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Research
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Some physico-mechanical properties of carrot (*Daucus carota* L.), cherry belle (*Rhaphanus sativus* L.) and nigella (*Nigella sativa* L.) seeds coated with pellets*

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Abstract

Seed growing has recently become significantly important in agriculture. Preparing the seeds to coat for plantation and using the coated seeds for plantation has brought about new perspectives in farming. Shape, size and one thousand seeds mass are among the most effective criteria for the success of seed coating. In this study; cherry belle, carrot and nigella seeds which have different sizes and shapes together with one thousand seeds mass and seedling emergence were studied. For this purpose, a seed coating equipment was designed, produced and analyzed through a horizontally shaped boiler. In the designed equipment, the seeds were coated in the form of approximately 2 mm diameter in order to pellet accordance with the ISTA norms. As the results of the performed tests show that; cherry belle was coated %99, nigella seed %99 and carrot seed %97. As for the seedling emergence; cherry belle germinated %95, nigella seed %17 and carrot %75. The results of the analysis indicate that the types of the seeds used in the test can be achieved by pneumatic plantation machine. But the nigella seeds did not show enough seedling emergence. It should be noted that carrots and nigella seeds aren't spherical. If carrots and nigella seeds are pelleted, the sphericity will increase up to 40-60%. By pelleting seeds their physico-mechanical properties will be more homogeneous.

Key words: Seed, coating with pellet, cherry belle, carrot, nigella, seedling emergence

Peletle kaplanmış havuç (*Daucus carota* L.*)*, fındık turp (*Rhaphanus sativus* L.*)* ve çörekotu (*Nigella sativa* L.*)* tohumlarının bazı fiziko-mekanik özellikleri

Öz

Tarımda tohumculuk alanı günümüzde oldukça önem kazanmıştır. Tohumların kaplanarak ekime hazırlanması ve ekim esnasında kaplı tohumların kullanılması tarım sektörüne farklı bakış açıları getirmektedir. Tohum kaplamada başarıya en etkili kriterlerin başında tohumların şekli, boyutları ve bin dane ağırlıkları gelmektedir. Bu çalışmada farklı tohum boyutlarına ve bin dane ağırlıklarına sahip olan fındık turp, havuç ve çörekotu bitkilerinin tohumları kaplanarak çimlenme olanakları araştırılmıştır. Bu amaçla yatay olarak çalışan bir kazan ile tohum kaplama düzeneği tasarlanarak imalatı gerçekleştirilmiştir. Oluşturulan bu düzenekte tohumlar peletleme yöntemi ile ortalama 2 mm çapında kaplanmış ve ISTA normları dikkate alınarak tohumların çimlenme parametrelerine bakılmıştır. Yapılan denemeler sonucunda fındık turp tohumu %99, çörekotu tohumu %99, havuç tohumu %97 oranında kaplanmıştır. Çimlenme oranı olarak; fındık turp tohumu %95, çörekotu tohumu %17 ve havuç tohumu ise %75 oranında çimlenme başarısı göstermiştir. Bu sonuçlara göre denemede kullanılan tohum çeşitlerinin pnömatik ekim makinası ile ekime uygun olarak kaplanabildikleri ortaya konulmuştur. Ancak çörekotu tohumları yeterli çimlenme oranı başarısını gösterememiştir. Havuç ve çörek otu tohumlarının küresel olmadığı dikkate alınmalıdır. Havuç ve çörek otu tohumları kaplandığı takdirde küresellikleri %40-60'a kadar çıkabilecektir. Tohumları peletleyerek fiziko-mekanik özelliklerini daha homojen hale getirebiliriz

Anahtar kelimeler: Tohum, peletle kaplama, fındık turp, havuç, çörekotu, çimlenme oranı

Introduction

Modern agriculture expresses the transition from resource based production to technology and organization based production. Conceptually, mechanization in this process is the carrying out of agricultural production processes via mechanical devices. In other words, agricultural mechanization is a production technology that speeds up production operations such as; tillage, sowing, planting, fertilization, irrigation, plant protection and harvesting (Yavuzcan et.al., 2001). The first stage of cultivation in plant production is the planting of the seed and their germination in proper conditions (Karakurt et.al., 2010). There is a tendency towards shift to hybrid seeds especially in recent years. However, planting with seedling methods are used since the planting of various small sized hybrid seeds via machines is problematic. It is possible to plant via coating small seeds and hybrid seeds the sowing mechanizations of which are problematic. Control of aging, that is protection of seed value together with the preservation or increase of its quality after acquiring the seed can be named as post-harvesting applications which can be grouped as seed storage, priming, seed conditioning and coating technologies (pellet and film coating) (Taylor et al., 1998). Pelletizing is the wrapping up the seed with powdered solid particles in order to make the small, light and irregular seeds suited for mechanical cultivation. Whereas film coating is coating the seeds with a thin layer of plasticizing materials (polymer etc.) without making any change in the original shapes of seeds (Kavak, 2006). The coating of small seeds in a boiler via pelleting method has been used in agricultural applications since the 1960's. Different methods are used for coating with pellet (Schiffers ve Fraselle, 1982). Seed coating applications have been popularized due to the available methods that have been used since the first application. Even though different applications are used for the development of plants (Hwang and Sung, 1991), the germination process of plants is simplified with the use of chemical (Powel and Matthews, 1982) and biological substances (Fairley and Draycott, 1978) (Fairley ve Draycott, 1978; Luchmeah ve Cooke, 1985; Evans et.al., 1993; Stout et.al., 1993). Doğan et.al., (2005) and Barut carried out a study in 2006 during which the shape property (sphericity ratio) of sesame seeds was enhanced which had a positive impact on plant spacing uniformity. They have put forth that pneumatic planting machine had greater success in seed planting in comparison with broadcast sowing as well as providing greater germination and more uniform sowing. In addition, significant decrease will be attained in the amount of seeds per decares as a result of coating the seeds in addition to the protection of the seeds against bugs and pests as well as the protection of the germination abilities of seeds for longer periods of time (Günay, 1977). The objective of this study was to coat the carrot and cherry belle seeds with high nutritional value (Baysal, 1998) in addition to nigella seeds which are important for the field of medicine despite their limited mechanization and seedling emergence (Banik et.al., 2003) with pellet+film thus making them suitable for mechanical cultivation as well as proving their germination capabilities.

Materials and Methods

The main material of the study consists of cherry belle, carrot and nigella seeds. Pellet coating apparatus at the laboratory scale was manufactured and used in the study. A reduced electric motor with an incline of about 30° and revolutions per minute of 40min^{-1} was used in the coating apparatus of the study. The plastic boiler in which the seeds were coated was given a semi-spherical form. A spraying apparatus made of glass was used for the application of plant nutritional elements and binding fluid (Figure 1). Compressor was used to provide air for the spraying apparatus and warm air blower for drying the seeds. Bentonite, vermiculite, talc powder, turf, perlite, lime and cement were used as coating material. Grinding machine and sieves were used for turning some large materials into dust. Arabic Gum dissolved in sugared water was used as binding fluid. In addition, humic acid, fulvic acid, zinc, fluid plant nutrient materials were used to enhance the seedling emergence of the seeds. BASF Sepiret 7280 was preferred as coloring material. Coating in the boiler method was applied in the study for coating the seeds (Schiffers and Fraselle, 1982). The seeds were placed in a spherical boiler which is rotated at 40 min^{-1}. The binding fluid material was sprayed inside the boiler using a spraying apparatus thus moisturizing the seeds.

Figure 1. Seed coating apparatus and spraying apparatus

The pelleting mixture prepared in powder form was passed through a 0,1 mm sieve and was sprinkled on the seeds inside the boiler. Thus, it was ensured that the seeds were covered with pellet coating powder attracted towards the seeds coated with an adhesive fluid that is rotated inside the boiler together with the coating material. The seeds to be coated were subject to a short term drying process following the completion of the first wrapping. Binding fluid was sprayed once again afterwards. The remaining pellet coating mixture was thrown inside the boiler thus increasing the seed diameters. After the seeds were coated with sufficient amount of pellet coating material, plant nutritional material in fluid form was sprayed. Finally, the seeds were de-moisturized via warm air. The seeds passed through the sieves were left to dry for 24 hours at room temperature under laboratory conditions. The seeds were re-coated with BASF Sepiret 3280 seed dye which was also used for film coating after which they were left to dry in a similar manner. The coating material was applied at a ratio of 1/40 which was determined as a result of pre-trials. Thus, 4000 g powder seed pellet was used for coating 100 g of seed. ISTA norms were taken into consideration when controlling the germination parameters and germination cups and germination papers were used for the germination of coated seeds. Counts were carried out by taking as basis the 7th day for cherry belle and the 14th day for nigella and carrot in calculating the seedling emergence (ISTA, 2013). Coating process was carried out after controlling the germination parameters of the selected seeds. The time for dissolving of the coated material in water which is effective on the germination of coated seeds was determined using a chronometer. Geometrical mean diameter (D_g) and sphericity (ϕ) were calculated using equations numbered as 1 and 2 (Aydın, 2003; Mohsenin, 1978; Olajide&Igbeka, 2003; Yalçın et.al., 2007).

$$D_g = (LWT)^{1/3} \quad [1]$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad [2]$$

Here; L represents length (mm); W, width (mm) and T thickness (mm).

The volumes (V) of the coated seeds were calculated using the equation numbered 3 (Özarslan, 2002; Topuz et al., 2005; Çetin et al., 2010).

$$V = \frac{M}{\rho_t} \quad [3]$$

Here; M (kg) represents mass, ρ_t (kg/m^3) represents density. Analyses for the acquired data were carried out via TARIST statistics software (Açıkgöz et.al., 1993).

Results and Discussion

Visuals related with carrot, nigella and cherry belle seeds before and after coating have been given respectively in Figure 2. As can be seen from Figure 2, it is understood that the sphericities and mean diameters of the seeds have increased. The times for dissolving in water of the coated seeds were measured as 275 seconds for carrot, 190 seconds for nigella and 170 seconds for cherry belle. The ratio of coated seeds not coated at the desired level has been given in Table 1. The coating of the seeds one-by-one and having one seed in each palette are put forth as coating quality criteria. These criteria are affected from the surface structure of the seeds as well as the experience of the coater. Table 2 shows the average seedling emergence of uncoated and coated seeds. Seedling emergence is among the important attributes that is considered in order to ensure that a seed gains a commercial identity. These percentages were; 70% for carrot, 75% for cherry belle and 70% for nigella (Anonymous, 2015). When the seedling emergence of coated seeds were examined, it was observed that successful seedling emergence have been attained especially for cherry belle seeds and that the ratios for carrot seeds were also successful. However, it is apparent that there is a 15% difference between the seedling emergence of coated and uncoated carrot seeds. Whereas the seedling emergence were not sufficient in the nigella seed application for both uncoated and coated seeds.

Figure 2. Seeds before and after coating

Table 1. Uncoated seed ratio among coated seeds (%)

Type	Empty	Ideal	Multi-seeded
Carrot	%1	%97	%2
Nigella	%0	%99	%1
C. Belle	%0	%99	%1

Table 2. Seedling Emergence (%)

Seed type	Seedling emergence
Carrot (Uncoated)	90
Carrot (Coated)	75.25
Nigella (Uncoated)	63.75
Nigella (Coated)	17
Cherry Belle (Uncoated)	97
Cherry Belle (Coated)	95

Figure 3. Germination of coated cherry belle seeds

The development of coated carrot and cherry belle seeds following germination was observed to be at a sufficient level (Figure 3-4). However, as can be seen in Figure 5, the development of nigella seeds following germination is quite slow in addition to the low seedling emergence.

Figure 4. Germination of coated carrot seeds

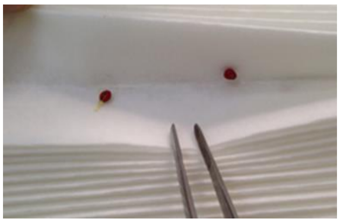

Figure 5. Germination of coated nigella seeds

Table 3. Seedling emergence of carrot seeds (%)

Seed	Seedling Emergence
Carrot (Uncoated)	90.00A
Carrot (Coated)	75.25 B

LSD (%5)=11.800

There was a statistically significant difference between the seedling emergence of coated and uncoated carrot seeds (Table 3).

Table 4. Seedling emergence of nigella seeds (%)

Seed	Seedling Emergence
Nigella (Uncoated)	63.75 A
Nigella (Coated)	17.00 B

LSD (%5)=5.99

There was a statistically significant difference between the seedling emergence of uncoated and coated nigella seeds (Table 4). Especially the seedling emergence of coated nigella seeds remained at quite low values. An important reason for this was the fact that certified nigella seeds with greater germination vigor could not be attained. Bejandi et.al., (2009) point out various problems in the cultures of medical plants. The most common problem is that the seeds of these plants have lower vigor. The fact that nigella plant which has an important place among industrial plants is planted at limited areas brings about various negativities related with this issue.

Table 5. Seedling emergence for cherry belle (%)

Seed	Seedling Emergence
Cherry Belle (Uncoated)	97.00
Cherry Belle (Coated)	95.00

LSD (%5)=2.999

The difference between the seedling emergence of uncoated and coated cherry belle seeds was not determined to be statistically significant (Table 5). The seedling emergence of uncoated and coated cherry belle seeds in the study were quite high and the difference between them was just 2%. Coating had no negative impact on seedling emergence. Various physico-mechanical properties of uncoated and coated seeds that had been measured and calculated were presented in Table 6. Measurements were made for the average diameters and 1000 seed weights for uncoated and coated seeds of three different seed varieties. The diameters of the seeds increased by 3-4 times on average. It was realized during the coating process that the seeds of cherry belle and nigella seeds can be coated more easily due to greater diameters as well the shape and structure of their seeds. Coating of carrot seeds was relatively more difficult. Table 6 showing the various physico-mechanical properties of the seeds examined in general, it was observed that the sphericities of coated seeds were better in comparison with those of the uncoated ones and that porosity was lower for coated seed piles.

Table 6. Various physico-mechanical properties of the seeds

Seed	Moisture (%)	L (mm) (SD)	W (mm) (SD)	T (mm) (SD)	M_{1000} (g) (SD)	P_b (kg/m^3) (SD)	P_t (kg/m^3) (SD)	ρ (SD)	ϕ (SD)	D_g (mm) (SD)	σ (N/mm^2)	υ (m/s) (SD)
Carrot (Uncoated)	7.4	1.61 (0.59)	0.80 (0.34)	0.59 (0.11)	2.20 (0.01)	482.90 (6.40)	1024.62 (5.76)	52.87 (0.87)	0.60 (0.17)	0.89 (0.23)	-	5.59 (0.36)
Carrot (Coated)	9.2	3.15 (0.21)	2.30 (0.19)	2.06 (0.20)	9.33 (0.08)	763.3 (3.90)	1113.65 (9.42)	31.46 (0.56)	0.78 (0.06)	2.46 (0.14)	14.56 (2.49)	12.89 (0.09)
Nigella (Uncoated)	5.7	2.63 (0.16)	1.16 (0.21)	1.02 (0.18)	2.42 (0.02)	472.27 (5.85)	1005.06 (6.15)	53.01 (0.84)	0.55 (0.07)	1.45 (0.16)	-	6.78 (0.14)
Nigella (Coated)	8.9	4.01 (0.17)	3.41 (0.13)	3.19 (0.12)	28.79 (0.09)	751.30 (5.30)	1117.62 (19.98)	32.76 (1.21)	0.88 (0.03)	3.51 (0.07)	7.21 (0.96)	15.69 (0.17)
Cherry Belle (Uncoated)	5.3	3.04 (0.21)	2.51 (0.27)	2.23 (0.29)	2.34 (0.02)	711.57 (3.16)	1096.50 (3.29)	35.11 (0.37)	0.85 (0.06)	2.57 (0.22)	-	11.16 (0.15)
Cherry Belle (Coated)	8.3	4.55 (0.14)	4.32 (0.16)	3.90 (0.28)	48.93 (0.13)	759.67 (3.64)	1134.36 (54.98)	32.90 (3.33)	0.93 (0.03)	4.25 (0.15)	6.10 (1.38)	16.65 (0.50)

L. length; W. width; T. thickness; M_{1000}. 1000 seeds weight; P_b. bulk density; P_t. true density; ρ. porosity ; ϕ. sphericity; D_g. geometrical mean diameter; σ. fracture strength; υ. critical speed; SD. standard deviation

It could clearly be seen that coating pelleting materials had caused an increase in 1000 seeds weights, volumetric and true densities. In addition, coated seeds reach terminal speed at relatively higher air speeds in comparison with uncoated ones. Friction coefficients on some surfaces for uncoated and coated seeds were given in Table 7. Table 7 showing friction coefficients of different surfaces examined, it can be seen that coated seeds had lower friction coefficients in comparison with uncoated seeds. The fact that coating material was the same for all uncoated seeds has resulted in similar surface properties. It could be observed that the friction coefficients of coated seeds on steel, aluminum and PVC surfaces were close to each other.

Table 7. Friction coefficients on different surfaces for uncoated and coated seeds

Seed	μ_S (SD)	μ_{Al} (SD)	μ_{PVC} (SD)
Carrot (Uncoated)	0.28 (0.01)	0.39 (0.01)	0.27 (0.01)
Carrot (Coated)	0.23 (0.01)	0.25 (0.01)	0.21 (0.01)
Nigella (Uncoated)	0.23 (0.01)	0.33 (0.01)	0.20 (0.00)
Nigella (Coated)	0.22 (0.01)	0.27 (0.01)	0.17 (0.01)
Cherry Belle (Uncoated)	0.25 (0.01)	0.32 (0.02)	0.25 (0.01)
Cherry Belle (Coated)	0.23 (0.00)	0.24 (0.01)	0.19 (0.01)

μ_S, friction coefficient on steel surface; μ_{Al}, friction coefficient on aluminum surface;

μ_{PVC}, friction coefficient on PVC surface; SD, standard deviation

Conclusions

The fact that diameter of carrot, cherry belle and nigella seeds are small, it has limited the mechanization options for the planting of these seeds. Carrying out the sowing operation via pneumatic sowing machine helps in the mechanization of hoeing, thinning, fertilization and other maintenance as well as harvesting operations. In addition, it also makes significant contributions to decreasing cost by decreasing labor and manpower. It also ensures the use of hybrid seed amount with high cost per decare to be used in an advantageous manner with regard to cost. Thus, it is required to enhance the mechanization options in the agriculture of such small seeds and raise the awareness of producers with regard to the use of coated seeds. In the study, carrot, cherry belle and nigella seeds were coated with the same coating material at a ratio of 1/40 via pelletizing method. Coating method was carried out with a single seed to each pellet at a ratio of 97-99% thus ensuring a successful coating process. It was observed that cherry belle seed coated with pellet reached a very successful seedling emergence with 95%. Even though it was observed that carrot seeds coated with pellet reached seedling emergence of 75,25% which might be considered as successful, greater levels should be reached by coating the carrot seeds with different coating materials. Whereas seedling emergence success of carrot and cherry belle seeds could not be attained for nigella seeds. In addition, different coating materials should be prepared for each seed type when carrying out the coating process with different coating materials for reaching higher seedling emergence. Academic circles that will work on seed coating as well as companies that currently carry out seed coating operations should give importance to studies on the coating of small scale seeds of different species. Coating of seeds eases mechanization operations. It was observed as a result of the measurements that various physico-mechanical properties of coated seeds are enhanced thus attaining more uniform seeds that are more suited for machine sowing in terms of seed size and shape. Sphericity factor is especially important for plant spacing uniformity. Sphericities of seeds such as carrot and nigella which are far from sphericity were coated thus attaining enhancements in their sphericities at ratios of about 40-60%. Coating of the seeds enables the achievement of seeds with more uniform physico-mechanical properties.

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