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Determination of Physical Properties, Color Properties, Mechanical Behavior and Germination Parameters of Three Different Forage Peas Cultivars

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A B S T R A C T

The physical properties of seeds and grain is a wide knowledge that can be useful in the sowing, harvesting and storage or in processing such as drying, freezing and other. This knowledge is important in the designing of machinery to harvest and in preparation of processing chain from grain to food. In this study, the physical properties, color characteristics, mechanical behavior, and germination parameters of three different cultivars (Reis, Töre, and Özkaynak) of forage peas were examined and compared. The statistical differences were observed between the cultivars on the length, width, geometric mean diameter, sphericity, and surface area of the forage pea cultivars. Significant differences were observed between cultivars on mass, thousand mass, volume, and bulk density. The effects of cultivars on the true density, and porosity of forage pea seeds were not significant. Töre and Özkaynak cultivars constitute the highest statistical group in terms of mass and thousand mass (0.172 g, 0.174 g, 139.34 g, 138.54 g, respectively). The effects of cultivars on *L**, *a**, *b**, chroma, and hue angles of forage pea seeds were significant. Many features of the seeds should be considered in sowing, harvesting, and post-harvest processes and technological applications of forage pea seeds. In light of the data obtained in this study, it can be assumed that the operations to be carried out will contribute to the reduction of harvest losses, and the improvement of storage conditions at the pre-harvest and post-harvest engineering technologies and food production process applications.

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Introduction

The forage pea (*Pisum sativum* ssp. Arvense L.) is an leguminous crop having promising potential to be utilzed as a forage crop. It is considered as a source of nutritious feed for livestock breeders. The crude protein content is around 18.05% during the flowering period in hay (Tan et al., 2013) and 8.94% after the seeds are harvested (Mustafa et al. 2014, Cacan et al. 2018). Crude protein contains 20-30% in the seed, especially lysine (Acıkgöz, 1991). Forage pea is used in rations instead of soybean in Western European countries. Forage peas, which are used as both herbage and hay forage crops, are also used as pasture plants and green manure. (Dogan, 2013).

Forage peas, which are generally grown for herbage and grain, are not perennial but have a taproot. It provides nitrogen to the soil by fixing a high amount of nitrogen through Rhizobium bacteria. It improves the structure of the soil and provides the nutrient element it needs to the soil, and therefore, it has significance in the rotation (Aslan, 2017). It also prevents erosion at a high rate. The carbon/nitrogen (C:N) ratio of legume plants is 15-20 (Acıkgöz, 2001). Forage peas are also being utilized as silage for livestock feeding (Aslan, 2017).

Although Turkey's ecological conditions are suitable for forage pea cultivation, the quantum of forage production is not sufficient to fulfill the demnand owing to its high consumption. In terms of the sustainability and economy of the cultivation of a product, the quality must be as high as its yield (Karayel and Bozoglu, 2017).

The yield and quality, which are economic characteristics of plants, are related to genotype and environment. Genotype is the cultivar of plant species although the environment is climate, soil conditions, and cultivation techniques. The suitability of the cultivars to the climatic and soil conditions is necessary to increase the yield and improve the quality (Isler and Kılınç, 2016).

The properties of seeds are used in seed research, plant breeding studies, pre-harvest and post-harvest engineering technologies, and food production process applications. Also, fundamental characteristics of seeds are used in seed research, plant breeding studies and mechanization applications (Dumanoğlu, 2021). The reported literatüre corroborated that there are studies conducted by authors; Cacan et al. (2018), Ozyazici et al. (2019), Ozeroglu (2021), and to study about cultivar aspects of forage yield and quality. Dumanoglu et al. (2021) have determined the physical and physiological properties of forage pea seeds. Uslu et al. (2021) and Acikbas and Ozyazici (2021) have reported about the germination properties of forage pea seeds. However, a detailed evaluation of the physical attributes, color characteristics, mechanical behavior, and germination parameters of forage pea seeds is lacking in the literature. In this study, physical properties, color characteristics, mechanical behavior, and germination parameters of three different cultivars (Reis, Töre, and Özkaynak) of forage peas were examined and compared. This study focused on forage pea, which is an important member of forage crops. It is thought that the results obtained will be included in the physical plans and control mechanisms of authorized institutions and organizations and will be used in mechanization and breeding areas.

Matarials And Methods

Three different forage pea cultivars *cv.* Reis, Töre, Özkaynak were procured from private seed companies during December 2021. The pictorial presenteation of the selected cultivars is presented in the Figure 1. The seeds were cleaned of any foriegn matter including broken as well as damaged seeds and were stored at room temperature (20-24°C). The study was carried out in the laboratory of Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Biosystem Engineering.

Physical Properties

The moisture content of the forage pea seeds was determined using the hot air oven (105°C for 24 h) method recommended by Braga et al. 1999. The length (*L*), width (*W*), and thickness (*T*) of randomly selected 100 seeds were measured using digital vernier caliper (Mitutoyo, Japan ± 0.01 mm) as shown in the Figure 2. To obtain the unit mass, each seed was weighted with an electronic balance to an accuracy of 0.001 g. The geometric mean diameter of the seeds (*Dg*, mm) was calculated using the following formula (Mahawar et al. 2019, Altuntas and Mahawar 2022):

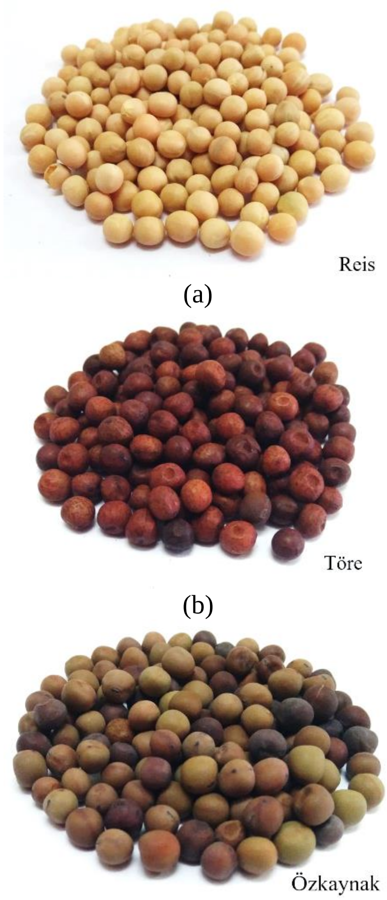
$$D_g = (L\times W\times T)^{1/3} \quad (1)$$

The sphericity (Φ, %), surface area (S_a) and volume (*V*) of the seeds were calculated using the following formula (Mohsenin, 1980):

$$\Phi = (Dg/L)\times 100 \quad (2)$$

$$S_a = \pi \times (Dg)^2 \quad (3)$$

$$V = \pi/6\,(L\times W\times T) \quad (4)$$



(c)

Figure 1. The investigated forage pea cultivars (a) cv. Reis (b) Töre (c) Özkaynak

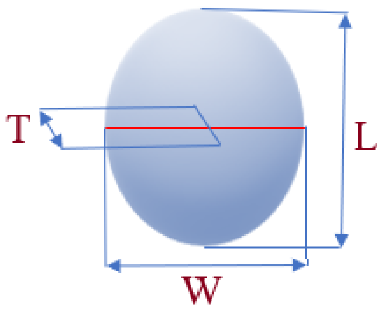


Figure 2. Three perpendicular axes: length (*L*), width (*W*) and thickness (*T*) of forage pea seed.

The seed volume and its kernel density were determined using the liquid displacement method. The hectoliter method was used to determine the bulk density (Mohsenin, 1980). The porosity (%Ɛ) was calculated according to Mohsenin (1980) by considering the bulk and kernel density values.

Color Properties

Color of the forage pea seeds was measured using a Minolta colorimeter (Konica Minolta, Model CR-400/410 Chroma Meters, Osaka, Japan). *L** indicates lightness: 100: white, 0: black, *a** indicates + red, - green, and *b** indicates + yellow, - blue (Itle and Kabelka, 2009). CIE *L**, *a**, and *b** color scales were determined for the color characteristics of forage pea seeds. The hue angle and chroma are effective parameters for characterizing visual color appearance (Bernalte et al., 2003). The chroma value of the product is an indicator of the vivid or pastel tone of the seeds, and pastel tones are close to 0 and vivid tones are close to 100.

Chroma was calculated as follow:

$$C=(a^{*2}+b^{*2})^{1/2} \tag{5}$$

When $a^* > 0$ and $b^* > 0$; the hue angle (α) of the seeds and was calculated using the following formula (Lancaster et al., 1997),

$$\alpha = tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{6}$$

Mechanical Properties

The coefficient of static friction is defined as the tangent value of the angle of slope between the sliding surface and vertical and horizontal planes. The coefficient of static friction was determined using a friction measurement device on different friction surfaces (PVC, galvanized steel, laminate, plywood, and rubber).

The angle of repose is the angle with the horizontal at which the seeds will stand when piled. It was determined using a topless and bottomless cylinder with a diameter of 300 mm and a height of 500 mm. The cylinder was filled to the top with seeds and slowly raised until a flat plate forms a cone on the surface. The angle of repose was calculated from the measurement of the height of the cone and the diameter of the cone (Kaleemullah and Gunasekar, 2002).

$$\text{Angle of repose} = \tan^{-1} (h / d) \tag{7}$$

when *h* the height of the cone (cm) and the diameter of cone (cm)

To determine the mechanical properties of forage peas, a biological material test device was used. This device has three main components, which are a moving platform, a driving unit, and a data acquisition (load cell, PC card, and software) system as shown in Figure 3. The rupture force in three different axes (L, W, T) and at three different speeds (20 mm min^{-1}, 40 mm min^{-1}, 60 mm min^{-1}) were taken Figureally on the test device. The *X*- axis (F_x force) is the longitudinal axis (L), the *Y*- axis (F_y force) is the transverse axis (W) at right angles to the *X*- axis in the plane of the suture, and the Z- axis (*Fz* force) is the transverse axis (T) at right angles to the plane of the suture (Figure 4). The values were read by keeping the speeds determined by the speed adjustment and fixation panel on the biological material test device. Samples were compressed along the *X*, *Y*, and *Z* axes to determine the rupture force (*F*), deformation (*D*), absorbed energy (E), hardness (*H*), and required power for cracking (*PC*) (Altuntas and Yildiz, 2007).

Absorbed energy, hardness and required power for cracking were obtained from the following equation:

$$E = (F \times D)/2 \tag{8}$$

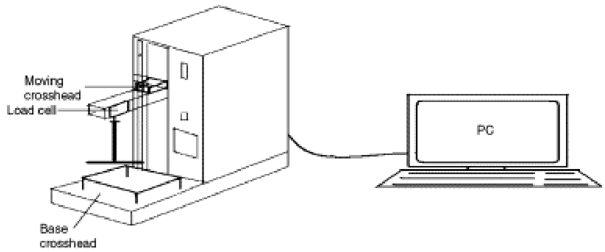
$$H = F/D \tag{9}$$

$$PC = \left[\frac{E * S}{60000 * D}\right] \tag{10}$$

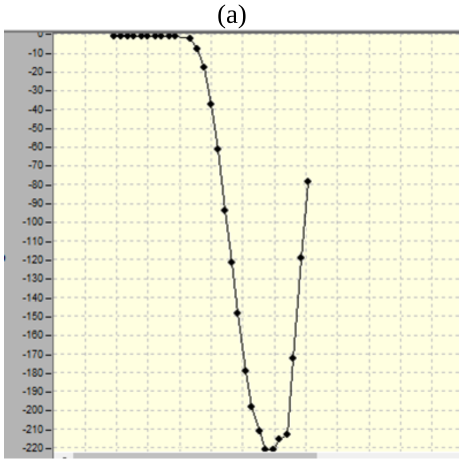
In equations; *F*: Rupture force (N), *D*: Deformation (mm), *E*: Absorbed energy (N mm), *H*: hardness, *PC*: Required power for cracking (W) and *S*: loading speed (mm min^{-1}).

Germination Properties

For germination test, the seeds were sterilized in 1% sodium hypochlorite solution for surface sterilization for 10 minutes and rinsed three times with distilled water before germination. Air-dried seeds were placed in 9 mm diameter petri dishes with filter paper (Ozkurt et al., 2018). Ten seeds were used in each petri dish and this process was repeated every two days to refresh the evaporated water. Petri dishes were kept at 21±2°C. All seeds were counted every day during the 14 days germination period, and seeds with a 2 mm radicle were considered germinated (Carpici and Erdel, 2015). In the study, germination percentage, germination rate, and radicle length Soltani et al. (2012), vigor index by Hamidi and Safarnejad (2010), and germination index by Torabi et al. (2011) were determined.



(a)



(b)

Figure 3. Biological material test device (Altuntaş & Yıldız, 2007) (a) and example of force-deformation curve of forage pea (b)

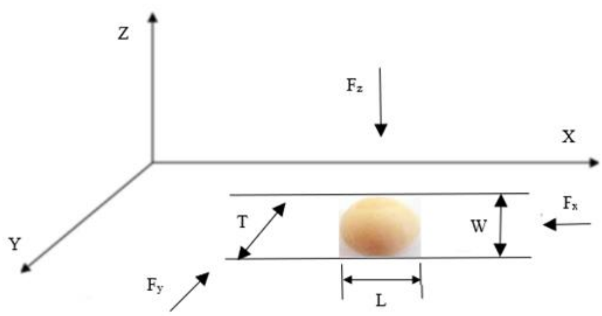


Figure 4. Representation of the three axial forces (*Fx*, *Fy*, and *Fz* axial forces) and three perpendicular dimensions of forage pea

Data Analysis

Statistical analysis of the obtained data was performed using SPSS statistical program. The data was analyzed using a randomized complete block design with a split block. In this design, the main factor was forage pea cultivars and the sub-factor was compression axis and speed. Before the analysis of variance for the data, a normality test was performed and its suitability for analysis was determined. Results were analyzed using analysis of variance (ANOVA) and the means were compared using the DUNCAN test.

Results and Discussion

The moisture contents of Reis, Töre, and Özkaynak cultivars were determined as 10.37%, 9.77%, and 9.10% d.b (dry basis), respectively. Detailed knowledge of physical properties is very important in the design of equipment for harvesting, cleaning, sorting, packaging, storage, and transportation during different agricultural operations. Size and shape are important in sizing, sieving, sorting, and other sorting processes.

The values of the L, W, T, Dg, sphericity, and surface area of the seeds of the forage pea cultivars are given in Table 1. Statistical differences were observed between the cultivars at the level of $P<0.01$ on the length, width, geometric mean diameter, sphericity, and surface area of the forage pea cultivars. Length, width, thickness, geometric mean diameter, and surface area values of Özkaynak cultivar were determined as 6.76 values may be added here 6.36 mm, 5.79 mm, 6.27 mm, 123.88 mm^2, respectively. It was determined that Reis cultivar was more spherical (94.17%) than other cultivars. A high sphericity value indicates that the forage peas are approaching a spherical shape.

Dumanoglu et al. (2021) reported the length value of forage pea seeds cultivars between 5.463 and 7.730 mm. It was reported that the highest width value was 7.022 mm in cv. Kristal and the lowest value was in cv. Taşkent (5.179 mm). Dumanoglu et al. (2022) reported that the seeds of cv. Vetch had a mean length of 4.876 mm, a width of 4.403 mm, and a surface area of 17.808 mm^2. Ganjloo et al. (2018) reported that the length, width, thickness, and geometric mean diameter values of green peas seeds at different moisture contents (15.21, 35.10, 55.18, and 75.15% w.b.) varied between 7.28 mm-10.48 mm, 5.80 mm-8.93 mm, 5.15 mm-8.61 mm and 5.90 mm-9.10 mm, respectively. It was seen that the data obtained were in harmony with the literature.

The values of seed mass, thousand mass, volume, bulk density, true density, and porosity of forage pea cultivars are given in Figure 5. Statistically differences ($P<0.01$) were observed between the cultivars on mass, thousand mass, volume, and bulk density. The effects of cultivars on the true density and porosity of forage pea seeds were not significant. Töre and Özkaynak cultivars constitute the highest statistical group in terms of mass and thousand mass (0.172 g, 0.174 g, 139.34 g, 138.54 g, respectively). The mass, thousand mass, volume, bulk density, true density, and porosity values of forage pea seeds were determined between 0.141g-0.174g, 85.93 g-139.34 g, 116.28 mm^3-130.67 mm^3, 844.79 kg m^{-3}- 872.59 kg m^{-3}, 1117.80 kg m^{-3}-1227.14 kg m^{-3} and 22.40%-27.80% respectively.

Thousand mass is an important quality factor and is related to yield. The higher the thousand mass of the seed, the higher the yield. In addition, the thousand mass is taken into account in determining the amount of seed to be planted per unit area (Moshatati and Gharineh, 2012). Dumanoglu et al. (2021) reported that the thousand mass of forage pea seeds varied between 112.57-266.40 g. The true density is one of the quality criteria, which is essential in separating the classes at world standards, as it gives information about the fullness of the grain (Moshatati and Gharineh, 2012). Ganjloo et al. (2018), reported that the bulk density and actual true density of green peas seeds are between 630.76-670.70 kg m^{-3} and 1088-1132 kg m^{-3}, respectively, at different moisture contents. Uzun et al. (2012) determined that the thousand seed mass of forage pea seeds were in the range of 167.1-193.6 g.

Table 1. Some geometric properties of seeds of forage pea cultivars.

Forage pea cultivars	L (mm)	W (mm)	T (mm)	S (mm)	Sp(%)	Sa(mm^2)
Reis	6,41±0,12b	6,10±0,09c	5,66±0,10	6,04±0,08c	94,17±0,89a	114,64±3,07c
Töre	6,69±0,11a	6,23±0,15b	5,69±0,14	6,17±0,12b	92,31±0,97b	119,97±4,59b
Özkaynak	6,76±0,13a	6,36±0,05a	5,79±0,12	6,27±0,08a	92,94±0,88b	123,88±3,12a
F value	23,21**	15,90**	$3,02^{ns}$	15,93**	10,78**	16,05**

L: Length, W: Width, T: Thickness, Dg: Geometric mean diameter, Sp: Sphericity, Sa: Surface area, power ±: standard deviation, **P<0.01, ^{ns}: Non significant. The difference between the same letters in the same column is insignificant.

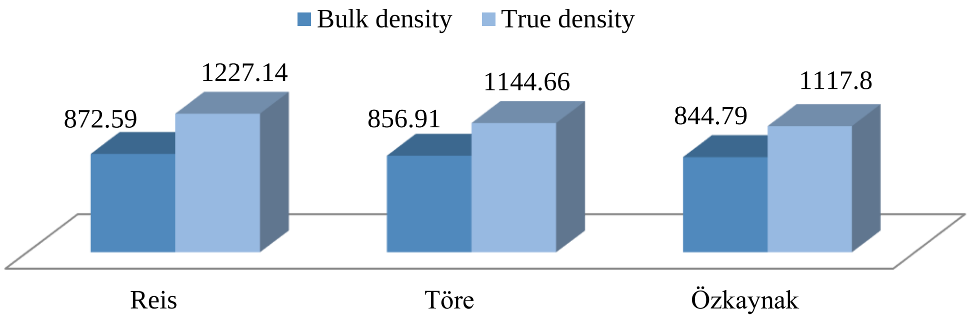


Figure 5. Bulk density and true density of forage pea cultivars.

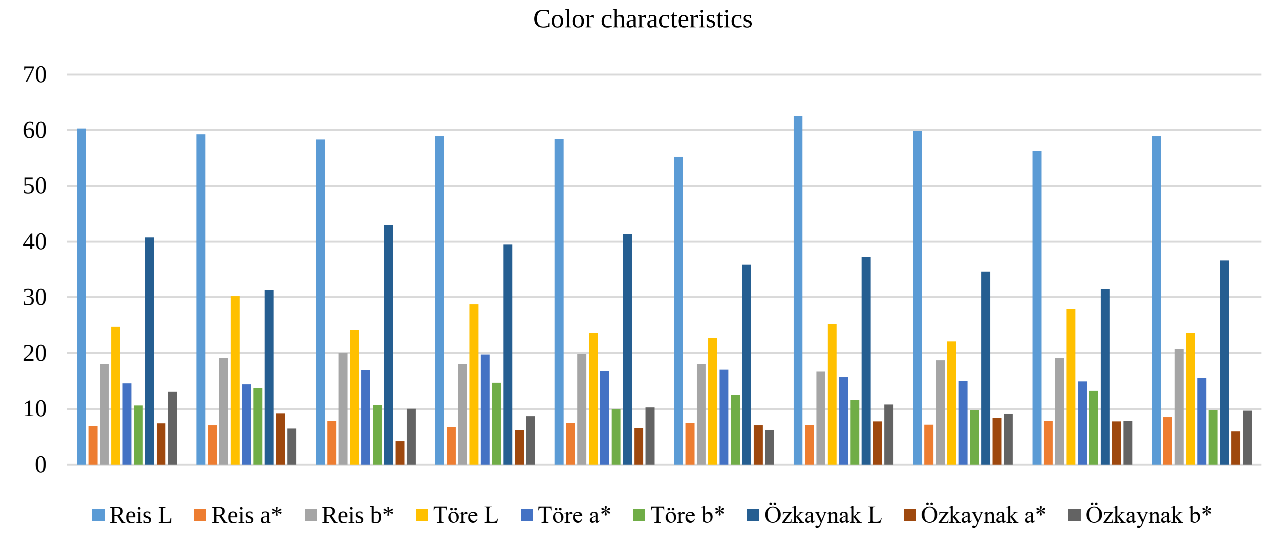


Figure 6. Color characteristics of the forage pea cultivars.

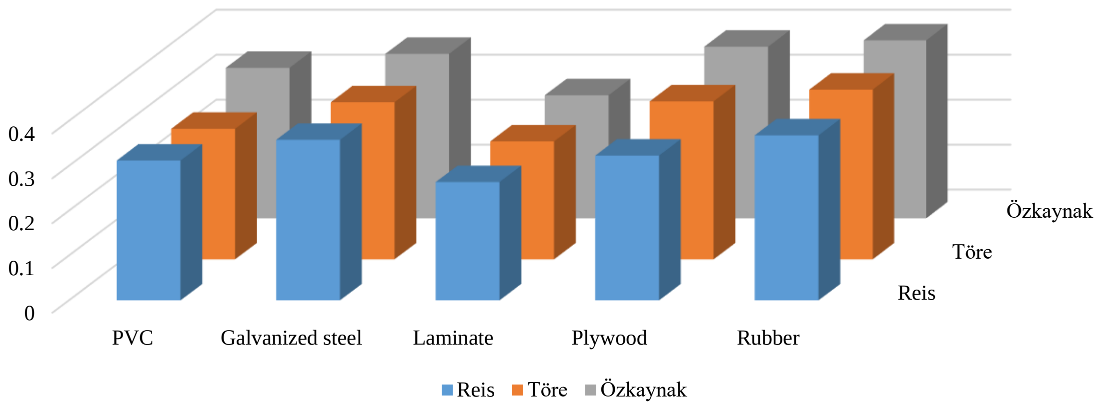


Figure 7. Static friction coefficient of seeds of forage pea cultivars.

The values of the color characteristics of the forage pea cultivars are given in Figure 6. The highest *L** and *b** values (mention the values) were measured in the Reis cultivar. In the Töre cultivar, the *a** value was measured the highest. Chroma and hue angle values were found to be high in Reis cultivar. The effect of cultivars on *L**, *a**, *b**, chroma, and hue angles of forage pea seeds was significant ($P<0.01$).

In seed production, quality is more important than the quantity of seed produced. This allows seed-producing companies to increase company credibility. It also means that producers get their money's worth when the seed grows (Mavi, 2010). One of the most important features in the grading and classification of seeds is color. Different seeds and cultivars are identified by their color characteristics (Anvarkhah et al., 2016). In addition, many studies have shown that color pigments in the seed coat affect germination, seedling emergence, seed quality, gas diffusion, seed dormancy, and water uptake and in some cultivars (Mavi, 2010).

For the mechanical behavior of the seeds of Reis, Töre, and Özkaynak cultivars, the static coefficient of friction, angle of repose, rupture force, deformation, rupture energy, hardness, and rupture power values were investigated. It was observed that the difference between the static coefficient of friction values on PVC and plywood surfaces was significant ($p<0.01$) level. The difference among the cultivar and static coefficient of friction (rubber) was statistically significant at $p<0.05$ level. No difference was observed on the laminate surface. The highest static coefficient of friction (values) was obtained on the surface with rubber material, while the lowest value (value) was obtained on the laminate material in all cultivars (Figure 7).

Different loading speeds and loading axes values of forage pea cultivars are given in Tables 2, 3 and 4. The rupture force along the width axis were higher than that of the length and thickness axis. The highest rupture force was observed for *cv*. Töre at 60 mm min^{-1} speed and width axis. The highest deformation value was observed in the Özkaynak cultivar at 60 mm min^{-1} speed and width axis. It is quite remarkable that there was a statistical difference in speed and axes in all cultivars.

Gul et al. (2021) suggested that the rupture force was higher at 30 mm min^{-1} loading speed as compared to the other loading speeds for grass pea cultivars. A decrease was observed in the rupture force values with the increase in loading speed. The reported literature iterates about the increase in the force due to the increase in speed. Mechanical damages cause more or less economic losses depending on the way the product was used.

Table 2. Textural attributes of various forage pea cultivars in different axes and 20 mm min^{-1} speed.

C		RF	D	RE	H	RP
Reis	L	158.51±26.61c	2.48±0.33b	200.08±57.44b	63.76±5.78b	0.026±0.004c
	W	317.94±36.29a	3.21±0.25a	512.63±86.02a	99.11±9.89a	0.053±0.006a
	T	204.97±55.44b	2.00±0.28c	207.75±77.82b	103.10±26.15a	0.034±0.009b
	F value	27.69**	31.20**	39.83**	12.08**	27.69**
Töre	L	166.86±8.71c	2.63±0.11b	219.33±18.85b	63.57±2.64c	0.028±0.001c
	W	334.80±12.49a	3.53±0.21a	591.69±49.53a	95.02±5.10b	0.056±0.002a
	T	275.13±55.55b	2.08±0.47c	290.00±109.66b	137.45±37.92a	0.046±0.009b
	F value	45.87**	40.13**	55.37**	19.63**	45.87**
Özkaynak	L	118.90±39.80c	2.59±0.32b	154.67±54.52c	46.26±16.44b	0.020±0.007c
	W	317.94±36.29a	3.24±0.26a	516.73±83.29a	98.33±10.80a	0.053±0.006a
	T	244.03±53.53b	2.14±0.26c	257.77±50.65b	117.05±35.68a	0.041±0.009b
	F value	36.87**	27.84**	58.57**	17.02**	36.87**

C:Cultivar, RF: Rupture force, D: Deformation, RE: Rupture energy, H: Hardness, RP: Rupture power ±: standard deviation, **P<0.01. The difference between the same letters in the same column is insignificant.

Table 3. Rupture force, deformation, rupture energy, hardness and rupture power of forage pea cultivars in different axes and 40 mm min^{-1} speed.

C		RF	D	RE	H	RP
Reis	L	174.44±13.05b	2.80±0.12b	244.60±23.32b	62.31±4.81b	0.058±0.004b
	W	322.81±32.50a	4.55±0.35a	734.14±95.13a	71.34±8.68b	0.108±0.011a
	T	221.94±64.37b	2.35±0.19c	260.37±78.23b	95.18±29.29a	0.074±0.021b
	F value	22.45**	162.27**	103.42**	6.34**	22.45**
Töre	L	177.14±3.91c	2.81±0.10b	248.89±13.37b	63.10±1.28c	0.059±0.001c
	W	358.21±10.81a	4.02±0.69a	721.43±135.94a	90.97±13.03b	0.119±0.004a
	T	279.47±26.12b	1.92±0.54c	271.75±88.80b	154.05±37.17a	0.093±0.009b
	F value	212.60**	29.91**	56.18**	29.35**	212.60**
Özkaynak	L	163.39±39.25c	4.45±0.46a	363.34±87.26b	37.01±9.72c	0.055±0.013c
	W	342.81±21.38a	4.55±0.35a	780.36±89.90a	75.69±6.06b	0.114±0.007a
	T	259.11±30.09b	2.37±0.29b	308.56±60.48b	110.13±14.28a	0.086±0.010b
	F value	58.31**	75.25**	72.24**	83.83**	58.31**

*C:Cultivar, RF: Rupture force, D: Deformation, RE: Rupture energy, H: Hardness, RP: Rupture power ±: standard deviation, **p<0.01. The difference between the same letters in the same column is insignificant.*

Table 4. Rupture force, deformation, rupture energy, hardness and rupture power of forage pea cultivars in different axes and 60 mm min^{-1} speed.

C		RF	D	RE	H	RP
Reis	L	181.63±18.33c	2.86±0.22b	261.40±44.13b	63.40±2.02b	0.091±0.009c
	W	338.00±26.38a	4.74±0.23a	800.32±73.51a	71.52±6.62b	0.169±0.013a
	T	261.46±89.79b	2.75±0.16b	363.54±137.42b	94.26±29.29a	0.131±0.045b
	F value	14.12**	211.76**	65.59**	5.93*	14.12**
Töre	L	190.54±6.81c	3.00±0.06b	286.25±15.88b	63.44±1.25c	0.095±0.003c
	W	370.63±10.89a	4.10±0.30a	759.40±64.49a	90.82±5.76b	0.185±0.005a
	T	287.76±25.95b	2.17±0.37c	311.85±60.14b	137.33±34.78a	0.144±0.013b
	F value	203.56**	83.75**	185.23**	23.54**	203.56**
Özkaynak	L	175.61±50.54c	4.54±0.49b	397.80±114.68b	39.14±12.67c	0.088±0.025c
	W	361.37±18.58a	4.99±0.33a	903.42±97.95a	72.54±4.03b	0.181±0.009a
	T	277.10±26.23b	2.56±0.23c	354.34±41.33b	109.09±15.61a	0.139±0.013b
	F value	50.65**	87.75**	80.01**	61.14**	50.65**

C:Cultivar, RF: Rupture force, D: Deformation, RE: Rupture energy, H: Hardness, RP: Rupture power ±: standard deviation, * P<0.05, **P<0.01. The difference between the same letters in the same column is insignificant.

As evident from Table 5, there was no statistical difference in the germination index, germination rate, final germination, and vigor index values of the cultivars. Although there was no statistical difference, the mean germination index of the cultivars was 21.55 and the lowest chinning index was obtained from Töre (20.0), while the germination index values of the other two cultivars were the same and gave the highest value. The mean germination rate of the cultivars was 4.39 and the Töre cultivar gave the lowest value (mention the value) and the Reis cultivar gave the highest value (mention the value). The germination rates of the cultivars were generally at a high level and the mean was as high as 97.77%. While the germination rate of the Töre cultivar was the lowest at 93.33%, the seeds of the other two cultivars were all germinated and a germination rate of 100% was obtained. İt has been reported in many studies that the mean germination rate of forage pea seeds is ≥95% (Okcu et al. 2005; Kücüközcü & Avci, 2020; Avci et al. 2020; Dumanoglu et al. 2021). The vigor index value, which is another examined parameter, was realized as 16.82 on mean, and the lowest vigor index value was obtained from the Töre cultivar, while the highest was obtained from the Özkaynak cultivar. Although not statistically significant, Reis and Özkaynak cultivars were the most prominent cultivars for these parameters.

The examined characteristics of the cultivars used in the study are given in Table 6. Cultivars examined in the study did not make a statistical difference in terms of fresh root weights, dry root weights, and fresh root lengths, dry shoot lengths, and fresh shoot weights. However, the cultivars created a statistically significant difference ($P \leq 0.01$) between fresh shoot weights and root numbers. The mean fresh root weight of the cultivars examined in the study was 0.29 g, and this mean value did not make a statistical difference in the cultivars.

While the highest root weight was obtained from the Töre cultivar, the lowest fresh root weight was obtained from the Özkaynak cultivar. It is an advantage for the plant that the roots are dense and the roots are dense in the soil ensuring the resistance of plants against various stress factors. As a matter of fact, the amount of nitrogen that plants that are leguminous forage plants such as forage peas will add to the soil is closely related and directly proportional to the density of the plant roots.

The dry root weights obtained from the study were not statistically affected by the cultivars, as were the fresh root weights. The mean dry root weight of the cultivars examined in the study was 0.06 g, and the highest dry root weight (mention the value) was obtained from the Özkaynak cultivar, while the lowest (mention the value) was obtained from the Reis cultivar. Although the equity cultivar was determined as the lowest cultivar in terms of fresh root weight, it came to the forefront as the highest cultivar in terms of dry root weight.

The mean root length of the cultivars examined in the study was 17.59 mm and these means did not make a statistical difference in the cultivars. While the highest root length (mention the value) obtained from the research was obtained from the Reis cultivar, the lowest root length (mention the value) was obtained from the Özkaynak cultivar. It has been reported that there is quite a difference between cultivars in terms of root length. Okcu et al. (2005) have determined the root lengths of Bolero, Sprinter, and Utrillo cultivars as 13.99 cm, 11.69 cm and 3.19 cm, respectively. Avci et al. (2020) determined that the mean root lengths of 2020 are between 7.03-8.00 cm. Demirkol et al. (2019), investigated different salt doses in a forage pea genotype, which they considered promising, and they found the radicula length to be 6.24 cm in the control application.

It was expected by the authors about some differences in the studies in question with the results of this study. As a matter of fact, the different times and methods in which the observations were taken may have caused this difference. In addition, the length of the roots of the plants is also an important feature in terms of resistance to abiotic stress factors, especially to arid conditions. Knowing the characteristics of the plants selected for breeding is important for the new cultivars to be improved and resistant.

The area under arid regions will increase in the coming years with the climate change that has been experienced in recent years and is anticipated to increase in the coming future. This will augment the importance of drought-resistant plants in countries like Turkey where arid and semi-arid climates are experienced intensely. The mean fresh shoot weight obtained from the study was 0.27 g and the mean value created a statistically significant difference ($P \leq 0.01$) in the cultivars. The highest fresh shoot weight (0.31 g)obtained in the study was obtained from the Özkaynak cultivar, and the lowest fresh shoot weight (0.22 g)was obtained from the Reis cultivar. It has been determined in many studies that there is a difference in shoot age weights between cultivars. Okcu et al. 2005 used the same cultivars used in our study, Avci et al. 2020, the mean fresh shoot weights were between 199 to 243 mg/plant, and Küçüközcü and Avci 2020, in their research including similar cultivars, determined the mean fresh shoot weight as 132.06-161.16 mg/plant. Dumanoglu et al. 2021 In the light of the data obtained in their research, reported that species and cultivars with high shoot weight are an important criterion in the evaluation of forage plants used in animal nutrition, and it is important in terms of providing a good genotype preference to scientists, especially in breeding studies.

Table 5. Germination related attributesof the forage pea cultivars.

	Germination Index	Germination Rate	Final Germination	Vigor Index
Reis	22.33±2.08	4.68±0.33	100±0	17.27±4.26
Töre	20±2.65	3.89±0.38	93.33±5.77	16.46±1.29
Özkaynak	22.33±2.08	4.61±0.35	100±0	16.74±2.03
Average	21.55	4.39	97.77	16.82
F value	1.04^{ns}	4.53^{ns}	4.00^{ns}	0.06^{ns}

±: standard deviation, ^{ns}: non significant.. The difference between the same letters in the same column is insignificant.

Table 6. Fresh root weight, dry root weight, fresh root length, fresh shoot weight, dry shoot weight, fresh shoot length, and a number of roots of the forage pea cultivars.

	Wet Root Weight (g)	Dry Root Weight (g)	Wet Root Length (mm)	Wet Shoot Weight (g)	Dry Shoot Weight (g)	Wet Shoot Length (mm)	Number of roots (number)
Reis	0.29±0.11	0.05±0.01	18.38±2.89	0.22±0.03b	0.06±0.01	11.76±2.01	16±3.31b
Töre	0.34±0.09	0.06±0.00	17.66±3.83	0.28±0.06ab	0.07±0.00	10.98±2.88	23±7.18a
Özkaynak	0.26±0.07	0.07±0.02	16.74±3.24	0.31±0.09a	0.07±0.02	11.47±3.16	13±2.65b
Average	0.29	0.06	17.59	0.27	0.066	11.40	17.3
F value	2.02^{ns}	1.09^{ns}	0.54^{ns}	4.64**	0.88^{ns}	0.19^{ns}	10.59**

±: standard deviation, **P<0.01, ^{ns}: non significant. The difference between the same letters in the same column is insignificant.

Although fresh shoot weights have a statistically significant effect on cultivars, the same is not true for dry shoot weights. The mean dry shoot weight obtained from the study was 0.066 g. According to the results of the research, the highest dry shoot weight (value) was obtained from cv. Töre and Özkaynak, while the lowest (value) was obtained from cv. Reis. Avci et al. 2020, determined the mean dry shoot weight of 2020 between 18.8-20.1 mg/plant and determined that the effect of these values on cultivars was not statistically significant. The mean fresh shoot length of the cultivars examined in the study was 11.40 mm and this value did not make any statistical difference on the cultivars.

The highest fresh shoot length (value) was obtained from cv. Reis, and the lowest fresh shoot length (value) was obtained from cv. Töre. The fresh shoot length is also an important criterion in the selection of forage crops used for animal feding as the plants with higher shoot lengths will yield more green parts.

It would be a correct approach to evaluate the selection of these species and cultivars as an indicator of obtaining more abundant quality roughage. The number of rootsmade a statistically significant difference ($P \leq 0.01$) in the cultivars.

While the highest root number (value) was obtained from the Töre cultivar among the cultivars examined in the study, the lowest root number (value) was obtained from the Özkaynak cultivar, which constitutes the same statistical group as Reis cultivar. The resistance of plants to abiotic stress factors is closely related to the durability of their root systems. Thus, if more roots are there in the plant, the more the area in contact with the soil means an increase in the rhizosphere area, which plays an important role in the uptake of plant nutrients. This is an indication that the plant has the potential to absorb more water and plant nutrients through its roots.

Conclusion

Many features of the seeds should be considered in sowing, harvesting, and post-harvest processes and technological applications of forage pea seeds. In the light of the data obtained in this study, it is assumed that the operations to be carried out will contribute to the reduction of harvest losses and to the improvement of storage conditions. The physical properties of seeds is a vast amount of data that can be useful in harvesting and storage or drying and other processes. This data is involved in designing machines for harvesting and in every part of the food processing chain. The main purpose of post-harvest biotechnical properties technology is to increase agricultural production through the dissemination of quality seeds of high-yielding cultivars. This includes identifying cultivars with high seed quality, thereby improving seedling and plant growth, and assessing seed quality using different methods. In this study, physical properties, color characteristics, mechanical behavior, and germination parameters of three different cultivars (Reis, Töre, and Özkaynak) of forage peas were examined and compared. Moisture contents of Reis, Töre and Özkaynak cultivars were determined as 10.37%, 9.77%, and 9.10% d.b, respectively.

Length, width, thickness, geometric mean diameter, and surface area values of Özkaynak cultivar were determined as 6.76 mm, 6.36 mm, 5.79 mm, 6.27 mm, and 123.88 mm^2, respectively. It was determined that the Reis cultivar was more spherical (94.17%) than other cultivars. Statistically significant ($p<0.01$) differences were observed between cultivars on mass, thousand mass, volume and bulk density. Töre and Özkaynak cultivars constitute the highest statistical group in terms of mass and thousand mass (0.172 g, 0.174 g, 139.34 g, 138.54 g, respectively). Although there was no statistical difference, the mean germination index of the cultivars was 21.55 and the lowest chinning index was obtained from the Töre (20.0), while the germination index values of the other two cultivars were the same and gave the highest value. In next future, the physical parameters examined need to be made in different cultivars and species. Thus this will be a guide in future plant breeding and mechanization studies.

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