ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome IX [2016], Fascicule 4 [October – December]
ISSN: 2067 – 3809

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BENDING AND SHEARING PROPERTIES OF SOME STANDARD CARNATION (dianthus caryophyllus l.) VARIETIES STEM

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Abstract: In this study, some engineering parameters such as strength and deformation were determined for five standard varieties of Carnation stem. The experiments were conducted on samples selected from carnation greenhouses in Antalya. Strength parameters consisted of maximum and bio yield force in shearing, shearing and bio yield stress, maximum energy in maximum force, maximum energy in bio yield point and modulus of elasticity. Deformation parameters are also maximum bio yield deformation and maximum breaking dilatation. The tests were conducted at five moisture contents (89.90, 88.65, 90.08, 98.54 and 88.94% (dry basis) for five different varieties (Toldo, Betsy, Jack, Loris and Naxsos), respectively. It was found that, except bending stress, shearing force, bio yield force, bending force, shearing stress, bio yield stress, energy in bio yield point, and energy in shear point were statistically different at $P < 0.05$ whereas breaking dilatation and bio yield deformation were statistically different at $P < 0.001$.
Keywords: carnation; shearing force; bending force; dianthus; harvest; cutting comp

INTRODUCTION

Growing flowers for cutting in the world began in the beginning of the 20th century and it has become an important commercial activity in many developed and developing countries, especially after the end of World War II. The total production land for ornamental plants reached about 610.000 ha. It is known that there are more than 50 countries in the world producing flowers for cutting. The most important producers of the European Union are Italy, Netherland and Spain. The countries of the European Union's produce 47 % of the total cut flower production in the world. Carnations are among the most extensively grown cut flower in the world [2].

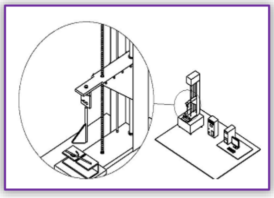
The carnation has been commercially grown in Turkey as a cut flower crop since 1945. The cut flower production area in Turkey mostly includes carnation (43 %), followed by rose (12.5 %) and gladiolus (12 %). In Turkey, the most important export production of cut flowers is the carnation consisting of 89 % of Turkey's cut flower export. The numbers of carnation exported in 2009 were 296,218,547 stems and the amount of money obtained was 21,828,260 USD [1].

Prasada and Gupta [17] studies showed that with increasing cutting rate from 200 to 1000 mm/min the shear strength of maize stalk decreased from 3.63 to 2.10 MPa. The average values of shear strength and shear energy of grasses were reported 16 MPa and 12 mJ mm^{-2}, respectively by McRandal and McNulty [13]. Kushwaha et al., [12] investigations revealed that the average value of shear strength of wheat straw was in the range of 8.6 to 13.0 MPa. Persson [16] believes that the bevel angle of blade to be effective on force and energy of cutting process of agricultural materials. When there was no problem of stalk holding versus cutting blade, Persson [16] recommends using smooth blade for cutting of grasses due to the lower force and energy requirement. Most studies on the mechanical properties of plants have been done during their development using breakdown criteria (force, stress and the effect of shearing velocity, energy) and the Young's modulus (Annoussamy et al., [3]; Hirai et al., [9]). Khazaei et al., [17] reported that with increasing cutting rate from 20 to 200 mm min^{-1} the shear strength of pyrethrum stalk decreased. The maximum values of shear force and energy for cutting of hemp were 243 N and 2.1 J, respectively [5]. Ince et al. [10] reported that the maximum shear stress and specific shear energy of sunflower stalks were 1.07 MPa and 10.08 mJ mm^{-2}, respectively. The physical properties of the cellular material are important for cutting, compression, tension, bending, density and friction [19-21].

Literature survey showed that there was no detailed study concerning the same engineering parameters (shear strength and shear energy) of the carnation stem. This study was carried out in determining strength parameters such as maximum force and bio yield force in shearing, shearing and bio yield stress, maximum energy in maximum force, maximum energy in bio yield point, modulus of elasticity and deformation parameters such as maximum bio yield deformation, maximum breaking dilatation of the carnation stem and different varieties of carnation. The obtained data would be useful in designing and developing harvesting equipment for the carnation.

MATERIAL AND METHODS

Seedling of five carnation varieties (Dianthus caryophyllus L. cv.' Toldo, Betsy, Jack, Loris and Naxos, which is a standard type) were planted on 01 June 2010 in plots (1.25 m long and 1.0 m wide) with a plant density of 32 plants m^{-2} (with four rows), and each plot contained 40 plants. Carnations were grown following regular farmer practices and randomly harvested manually from a plastic greenhouse in a field located southern Antalya, Turkey. During cutting tests, samples were stored in plastic bags in a refrigerator to keep them from drying further. Plants from October, 2010-harvest season were used in all the experiments.


a)

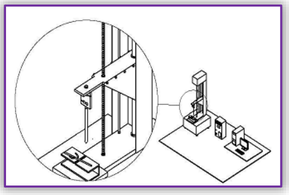

b)

Figure1. Computer-aided (a) cutting and (b) bending system's equipment

All of the tests were done at the Biological Test Devices, Laboratory of Agriculture Machinery, Akdeniz University, Antalya, Turkey. Carnations were harvested at moisture contents of 89.90 %, 88.65%, 90.08%, 98.54% and 88.94% (d.b.) in five varieties (Toldo, Betsy, Jack, Loris and Naxsos), respectively. In order to determine the variable of carnation, cutting apparatus was used (Figure 1a). The cutting and bending system had three main components: a stable forced and moving platform (slot, knife), a driving unit and a strain-gauge load cell (Figure 2).

The diameter of the specimen was measured by micrometer, and the specimen was weighed, oven-dried at 102°C for 24 h and then weighed again to determine the moisture content. The samples were for each carnation varieties; the 30 samples were randomly selected from the harvested carnations varieties. The average and SD values of the cross-sectional dimensions of carnation stem were 5.2±0.3, 5.8±0.2, 6.1±0.3, 5.6±0.3 and 4.8±0.2 mm, in five varieties (Toldo, Betsy, Jack, Loris and Naxos), respectively.

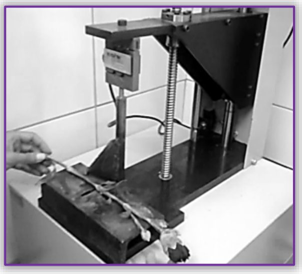


Figure 2. Cutting of carnation stem

There are three methods of positioning a cutting edge relative to counter edge defined as perpendicular, oblique and oblique variable for these studies. In the present study, perpendicular cutting was employed, since most researchers have used this method to determine the cutting forces of biological materials [10-11, 20]

The sliding plate was loaded at the range of 30 mm min^{-1} and, as for shear test, a strain-gauge load cell measured the applied force and a force-time record obtained up to the specimen failure. The shearing stress τ in MPa was calculated based on Eq. (1) and also reported by previous studies [5-7-10,14].

$$\tau = F_{smax} / A \qquad (1)$$

where, F_{smax} was the maximum shearing force of curve, N; A was the wall area of the specimen at the failure cross-sections, mm^2. The knife displacement was computed and the forces versus displacement curves were plotted for each stem diameter.

To determine modulus of elasticity, the stems were arranged with major axis of the cross-sections in the horizontal plane and placed on the slot. A strain gage load cell measured the bending force and a force time record obtained up to the failure of the specimen (Figure 1b).

Most specimens were slightly elliptical in cross-section and second moment of area in bending about a major axis (I_b) was calculated based on equation (Eq. (2)), [7-8]:

$$I_b=\pi/4[ab^3-(a-t)(b-t)^3] \qquad (2)$$

Where "a" is the semi major axis of the cross–section in mm, "b" is the semi minor axis of the cross-section in mm and "t" is the mean wall thickness in mm. Modulus of elasticity was assessed using a three–point bending test similar to those described by previous studies (Figure 1b) [14].

The modulus of elasticity, E, was calculated from the expression obtained for a simply supported beam located at its center (Eq. (3)), [6-20]:

$$E=F_b l^3/48\delta I_b \qquad (3)$$

where, F_b was the applied load, N; I was the distance between the metal supports, mm; δ was the deflection at the specimen center, mm; and I_b the second moment of area, in mm^4.

A sample force-displacement curve of the carnation stem was similar to that for straight cut against a counter shear reported (Figure 3) [20]. The curve explained three sections: A, B and C, representing compression only, compression and cutting and cutting only, respectively. In section A, the force increased from zero at the moment of initial contact between the knife and the stem, and then decreased due to the failure in stem structure. The compression continued in section B along with cutting as the knife moved. When the force reached its peak point, pure cutting took place in section C and the force dropped as the cutting was completed.

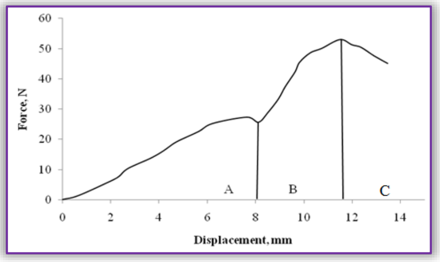


Figure 3. The force versus displacement curve for carnation

The bio yield forces, bio yield stress, bio yield deformation and maximum breaking dilatation were calculated by using the force curves [4-5-7,10]. Maximum energy in maximum force and maximum energy in bio yield point were calculated as the area (evaluated by numerical integration) beneath the entire force displacement. Maximum breaking dilatation is described as the rate of the total dilation to first length of the carnation stems. Bio yield deformation and maximum breaking dilatation were calculated by using computer program.

RESULT AND DISCUSSION

The initial moisture content of the samples were 89.90 %, 88.65%, 90.08%, 98.54% and 88.94% (d.b.) in five varieties (Toldo, Betsy, Jack, Loris and Naxsos), respectively. The results with respect to mechanical characteristics of carnation varieties together with statistical analysis are presented Tables 1 and 2. It was found that, except bending stress, shearing force, bio yield force, bending force, shearing stress, bio yield stress, energy in bio yield point, and energy in shear point were statistically different at $P < 0.05$ whereas breaking dilatation and bio yield deformation were statistically different at $P < 0.001$ (Table 1). These differences are due to different mechanical, physical and physiological properties of stem varieties. This information is very useful for selecting suitable equipment design [18]. Also work performance and efficiency productivity and quality as well as user comfort and safety of work can be improved [15].

Table 1. Variance analyzes results with respect to mechanical characteristics of carnation varieties

Source of variation	d.f.	Characteristics (variable)									
		Shearing force (N)	Bioyield force (N)	Bending force (N)	Shearing stress (MPa)	Bioyield stress (MPa)	Bending Stress (MPa)	Energy in bioyield point (J)	Energy in shear point (J)	Breaking dilatation (mm)	Bioyield def. (mm)
Replication	9										
Varieties (V)	4	***	***	***	***	***	N.S.	***	***	*	*
Error (V)	36										
Total	49										

N.S.: Not significant, * Sinificant at P<0,05, *** Sinificant at P<0,001

Table 2. The average values of mechanical characteristics in carnation varieties

Mechanical Characteristics	Betsy	Loris	Toldo	Jack	Naxos
Shearing force (N)	43.34 c*	55.65 b	53.24 b	74.47 a	38.57 c
Bio yield force (N)	17.94 b	39.84 a	23.93 b	40.60 a	14.30 b
Bending force (N)	7.74 b	11.40 a	8.12 b	10.98 a	6.55 b
Shearing stress (MPa)	6.25 b	8.29 ab	8.05 ab	9.37 a	7.77 ab
Bio yield stress (MPa)	2.51 b	5.93 a	3.57 ab	5.22 ab	2.88 ab
Bending stress (MPa)	1.12	1.71	1.23	1.39	1.32
Energy in bio yield point (J)	38.62 c	108.34 ab	87.70 b	131.46 a	20.57 b
Energy in shear point (J)	140.36 c	264.14 a	212.25 b	266.49 a	123.78 c
Breaking dilatation (mm)	10.85 b	11.23 b	12.84 a	11.44 ab	11.06 b
Bio yield deformation (mm)	6.99 ab	7.78 ab	8.16 ab	8.57 a	6.42 b

*Different letters show different means according to Duncan test results at 5 % confidence interval.

The highest shearing force, bio yield force, bending force, shearing stress, energy in bio yield point, and energy in shear point, and bio yield deformation were obtained Jack variety (Table 2). Selection of suitable cutting apparatus and equipment plays an important role on shearing cutting force requirements. According to our results the cutting properties of carnation stems varied as a function of the variety.

As can be seen in Table 2, average values for shearing force were 43.34, 55.65, 53.24, 74.47 and 38.57 N for varieties of Betsy, Loris, Toldo, Jack and Naxos, respectively and average value of bending force were 7.74, 11.40, 8.12, 10.98 and 6.55 N for varieties of Betsy, Loris, Toldo, Jack and Naxos, respectively. The maximum value of energy in shear point was 266.49 J for Jack stems, among the five varieties investigated and the minimum value was 123.78 J for Naxos.

The maximum value of shearing and bio yield force was 74.47 N and 40.60 N for Jack stems, among the five varieties investigated and the minimum value was 123.78 N and 14.30 N for Naxos but the maximum value of bending force (11.40 N) was obtained at Loris and the minimum value of its (6.55 N) was obtained at Naxos. The highest shearing, bio yield and bending stress (9.37, 5.93 and 1.71 MPa, respectively) were obtained at Jack variety for shearing and bio yield stress and Loris variety for bending stress. The lowest shearing, bio yield and bending stress (6.25, 2.51 and 1.12 MPa, respectively) were found at Betsy variety.

The highest breaking dilatation was obtained for Toldo while the lowest was for the Betsy variety and the highest bioyield deformation was obtained for Jack while the lowest was for the Naxos variety. The highest shearing and bioyield stress (9.37 and 5.93 MPa) were obtained at variety of Jack and Loris, respectively, the lowest shearing and bioyield stress (6.25 and 2.51 MPa) were obtained at variety of Betsy.

The study results showed that there is significant difference between mean values of mechanical characteristics of carnation based on the variety. Study results could be considered in designing the prototype or realization of a good cutting.

CONCLUSIONS

Variety of carnation is the important factor affecting shearing force, bio yield force, bending force, shearing stress, bio yield stress, energy in bio yield point, and energy in shear point, Breaking dilatation and bio yield deformation of the carnation stem.

Shearing force, bio yield force, bending force, shearing stress, bio yield stress, energy in bio yield point, and energy in shear point, were statistically different at $P < 0.05$ among the studied varieties. Breaking dilatation and bio yield deformation were statistically different at $P < 0.001$, among the studied varieties.

There was no significant difference among the bending stress of Betsy, Loris, Toldo, Jack and Naxos. Jack variety with 74.47 and 40.60 N had the highest shearing and bioyield force and highest energy in bioyiled and shearing point with 266.49 and 131.46 J, respectively, among the studied varieties.

As a result, it was showed that, the Shearing force, bio yield force, bending force, shearing stress, bio yield stress, energy in bio yield point, and energy in shear point are related to carnation stems' physical and mechanical properties.

Acknowledgements

This study was partly supported by the Department of Agriculture Machinery, Akdeniz University and Batı Akdeniz Agricultural Research Institute. Antalya, Turkey

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