obtained field emergence values of black carrots were converted into angular transformation and analysis of variance was applied (Önal, 1983).



The distance between the rows is 7.5 cm seeding techniques.

Distance between ridges: 72 cm

Width of ridges: 30 cm

Height of ridges: 25 cm

Figure 6. Measurements of ridges

2.6. Field data collection

In measurements with a penetrometer, a penetrometer tip with a base area of 1 cm^2 and a peak angle of 30° was used, and the measurement range was 0-250 N cm^{-2}. These values were evaluated in Excel. Otherwise, uniformity of plant placement terms such as variance coefficient of seeding uniformity was calculated to assess the seeding performance of the centralized seed-metering device based on the standard ISO-7256/2 (ISO, 1984). The variance coefficient of seeding uniformity was calculated as follows (i=1. 2. 3. …. n) (Lei et al., 2021). In the spacing measurements of plants, the distances between sequential plants in the row were measured, starting from the first plant. Measurements were made 30th day of after emergence was completed, and for each measurement, they were carried out with the help of tape measure on 10 m long, in five rows, on randomly selected rows from the plots. Average plant spacing and coefficient of variation values were calculated using the equations were given below.

$$Z_{avg} = \frac{1}{n} \sum_{i=1}^{n} X_i$$

$$SD = \left\{ \sum_{i=1}^{n} [(X_i - \overline{X})^2]/(n-1) \right\}^{\frac{1}{2}}$$

$$CV = \frac{SD}{Z_{avg}} \times 100$$

$$FER\ (\%) = \frac{N_x}{N_0} \times 100$$

Z_{avg} : Average of the plant spacing (mm)
SD : Standard deviation
CV : Coefficient variation (%)
FER : Field emergence rate (%)
N_x : Number of plants emerged per meter
N_o : Number of seeds planted per meter

3. Results and Discussion

3.1. *Variation of penetration resistance*

After seed bed and ridge preparation, the penetration resistance value was measured on the gap ridges as 2.5 Mpa on average at 25 cm tillage depth. After the ridges were formed by disc ridger, the average of the highest penetration resistance values of the press wheels at a planting depth of approximately 1 cm varied between 0.21 and 0.25 MPa (Fig. 7).

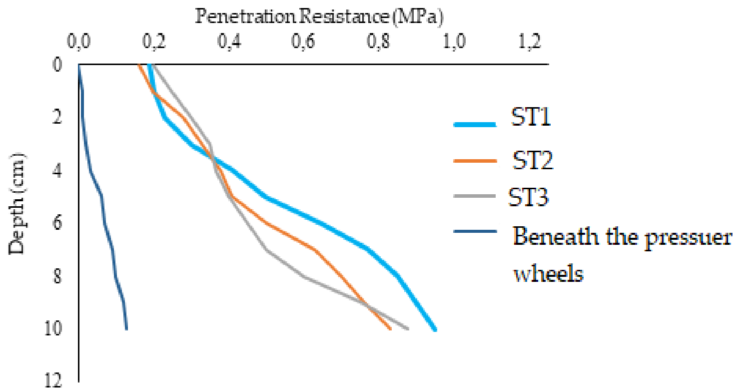


Figure 7. Variation of penetration resistance on the ridges

3.2. *Field emergence rate*

As a result of the trials, the variation of emergence values was given in Table 4. According to the Table 4, the emergence values obtained in ST_1, ST_2 and ST_3 showed variation between 46.79% and 70.23%, 52.24% and 77.71%, finally 48.04% and 77.62%, respectively. In general, higher germination rates were obtained in the middle row (P_3) for all three seeding techniques. Considering the theoretical seed spacing, 116% and 125%, 107% and 114%, 116% and 125% respectively adjusted Z_2 and Z_3 theoretical spacing compared to Z_1 theoretical spacing in all seeding techniques 114%, more emergence rates were obtained.

Table 4. Emergence values in different seeding techniques (%)

ST_1				ST_2				ST_3			
Target spacing	**Hole positions**	**FER (%)**		**Target spacing**	**Hole positions**	**FER (%)**		**Target spacing**	**Hole positions**	**FER (%)**	
Z_1	P_1	50.12		Z_1	P_1	52.84		Z_1	P_1	48.04	
	P_2	46.79			P_2	65.59			P_2	54.96	
	P_3	61.17			P_3	74.86			P_3	73.75	
	Avg.	***52.69***			***Avg.***	***64.43***			***Avg.***	***58.92***	
Z_2	P_1	61.09		Z_2	P_1	63.46		Z_2	P_1	62.43	
	P_2	57.53	59.86_c		P_2	66.26	68.91_b		P_2	63.33	66.26_a
	P_3	64.56			P_3	77.71			P_3	76.67	
	Avg.	***61.06***			***Avg.***	***69.14***			***Avg.***	***67.48***	
Z_3	P_1	61.11		Z_3	P_1	72.11		Z_3	P_1	66.22	
	P_2	65.90			P_2	70.54			P_2	73.33	
	P_3	70.23			P_3	76.84			P_3	77.62	
	Avg.	***65.74***			***Avg.***	***73.16***			***Avg.***	***72.39***	
Mean of seeding techniques										***LSD=2.479***	

According to the results of variance analysis applied to emergence rate, it was established a statistically significant difference between seeding technique (F=19.22), plant spacing (F=29.38), hole position in the disc (F=40.52) and plant spacing x hole position interaction (F=2.78). A relationship has been identified. When emergence averages were evaluated in terms of seeding techniques, the highest field emergence value was obtained as 68.91% in ST_2 and the lowest was 59.86% in ST_1. In other words, there was no statistical difference in field emergence averages between ST_2 (68.91%) and ST_3 (66.26%) ($p<0.01$). Obtaining high germination values in ST_2 and ST_3 may be caused by the 25% and 50% decrease in the number of holes in the P_3 hole position in these seeding techniques.

The emergence values were determined as 58.68%, 65.89% and 70.43% (LSD = 2.479), respectively. There was a significance among the emergence rates obtained at all three theoretical spacing ($p<0.01$). The highest field emergence was obtained at the theoretical seed spacing of Z_3 (70.43%) and there was no statistical difference between it and Z_2 (65.89%). The reason is that decrease in the transmission rate of the pneumatic precision vegetable seeder, and therefore the rolling and drifting of the seed in the furrow is reduced due to the decrease in the disk peripheral velocity. Given the hole positions (in other words plant rows), the average of emergence obtained in P_1 (upper position), P_2 (mid-position) and P_3 (bottom position) were obtained as 59.71%, 62.69% and 72.60%, respectively (LSD = 2.479) and a statistical difference was determined between them. There was no statistical difference between the P_1 and P_2 hole positions, and the emergence value (72.60%) were stated in P_3 (bottom position-mid row) was found to be statistically significant compared to the other two positions. When the row distance x hole position interaction was examined, the highest emergence rates (LSD=1.856) were determined as 74.89% in the Z_3K_3 parameter ($p<0.05$). In triplet sowing, the field emergence rate was found to be higher because the P_3 (mid-row) hole position was on the lower axis of the seed plate, left less distance on the seed guide, and the seeds on the lower axis dropping to the furrow vertically in the seed trajectory.

3.3. Uniformity of plant distribution (Z_{avg} and CV)

The variance in the average plant spacing and coefficient of variation values, which express uniformity of seed distribution of three-row seeding techniques in the field conditions, were specified collectively in Table 2. According to the results achieved from field conditions, average in-row theoretical plant spacing between 6.13 and 9.81 cm were obtained in different hole positions in the ST_1 seeding technique. It was determined that the mean of plant spacing values increased by 2.10, 1.49 and 1.39 times, respectively. Considering the hole positions, increases of 2.21, 1.61 and 1.44 times in the Z_1, Z_2 and Z_3 planting distances were determined in the P_1; 2.07, 1.47 and 1.49 times in the P_2, and 2.02, 1.39 and 1.26 in the P_3, respectively. As the ST_1, the coefficient of variation values obtained in different rows and theoretical plant spacing, which express the uniformity of seed placement on the row, showed an alteration between 65.49% and 86.77%. When it is taken into consideration all three hole positions, it was determined that the coefficient of variation values of the P_3 was lower than the others and were 73.17% at Z_1, 65.49% at Z_2 and 70.43% at Z_3 plant spacing. With the increase in the theoretical plant spacing, the average coefficient of variation value of plant distribution was found to be higher at Z_3 (80.68%). Considering the averages of the hole positions, coefficient of variation value of the hole positions, at the theoretical plant spacing Z_1, Z_2 and Z_3 was determined as 82.10%, 78.73% and 69.70%, respectively.

In ST_2, Z_{avg} were determined between 4.59 cm and 10.50 cm in different hole and target spacing. It was determined that the Z_{avg} values of each plant row increased by 1.50, 1.32 and 1.19 times in Z_1, Z_2 and Z_3 planting distances, respectively. Considering the hole positions, it was determined that there were increases of 1.75, 1.52 and 1.21 in the P_1, for Z_1, Z_2 and Z_3 target spacings, 1.51, 1.26 and 1.17 in the P_2, and 1.37, 1.21 and 1.19 in the P_3, respectively. In general, the average of the CV values of the each rows with ST_2 showed a change between 66.44% and 88.36%. There was a decrease in the coefficient of variation values determined due to the increase in the target seed spacing. These values for each theoretical seed spacing were obtained as 77.12%, 76.95% and 70.31% on average. When three different plant rows were examined separately, the CV values obtained in the left row (P_1) were determined to be the highest with 88.36%, 85.53% and 74.01% depending on target seed spacing, and the middle rows (P_3) were determined to be the lowest with 73.66%, 70.62% and 66.44% at the target seed spacing. In ST_2, the average of CV values each seed spacing were determined as 82.63%, 73.07% and 70.24% in the P_1, P_2 and P_3, respectively. In the ST_3 seeding technique, Z_{avg} were obtained between 5.27 cm and 17.87 cm, depending on the target spacing, and Z_{avg} values were determined as 1.58, 1.37 and 1.28 times higher for Z_1, Z_2 and Z_3, respectively, compared to the theoretical spacing. Given the hole positions, 1.91, 1.56 and 1.42 increase rates were determined in the P_1, 1.74, 1.51 and 1.34 in the P_2, and 1.34, 1.21 and 1.28 in the P_3, for each theoretical spacing, respectively.

Table 5. Average spacing and coefficient of variation values of uniformity of plant distribution in three-row seeding techniques

Seeding Techniques	Target spacing	Hole positions	Transmisyon oranı (i)	V_P (m s^{-1})	K	Z_t (cm)	Z_{avg} (cm)	CV (%)
ST1	Z_1	P_1	0.760	0.110	96	3.00	6.64	82.50
		P_2		0.096	96	3.03	6.27	76.73
		P_3		0.080	96	3.04	6.13	73.17
		Avg.				**3.02**	**6.34**	**77.47**
	Z_2	P_1	0.484	0.070	96	4.71	7.59	77.04
		P_2		0.061	96	4.73	6.97	74.69
		P_3		0.052	96	4.74	6.58	65.49
		Avg.				**4.73**	**7.05**	**72.41**
	Z_3	P_1	0.348	0.050	96	6.59	9.47	86.77
		P_2		0.044	96	6.60	9.81	84.78
		P_3		0.036	96	6.75	8.53	70.43
		Avg.				**6.65**	**9.27**	**80.68**
ST2	Z_1	P_1	0.760	0.110	96	3.00	5.24	88.36
		P_2		0.096	96	3.03	4.59	75.44
		P_3		0.080	72	4.06	5.55	73.66
		Avg.				**3.36**	**5.05**	**77.12**
	Z_2	P_1	0.484	0.070	96	4.71	7.15	85.53
		P_2		0.061	96	4.73	5.97	73.29
		P_3		0.052	72	6.31	7.64	70.62
		Avg.				**5.25**	**6.93**	**76.95**
	Z_3	P_1	0.348	0.050	96	6.59	7.99	74.01
		P_2		0.044	96	6.60	7.71	70.48
		P_3		0.036	72	8.79	10.50	66.44
		Avg.				**7.33**	**8.73**	**70.31**
ST3	Z_1	P_1	0.760	0.110	96	3.00	5.73	83.87
		P_2		0.096	96	3.03	5.27	74.12
		P_3		0.080	48	6.26	8.37	70.02
		Avg.				**4.09**	**6.45**	**74.90**
	Z_2	P_1	0.484	0.070	96	4.71	7.33	82.55
		P_2		0.061	96	4.73	7.12	70.13
		P_3		0.052	48	9.75	11.76	62.81
		Avg.				**6.39**	**8.74**	**71.83**
	Z_3	P_1	0.348	0.050	96	6.59	9.33	76.84
		P_2		0.044	96	6.60	8.84	70.78
		P_3		0.036	48	13.92	17.87	61.17
		Avg.				**9.04**	**11.53**	**69.59**

When the coefficient of variation values in transplantation with ST_3 are examined, it is seen that a change occurred between 61.17% and 83.87%. It is seen that the CV obtained in three plant rows have the highest values in the P_1, and the lowest values in the P_3. The coefficients of variation obtained in the P_1 were determined as 83.87% for Z_1, 82.55% for Z_2 and 76.84% for Z_3. In addition to these, it was observed that the lowest CV values were determined in the P_3, at rates of 70.02%, 62.81% and 61.17% for Z_1, Z_2 and Z_3 target spacing, respectively. In ST_3, the average CV values for the hole positions in the upper, middle and lower axis at the target seed spacing of Z_1, Z_2 and Z_3 were found as 81.09%, 71.68% and 64.67%. The average coefficient of variation of the seeding techniques was determined as 76.84%, 75.34% and 72.48% in ST_1, ST_2 and ST_3, respectively. Variance analysis was performed on the CV values obtained to compare the plant distribution uniformity of the triple seeding techniques of black carrot. As a result of the variance analysis, only the hole position parameter was found to be statistically significant (F=17.29). There is no significance on other parameters and their interactions. As a result of the variance analysis, the average of the coefficient of variation value acquired at the P_1 hole position was determined as 81.94% and was found to be higher than the other positions, and no statistical difference was determined between the P_2 (74.49%) and P_3 (68.20%) positions. The fact that there are 72 holes in the P_3 position in ST_2 and also 48 holes in the P_3 position in ST_3 was effective in the low CV values. Önal (2011) emphasizes that the number of holes in the vacuum plate should be chosen as 64 for lint-free cotton seeds and 27 for corn seeds, and that the use of a 72-hole vacuum plate for nappy free cotton seeds should not be preferred due to the formation of a continuous vacuum zone in the hole orbit. Therefore, depending on the hole positions in the three rows, it is stated that the CV values decreases due to the decrease in the effect of the vacuum trajectory in the K_3 (the number of holes is 25% in ST_2 and 50% in ST_3).

4. Conclusions

Among the three-row planting techniques, ST1 was applied by producer in the region. In the ST2 seeding technique, field emergence rates (68.91%) were higher than ST1 (59.86%), and in terms of coefficient of variation values, which express the uniformity of plant distribution, lower values were found compared to ST1. Considering the hole positions (planting rows), the average field emergence rates obtained in P1 (upper), P2 (mid) and P3 (lower) hole positions were obtained as 59.71%, 62.69% and 72.60%, respectively, and there was no statistical difference between them. In triplet seeding techniques, the field emergence rates were found to be higher because the P3 (mid-row) hole position was on the lower trajectory of the vacuum plate, traveling less distance on the seed router, and the seeds on the lower axis falling vertically from the seed slide to the furrow. The average of the coefficient of variation values obtained at the P1 hole position was determined as 81.94% and was found to be higher than the other two positions, and no statistical differences were determined between the P2 (74.49%) and P3 (68.20%) locations. Depending on the hole positions in the three rows, able to be stated that the coefficient of variation values decreases due to the decrease in the effect of the vacuum trajectory in the lower row (P3) (the number of holes is 25% in ST2 and 50% in ST3). For this reason, currently, it has gained importance to use pneumatic precision vegetable planters with three separate units (planting each narrow row independently). It should be encouraged domestic production of these planters. Additionally, using calibrated and coated black carrot seeds will increase planting quality.

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