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Germination Parameters of Different Types of Black Carrot Seeds of Ereğli Local Population

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HIGHLIGHTS

- Black carrot is an important agricultural product for nutrition.
- Protecting gene resources in seed production should be a priority.
- It is important to cover the seeds for field emergence and yield.

Abstract

Consumer interest in healthy foodstuffs and vegetables has continuously been increasing. In this sense, quality has become a prominent issue in the production, consumption and marketing of vegetables. Seeds and planting processes significantly affect the quality of vegetables. Black carrot production is an important source of income for local farmers of Ereğli and Karapınar Districts of Konya province. Bare seeds of Ereğli local population are commonly used in black carrot production. Farmers produce their own seeds. These seeds undergo only one sieving and are not calibrated. In this study, uncalibrated bare, calibrated and coated seeds were planted and germination parameters were investigated. Experiments were conducted in Kuzukuyu village of Ereğli District, at three different planting distances (2.5, 5.0 and 7.5 cm) in randomized blocks design (3x3) with 3 replications. Planting was done in three rows on a ridge (with 7.5 cm row spacing) at a forward speed of 0.64 m s^{-1}. Mean germination time was calculated as 19.90 days for uncalibrated bare seeds, 20.14 days for calibrated bare seeds and 20.79 days for coated seeds; germination rate index values were respectively calculated as 0.431, 0.761 and 0.656 [seeds (m days)$^{-1}$]; field emergence rates were respectively calculated as 37.13%, 60.97% and 55.19%; number of plants per unit area were respectively determined as 42.35, 69.14 and 59.61 plants m^{-2}. It was concluded based on present findings that calibrated bare and coated seeds should be used in planting process of black carrot seeds of Ereğli local population. Farmers should be trained on black carrot seed production.

Keywords: Black carrot, number of plants, mean germination time, germination rate index, germination ratio

1. Introduction

Carrots have been cultivated all around the world for centuries. It is largely cultivated also in Turkey. Black carrot (*Daucus carota* ssp. *sativus* var. *atrorubens* Alef.) originates from Turkey, Middle and Far East and has been cultivated for at least 3 000 years (Montilla et al., 2011). In Turkey, black carrots are produced

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especially in Ereğli and Karapınar Districts of Konya province and Kırıkhan District of Hatay province. Generally local populations are used as seed materials.

Worldwide, carrot (including black carrot) is produced on 1.125 million hectares and annual production is around 40.95 million tons with an average yield of about 36.38 t ha^{-1} (FAO, 2021).

In Konya Region, in 2021, a total of 353 700 tons of carrots were produced from 4 990 ha land area and the average yield was 70.9 t ha^{-1} (TUIK, 2021). It is estimated that in 2019, concentrate companies made approximately 120-130 thousand tons of black carrot purchase contracts in the region. In other words, about 1/3 of the carrot production of Konya Region is constituted by black carrot production. It can be emphasized that this production quantity is used as fermented beverage and concentrate. Therefore, there is an increasing interest in black carrot production and cultivation areas are becoming widespread in Ereğli and Karapınar Districts. Black carrot has an economic importance for these districts.

There is no registered black carrot variety and carrot seeds of Ereğli local population are used in production. Agricultural enterprises of the region also produce black carrot seeds of Ereğli local population. These seeds are passed through a single sieve, cleaned and classified (calibrated).

In Turkey, number of studies on seed production and planting of black carrots is limited. Kiracı (2013) created a gene pool for different types of purple carrots grown in Konya province and surroundings and used in industry, made the selection of the lines in the gene pool and identified the carrot lines that are preferred for industrial consumption and have high anthocyanin, sugar and β-carotene contents. Lökoğlu (2019) conducted a study to overcome seed production problems of black carrots and investigated the effects of root size and storage conditions on seed yield and quality in the first phase and the effects of planting spacings on seed yield and quality traits in the second phase of the study. Örnek et al. (2018) conducted a study with bare black carrot seeds of Ereğli population with a thousand-seed weight of 1.64 g and a laboratory germination rate of 91% under field conditions and planted seeds at 46.50 mm plant spacing and 0.84 m s^{-1} forward speed. The average germination time was reported as 18.33 days, germination rate index as 0.665 [(seeds (m day)$^{-1}$] and field emergence rate as 49.17%. Bülbül (2017) used a vertical spindle rototiller to prepare seedbeds for black carrot seeds and planted seeds with the use of different pressure wheels, plant spacing (2.5, 5 and 7.5 cm) and a forward speed of 0.75 m s^{-1}). Mean germination time was reported as 19.68 days, germination rate index as 0.479 [seeds (m days)$^{-1}$] and field emergence rate as 43.11%. Önal and Hacıseferoğulları (2022), in their research the bare and covered Kırıkhan population determined the average germination time, germination rate index and field emergence values as 9.40 and 9.18 days, 1.688 and 1.547 [seeds (m days)$^{-1}$], and 54.15% and 52.39%, respectively, in sowing using black carrot seeds.

The angle that a seed makes with the horizontal while falling onto the line is expressed as the impact angle. In planting uncoated (bare) and coated seeds with vacuum-type perforated planters, seed displacements on the line relatively decrease at impact angles above 40° and get minimum values at impact angle range of 75°-85° (Önal, 2011). The coating-induced increase is seed weight increases impact angles and these seeds fall onto the line close to the vertical direction and less spatter on the line. In this case, a more uniform seed spacing is achieved (Barut, 2006). Sowing depth uniformity of coated seeds is better than uncoated seeds, and seed germination is also affected by properties and thickness of the coating material.

There is no research on calibrated bare and coated black carrot seeds of Ereğli population in Konya region. In this study, bare seeds were cleaned and sorted before sowing and sorted seeds were also coated. These seeds in three different structures were sown at three nominal sowing distances by using a vacuum-type pneumatic precision vegetable planter that can plant in narrow row spacing in field conditions and field emergence characteristics were evaluated.

2. Materials and Methods

A vacuum-type pneumatic precision vegetable planter with four planter units was used for planting black carrot seeds (Figure 1). Planting was performed at narrow row spacing. In this research, a stainless-

steel press wheel at the front, a rubber press wheel at the rear and medium triple narrow intermediate rubber wheels were used for sowing black carrot seeds (Figure 2).

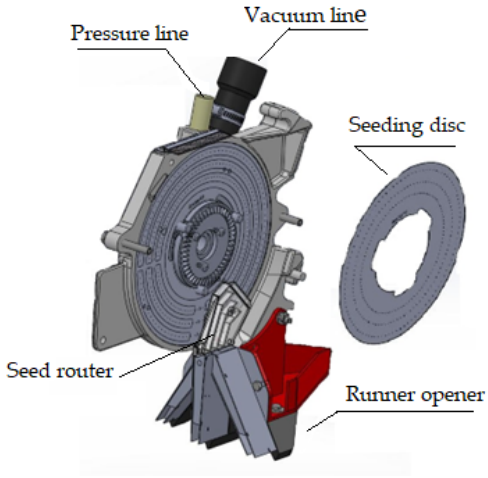

Figure 1. Schematic view of a planter unit and a planter disc

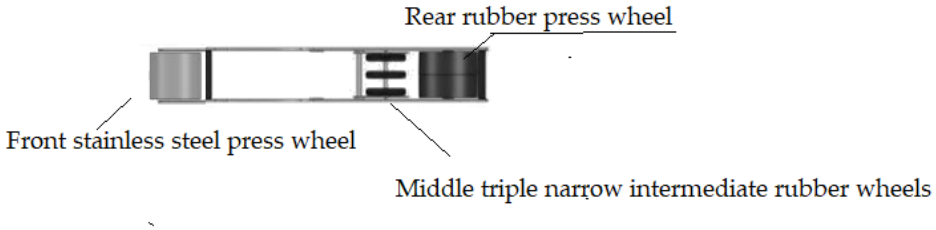

Figure 2. Schematic view of press wheel

Planter disc has a diameter of 235 mm and a thickness of 0.25 mm. In sowing, the diameter of the planting disc used is 235 mm and the thickness is 0.25 mm. There are 96 holes on planter disc arranged in three rows. From the top-hole axis, the hole axes have diameters of 210, 185 and 155 mm, respectively. Although the linear velocity values of three rows on planter disc are different, planting is done at the same planting spacing. Planting was carried out at an average vacuum pressure of 35 mbar and an air pressure of 15 mbar.

Black carrot seeds produced under farmer conditions in 2020 were used as the seed material of the study (Figure 3). Uncalibrated bare seeds (T_1) used in black carrot production contain foreign matter and weak grains. The average 1000-grain weight of these bare seeds (T_1) was 1.71 g and the germination rate was 76%. As a second process, these seeds were calibrated, passed through an oblong sieve of 1.75 mm, 1.50 and 1.25 mm, subjected to gravity and classified based on their specific gravity (T_2). The average 1000-grain weight of these classified seeds was 2.04 g and the germination rate was 86%. The classified bare seeds were coated with a special recipe integrated with a polymer structure by processing (subjecting to special processes) different materials (T_3). The germination rate of resultant coated seeds was determined as 84% and the sphericity value was determined as 0.62.

In present experiments, 3-row planting discs with a hole diameter of 0.5 mm were used for planting uncalibrated bare seed, 0.7 mm for calibrated bare seeds and 1.2 mm for coated seeds. Experiments were conducted in Kuzukuyu neighborhood of Ereğli District. All operations were carried out with the use of Hattat A78 brand tractor. Experimental soils were loamy-sand in texture with 4% clay, 10% silt and 86%

sand. Seed bed had a pH of 8.96, was strong alkaline with a lime content of 39.2% and organic matter content of 1.31%. Bulk density of 0-15 cm soil profile was 1.38 g cm^{-3} and average moisture content was 9.99%.

Normal bare seeds (T_1) Calibrated bare seeds (T_2) Coated seeds (T_3)

Figure 3. Seeds used in present experiments

From planting to end of germination of black carrot seeds for one month duration, daily average, minimum and maximum temperatures were respectively measured as 19.6 ºC, 11.3 ºC and 27.6 ºC; average, minimum and maximum soil temperatures at a depth of 5 cm were respectively measured as 25.6 ºC, 21.0 ºC and 30.7 ºC and there was no precipitation during the germination period (TSMS, 2021).

The agronomic practices and amount of irrigation water applied throughout emergence period are given in Table 1. In previous year, wheat was planted in the research area. Experimental plots were first plowed with a moldboard plow, 30 kg da^{-1} NPK 12-30-12 compound fertilizer was applied to soil surface with a centrifugal fertilizer spreader and seed bed was prepared with a vertical spindle rototiller.

Table 1. Agronomic practices and irrigations

Date	Agronomic practices
26.04.2021	Plowing with mold board plow
28.04.2021	Fertilizer application with centrifugal fertilizer spreader (30 kg da^{-1} NPK 12-30-12 composed)
28.04.2021	Seed bed preparation with vertical rototiller
29.04.2021	Preparation of planting ridges
29.04.2021	Planting
	Irrigations
30.04.2021	1st Sprinkler irrigation (72 mm)
03.05.2021	2nd Sprinkler irrigation (54 mm)
08.05.2021	3rd Sprinkler irrigation (36 mm)
12.05.2021	4th Sprinkler irrigation (36 mm)
18.05.2021	5th Sprinkler irrigation (36 mm)
22.05.2021	6th Sprinkler irrigation (54 mm)
27.05.2021	7th Sprinkler irrigation (54 mm)

Planting ridges were created with a pneumatic precision vegetable planter before planting (Figure 4). Sprinkler irrigation was applied 7 times from planting to last day of emergence. Totally, 342 mm of irrigation water was given.

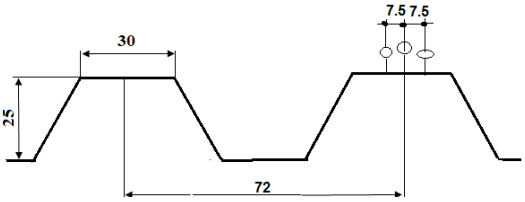

Figure 4. Schematic view and dimensions of planting ridges (cm)

Planting was done on three narrow rows with 7.5 cm spacing between the rows. The nominal planing distances on each row were chosen as 2.5, 5.0 and 7.5 cm and forward speed was chosen as 0.64 m s^{-1}.

Experiments were conducted with Ereğli local population black carrot seeds subjected to 3 different processes (T_1, T_2 and T_3) and 3 different planting distances (Z_1, Z_2 and Z_3) in randomized blocks design (3x3) with 3 replications. Experimental plots were 125 m long and 2.8 m wide (350 m^2). Soil penetration resistance was measured from the plots formed after seed bed was prepared and empty planting ridges formed, as well as from the tracks of pressure wheel formed on the ridge after planting process. Five measurements were made from five randomly selected plots with a penetrometer with a base cone area of 2 cm^2 and an apex angle of 30º.

To determine germination parameters of the seeds, 1 m long sections of randomly selected 3 planting ridges of each plot were selected and carrot sprouts emerging to soil surface were counted throughout the germination period and mean germination time (MGT), germination rate index (GRI) and field emergence rate (FER) values were calculated with the following equations (Erbach, 1982; Işık et al., 1986).

$$MGT=\frac{N_1D_1+N_2D_2+\ldots N_nD_n}{N_1+N_2+\ldots+N_N} \quad \text{(day)}$$

$$GRI=\frac{\text{Number of germinated seeds per meter}}{MGT} \quad [\text{seeds (m day)}^{-1}]$$

$$FER=\frac{\text{Number of germinated seeds per meter}}{\text{Number of planted seeds per meter}} \times 100 \quad (\%)$$

N: Number of germinated seeds in each count

D: Number of days passed after planting

To determine the number of plants per unit area, the plants in randomly selected 1.4 m sections of each row (1 m^2) was counted in 5 replications. About 32 days after planting, main root lengths and plant heights of randomly selected carrot plants were measured in 10 replications (Eker, 1988).

Data normality was checked with the use of Shapiro-Wilk test. Experimental data were subjected to analysis of variance with the use of MINITAB 16 software. Significant means were compared with the use of LSD analysis of MSTAT-C software.

3. Results and Discussion

3.1. Penetration resistance

Penetration resistance values measured from the seed beds are presented in Figure 5. It was observed that penetration resistance measured at 25 cm soil tillage depth passed over 2 MPa value.

Penetration resistance values measured from empty ridges and pressure wheel tracks are presented in Figure 6. Penetration resistance at 1 cm planting depth was about 0.15 MPa.

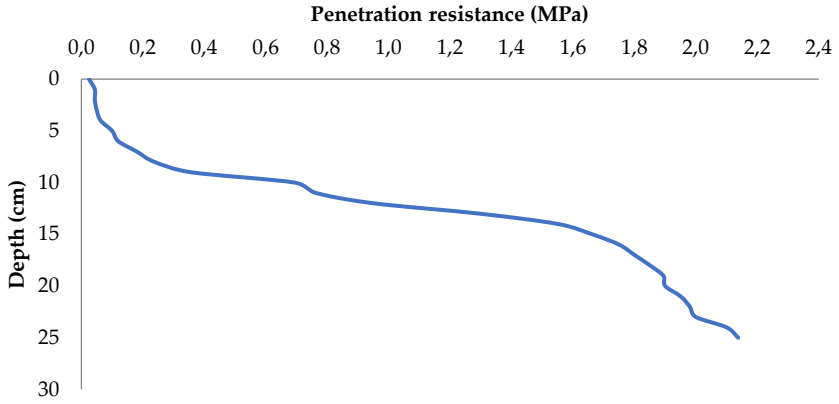

Figure 5. Penetration resistance curve of seed bed

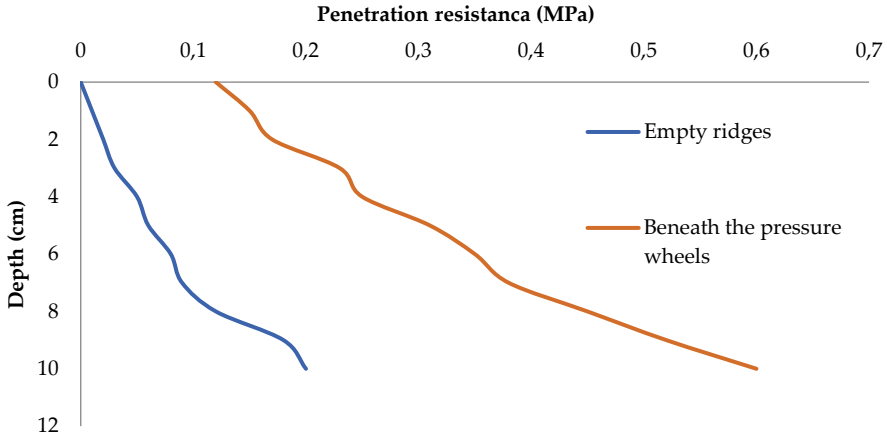

Figure 6. Penetration resistance of empty ridges and pressure wheel tracks

3.2. Germination and growth parameters

Change in germination parameters (mean germination time - MGT, germination rate index - GRI, field emergence rate - FER) with experimental treatments are provided in Table 2.

Table 2. Germination parameters of black carrot seeds

Seeds	Planting distance	MGT (day)	GRI [seed (m day)$^{-1}$]	FER (%)	Mean MGT	Mena GRI	Mean FIR
T_1	Z_1	20.16	0.544	27.46	19.90	0.431_b	37.13_b
	Z_2	19.75	0.382	35.98			
	Z_3	19.80	0.367	47.95			
T_2	Z_1	20.46	1.157	57.98	20.14	0.763_a	60.97_a
	Z_2	20.11	0.649	61.64			
	Z_3	19.85	0.483	63.27			
T_3	Z_1	22.03	0.961	52.01	20.79	0.658_a	55.19_a
	Z_2	19.34	0.592	54.50			
	Z_3	21.03	0.422	59.07			
						LSD=0.251(p<0.01)	LSD=8.183 (p<0.01)

Mean germination time was calculated as 19.90 days for T_1, 20.14 days for T_2 and 20.79 days for T_3. While coated black carrot seeds (T_3) had higher values, uncalibrated bare seeds (T_1) had lower values. Since T_1 seed

was not calibrated, germination was completed early due to weak and undersized seeds and germination was completed later in T_3 seed due to coating. However, there was no statistical difference between the mean germination times of the seeds. However, differences in mean germination time values of black carrot seeds were not found to be significant. A duff layer is usually formed in seed bed; thus 7 sprinkler irrigations were performed throughout the germination period to keep soil surface moist and prevent formation of a duff layer. Such a case resulted in insignificant differences in mean germination times. Bülbül (2017) reported mean germination time values of uncalibrated bare black carrot seeds of Ereğli local population as 18.82 days in 2015 and 19.38 days in 2016.

The highest germination rate index (0.763) was obtained from T_2 seeds and the lowest (0.431) from T_1 seeds. Germination rate index of T_3 seeds was calculated as 0.658 [seeds (m days)$^{-1}$]. Differences in germination rate index values of the seeds were found to be significant (F=7.58). Germination rate index values varied also with nominal planting distances and values were calculated as 0.887 for Z_1, 0.541 for Z_2 and 0.424 [seeds (m day)$^{-1}$] for Z_3. Resultant differences were found to be significant (F=15.27). Bülbül and Hacıseferoğulları (2016) used different types of pressure wheels and reported germination rate index values as between 0.194 - 0.971 [seeds (m days)$^{-1}$]. Örnek et al. (2018) planted uncalibrated bare black carrot seeds at 22.36, 46.50- and 68.70-mm nominal distances and reported germination rate index values as 1.007, 0.616 and 0.467 [seeds (m days)$^{-1}$], respectively. Present germination rate index values were similar with those earlier findings.

Field emergence rates of uncalibrated bare seeds were calculated as 37.13% for T_1, 60.97% for T_2 and 55.19% for T_3. Differences in field emergence rates were found to be significant (F=7.55). For nominal planting distances, the lowest field emergence rate (45.81%) was obtained from Z_1, followed by Z_2 (50.70%) and the highest value (56.76%) was obtained from Z_3. However, resultant differences were not found to be significant. Bülbül and Hacıseferoğulları (2016) conducted a study with a pneumatic precision vegetable planter with a front and rear pressure wheels and a triple narrow tire in the middle with adjustable pressure and reported field emergence rates as between 33.33 - 48.07%. Örnek et al. (2018) used a pneumatic precision vegetable seed drill at 0.84 m s^{-1} forward speed and 22.36, 46.50- and 68.70 mm nominal planting distances and reported field emergence rates as 55.24%, 49.17% and 54.42%, respectively.

Change in plant height and root depths of black carrot seeds with experimental treatments are provided in Table 3.

Table 3. Plant height and root depths of different black carrot seeds

Seeds	Planting distance	Plant height (mm)	Root depth (mm)	Mean plant height (mm)	Mean root depth (mm)
	Z_1	55.35	142.34		
T_1	Z_2	52.78	158.34	56.08$_b$	156.17$_b$
	Z_3	60.12	167.82		
	Z_1	65.41	183.08		
T_2	Z_2	64.55	166.86	66.23$_a$	179.18$_a$
	Z_3	68.72	187.59		
	Z_1	63.64	190.06		
T_3	Z_2	63.60	178.48	63.69$_{ab}$	182.10$_a$
	Z_3	63.84	180.75		
				LSD=7.822 ($p<0.01$)	LSD=19.620 ($p<0.05$)

Average plant height was determined as 56.08 mm for T_1, 66.23 mm for T_2 and 63.69 mm for T_3. The lowest plant height was obtained from T_1 seeds because of high rate of undersized seeds since they were not calibrated. Differences in plant heights of the seeds were found to be significant. Plant heights also varied with nominal planting distances. Average plant height was determined as 61.47 mm for Z_1, 60.31 mm for Z_2 and 64.23 mm for Z_3, but resultant differences were not found to be significant. Bülbül (2017) used a V-channel triple casting pressure wheel with sheet metal front wheel, rubber rear wheel and middle wheel, pressure of which can be adjusted with a spring, and nominal planting distances of 2.5 cm, 5.0 and 7.5 cm. Plant heights were reported as between 40.23 – 42.27 mm. Those values were greater than the present ones. Kayışoğlu (1993) applied a pressure from the bottom of pressure wheel in sunflower planting and obtained a plant height of 7.41 cm.

Root length was determined as 182.10 mm for T_3, 179.18 mm for T_2 seed and 156.17 mm for T_1 seeds. The differences in root lengths of T_2 and T_3 seeds were not found to be significant, but differences from T_1 seeds were found to be significant. Root length was measured as 171.83 mm for Z_1, 168.89 mm for Z_2 and 178.72 mm for Z_3. Kayışoğlu (1993) emphasized that there should be a strong ground on which the plant receives support while applying a pressure from pressure wheel and sheet metal pressure wheel in front of vacuum-type pneumatic vegetable planter provided a sufficiently compacted hard zone under the seed bed and three-row narrow rubber wheel in the middle-performed compaction at planting depth, thus obtained higher root lengths. Plant root length values were found to be high due to compaction at the level of the plant. Root length values of T_1 seeds (uncalibrated bare seeds) were found to be lower than the other two seeds. Bülbül (2017) planted black carrots with different types of pressure wheels and reported root length as 72.54 mm for seed beds prepared with vertical spindle rototiller. Present root lengths were greater than this value. Kayışoğlu (1993) reported root length of sunflower as 7.70 cm when a pressure applied from farrow bed and 6.84 cm when a pressure was applied from the surface.

3.3. Number of plants per unit area

Number of plants per unit area values obtained from triple ridge planting of different seeds and at different planting distances is provided in Table 4.

Table 4. Number of plants per unit area

Seeds	Planting distance	Number of plants per unit area (plant m^{-2})	Mean number of plants per unit area (plant m^{-2})
	Z_1	55.21_{bc}	
T_1	Z_2	41.77_{cde}	42.35_{c}
	Z_3	30.08_{e}	
	Z_1	101.53_{a}	
T_2	Z_2	58.88_{b}	69.14_{a}
	Z_3	47.11_{bcd}	
	Z_1	97.85_{a}	
T_3	Z_2	45.67_{cde}	59.61_{b}
	Z_3	35.32_{de}	
		LSD=16.97 ($p<0.01$)	LSD=9.508 ($p<0.01$)

The highest number of plants per unit area (69.14 plant m^{-2}) was obtained from T_2 seeds, followed by T_3 seeds with 59.61 plant m^{-2} and the lowest value (42.35 plant m^{-2}) was obtained from T_1 seeds. Differences in number of plants per unit area were found to be significant (F=33.17). Number of plants per unit area (1 m^2) decreased with increasing planting distances. Number of plants per unit area was determined as 84.86 plant m^{-2} for Z_1, 48.74 plant m^{-2} for Z_2 and 37.50 plant m^{-2} for Z_3. Resultant differences in number of plants per unit area values were found to be significant (F=112.14). In terms of interactions, the greatest number of plants per unit area was achieved in T_2Z_1 and T_3Z_1 combinations and there were significant differences (F=8.09). For Karapınar region of Konya province, number of plants per unit area should be between 60-90. However, number of plants obtained with T_1 seeds was found to be far from these values. With these seeds, even at Z_1 nominal planting distance, 60-90 plant m^{-2} could not be reached. Bülbül (2017) used 3-row planter disc with 96 holes and reported number of plants at 2.38, 4.65 and 6.78 cm nominal plant distances respectively as 46.82, 31.60 and 28.93 plant m^{-2} in 2015, as 52.55, 47.45 and 40.87 plant m^{-2} in 2016. Present values obtained from T_2 and T_3 seeds were greater than those earlier values.

4. Conclusions

Black carrot seeds of Ereğli local population should be cleaned and sorted before planting. Local producers do not produce seeds under primitive conditions and seed characteristics differ from producer to producer. In particular, they do not perform the cleaning process effectively. In this case, the hairs in unclassified seeds (due to insufficient cleaning) can cling onto disc holes and cause clumps in seed storage due to static electricity. Thus, it prevents the mixer from doing its job. Mixer should be checked at certain intervals during planting. Such a case has a negative effect on both field emergence and uniform distribution

on a row. Further research should be conducted to improve coating properties of calibrated bare seeds. Research should be done on different coating materials and ratios. Studies should be conducted on hole diameters for different seed characteristics. Further research is also recommended on singling unit of domestically-made machine since singling of three hole rows is done with a single piece manufactured as singling unit. In this case, especially the holes in upper row cannot be singled out effectively. Local farmers should be trained on black carrot seed production. Calibrated bare and coated black carrot seeds should be used in black carrot farming.

Author Contributions: The authors have an equal contribution. All authors have read and agreed to the published version of the manuscript. This article summarized from Mehmet ARIKAYMAK's MSc thesis.

Conflicts of Interest: The authors declare no conflict of interest.

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