Determination of the required force to pick cottonseed from four cotton varieties boll in three different harvesting time

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Abstract: The cotton plant contains fruits called capsules or bolls, in which the cotton fiber grows, and after the growth stages, the fibers appear through separating the carpels. This research investigated the required force to pick the cottonseed from four cotton variety (Golestan, Khorshid, Sajedi, and Kashmar) in three levels of moisture (three harvesting times) and three revolutions (1500, 2500 and 3500 rpm). To measure this force, designed and manufactured a device similar to a spindle cotton picker and using the actual needle of John Deere machine 9920. The bolls were tested in different revolution and moisture levels with the device. The results of experiments showed that the cross-effects of variety on speed, harvesting time on variety and harvesting time on speed were significant in picking fibers. Considering the revolution of needle and variety, the most appropriate revolution for the Golestan, Khorshid and Kashmar varieties is 3500rpm, and the most appropriate revolution for Sajedi is 2500 rpm. In addition, the results showed that there is a significant difference in the different harvesting times of the khorshid variety. But, there was no significant difference in Golestan and Sajedi varieties between different harvest times. Kashmar variety showed the strongest force in the first harvesting time and the weakest force in the third harvesting time. However, the minimum picking force was obtained for Golestan variety as 0.399 N at 2500 rpm; in different harvesting times, the khorshid variety had the minimum force (0.251 N) and the Golestan variety had the maximum force (0.891 N) during the first harvesting time.

Keywords: cotton, force, fiber, harvest, cottonseed

Citation: Jahanian, M., M. Azadbakht, S. Nowrouzieh, and A. Asghari. 2020. Determination of the required force to pick cottonseed from four cotton varieties boll in three different harvesting time. Agricultural Engineering International: CIGR Journal, 22 (1):68-75.

1 Introduction

Cotton or Gossypium is a perennial herb of the Malvaceae family (Wendel et al., 2009). Cotton's fruit is a capsule or boll, which is separated from the carpel and the cotton fibers appear at the time of harvesting (Khajepour, 2004). Through blossoming and pollination of the flower, the life of the boll begins and it blossoms 50 days later. At this time, the boll takes three steps: growing, filling, and maturity. At the stage of growing, the fibers are produced and prolonged, and the seeds get to their maximum volumes. At the fourth to sixth week, the filling stage is completed by creating the secondary wall of fibers and the filling of empty space with them. When the size of the boll is completed and it has reached its maximum weight, the maturity phase begins with the drying of the carpels wall and the wrinkling of them to the rear; this causes a kind of

Received date: 2018-07-26 **Accepted date:** 2019-09-03
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opening and creation of seams between the walls of the carpels and thus, the boll is opened (Wright et al., 2011). The most important agricultural combination of cotton is fibers, and the best varieties have firm, long, and soft fibers. The 35%-45% of total cottonseed are fibers and 50% of in includes seeds. After ginning and separation of the fiber, the remaining seed contains 50% of the kernel, 11% of fluff lint and 38% of the bark (Khadi et al., 2010). Cotton fibers have unique properties such as the ability to be washed, durability, strength, steam conductivity, flexibility, ease of shrinking, or initial accumulation and coloring, such that other fibers do not have these properties in one and the same (Haeri and Asayesh, 2009). Nowadays, US industrial fabric manufacturers use about 6.7 million cotton bales. Finally, about 57% of it becomes apparel, more than one-third is turned into home appliances and the remainder is used in industrial products (Adebija and Jackson, 2013).

The top countries producing cotton fiber during 1997-2007 were China, with an average production value of 6.7 billion $ (25% of the world's total), and the United States with 6 billion$ (20% of the world's total), followed by these two countries, India, Pakistan, and Uzbekistan, with average production value of 3.5, 2.6 and 1.5 billion dollars, are in the next categories, respectively. Unfortunately Iran, with an average value of 177 million $ (0.6% of the world's total) and a negative growth rate of 2.4%, has not found a place among the best cotton makers these years (Asiabani et al., 2012). Due to the manual harvesting of cotton, there is a strong dependence on the labor force, with the high cost of manual harvesting leading to reduced cropping area and reduced production in Iran (Barzegar and Salimikochi, 2014; Nowrouzieh et al., 2003). The current yield of cotton production tends to decrease the average, which is a national challenge (U.S. Cotton Bale Dimensions, 2013). Over the years, due to the variety of planting methods in different parts of the world and trying to harvest more effectively and without damage to the plant and the quality of cotton, various mechanisms are used in the world (Deshmukh and Mohanty, 2016). One of the machines used for picking up is spindle harvesting machines that separate it from the boll. Because the plant continues to grow during the season, then it is possible to enter the machine several times (Baker et al., 2010). Spindle cotton picker combines equipped with cottonseed-cut needles have the ability to harvest cotton with an efficiency of 95%-98%, but problems and inadequacies that occur during work and on the field can increase the amount of trash (Willcut et al., 2002). Research has shown that harvesting with cotton picker machines reduces the quality of the fibers at high speeds and typically has 10%-30% higher external material than the manual harvesting of cotton (Faulkner et al., 2011; Nowrouzieh et al., 2010). In order to get rid of the problems of harvesting and the optimal use and design of harvesting machines, it is necessary to know the minimum amount of force as well as the force necessary to pick the cottonseed out of the boll.

In a study by Kevin and Hughs (2006) on the effect of the rotational speed of the cottonseed-cut needles in cotton harvesting combines at three levels of 1500, 2000 and 2400 rpm, on the trash rate (unharvested cottonseed) impurities and wastes in harvested cotton, as well as the quality of the fibers, showed that the cotton on the stems in the field at a speed of 1500 rpm was significantly more than two speeds of 2000 and 2400 rpm. As a result, it was determined that the minimum rotational speed for cottonseed-cut needles is 2000 rpm in order to function properly and reduce the amount of trash (Kevin and Hughs, 2006).

Two types of spindles were used in another study by Baker et al. (2010), one of them was 12.5 mm round tapered, barbed spindle, and the other was 8.4 mm of a square straight and smooth spindle; they tested the amount of cotton fly-off, and the fibers separation force of the spindles, it was found that the number of wastes in 1500 rpm was higher than 2000 rpm; in addition, the minimum amount of waste was observed in 2000 revolution when compared to 3000 and 4000 rpm (Baker et al., 2010).

In a study by Limbasiya (2015), were designed a hand-like mechanism to pick cottonseed out of the boll, i.e. holding the stem with one hand and pulling it from the boll with three fingers and thumbs, on the other hand, using arm

force. The minimum force for each finger was measured at 6 N. The direction of the force, when the fingers were closed, was vertical and this force at the start was longer than the end. It was concluded that the amount of force per finger for this model should be more than 6 N (Limbasiya, 2015).

Nazarzadehoghaz et al. (2014) conducted a research on a semi-mechanized, cotton-picking machine that was controlled by the workers; they realized that the uniformity of the fibers harvested by this machine was 84.1%, which was higher than the manual method (80.9%). Furthermore, the purity of the cotton through the picking machine (97.88%) was higher than manual method (96.15%). In the automated method, 39600 joules are consumed more energy per hour. Also, the land capacity of the cotton picking machine was calculated to be 4.792 kg h^{-1}, which was less than 10.031 kg h^{-1} in the manual method (Nazarzadehoghaz et al., 2014).

Also, Cozkun (2002) measured the separation force of cottonseed from the carpels of boll in a moisture content of 7.806%, 0.248 N with using an air vacuum machine. By increasing the moisture content, separating cottonseed from the carpel became possible with increasing velocity; in addition, the strong relationship between vacuum pressure and picking force, cottonseed's moisture content and the number of seeds with r^2 were 0.9888, 0.9934 and 0.7496, respectively (Bülent, 2002).

Spindle machines require precise adjustments in order to minimize the losses and improve the quality of the fiber (Anthony and Jackson, 2013). Due to the high cost of purchasing, fix and maintaining cotton picking machines, it is very necessary to have a smaller and lighter machine that can harvest small farms. Therefore, the purpose of this research is to determine the necessary force for picking cottonseed in three levels of moisture content (different harvest time of cotton) and three levels of picking speed so that the design and construction of a small cotton picking machine are facilitated.

2 Materials and methods

Golestan, Khorshid, Sajedi, and Kashmar varieties were used for sampling. The samples were separate bolls from the plant and transferred to the laboratory. The bolls were selected randomly from all parts of the plant. In order for samples to be uniform, the selected bolls were the same in terms of handling and without loss of cottonseed. Sampling was conducted at three times so that the plant could undertake different conditions of growth and moisture content. In November 2017, samples were taken from a land plot at the Hashemabad Cotton Research Center-Gorgan, in three harvest time with a time interval of two weeks.

After transferring to the laboratory, three samples were selected from each varieties and the cottonseed was completely removed from the carpel. Cottonseed and empty bolls were weighed with a precision of 0.01 (Shinko Electrinic scale, Japan. Model: DJ 2000 A. Max/D: 2100 g d.) and placed in an oven at 103°C for 18 hours in separate plates. The moisture content of different parts was calculated to determine moisture content based on its weight using standard method (Mohsenin, 1986). This was exclusively done for each sampling time, after harvest of the land. Moisture contents are available in Table 1. Moisture content does not adhere to the same process during the third harvest time, due to the rainy conditions of the environment.

Table 1 Percentage of moisture content (w.b. %) based on the moisture content of cottonseed and bolls in all harvest times and varieties

	Percentage of moisture content (w.b. %)					
Variety	First Harvest Time	Second Harvest Time	Third Harvest Time			
	Seed Cotton	Empty Boll	Seed Cotton	Empty Boll	Seed Cotton	Empty Boll
Golestan	9.26 ±0.363	13.98 ±3.28	9.58±0.363	14.87±3.28	8.7±0.363	21.36±3.28
Khorshid	8.95 ±0.227	12.83 ±2.36	8.6±0.227	11.98±2.36	9.15±0.227	17.37±2.36
Sajedi	9.48 ±1.23	13.82 ±5.003	7.29±1.23	12.58±5.003	10.2±1.23	23.76±5.003
Kashmar	8.91 ±1.127	13.57 ±4.58	7.64±1.127	16.34±4.58	10.4±1.127	24.97±4.58

Fabricate the device to measure the cottonseed picking force, a device similar to a cotton picker was designed and

manufactured using the actual needle of John Deere machine 9920. As shown in Figure 1, the needle (1) receives the power required to move by the belt (2) of the engine (Model: Sewing Machine Motor. 1500 W. Max: 7500 rpm.) (3) and, on the other hand, the force meter (Model: FG-6005SD. Max force: 50 N. measure time: 10 ms) (4) on a separate base (5) having the boll connected to its rod (6), is responsible for keeping the boll and recording the force as well. In the spindle cotton picker machines, the needles perform the harvest by moving around their axis; however, this is not possible in this device, due to the connections of the engine attached to the needle, and, instead, we used a different engine (Model: Gear box motor LANDA. 12v. Max: 70 rpm) (7) and belt (8), to move the base like spindle cotton picker machines. By turning the force meter, the boll is actually moving. The cottonseed is picked by moving the needle and the boll together.

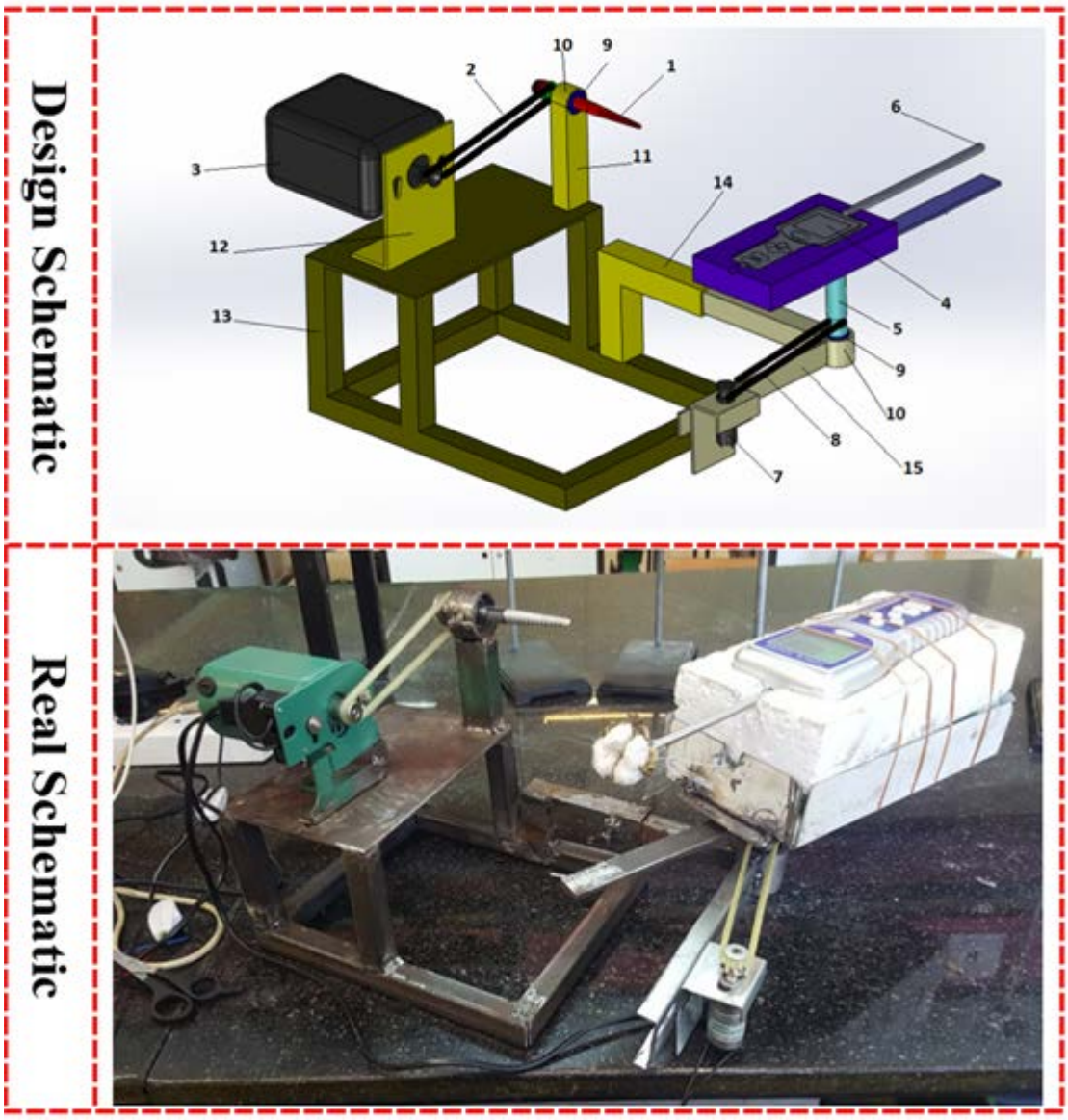

Figure 1 The Schematic of the device used

Note: 1. Needle (the original sample of the needle of cotton picker machine) 2. Belt (power transfer from the engine to the needle) 3. Engine (needle driver) 4. Force meter 5. The base of the force meter 6. Boll connector (the boll's maintenance rod transferring force to force meter) 7. Engine (The base of force meter driver) 8. Belt (Power transfer from the engine to the base of force meter) 9. Ball bearings 10. Bearings 11. Needle base 12. Engine base 13. Chassis 14. Horizontal and vertical adjusters of force meter. 15. Engine and force meter holder.

2.1 The method of measuring cottonseed picking force from the boll

The designed machine was used to measure this force (Figure 1). The needle was connected to a dimmer by the engine so that the user could reach the desired revolutions requirement (1500, 2500, and 3500 rpm). A tachometer was used to ensure the revolutions of the needle, with the needle pointing at the desired revolutions (100 revolutions or less); the second engine that turned the boll being moved by the key (at 60 rpm Like the cotton picking machine), and passed the boll through the needle. The picking force is transmitted to the force meter at the moment of being pulled out with a tensile force attached to the rod connected to the force meter. After picking, the weights of picked cottonseed were calculated, and the picking force was divided into weight to minimize the difference in access to different parts of the carpels in the vicinity of the needle in the samples.

The moisture levels (harvesting time) considered in this study were at three levels: First harvest time, second harvest time and third harvest time. The speeds were set at three levels of 1500, 2500 and 3500 rpm on the machine. These factors were applied to bolls of four cotton varieties (Golestan, Khorshid, Sajedi, and Kashmar). The bolls' base' rotational speed was considered constant in all samples. The experiments were carried out in a completely randomized design with a factorial experiment in 3 replications. The results were analyzed using SAS software.

3 Results and discussion

The results of the analysis of harvest time variance, the varieties, and the needle speed, as well as the interaction between them on the cottonseed picking force from the boll, can be seen in Table 2.

Harvest time factors in variety and harvest time in speed were significant at a probability level of 0.01; the variety factor in speed was also significant at a probability level of 0.05. However, factors of harvest time, variety and speed were not significant. Significant cross-factors (harvest time in variety, harvest time in speed and variety in speed) were investigated in LSD test.

Table 2 The results of the analysis of variance of data for the picking force necessary to extract cottonseed from cotton bolls

Sources of Changes	DF	Mean square	Sum of Squares	*F* Value
Harvest time	2	0.211	0.423	1.93^{Ns}
Variety	3	0.193	0.58	1.76^{Ns}
Speed	2	0.229	0.458	2.09^{Ns}
Variety × Speed	6	0.31	1.859	2.82^{*}
Harvest time × Variety	6	0.567	3.403	5.17^{**}
Harvest time × Speed	4	0.514	2.055	4.68^{**}
Error	84	0.11	9.214	

Note: **Significant at 1% probability level, *Significant at 5% probability level, Ns not significant.

3.1 The impact of the variety in the needle revolution on the cottonseed picking force from the boll

After attaining the significant result on the factor of the variety in the revolution, according to Table 2, we examined the LSD test on this factor (Figure 2). There were no significant differences between different revolutions in Golestan, Khorshid and Kashmar varieties. Therefore, the most suitable revolution is 3500 rpm, which shortens harvest time. Sajedi variety due to being more rareripe, than other varieties, grows completely at harvest time, and cotton fibers are pulled out of the carpels by continuous needle rotation one after another. As the revolution of the needle goes up, the conjugation in fibers disappears and the fibers are not completely removed from the carpel, as the amount of fiber harvested in each sample shows the increase in the revolution decreases the amount of fiber harvested and thus the force. Therefore, due to the less weight of the harvesting, the force decreases with an increase in the rotation, but the amount of remaining fibers on the carpel (product loss) increases. So the best revolution for this variety is 2500 rpm, which reduces the drop, while the difference is not significant at 3,500 rpm in force. There is no significant difference between different varieties in 1500 and 3500 rpm. But at 2500 rpm, Sajedi variety needs more force than other varieties. The lowest picking force belonged to Golestan variety at 2500 rpm (0.399 N) and the highest picking force was for Sajedi variety at 1500 rpm (0.819 N).

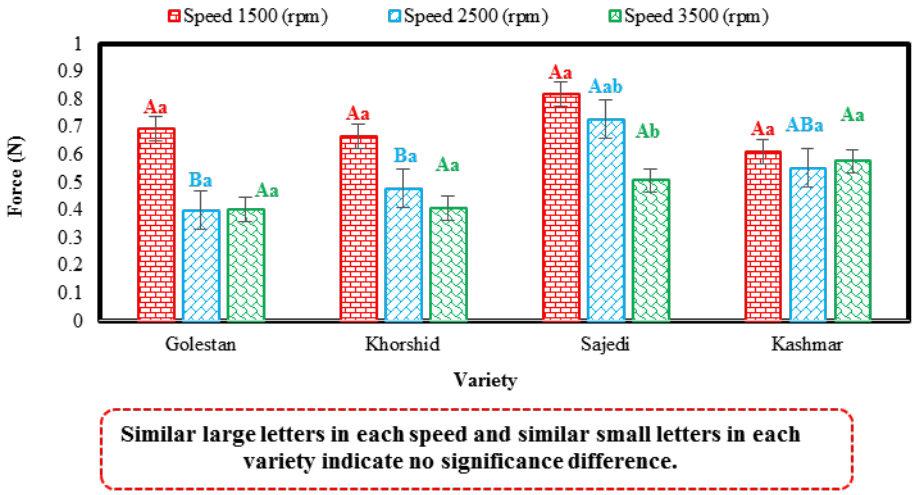

Figure 2 Interaction of the variety in the revolution on the picking force of cottonseed from the boll

3.2 The impact of harvest time in the variety on cottonseed picking force from the boll

The significance of the harvest time factor is observed in Table 2. Therefore, the comparison was made between the means; the results are shown in Figure 3. There is a significant difference in the different harvest times of the Khorshid variety due to the difference in the openness of the carpels and the rate of the bolls' maturity in different harvest times. As shown in Figure 4, the second harvest time's bolls are more open than the first harvest time's, and the angle between the carpels is wider; at this time, due to the more complete maturity of the fiber, the complexity of the fiber is greater, so the picking force is more than the first harvest time. Because of the poor quality of the fibers, and the uncompleted growth, the fibers in the third harvest time due to the air cooling, and does not create conflict between the fibers of the carpels in bolls, this reduces the force of the picking.

The Kashmar variety in the first harvest time has the maximum force while in the third harvest time it has the minimum force, that is because of the fact that at the end of the growth season, the bolls of the next harvest times less blossom with air cooling, and the openness of carpels in the first harvest time compared to the third, reduces the picking force as shown in Figure 5. The lowest harvest time force was 0.251 N (the first harvest time of the khorshid variety), and the highest picking force was 0.891 N (the first harvest time of the Golestan variety).

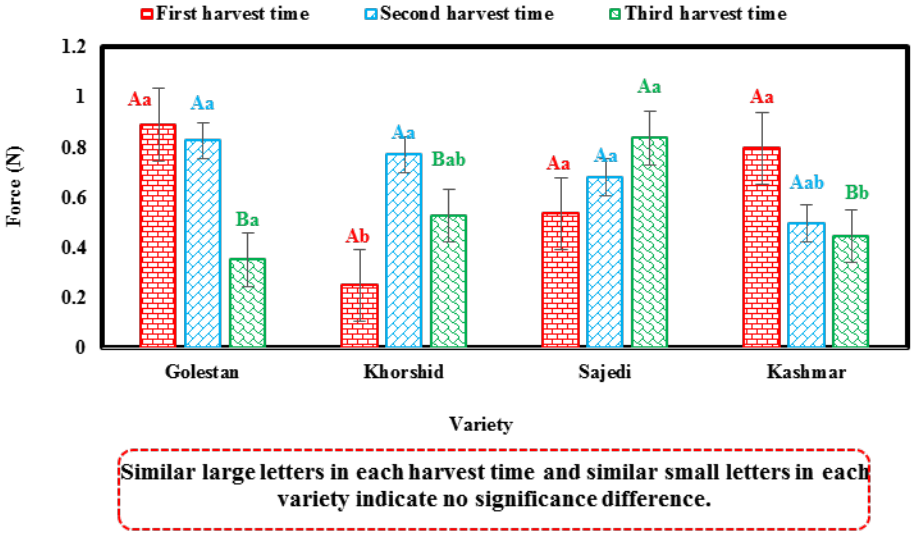

Figure 3 The interactional effect of the harvest time in the variety on the cottonseed picking force from the boll

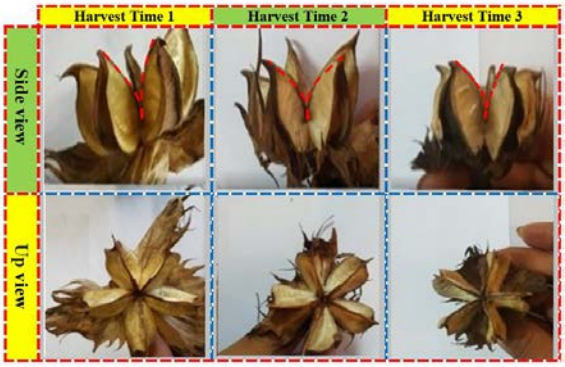

Figure 4 Comparison of the angles of the Khorshid boll in all three harvest times

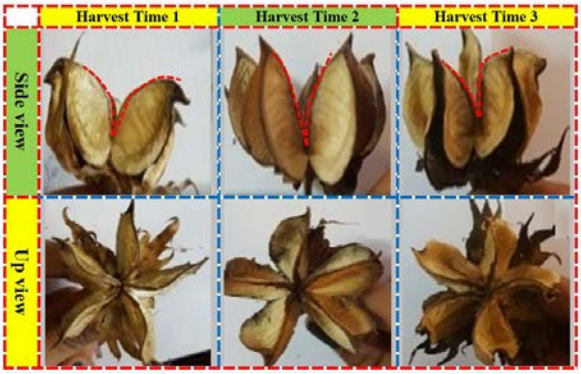

Figure 5 Comparison of the angles of the Kashmar boll in all three harvest times

3.3 The impact of harvest time in the needle revolution on the cottonseed picking force from boll

As shown in Table 2, this factor was announced as significant. The comparison of the means (Figure 6) results in the fact that the varieties examined in this study are of both rare ripe and delayed categories. There is not a visible significant difference in the first and third harvest time where the varieties are not in the same growth conditions. However, in the second harvest time, the varieties are almost at the same level of maturity, the difference in the diverse revolutions on the picking force can be verified. Because of the complexity of the fiber, the 1500 rpm, require the greatest force, because all the fibers inside the carpel are pulled out by this complexity; however, due to ripping the length of the fiber, the 3500 rpm resulting in a lower volume of the fiber needing less force. The lowest picking force is 0.462 (first harvest time, 2500 revolutions) and the highest is 0.964 (second harvest time, revolution 1500).

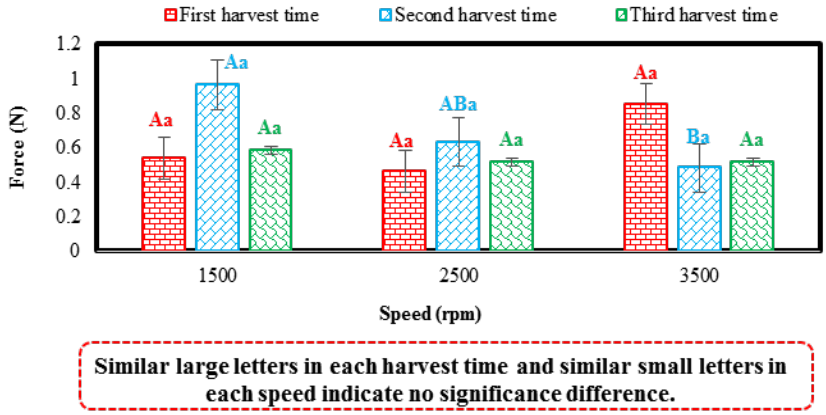

Figure 6 Interaction of the harvest time in the needle revolution on the picking force of cottonseed from the boll

4 Conclusion

According to the analysis, the best time to harvest (moisture level) and the adjustment for the revolution of the cotton picking machine to use the harvesting of these varieties are as follows:

- The best revolution for the Golestan variety is 2500 rpm, given the lower force, the best time to harvest the cottonseed is the second harvest time to greater volume and higher yield.
- The Khorshid variety is a delayed variety, according to the results, the minimum amount of force required for harvesting is attained by the revolution of 3500 rpm in the first harvest time. But due to the high loss remaining fiber in the boll at 3500 rpm, the appropriate revolution can be about 2500 rpm.
- In Sajedi variety, there was no significant in different harvest time, we can select a speed for all time. If the needle speed goes up, force comes down due to being more

fibers on carpel. So the speed of 2500 rpm is higher than the higher efficiency.

- Minimum picking force for the Kashmar variety in the third harvest time was calculated at a rate of 2500 rpm.

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