Turk J Agric For
26 (2002) 363-368

Determination of Relationships between Various Aerodynamics, Physio-Mechanical and Fiber Properties in Cotton

Mustafa Bülent COŞKUN
Department of Agricultural Machinery, Faculty of Agriculture, Adnan Menderes University, Aydın - TURKEY

Received: 19.08.2002

Abstract: The relationships between aerodynamic properties such as vacuum pressure and suction speed and the fiber and physio-mechanical properties of cotton during harvesting were determined by using the Nazilli 84 cotton variety. Aerodynamic properties such as vacuum pressure and suction speed and physio-mechanical properties such as wet and dry lock masses, lock moisture, number of seeds per lock, carpel openness, carpel depth, carpel angle and force of lock break-off were measured. In addition fiber length, fiber strength, fiber elongation and fiber fineness were determined. The statistical relationships between the aerodynamic, physio-mechanical and fiber properties were also determined. It was observed that as suction speed increased the vacuum pressure requirement decreased. Moreover, a higher vacuum pressure was required for breaking off locks with seeds greater in number, with a large mass, and long, durable, flexible and thick fibers. Cotton locks showing high resistance to break off and moist cotton locks require a higher speed to be separated from the carpel.

Key Words: Cotton, physio-mechanical properties, fiber properties, aerodynamic properties

Pamuğun Aerodinamik, Fiziko-Mekanik ve Lif Özellikleri Arasındaki İlişkilerin Belirlenmesi

Özet: Bu çalışmada, pamuk hasadında yararlanılabilecek vakum basıncı ve emme hızı gibi aerodinamik özellikler ile pamuğun lif ve fiziko-mekanik özellikleri arasındaki ilişkiler belirlenmeye çalışılmıştır. Bu amaçla oluşturulan deneme düzeneğinde Nazilli 84 pamuk çeşidi denemeye alınmıştır. Denemelerde vakum basıncı ve emme hızı gibi aerodinamik özellikler ile yaş ve kuru lüle kütleleri, lüle nemi, lüledeki tohum sayısı, çenet açıklığı, çenet derinliği, çenet açısı ve lüle kopma kuvveti gibi fiziko-mekanik özellikler ölçülmüştür. Ayrıca uzunluk, dayanıklılık, esneklik ve incelik gibi lif özellikleri belirlenmiştir. Pamuğun ölçülen aerodinamik, fiziko-mekanik ve lif özellikleri arasındaki istatistiksel ilişkiler ortaya konmuştur. Emme hızı arttıkça vakum basıncı gereksinimi azalmaktadır. Ayrıca tohum sayısı fazla, büyük kütleli, uzun, dayanıklı, esnek ve kalın lif özelliğine sahip pamuk lülelerinin koparılması için daha yüksek vakum basıncına gereksinim duyulmaktadır. Nemli ve kopma kuvveti fazla olan pamuk lüleleri çenetten yüksek hızlarda ayrılabilmektedir.

Anahtar Sözcükler: Pamuk, fiziko-mekanik özellikler, lif özellikleri, aerodinamik özellikler

Introduction

Cotton is an important and strategic agricultural product. One of the major problems faced in cotton grown in different sized areas is harvesting (Tunçer and Işık, 1999). In Turkey a large portion of cotton harvesting is done by the human labor force. However, increasing labor costs have encouraged producers to use machinery (Sabancı and Işık, 1989; Evcim and Öz, 1997). The cotton harvesting machinery used in Turkey is generally high capacity. Because of its construction this machinery cannot be used in small areas. Considering the current situation of cotton facilities in Turkey, it would be beneficial to develop a simple machine that would decrease the requirement for labor. For the development of such machinery the relationship between the fiber, physio-mechanical and aerodynamic properties of the materials has to be taken into account.

Materials and Methods

The trial mechanism in Figure 1 was used to determine the relationships between aerodynamic properties and fiber and physio-mechanical properties. In the mechanism an electric engine of 1 kW, a vacuum unit providing vacuum up to 0.025 m^3 s^{-1} and –70 kPa, two vacuum meters, two circular valves, one wire strainer with dimensions of 1 x 1 mm, an air channel consisting of a PVC pipe and a material tying apparatus. For the measurements we used a flow measure with a telescopic probe with a measurement interval of 0.0001-195

$m^3\ s^{-1}$, a dynamometer with a sensitivity of 0.001 and a measurement interval of 0-2 kg, a vacuum meter with a sensitivity of –1 kPa and a measurement interval of 0 to –100k Pa, a compass with a sensitivity of 0.02 mm, a sensitive scale with a sensitivity of 0.01 g and a steam oven running between 30 and 230 °C. In the trials the Nazilli 84 cotton variety was utilized.

From Nazilli 84, 75 cotton bolls out of a parcel with three repetitions were collected during the harvesting period. The bolls were tied rigidly to the dynamometer. The suction pipe, which had a fixed diameter, was brought near the boll while the circular valve in the air channel opened and the lock was broken off by the effect of the vacuum. The values of break-off force, vacuum pressure and air flow were measured as the lock broke off the carpel. The locks were prevented from going through the channel with the help of a strainer inserted into the air channel. Three hundred trials were performed in total. After each trial, locks for fiber analysis and measurement of moisture, the carpel and bolls for the measurement of dimensions were counted. The value of moisture in the dry base was found in the direction of the method indicated in the literature (Wells and Meredith, 1986). At first, the locks were scaled in wet form and then they were dried under 70 °C for 72 h. Their dry weights were scaled to determine the moisture value. The values of carpel openness and carpel depth in the boll were measured by taking the dimensions of the boll in Figure 2 into consideration. After determining the seed number per lock, HVI analysis was performed to determine the fiber length, fiber strength, fiber fineness and fiber elongation.

The breaking off value measured in terms of the calculations made after measurements was converted into force by using the equation

$$F = m.g \qquad 1$$

The flow value measured in the air channel was converted into the value of suction speed in the air channel by using the equation

$$V = 1.273\,\frac{Q}{D^2} \qquad 2$$

This value was converted into the value of suction speed at the edge point of the channel by using the equation

$$V_s = \frac{V.D^2}{D_e^2} \qquad 3$$

Furthermore, the value of the carpel angle was calculated with the equation

$$\alpha = \mathrm{arctg}\left(\frac{1}{2}\cdot\frac{CO}{CD}\right) \qquad 4$$

by making use of carpel openness and carpel depth.

The values of moisture at the dry phase were calculated by the equation

$$\%N = \frac{W_w - W_d}{W_d}\ .\ 100 \qquad 5$$

with the help of values of wet and dry lock mass (Yağcıoğlu, 1999).

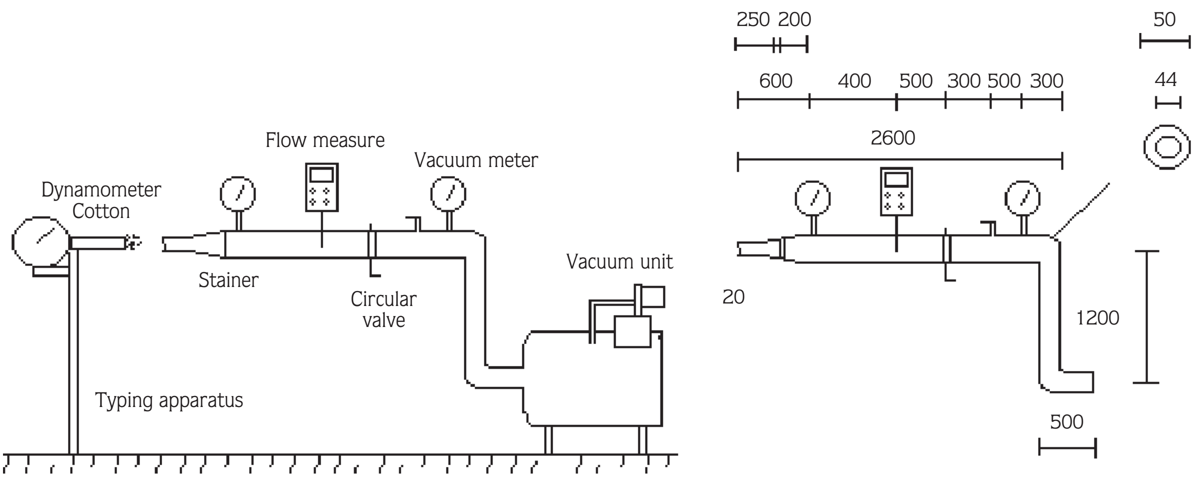

Figure 1. Trial mechanism.

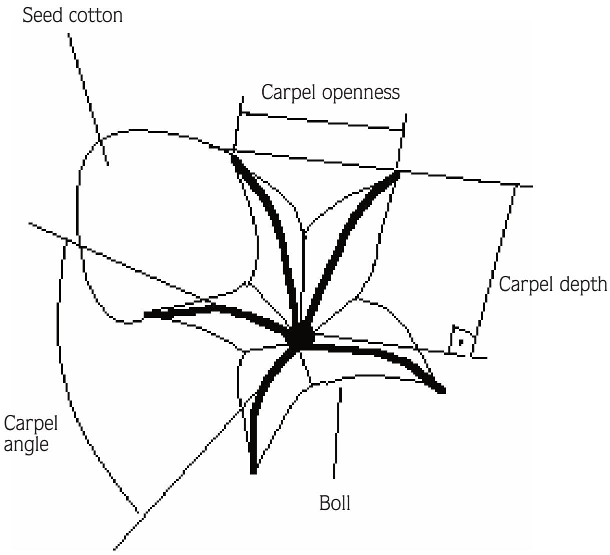

Figure 2. Boll dimensions.

Results and Discussion

The measured average values of the aerodynamic, physio-mechanical and fiber properties of the cotton varieties are presented in Table 1. The average vacuum pressure was –3.528 kPa, the suction speed was 1.620 m s^{-1}, the force of lock breaking off was 0.284 N, the dry lock mass was 1.16 g, the wet lock mass was 1.271 g, the lock moisture was 8.706%, the number of seeds per lock was 7.019, the carpel openness was 39.958 mm, carpel depth was 22.953 mm, carpel angle was 40.969°, fiber length was 26.667 mm, fiber strength was 28.550 g.tex^{-1}, fiber fineness was 5.617 micronaire and fiber elongation was 10.567%. These fiber and physio-mechanical properties match the literature data.

During studies conducted to determine the force of lock break-off, it was found that breaking tension values for various varieties of cotton were around 0.197-0.248 N (Yelin, 1985). It seems that there was no significant difference between the value 0.248 N obtained in our trials and those in the literature. Carpel openness was found to be 39.95 mm.

In the literature is this value 50.57-58.65 mm (Yelin, 1985). The difference between these values results from the varieties and the number of materials studied.

In the literature the lock weight of the Nazilli 84 variety is around 1.19-1.48 g, fiber length is 31.6 mm and fiber thickness is 5.2 micronaire (Kaynak et al., 2001). The values obtained in our trials and those in the literature are in close harmony. A similar harmony can also be found with respect to values such as fiber thickness (3.7-4.8 micronaire), fiber strength (18.9-23.9 g/tex), fiber length (28.82-30.73 mm) and fiber elongation (8.1-8.8%) (Evcim et al., 1999).

Table 1. Aerodynamic properties, and repetition averages of the fiber and physio-mechanical properties.

Trial parameters		Nazilli 84			
		1	2	3	Average
Aerodynamic properties	Vacuum pressure (kPa)	-3.690	-3.575	-3.318	-3.528
	Suction speed (m s^{-1})	1.575	1.583	1.703	1.620
Physio-mechanical properties	Force of lock breaking off (N)	0.238	0.262	0.350	0.284
	Dry lock mass (g)	1.215	1.249	1.017	1.161
	Wet lock mass (g)	1.327	1.367	1.117	1.271
	Lock moisture (%)	8.478	8.608	9.031	8.706
	Number of seeds per lock	7.100	7.200	6.757	7.019
	Carpel openness (mm)	39.052	42.033	38.790	39.958
	Carpel depth (mm)	22.477	23.773	22.609	22.953
	Carpel angle (degree)	40.931	41.322	40.650	40.969
Fiber properties	Fiber length (mm)	26.750	26.650	26.600	26.667
	Fiber strength (g.tex^{-1})	28.900	29.450	27.300	28.550
	Fiber elongation (%)	10.700	10.800	10.200	10.567
	Fiber fineness (micronaire)	5.650	5.700	5.500	5.617

Within the scope of this study, values such as vacuum pressure, suction speed, seed number on lock, depth of carpel and angle of carpel were established for the Nazilli 84 variety for the first time.

Some of the relationships between parameters are given in Figures 3 to 5. Moreover, the relationship between aerodynamic properties is given in Figure 3.

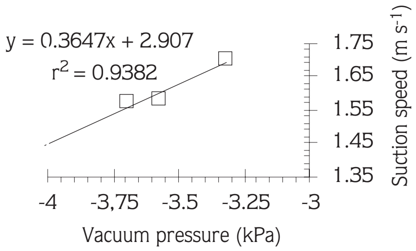

Figure 3. The relationship between vacuum pressure and suction speed.

Figure 3 shows that there is a strong relationship between suction speed and vacuum pressure (r^2 = 0.9382). As suction speed increased the requirement for vacuum pressure decreased.

The relationships between the physio-mechanical properties of cotton and vacuum pressure are presented in Figure 4. As wet lock mass and dry lock mass and the number of seeds per lock increased, a much higher vacuum pressure was required for breaking off the locks (Figure 4). The relationships between carpel openness, depth, angle, and vacuum were weak. As the moisture of the lock increased, the requirement for vacuum pressure decreased. Therefore it can be concluded that locks of great mass and volume can be separated with a very low speed (with high vacuum pressure) and locks of smaller volume and high moisture can be broken off with high speed (with low vacuum pressure). On the other hand, locks with high breaking off force can be separated with high speeds (with low vacuum pressure). The relationships between vacuum pressure and the force of breaking off, wet lock mass, dry lock mass, lock moisture and number of seeds per lock were high and their r^2 values were 0.9888, 0.8069, 0.8151, 0.9934 and 0.7496 respectively.

The relationships between vacuum pressure and carpel openness, depth and angle were low and their r^2 values were 0.0815, 0.0154 and 0.3602 respectively.

The relationships between fiber properties and vacuum pressure are given in Figure 5. The relationships between the vacuum pressure and the fiber length, strength, elongation and fineness were high and their r^2 values were 0.8434, 0.7218, 0.8008 and 0.7273 respectively (Figure 5).

For the suction of locks an average suction speed of 1.62 m s^{-1} and an average –3.528 kPa vacuum pressure were required. Lock break-off force was an average of 0.284 N. As suction speed increased, the requirement for vacuum pressure decreased. For the break-off of locks with more seeds, large mass, and long, durable, flexible and thick fibers, a much higher vacuum pressure was required. The locks with high resistance to break off and the moist locks require higher speed to be separated from the carpel.

Symbols

- %N Moisture in dry state (%)
- α Carpel angle (degree)
- CD Carpel depth (mm)
- CO Carpel openness (mm)
- D Diameter of air channel (m)
- D_e Diameter of edge point of air channel (m)
- F Break-off force (N)
- g Acceleration of gravity (m s^{-2})
- m Break off value measured in terms of mass (kg)
- Q Air flow measured in air channel (m^3 s^{-1})
- V Suction speed at the air channel (m s^{-1})
- V_s Suction speed at the edge point of air channel (m s^{-1})
- W_d Dry lock mass (g)
- W_w Wet lock mass (g)

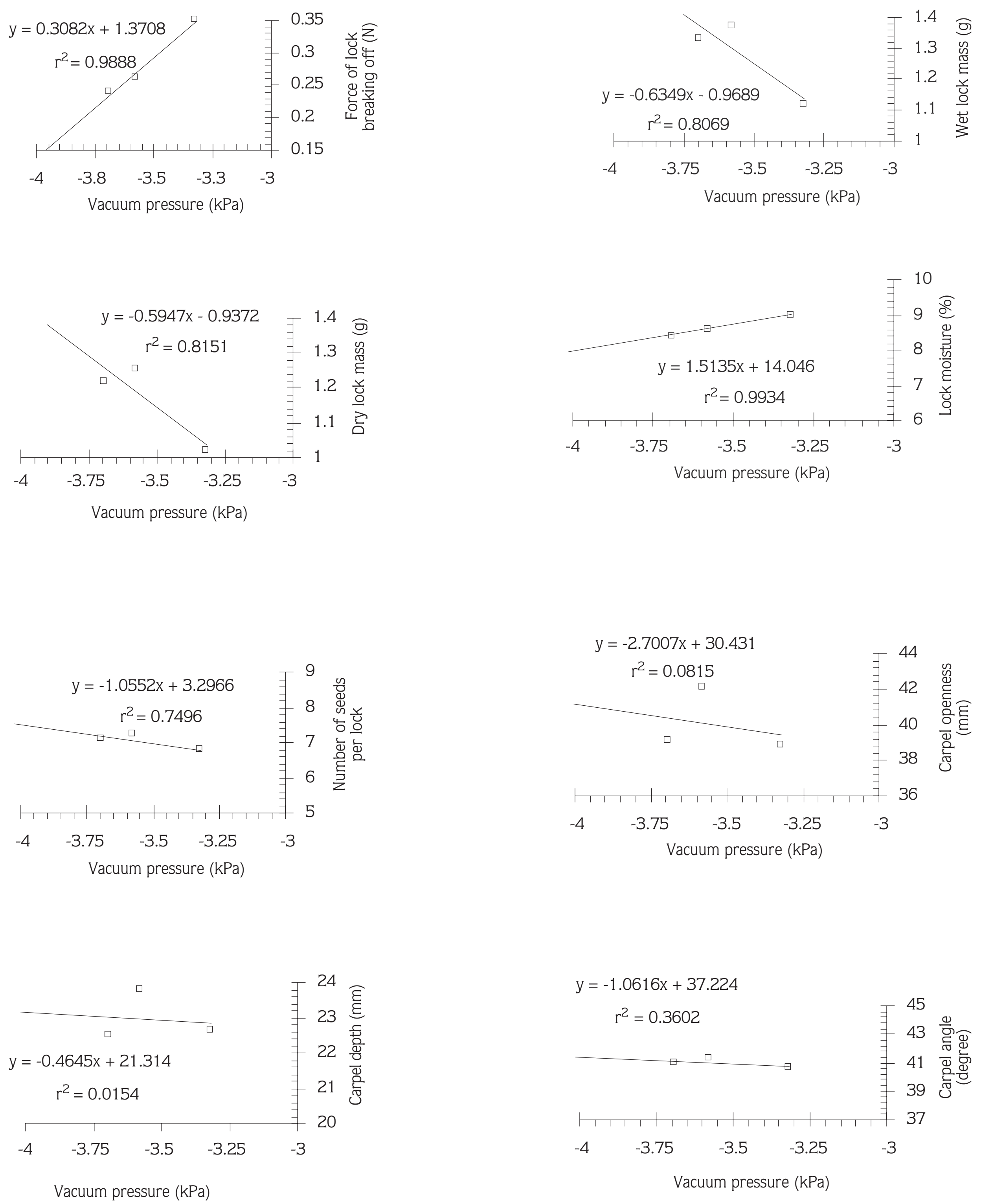

Figure 4. Relationships between vacuum pressure and physio-mechanical properties.

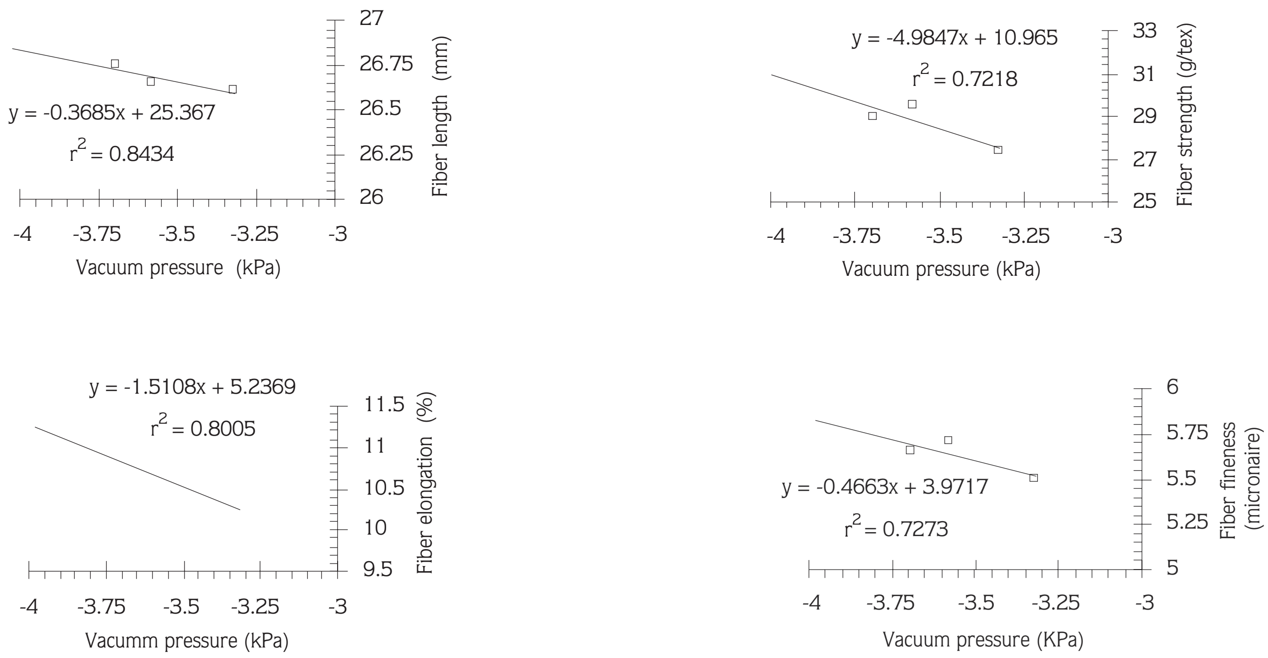

Figure 5. Relationships between vacuum pressure and fiber properties.

References

Evcim, Ü. and E., Öz, 1997. Farklı Pamuk Çeşitlerinin Makinalı Hasadında Kantitatif Performansın Belirlenmesi. Tarımsal Mekanizasyon 17. Ulusal Kongresi. Bildiri Kitabı 2. Cilt, s: 84, Tokat.

Evcim, Ü., E. Öz and Ö.K. Caner, 1999. Determining the Effect of Machine Picking on Cotton Lint Quality under Practical Conditions. 7th International Congress on Mechanization and Energy in Agriculture. p: 91, Adana.

Kaynak, M.A., A. Ünay, İ. Özkan and H. Başal, 2001. Pamukta (Gossypiumhirsutum L.) Kombinasyon Melezlemesi ile Oluşturulan Populasyonlarda Önemli Agronomik ve Teknolojik Özelliklerin Saptanması. GAP II. Tarım Kongresi, 2. Cilt, s: 849, Şanlıurfa.

Sabancı, A. and A., Işık, 1989. Çukurova Bölgesinde Pamuk Hasadında Toplama Bedeli Değişimleri ve Makinalı Hasadın Geleceği. Tarımsal Mekanizasyon 12. Ulusal Kongresi. Bildiri Kitabı, s: 35, Tekirdağ.

Tunçer, K, and A., Işık, 1999. Makineli Pamuk Hasadı ve Türkiye'deki Gelişmeler. Türk Dünyasında Pamuk Tarımı Lif Teknojisi ve Tekstil 1. Sempozyumu, Bildiri Kitabı, s: 209, Kahramanmaraş.

Wells, R. and W.R. Meredith, 1986. Normal vs. Okra Leaf Yield Interactions in Cotton. Crop. Sci. Vol: 26, p: 223.

Yağcıoğlu, A., 1999. Tarım Ürünleri Kurutma Tekniği. E.Ü.Z.F Yayın No: 536. İzmir.

Yelin, D., 1985. Gossypium hirsutum L. Türü İçinden Beş Pamuk Çeşidinin Yarım Diallel Melez Populasyonlarında, Verim ve Makinalı Hasada İlişkin Tarımsal Özelliklerin Kalıtımı Üzerinde Araştırmalar. Doktora Tezi. Ç.Ü. Fen Bilimleri Enstitüsü, Adana.