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Determination of Some Physical Properties of Some Pumpkin (*Cucurbita moschata* Duch.) and Winter Squash (*Cucurbita maxima* Duch.) Genotype Seeds

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ABSTRACT

In this study, some physical properties of pumpkin line ('14 BO 01') (*Cucurbita moschata* Duch.) and winter squash variety seeds ('55 ÇA 15' and 'Arican 97') (*Cucurbita maxima* Duch.) were evaluated at five different moisture content levels. Length, width and thickness increased linearly, as the moisture content increased from 8.62 to 25.49% dry weight basis (dwb) for 'Arican 97', from 9.60 to 25.60% for '55 ÇA 15' and from 6.81 to 23.07% for '14 BO 01'. All the diameters of seeds were significantly related with the seed moisture contents ($P < 0.05$). The sphericity varied from 0.548 to 0.565 for 'Arican 97', from 0.548 to 0.565 for '55 ÇA 15' and from 0.482 to 0.504 for '14 BO 01' as the moisture content increased. With the increase in moisture content, the surface area varied from 290.08 to 330.86 mm^2 for 'Arican 97', from 349.22 to 382.12 mm^2 for '55 ÇA 15' and from 333.29 to 398.35 mm^2 for '14 BO 01'. The bulk and true densities decreased from 411.86 to 366.03 kgm^{-3}, from 390.35 to 347.37 kgm^{-3} and from 375.54 to 316.55 kgm^{-3} for 'Arican 97', '55 ÇA 15' and '14 BO 01', whereas the seed moisture content increased, respectively. The angle of repose increased from 17.11° to 22.87° for 'Arican 97' as the moisture content increased. These values increased from 15.25° to 23.87° for '55 ÇA 15' and from 16.42° to 24.17° for '14 BO 01' with the increase in moisture content. Porosity values ranged between 41.30–43.20%, 45.08–47.36% and 45.47–50.49% with the increasing moisture contents for 'Arican 97', '55 ÇA 15' and '14 BO 01', respectively.

Keywords: density, dimensions, physical properties, seed moisture content

Abbreviations: dwb, dry weight basis, %; **Ø**, sphericity, decimal; **L**, length, mm; **W**, width, mm; **T**, thickness, mm; **S**, surface area, mm^2 ; **ε**, porosity, %; ρ_t, true density, kgm^{-3}; ρ_b, bulk density, kgm^{-3}; **H**, height of cone, mm; **D**, circular plate, mm; **θ**, angle of repose, degree

INTRODUCTION

Pumpkin is one of the vegetables that meets some of the requirements of healthy nutrition. It is a tasty and valuable vegetable crop, containing a lot of biologically active substances and distinguished for dietary qualities. The name 'pumpkin' is commonly used for cucurbits of some species, similar in botanical characteristiscs. In Central Europe countries, pumpkins belonging to *Cucurbita pepo* L. (called also 'squash'), *Cucurbita maxima* Duch. (called 'winter squash') and *Cucurbita moschata* Duch. ex Poir species are mostly grown. Since pumpkin species and cultivars differs in nutritional and technological value of fruits, breeders and scientists seek genotypes of the highest suitability for human nutrition (Marek *et al.* 2008).

Cucurbita spp. is collectively ranked among the 10 leading vegetable crops worldwide. China and India are the world leading producers. Other major producers are Russian Federation, U.S.A, Iran, Egypt, Mexico, Ukraine, Italy, and Turkey (FAOSTAT 2010). Squashes (*Cucurbita* spp.) are members of the economically important *Cucurbitaceae*. There are three economically important *Cucurbita* species, namely *Cucurbita pepo* L., *Cucurbita maxima* Duch. and *Cucurbita moschata* Duch., which have different climatic adaptations and are widely distributed in agricultural regions worldwide (Robinson and Decker-Walters 1997; Paris and Brown 2005; Wu *et al.* 2007). The *Cucurbita* genus is of American origin. *C. maxima* is the most diverse *Cucurbita* species after *C. pepo* and is found throughout tropical and temperate regions. The centre of diversity, *C. maxima*, lies in South American temperate zones, where landraces exhibit an array of interesting traits. Many landraces of this species are also found in North America, Australia and different countries of Africa (Zambia and Nigeria); Asia (China, India, and Iran) and Europe (Spain and Turkey) (Ferriol and Pico 2008).

Turkey is one of the important diversity centers for cultivated cucurbits because of their adaptation to diverse ecological conditions as a result of natural selection and also farmers' selections (Sari *et al.* 2008). In addition, pumpkins are one of the most important cucurbit crops in Turkey. Only one improved cultivar of winter squash is currently grown commercially in Turkey. Farmers have maintained local population of winter squash and exchanged seeds with surrounding areas, mainly at local markets. It is a traditional vegetable often grown in small gardens. However, for decades, the old winter squash landraces have progressively been replaced by new cultivars, including 'Arican 97', which ensure higher yields and incomes and meet the requirements of processors and consumers (Sari *et al.* 2008; Balkaya *et al.* 2009b, 2010).

Turkey has also biological diversity in the cultivar of win-ter squashes. In addition, pumpkins are one of the important species of Cucurbitaceae vegetable in Turkey. The total pumpkin production was approximately 403 000 tons in 2010. Winter squash supply approximately 89 000 tons of this quantity. According to the Statistical Institute of Turkey records, there is no information about winter squashes regarding the distribution by regions and cities. However, according to observations of the land in Turkey, the production of winter squash is mainly produced at the Black Sea, Aegean, Central Anatolia and Southeast Anatolia region and

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provinces (Balkaya *et al.* 2011). Ankara is the leading producer province on the production of winter squash with 9447 tons in Turkey. Other major producers are Sakarya (7102 tons), Samsun (6599 tons), Kırklareli (4720 tons), Eskişehir (4398 tons) (Tuik 2010). Pumpkins belong to edible fruit vegetables. Because of this, pumpkins have good chance availability species in terms of vegetable cultivation industry. Establishment of commercial field will be possible with the development of industrial areas in the future (Balkaya *et al.* 2011). Handling, evaluation and standardization processes of pumpkin and squash seeds, primarily depend on obtaining good quality seeds. This also require the technological improvements and machinery. In order to design equipment used in cleaning, sowing, harvesting, handling, classification, transportation, packaging, storage, aeration and drying of seeds, it is necessary to know various physical and mechanical properties as function of seed moisture content (Tavakoli *et al.* 2009a, 2009b). However, the knowledge of physical properties of agro-materials is of importance to plant breeders, engineers, machine manufacturers, food scientists, processors, and consumers (Ozturk *et al.* 2009a). Dimensions of seeds can be used to calculate surface area and sphericity of seeds, which are important during modelling of seed drying, aeration, heating, and cooling. Bulk density, true density and porosity (the ratio of inter-granular space to the total space occupied by the grain) are used in design of storage bins and silos, separation of desirable materials from impurities, cleaning and grading and quality evaluation of the products. The angle of repose is also important in designing of storage and transporting structures. Flow-ability of seed is usually measured using the angle of repose (a measure of the internal friction between seeds) that will be useful in hopper design, since the hopper wall's inclination angle should be greater than the angle of repose to ensure the continuous flow of the materials by gravity. The static coefficient of friction of the grain against the various surfaces is also necessary in designing of conveying, transporting and storing structures (Mohsenin 1980; Tavakoli *et al.* 2009a, 2009b). The data have also been used for assessing the product quality (Teotia *et al.* 1989; Ozturk *et al.* 2009a).

In recent years, many researchers have studied the physical properties of different seeds such as pumpkin seeds (*Cucurbita moschata* Duch.) (Joshi *et al.* 1993), edible squash seeds (*Cucurbita pepo* L.) (Paksoy and Aydin 2004; Milani *et al.* 2007), rapeseed (*Brassica napus*) (Izli *et al.* 2009), bay laurel seeds (*Laurus nobilis* L.) (Yurtlu *et al.* 2010), barbunia bean seeds (*Phaseolus vulgaris* L. cv. 'Barbunia') (Cetin 2007), lentil seeds (*Lens culinaris* Medik) (Amin *et al.* 2004), sweet corn seeds (*Zea mays saccharata* Sturt.) (Coskun *et al.* 2006), roselle seeds (*Hibiscus sabdariffa* L.) (Mendoza *et al.* 2008), sunflower seeds (*Helianthus annuus* L.) (Gupta and Das 1997), watermelon seeds (*Citrullus lanatus* L.) (Koocheki *et al*. 2007), pumpkin (*Cucurbita pepo* L.) and watermelon seeds (*Citrullus lanatus* L.) (Altuntas 2008) and dent corn seeds (*Zea mays* var. *indentata* sturt) (Sezer *et al.* 2011).

The objective of this study was to determine some seed moisture dependent physical properties of seeds of one pumpkin line and two winter squash varieties grown in the Black Sea Region in Turkey.

MATERIALS AND METHODS

All tests were carried out at the Biological Material Laboratory in Agricultural Machinery Department of Agricultural Faculty of Ondokuz Mayis University, Samsun, Turkey. One pumpkin line (14 BO 01) developed by Balkaya *et al.* (2009a) and two winter squash varieties ('55 ÇA 15' and 'Arican 97') were used in this study. The seed moisture content was determined by using the standard hot air oven method, for samples of at least 20 g, maintained at 105°C for 24 h (Sacilik 2003; Gosling 2007; Yurtlu *et al.* 2010). Five levels of seed moisture content were selected as 8.62, 11.39, 17.57, 23.68, 25.49% dry weight basis (dwb) for 'Arican 97' winter squash seeds; 9.60, 13.65, 18.44, 21.34, 25.60% dwb for '55 ÇA 15' winter squash seeds and 6.81, 11.78, 15.75, 20.16, 23.07% dwb for '14 BO 01' pumpkin line seeds, recpectively.

The samples at the selected seed moisture contents were prepared by adding distilled water to sealed bags of seed and stored in a refrigerator at 5°C for 7 days to achieve uniformity of moisture sample distribution. Before starting a test, the required quantity of seed was taken out of the refrigerator and allowed to warm up to room temperature (Deshpande *et al.* 1993).

Randomly selected 30 seeds from each seed moisture content group were used for determining the size of the seeds. To determine the size dimensions of selected seeds namely length, width and thickness were measured by a digital caliper having an accuracy of 0.01 mm. Seed mass measurements were conducted with a precision electronic balance having an accuracy of 0.001 g. The physical properties of the seeds were determined by the following methods. The geometric mean diameter (D_g), and arithmetic mean diameter (D_a) were calculated at different seed moisture content levels according to Mohsenin (1980). Sphericity (Ø) was determined by the following equation (Mohsenin 1980):

$$\phi = \frac{(LWT)^{1/3}}{L}$$

The surface areas (S) of the seeds were calculated from the relationship given by Mohsenin (1980), Baryeh (2002) and Yurtlu *et al* (2010):

$$S = \pi D_g^2$$

Bulk density (ρ_b) was determined with a mass hectolitre tester, which was calibrated in kg cm^{-3} (Desphande *et al.* 1993; Ozturk *et al.* 2009b). The true density (ρ_t) was determined using the liquid displacement method. Toluene (C_7H_8) was used, rather than water for seed immersing, because water is absorbed more than toluene by the seeds. A weighed quantity of seed was immersed in toluene; the volume of toluene displaced was read from the graduated scale on the cylinder (Mohsenin 1980; Singh and Goswami 1996; Sacilik 2003). The true and bulk densities were evaluated for each seed moisture content level in five replications. The porosity (ε) was calculated by the equation given below (Mohsenin 1980):

$$\varepsilon = \left[1 - \left(\frac{\rho_b}{\rho_t}\right)\right]100$$

The height of cone (H) and the radius of the circular plate (D) were measured. The angle of repose (Θ) was calculated using the following relationship (Mohsenin 1980; Kaleemullah and Gunasekar 2002; Ozturk *et al.* 2009b).

$$\Theta = \tan^{-1}\left(\frac{2H}{D}\right)$$

RESULTS AND DISCUSSION

Dimensions and size distribution of pumpkin line and winter squash seeds

Mean values and standard errors of seeds length, width, thickness, arithmetic and geometric mean diameter are given in **Table 1**. According to results, all the seed dimensions increased with increasing seed moisture contents. All the diameters of seeds were significantly related with the seed moisture contents ($P < 0.05$).

Arithmetic and geometric mean diameters increased from 11.16-11.84 to 9.60-10.25 mm for 'Arican 97'; 12.41-12.82 to 10.53-10.88 mm for '55 ÇA 15'; 12.78-13.68 to 10.26-11.23 mm for '14 BO 01' seeds as the seed moisture content increased, respectively. Equations representing relationship between geometric mean diameter and arithmetic mean diameter and seed moisture contents are given in **Table 2**.

Sphericity

The relation between sphericity and seed moisture contents were found to be significant. Regression equations indicating the relationships between sphericity and seed mois-

Table 1 Mean and standard error values for dimensions of pumpkin line and winter squash variety seeds as a function of seed moisture contents.

	Seed moisture content	Seed dimensions, mm			Mean diameter, mm	
	(%) (dwb)	Length (L)	Width (W)	Thickness (T)	Arithmetic (D_a)	Geometric (D_g)
Arican 97	8.62	17.56±0.26	11.53±0.18	4.39±0.08	11.16	9.60
	11.39	17.96±0.21	11.82±0.19	4.58±0.09	11.45	9.88
	17.57	18.13±0.17	11.87±0.29	4.74±0.08	11.58	10.03
	23.68	18.18±0.18	12.39±0.13	4.78±0.11	11.78	10.23
	25.49	18.22±0.23	12.56±0.22	4.75±0.11	11.84	10.25
55 ÇA 15	9.60	19.74±0.24	12.86±0.18	4.64±0.10	12.41	10.53
	13.65	19.87±0.25	13.12±0.18	4.60±0.10	12.53	10.54
	18.44	19.92±0.24	13.27±0.20	4.68±0.08	12.62	10.71
	21.34	19.98±0.21	13.44±0.19	4.72±0.08	12.72	10.80
	25.60	20.26±0.25	13.63±0.18	4.86±0.11	12.82	11.01
14 BO 01	6.81	21.38±0.42	13.07±0.29	3.97±0.07	12.78	10.26
	11.78	21.94±0.33	13.49±0.27	4.07±0.09	13.16	10.60
	15.75	21.97±0.37	13.94±0.17	4.12±0.06	13.34	10.76
	20.16	22.32±0.37	14.08±0.25	4.32±0.08	13.57	11.05
	23.07	22.41±0.40	14.10±0.26	4.52±0.09	13.68	11.23

Table 2 Equations representing relationship between length, width, thickness, arithmetic mean diameter, geometric mean diameter and seed moisture contents.

	Seed moisture content (%) (dwb)	Regression equation	R^2
Arican 97	8.62–25.49	L =17.46 + 0.3189 M	0.802
		W = 11.08 + 0.5518 M	0.949
		T = 4.303 + 0.1999 M	0.785
		D_a =10.94 + 0.03572 M	0.981
		D_g = 9.387 + 0.03515 M	0.934
55 ÇA 15	9.60–25.60	L = 19.38 + 0.03494 M	0.901
		W = 12.43 + 0.04629 M	0.991
		T = 4.615 + 0.003504 M	0.792
		D_a = 12.11 + 0.03010 M	0.973
		D_g = 10.18 + 0.03047 M	0.939
14 BO 01	6.81–23.07	L = 20.06 + 0.6102 M	0.903
		W = 12.72 + 0.06568 M	0.883
		T = 3.620 + 0.03642 M	0.967
		D_a = 12.46 + 0.05438 M	0.959
		D_g = 9.876 + 0.05838 M	0.989

ture contents are presented in **Fig**. **1**. The sphericity of seeds increased from 0.548 to 0.567 with an increasing the seed moisture content increased from 8.62 to 25.49% for ‘Arican 97’. These values were found for ‘55 ÇA 15’ and ‘14 BO 01’ from 0.535 to 0.545; 0.482 to 0.504 as seed moisture contents increased from 9.60 to 25.60 and 6.81 to 23.07%, respectively.

Surface area

The relationship between the surface areas of seeds and the seed moisture content are given in **Fig. 2**. As seen from **Fig. 2**, the surface area increases linearly with increasing seed moisture content. The surface area of ‘Arican 97’ seeds increased from 290.08 to 330.86 mm^2, as the seed moisture content increased from 8.62 to 25.49%. These values changed from 349.22 to 382.12 mm^2 for ‘55 ÇA 15’ seeds and from 333.26 to 398.35 for ‘14 BO 01’ seeds at the range of 9.60–25.60 and 6.81–23.07%, respectively. Equations representing relationship between sphericity and seed moisture content can also be seen in **Fig. 2**.

Bulk density

The dependence of bulk density of seeds on seed moisture content is given in **Fig. 3**. As seen in the **Fig**. **3**, bulk density decreased with increasing seed moisture contents. As seed moisture content increased from 8.62 to 25.49%, the bulk density of the seeds of ‘Arican 97’ decreased from 411.86 to 366.03 kgm^{-3}. Bulk density values decreased from 390.35 to 347.37 and 375.54 to 316.55 kgm^{-3}, with increasing seed moisture contents from 9.60 to 25.60% and from

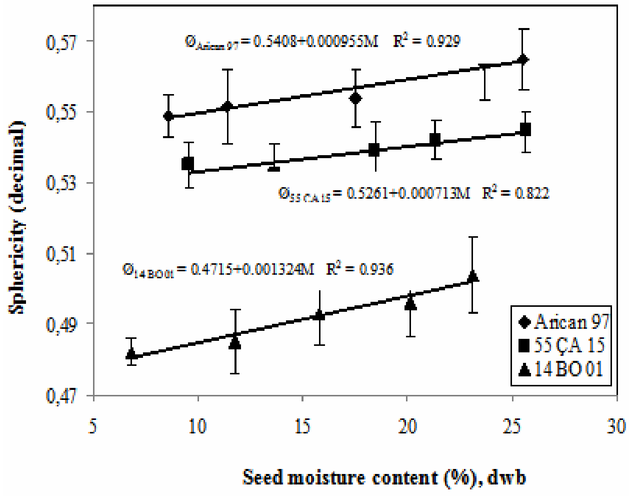

Fig. 1 Sphericity of seeds as a function of seed moisture content.

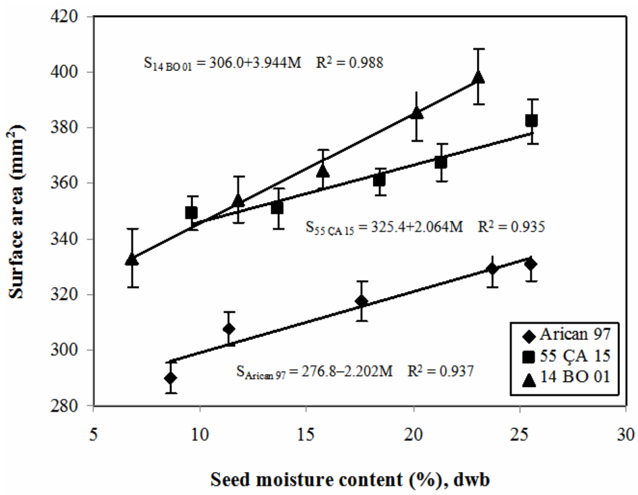

Fig. 2 Surface area of seeds as a function of seed moisture content.

6.81 to 23.07% for ‘55 ÇA 15’ and ‘14 BO 01’, respectively. Smilar tendency in bulk density with an increase in seed moisture content was also reported for cucurbit seeds (Milani *et al.* 2007).

True density

The dependence of true density of the seeds on seed moisture content is also given in **Fig. 3**. As seen in the **Fig. 3**, true density values decreased with increasing seed moisture contents. These values varied from 703.97 to 649.57,

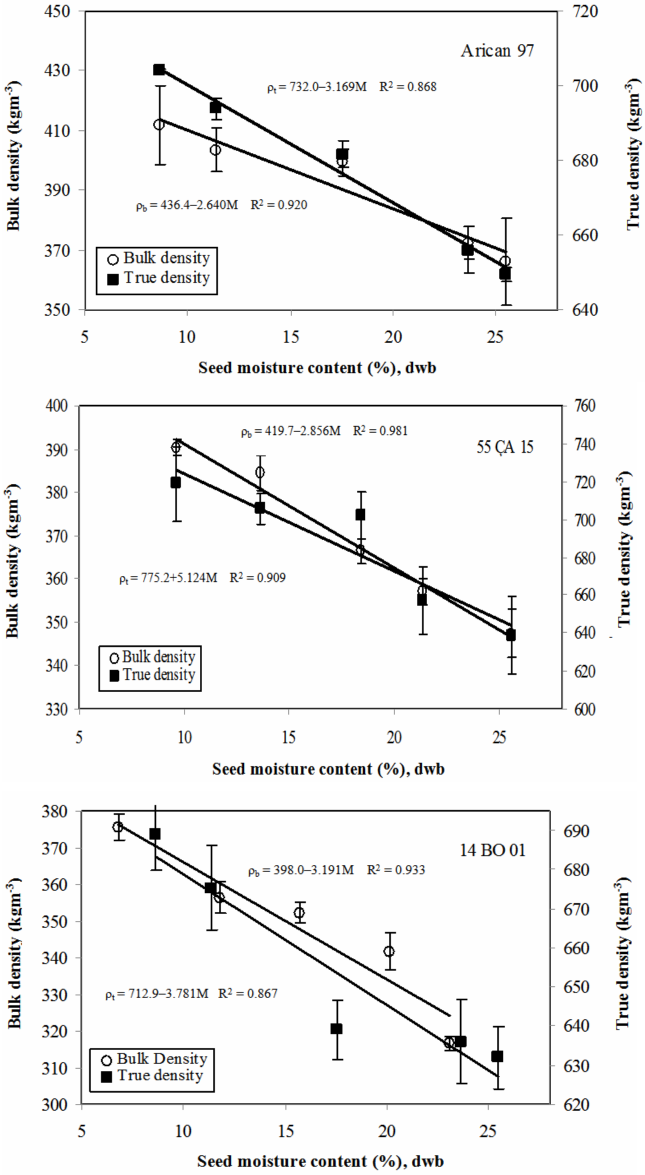

Fig. 3 Bulk density and true density of seeds as a function of seed moisture content.

718.71 to 638.77 and 688.87 to 631.94 kgm^{-3} ranging from 8.62 to 25.49, 9.60 to 25.60 and 6.81 to 23.07% seed moisture content for 'Arican 97', '55 ÇA 15' and '14 BO 01' seeds, respectively. The regression equations between the true density and seed moisture contents were given in **Fig. 3**. A decrease in true density with increasing seed moisture content was also reported for cucurbit seeds (Paksoy and Aydin 2004; Milani *et al.* 2007).

Porosity

The relationship between porosity and seed moisture content can be seen in **Fig. 4**. The calculated porosity increased from 41.30 to 43.20, 45.08–47.36 and 45.47–50.49% as the seed moisture content increased from 8.62 to 25.49, 9.60–25.60 and 6.81–23.07% for seeds, respectively. The form of the plot is similar to that for sunflower (Gupta and Das 1997), edible squash seeds (Paksoy and Aydin 2004) and cucurbit seeds (Milani *et al.* 2007).

Angle of repose

The test results of the angle of repose increased from 17.11° to 22.87° with an increase in seed moisture content from 8.62 to 25.49% for 'Arican 97' seeds, from 15.25 to 23.87° with an increase in seed moisture content from 9.60 to

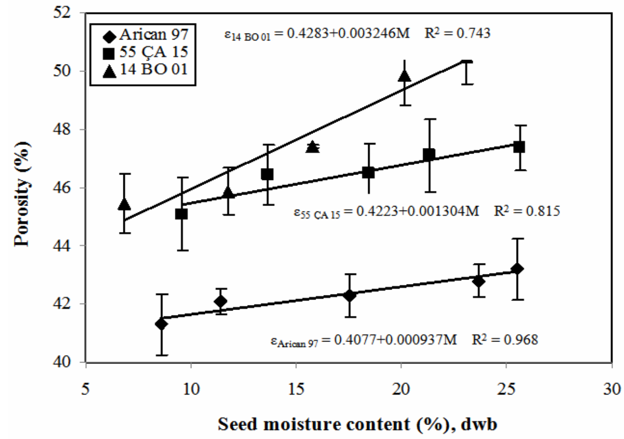

Fig. 4 Porosity of seeds as a function of seed moisture content.

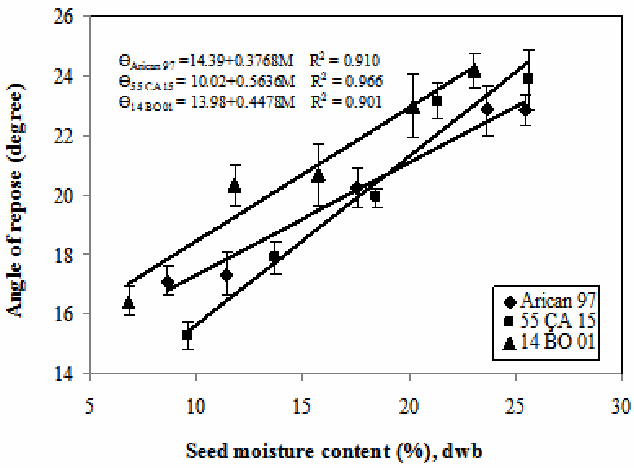

Fig. 5 Angle of repose of seeds as a function of seed moisture content.

25.60% for '55 ÇA 15' seeds (**Fig. 5**). These values were found to be between 16.42 and 24.17° as the seed moisture content increased from 6.81 to 23.07% for '14 BO 01' seeds. The relationship between the angle of repose and seed moisture content can be expressed by means of the equation given in **Fig. 5**.

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