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Physical Properties and Germination Characteristics of Black Carrot Seeds of Kırıkhan Local Cultivar in Ereğli District of Konya Province

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ABSTRACT

Black carrot production is an important agricultural activity for local farmers of Ereğli and Karapınar districts of Konya province. About 20% of the black carrots produced are used in turnip industry and 80% is used in concentrate production. The color value of black carrots of Kırıkhan local cultivar is higher than that of black carrots of Ereğli cultivar. Therefore, concentrate companies prefer the local cultivar of Kırıkhan in Ereğli and Karapınar Districts of Konya. In this study, some physical properties of black carrot seeds of local population of Kırıkhan cultivar were determined and seeds were sown at three different on-row seed spacings (2.5, 5 and 7.5 cm). Sowing was performed on ridges in three narrow rows as to have 7.5 cm between the rows and at a forward speed of 0.64 m s^{-1}. Average length values of the classified bare and coated black carrot seeds were respectively determined as 3.52 and 4.02 mm, geometric mean diameter values as 1.65 and 2.31 mm, sphericity values as 47.49 and 58.73%, thousand-seed weights as 2.20 and 6.67 g, germination rate values as 82.50 and 76.30%. Fracture resistance value of the coated seeds was measured as 4.89 Nmm^{-2}, water dissolution time as 18.48 s and one-seed ratio in coating as 96%. In field trials conducted at different sowing distances, average germination time of classified bare seeds and coated seeds were repectively determined as 9.40 and 9.18 days, germination rate index values as 1.688 and 1.547 [plant (m day)$^{-1}$] and the field emergence rate values as 54.15 and 52.39%.

1. Introduction

Carrot (*Daucus carota* L.) belongs to the genus Daucus with 22 species and it is the most important cultured member of the Apiaceae family. An estimated 13 sub-species of Daucus carota have been identified (Simon and Goldman, 2007). One of these sub-species is the cultivated carrot and the other twelve are wild forms that do not have a usable root structure.

Carrot grows in 60-150 days depending on genotype and environmental conditions and does not bloom during the vegetative life cycle (Simon et al., 2008). Climate and especially temperature have quite a significant effect on carrot production. The optimum temperature for germination is 10°C. The most suitable carrot color is formed at temperatures between 15.5 - 21°C and the product gets a bad color at temperatures below and above this range of temperature. The longest roots are also formed at these temperatures (Günay, 2005).

In Turkey in 2021, carrot cultivation was practiced on 100 686 da land area and there was a production of 590 483 tons. Konya Region has 49.56% of these production areas and meets about 60% of total production (TÜİK, 2022a).

In Turkey, carrots are mostly produced in Central Anatolia and Konya Region. Yellow carrot is produced in Kaşınhanı Region of Konya and black carrot is produced in Ereğli and Karapınar Districts. Black carrot production is also practiced in Kırıkhan District of Hatay Province. In this region, local population black carrot seeds of Kırıkhan cultivar are used. It was reported that Kırıkhan cultivar had greater anthocyanin content than the other black carrot cultivars (Anonymous, 2019). Kırıkhan Chamber of Commerce and Industry obtained geographical indication registration for "Kırıkhan Black Carrot" on November 18, 2022 (Anonymous, 2022b).

Black carrots have a purple color because of high anthocyanins content. These anthocyanins have high light, heat and pH stability and are preferred as natural food colorants. Therefore, it is used as a natural colorant in food, textile, cosmetics and pharmaceutical in-

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dustries as an alternative of synthetic colorants. Black carrot extracts are used for coloration of fruit juice, jelly, candies, jams, canned and frozen desserts, ice cream, soft drinks and other fermented beverages (Ersus and Yurdagel, 2007; Barczak, 2005)).

In Hatay Kırıkhan Region, black carrots are generally sown in August - September and harvested in January - February. On the other hand, in Konya Region, black carrots are sown in April - May and harvested in November - December. In both regions, usually local populations are produced. Depending on climatic conditions, growth season is around 120-140 days for Kırıkhan local population and 140-150 days for Ereğli local population. The color value of black carrots of Kırıkhan local population is higher than that of black carrots of Ereğli population. Therefore, concentrate companies prefer the local population of Kırıkhan in Ereğli and Karapınar Districts. Seed production of Kırıkhan population is also practiced in the region. Black carrot seeds used by local producers of the region are only subjected to a sieving; cleaning and classification (calibration) are not practiced at all.

Previous studies on black carrot cultivation have mostly focused on Ereğli local cultivar seeds (Bülbül, 2017; Örnek et al., 2018, Arıkaymak, 2021). However, there is no research on seeds of Kırıkhan cultivar in Konya Region. In this study, some physical properties of black carrot seeds of local population of Kırıkhan cultivar were investigated under field conditions of Ereğli District of Konya Province. Contrary to local practices, bare seeds were cleaned, graded (calibrated) and also coated before planting. Vacuum type pneumatic precision seed drill able sow at narrow row spacing was used and field emergence characteristics were evaluated at three nominal sowing distances.

2. Material and Method

In present experiments, black carrot seeds of Kırıkhan cultivar, commonly grown by local farmers, were used (Figure 1). Classified (calibrated) bare seeds were first passed through 1.75 to 1.25 mm oblong sieves and classified based on their specific gravity (T_1). The classified bare seeds were coated with a special recipe created by processing (subjecting to special processes) materials with different properties in twice the amount of seed mass (T_2).

Figure 1
Bare and coated seeds used in experiments

Three groups of 100 each were formed from both seeds and 100 seeds were randomly selected from them. Length, thickness and width values of the bare seeds and length and largest diameter values of the coated seeds were determined with the use of "Image Tool version 3.0" image analysis software.

Geometric mean diameter and sphericity values of the coated and bare seeds were calculated with the following equations (Mohsenin, 1970; Önal, 2011).

$Dg=(L \cdot D^2)^{1/3}$ (Coated seeds)

$Dg=(L.W.T)^{1/3}$ (Bare seeds)

$\emptyset=Dg/L.\ 100$

Dg: Geometric mean diameter (mm)

L: Length (mm)

D: Largest diameter (mm)

W: Width

T: Thickness

Ø: Sphericity (%)

For seed mass measurements, 1000 randomly selected seeds were counted in a Contador brand seed counting device in three replicates and their masses were weighed on precision scales and averaged.

ISTA 2018 norms were taken into account in the germination tests of bare and coated black carrot seeds and the tests were carried out in a climate cabin (Anonymous, 2018).

From the coated seeds, 100 seeds were randomly selected in three replications. Selected seeds were broken and the number of seeds and empty coatings were counted.

Again, from the coated seeds, 100 seeds were randomly selected in three replications. Selected seeds were placed in water and the dissolution time of the coating material was measured in seconds with a chronometer and the averages were taken (Özcan, 2019).

A biological material test device was used to determine the fracture strength of coated black carrot seeds (Öğüt ve Aydın, 1992). The device has a fixed top and movable base, drive unit and data acquisition system. The coated seeds were placed on the movable table of the platform and pressed against the 1.20 mm diameter fixed upper probe at a loading speed of 50 mm min^{-1} (Figure 2). The breaking force of the seeds was measured with a 1 N precision force dynamometer and data acquisition system. The fracture resistance value of the seed was determined by dividing the measured force value by the area of the probe.

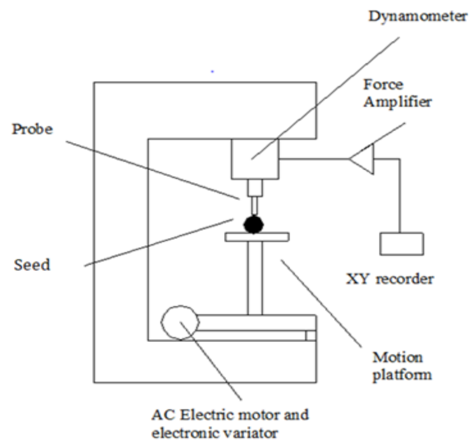

Figure 2
Biological material test unit

Field trials were carried out in Kuzukuyu neighborhood of Ereğli District in 2021. Experimental soils were loamy sand in texture with 86% sand, 4% clay and 10% silt. Soil pH was determined as 8.96, lime content as 39.2% and organic matter content as 1.31%.

In present experiments, a high precision vacuum type pneumatic precision vegetable planter with four planting units was used. Sowing was done in narrow row spacing with this seeding machine, and the schematic view of the unit, the used furrow opener and the planting disc is presented in Figure 3.,

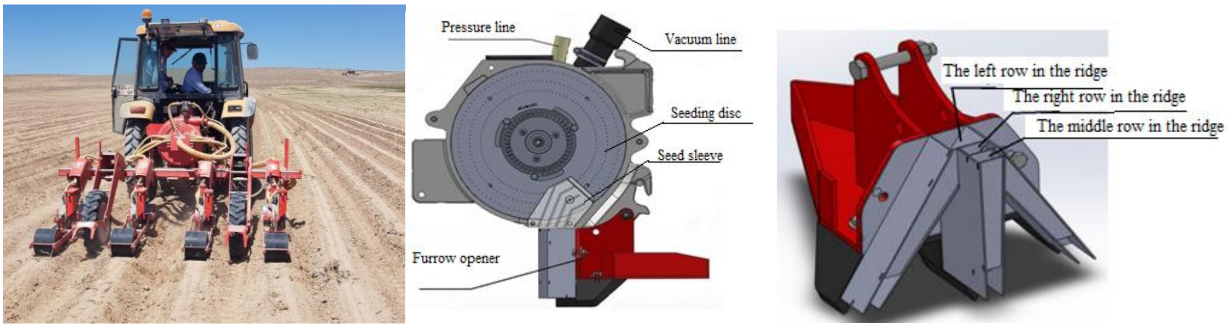

Figure 3
Pneumatıc precısıon planter (for vegetables and for small seed sowıng), schematic view of the unit and furrow opener

In the sowing process, a planting disc with a diameter of 235 mm and a thickness of 0.25 mm was used. There are 96 holes in the planter disc in the form of three rows. From the top row, the hole axes have diameters of 210, 185 and 155 mm. Although the linear velocity values of the three rows on the sowing disc are different, sowing is done at the same on-row plant spacing. In present experiments, planting discs with a hole diameter of 0.7 mm was used for calibrated bare seeds and a hole diameter of 1.2 mm was used for coated black carrot seeds of Kırıkhan cultivar. Sowing was carried out at an average vacuum pressure of 35 mbar and an air pressure of 15 mbar. In the present pneumatic precision seed drill, sheet metal pressure wheels were used in the front, rubber pressure wheels were used in the back and triple rubber pressure wheels were used in the middle.

From sowing (07.06.2021) to full germination (07.07.2021) of Kırıkhan black carrot seeds, daily average, minimum and maximum temperature values were respectively measured as 22.1 ^{0}C, 14.7 ^{0}C and 529.1 ^{0}C; mean, minimum and maximum soil temperature values at a depth of 5 cm were respectively measured as 29.6 ^{0}C, 24.4 ^{0}C and 34.9 ^{0}C and a total of 28 mm precipitation has occurred during this period (Anonymous, 2021).

Wheat was cultivated in experimental fields in previous year. Experimental fields were initially tilled with moldboard plow. Then, 50 kg da^{-1} DAP fertilizer was applied with a centrifugal fertilizer spreader and seed bed was prepared with a vertical spindle rototiller. Sowing ridges were formed with the use of a ridge making machine as to have 75 cm ridge distance 30 cm ridge width and 25 cm ridge height (Figure 4). The sowing process was carried out with a pneumatic precision vegetable sowing machine in three narrow rows on each ridge with 7.5 cm row spacing. On-row nominal sowing distances were 2.5, 5.0 and 7.5 cm. By taking into account the forward speed applied in farmer conditions, forward speed of the precision vegetable planter was set as 0.64 m s^{-1}.

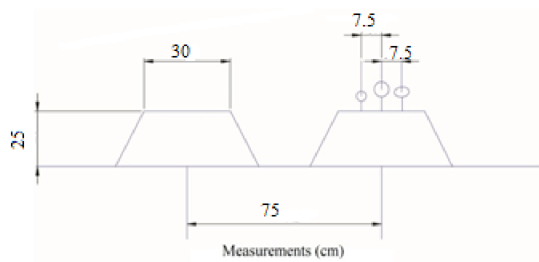

Figure 4
Schematic view of sowing ridge and dimensions (cm)

Irrigation water was supplied from a deep well and sprinkler irrigation system was used to apply irrigation water to the land. In the sprinkler irrigation system used, the sprinkler and lateral spacing was arranged as 10x10 m. Average flow rate of the sprinklers was measured as 1.8 m^3 h-1. During the germination period, 8 sprinkler irrigations were applied to the experimental plots and a total of 432 mm of water was applied.

In present experiments, calibrated bare (T_1) and coated (T_2) local population standard black carrot seeds of Kırıkhan cultivar were used and sowing was practiced at three different nominal sowing distances (Z_1, Z_2 and Z_3). Experiments were conducted in "Randomized Blocks Design" with three replications. Plot length was 150 m and width was 2.8 m (350 m^2) and no space was left between the plots.

Soil samples were taken from the seed beds of randomly selected five plots at 0-5 cm, 5-10 cm and
10-15 cm depths in three replicates. Sampling cylinders made of stainless steel have a diameter of 5 cm and a volume of 100 $cm^{3.}$ Soil moisture content and bulk density values were calculated with the use of the following equations (Blake and Hartge, 1986).

$$W=\frac{M_W}{M_S}\ x\ 100$$

W : Moisture content (dry-based) (%)
Mw: Mass of water in sample (g)
Ms : Oven-dried mass of sample (g)

$$P_b=\frac{M}{V_t}$$

P_b: Bulk density (g cm^{-3})

M: Oven-dried mass of sample (g)

V_t: Volume of sampling cylinder (100 cm^3)

Soil penetration resistance values were measured from the plots formed after the seed bed was prepared, from an empty ridge after the ridges were formed and from the footprint of pressure wheel on the ridge after planting. The base area of the cone used for this purpose is 2 cm^2 and the apex angle is 30°. The measuring range of the penetrometer is 0-250 N cm^{-2} and 5 measurements were made from randomly selected five plots.

To determine the germination values of the seeds, the carrot sprouts emerging to the soil surface were counted during the germination period from 1 m section of randomly selected three ridges of each plot. Following equations were used to calculate mean germination time (MET), germination rate index (GRI) and field emergence rates (FE) (Erbach, 1982; Isık et al., 1986).

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

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

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

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 (%)

The factorial (2x3) randomized plot design was used to examine the data (Düzgüneş et al., 1987). The GLM (ANOVA) procedure of MINITAB was used to conduct the statistical analysis. The Tukey test was used to determine the significant differences between the means. In all statistical analyses, the significance level was accepted as 0.05.

3. Results and Discussion

3.1. Seed physical properties

Some physical properties of seeds used in this study are provided in Table 1. The length, width, thickness, geometric mean diameter and sphericity values of the classified bare black carrot seeds at 3.53% moisture content were respectively measured as 3.52 mm, 1.56 mm, 0.86 mm, 1.65 mm and 47.49%.

Table 1
Physical properties of bare and coated black carrot seeds

Property	Bare seeds (calibrated)	Coated seeds
Moisture (w.b) (%)	%3.53	%4.97
Length (mm)	3.52±0.193	4.02±0.221
Width (mm)	1.56±0.092	-
Thickness (mm)	0.86±0.087	-
Maximum diameter	-	1.77±0.068
Geometric mean diameter (mm)	1.65±0.082	2.31±0.031
Sphericity (%)	47.49±2.031	58.73±0.808
Thousand-seed weight (g)	2.20±0.100	6.67±0.067
Germination ratio (%)	82.50±4.55	76.30±2.32
Fracture resistance (N mm^{-2})	-	14.89 ±0.601
Water dissolubility time (s)	-	18.48 ±2.12
Number of seeds in coating		
Empty seed ratio (%)	-	2.33±0.34
One-seed ratio (%)	-	96.0±0.58
Two-seed ratio (%)	-	1.67±0.33

Length, maximum diameter, geometric mean diameter and sphericity values of the coated seeds at 4.97% moisture content were respectively measured as 4.02 mm, 1.77 mm, 2.31 mm and 58.73%. Size characteristics of the coated seeds increased and the sphericity value increased by 1.24 times. Seed weights of the classified black carrot seeds of Kırıkhan cultivar increased with coating process and the average thousand-seed weight was determined as 2.20 g for bare seeds and 6.67 g for coated seeds. Germination rates of bare and covered seeds were determined as 82.50% and 76.30%. Certification conditions require the seeds to have a germination ratio greater than 75% (Anonim, 2022c). Differences in germination percentages of covered and bare seeds were at an acceptable level. Therefore, it was observed that sowing with seed coating was not an important factor that will make germinationdifficult.

The fracture resistance value of the coated seeds was determined as 14.89 Nmm^{-2}. This value is important for processing, packaging, transportation of the seeds, filling the seeds into the storage of sowing machine and not disintegrating the coating with the scraper effect. Dissolution of coating materials in water is a desired feature in coating processes. The less time the coating dissolves in water, the easier the plant emerge. Average water dissolution time of the coated black carrot seeds was found to be 18.48 s. Number of seeds in the coating is also an important criterion in coating studies. Seed consumption is especially important for the seeds to be planted with precision. In coated seeds, one-seed ratio was 96%, two-seed ratio was 1.67% and empty seed ratio was 2.33%.

3.2. Physical properties of seed beds

Bulk density and moisture contents of soil samples taken from seed beds before the formation of ridges are provided in Table 2. Bulk density and moisture levels were lower at 0-5 cm depth than at 5-10 and 10-15 cm depths. As the average of blocks, bulk densities at different depths were respectively measured as 1.42, 1.48 and 1.50 g cm^{-3} and moisture contents were measured as 7.56, 11.63 and 12.29% respectively.

Table 2

Bulk density and moisture content of soil

	Depth (cm)	I. Block	II. Block	III. Block	Average of blocks
Bulk density (g cm^{-3})	0-5	1.43	1.34	1.45	1.42
	5-10	1.48	1.46	1.51	1.48
	10-15	1.49	1.48	1.53	1.50
Moisture content (%)	0-5	7.79	7.85	7.03	7.56
	5-10	11.92	11.34	11.72	11.63
	10-15	12.27	12.12	12.49	12.29

The penetration resistance values measured in the seed bed are presented in Figure 5. The penetration resistance value measured at approximately 25 cm tillage depth exceeded 2 MPa. Higher bulk densities resulted in having higher penetration resistance since soil compaction is an indicator of bulk density

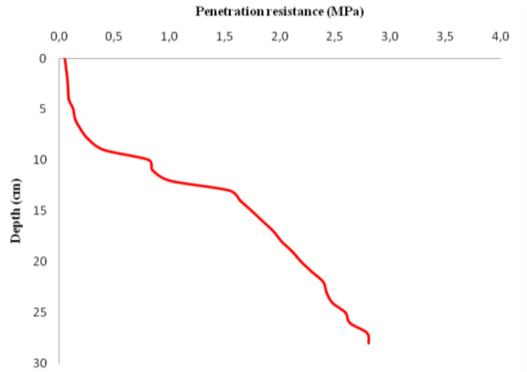

Figure 5

Penetration resistance curve for seed bed

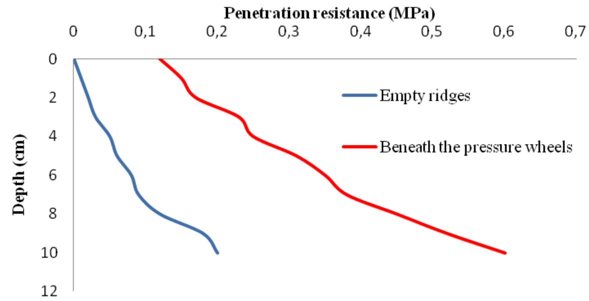

Figure 6

Penetration resistance curves for empty ridges and beneath pressure wheels

The penetration resistance values measured from the empty ridges and beneath the pressure wheels are presented in Figure 6. A penetration resistance of 0.15 MPa was determined at 1 cm sowing depth.

3.3. Seed germination parameters

Change in germination parameters with the experimental treatments is provided in Table 3.

Mean germination time (MET) was identified as 9.04 days for bare black carrot seeds (T_1) and 9.18 days for coated seeds (T_2). Although germination was completed later in T_2 seed due to coating, there was no significant difference between the mean germination times of the seeds. Fine-grained seed beds are known to form a sticky mud layer over the soil surface, thus eight time sprinkler irrigations were practiced throughout the germination period to keep the soil surface moisture and to prevent the formation of hard crusted layer. Such a case then resulted in having no difference between the average emergence times of the seeds. The mean germination time values decreased with increasing on-row seed spacing in both seed types. In T_1 and T_2 seeds, mean germination times were respectively measured as 10.67 and 10.53 days at Z_1 nominal planting distance, as 9.01 and 9.51 days at Z_2 nominal planting distance and as 7.43 and 7.49 days at Z_3 nominal planting distance. This difference in low nominal planting distance was due to the higher planting disc circumference speed as compared to other planting distances. Seeds fall on the line at a higher speed, can be displaced in the line and change in depth, so the germination time values are prolonged. Bülbül (2017) found the mean germination time values of non-calibrated bare local population seeds of Ereğli cultivar as 18.82 days and 19.38 days in 2015 and 2016. Arıkaymak (2021) reported mean germination time of calibrated bare and coated local population black carrot seeds of Ereğli cultivar as 20.14 and 20.79 days. Low mean germination times of the present study could be attributed to seed cultivar and sowing time.

Maximum average germination rate index value was found to be 1.688 in T_1 seeds and 0.1547 [nummer (m day)$^{-1}$] in T_2 seeds. This difference was found to be significant. GRI values at Z_1, Z_2 and Z_3 nominal planting distances were determined as 1.672, 1.636 and 1.545 [nummer (m day)$^{-1}$], respectively and differences were found to be significant. High germination rate index values of T_1 seeds were mostly because of high field emergence rates and high germination rate index at low nominal planting distance was because of high number of plants per unit length. Örnek et al. (2018) determined the average ERI values of uncalibrated barse seeds at 22.36, 46.50 and 68.70 mm nominal planting distances as 1.007, 0.616 and 0.467 [plant (m days)$^{-1}$], respectively. Bülbül and Hacıseferoğulları (2016) conducted a study with different pressure wheels and reported germination rate index values as between 0.194 and 0.971 [nummer (m days)$^{-1}$]. Present germination rate index values were lower than those of the earlier studies. Such a case probably was resulted from low average mean germination time values of the present study.

Table 3
Germination parameters of base and coated black carrot seeds of Kırıkhan cultivar

		MET (day)	GRI [nummer (m day)$^{-1}$]	FE (%)
Seeds	T_1	9.04	1.688^a	54.15
	T_2	9.18	1.547^b	52.39
	SEM	0.1205	0.01872	0.6401
	P-value	0.429	0.000	0.075
On-row plant spacing	Z_1	10.59 ^{a}	1.672 ^{a}	35.50 ^{c}
	Z_2	9.26 ^{b}	1.636 ^{a}	5830 ^{b}
	Z_3	7.46 ^{c}	1.545 ^{b}	66.05 ^{a}
	SEM	0.1475	0.02293	0.7840
	P-Value	0.000	0.006	0.000
Seed x Spacing	T_1 x Z_1	10.67	1.759	36.84
	T_1 x Z_2	9.01	1.730	59.55
	T_1 x Z_3	7.43	1.573	66.07
	T_2 x Z_1	10.53	1.584	34.17
	T_2 x Z_2	9.51	1.542	57.06
	T_2 x Z_3	7.49	1.516	63.93
	SEM	0.2087	0.03242	1.1087
	P-Value	0.329	0.124	0.468

$^{a, b}$Means with different superscripts within a column differ significantly ($P<0.05$), SEM: Standard error means, T_1: Calibrated bare seed, T_2: Coated seed, Z_1, Z_2 and Z_3 nominal sowing distances, MET: Mean germination time; GRI: Germination Rate Index; FE: Field emergence rate

Field emergence rates (FE) were found to be 54.15% in calibrated bare seeds (T_1) and 52.39% in coated seeds (T_2) (Table 3). The lowest field emergence rate (35.50%) was obtained from Z_1 nominal planting distance, 58.30% from Z_2 nominal planting distance and 66.05% from Z_3 nominal planting distance. On-row seed distance parameter was found to be significant. Such a case was due to the reduction in transmission ratio of the pneumatic precision vegetable seed drill, as well as the reduction of disc circumferential speed. Similar relationships were also reported by Tasbas (1994) for maize seeds, by Hacıseferoğulları (2005) for sugar beet seeds and by Bülbül (2017) for black carrot seeds. Bülbül and Hacıseferoğulları (2016) conducted a study with pneumatic precision vegetable planting machine with rubber pressure wheels in the front and back and three narrow rubber wheels in the middle and reported germination rate values as between 33.33 - 48.07%. Örnek et al. (2018) conducted a study at 0.84 m s^{-1} forward speed of pneumatic precision vegetable seed drill and at 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.

Interactions did not have significant effects on any of the investigated germination parameters.

4. Conclusion

In Konya Ereğli Region, Kırıkhan local cultivar seeds yielded satisfactory outcomes for field emergence characteristics. Local seed producers do not produce seeds under primitive conditions and the seeds used vary from producer to producer. Therefore, training should be provided to seed producers. Classification (calibration) of these seeds and sowing them by coating will increase sowing regularity and quality criteria. When sowing calibrated bare seeds, the top row holes of the disc cannot be singled effectively. This is because the rows of holes are singled through a whole singling unit. Research should be done on the singling organ of the domestically made pneumatic precision vegetable planting machine used in this study. Studies should also be carried out on planting disc hole diameters based on seed type. Research should be done by planting this seed as a second crop in the region.

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