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Investigation of Boll Properties on Cotton Picker Machine Performance

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***Abstract*—**Cotton, as a strategic crop, plays an important role in providing human food and clothing need, because of its oil, protein, and fiber. Iran has been one of the largest cotton producers in the world in the past, but unfortunately, for economic reasons, its production is reduced now. One of the ways to reduce the cost of cotton production is to expand the mechanization of cotton harvesting. Iranian farmers do not accept the function of cotton harvesters. One reason for this lack of acceptance of cotton harvesting machines is the number of field losses on these machines. So, the majority of cotton fields are harvested by hand. Although the correct setting of the harvesting machine is very important in the cotton losses, the morphological properties of the cotton plant also affect the performance of cotton harvesters. In this study, the effect of some cotton morphological properties such as the height of the cotton plant, number, and length of sympodial and monopodial branches, boll dimensions, boll weight, number of carpels and bracts angle were evaluated on the performance of cotton picker. In this research, the efficiency of John Deere 9920 spindle Cotton picker is investigated on five different Iranian cotton cultivars. The results indicate that there was a significant difference between the five cultivars in terms of machine harvest efficiency. Golestan cultivar showed the best cotton harvester performance with an average of 87.6% of total harvestable seed cotton and Khorshid cultivar had the least cotton harvester performance. The principal component analysis showed that, at 50.76% probability, the cotton picker efficiency is affected by the bracts angle positively and by boll dimensions, the number of carpels and the height of cotton plants negatively. The seed cotton remains (in the plant and on the ground) after harvester in PCA scatter plot were in the same zone with boll dimensions and several carpels.

***Keywords*—**Cotton, bract, harvester, carpel.

I. Introduction

COTTON is the world's most economically valuable non-food crop. The global industry also employs more people than any other agricultural product. Cotton, as a strategic crop, plays an important role in providing the human food and clothing needs due to oil, protein and fiber. Cotton or Gossypium is a perennial herb of the Malvaceae family [1].

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 values of $3.5 billion, $2.6 billion and $1.5 billion, 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 [2].

Due to the differences in climate conditions and temperature fluctuations throughout the country, Iran is capable of producing a diverse range of vegetation such as wheat, rice, maize, dates, figs, melons and cotton. Iran has been one of the largest cotton producers in the world in the past, but for economic reasons, unfortunately its production was reduced now. Iran has the capacity to increase cotton production, but the low price of cotton compared with other agricultural products discourages farmers from embarking upon cotton cultivation. For example, Golestan province was in the past known as "the land of white gold" because of its vast cotton farms. The cotton industry was the driving force behind Golestan's economy, creating jobs and generating revenues either directly or indirectly through cotton farming and related industries. But the area under cotton plant was 5213 ha in 2018 [3].

One of the ways to reduce the cost of cotton production is to expand the mechanization of cotton harvesting. Most cotton crops in Iran are harvested by hand. 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 [4], [5].

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 globally [6].

Cotton harvester machines are classified into two broad groups or machine types: pickers and strippers. The first patent for a mechanical cotton picker was granted to S.S. Rembert and J. Prescott of Memphis, Tennessee, on Sept. 10, 1850 [7].

In 1895, August Campbell obtained a patent on a spindle that provided the basic principle for the barbed-spindle widely used on modern-day cotton pickers [7]. Variations of these spindles were used widely on picker harvesters to selectively remove the seed cotton from open bolls, while burs, unopened bolls, leaves, and other plant components that remain attached to the plant.

Brown and Ware [8] reported that, in 1914, an unidentified farmer used a sled-type stripper (made by attaching a section of a picket fence to a sled) in the first attempt to strip cotton

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on the Texas High Plains. Subsequently, farmers and local shops developed horse-drawn cotton sleds. Concurrently, gin manufacturers developed extracting and cleaning equipment that enabled sledded cotton to be ginned and cleaned [9], [10].

The cotton harvester machines are not widely accepted by farmers in Iran; thus, the majority of cotton is harvested by hand. The loss in harvesting by machine is one of the main reasons for not using the cotton harvester. Although the correct setting of the harvesting machine is very important in preventing cotton losses, the morphological properties of the cotton plant can affect the performance of cotton harvesters.

A study in Turkey was carried out to determine the effect of two varieties and two rows spacing on the quantitative and qualitative performances of a mechanical cotton picker widely used there [11]. No significant relationship between treatments and the other qualitative parameters was found except for micronaire. Depending on the trash content, there was a decrease in the reflectance (Rd) values of the machine picked samples in comparison to the hand-picked samples, and an increase in yellowness (+b) values.

The fundamental indication of the measured values was that the success of the defoliation process significantly influenced the lint quality values [12].

The effect of the rotational speed of the cottonseed-cut needles in cotton harvesting combines at three levels of 1500 rpm, 2000 rpm and 2400 rpm, on the trash rate (unharvested cottonseed) impurities and wastes in harvested cotton, as well as the quality of the fibers was studied by [13]. Their results showed that the cotton on the stems in the field at a speed of 1500 rpm was significantly more than two speeds of 2000 rpm 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 [14].

Researchers carried out a study at four locations with three different cotton varieties to determine the qualitative and quantitative performance of two narrow row (0.76 m) tractors mounted with a vertical spindle prototype cotton picker manufactured in Turkey. Results revealed that plant and field conditions and defoliation were effective on the quantitative performances results. In general, the prototype picker showed a successful performance and could pick with average 3% ground loss if suitable conditions are provided. No significant effect was observed between the treatments (hand and mechanical picking) and fiber quality values. The prototype picker used in the study was found suitable for small-scale farms [11].

Two types of spindles were used in [13]; one of them was a 12.5 mm round tapered, barbed spindle, and the other was an 8.4 mm square straight and smooth spindle. They tested the amount of cotton fly-off and the fiber separation force of the spindles; it was found that the amount of wastes at 1500 rpm was higher than 2000 rpm. In addition, the minimum amount of waste was observed at 2000 rpm compared to 3000 rpm and 4000 rpm [13].

In [15], a hand-like mechanism was designed to pick seed cotton 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 6 N. The direction of the force, when the fingers were closed, was vertical and this force at the start was more than the end. It was concluded that the amount of force per finger for this model should be more than 6 N [15]. Also, [7] measured the separation force of seed cotton from the carpels of boll using an air vacuum machine. The moisture content of seed cotton was 7.8% and the separation force was about 0.248 N. The force of separating seed cotton from the carpel was increased by increasing the moisture content and air velocity; in addition, there was strong relationship between vacuum pressure and picking force, seed cotton's moisture content and the number of seeds [16].

Reference [17] focused on cotton harvester performance showing that harvesting machine setup and adjustment in terms of compressor plate, spindle tip clearance and the addition of scrapping plates had a substantial effect on fiber quality and turn out, ground speed and drum arrangement while having little or no effect on fiber quality and gin turnout [17].

Reference [18] found that spindle machines require precise adjustments in order to minimize losses and improve the quality of the fiber.

The performance of cotton harvesters is affected not only by the correct settings, but also by the morphological properties of cotton plant. In other words, in this case, cotton losses in field after harvesting are the result of a combination of mechanical harvesting and the cotton plant properties.

In this study, some cotton morphologic properties such as boll dimensions, number of carpels, and bracts angle were evaluated on the performance of cotton picker machine. Also, the effect of these properties on the performance of the cotton picker is determined by statistical methods.

II. Materials and Methods

A field experiment was conducted to study the effect of some cotton morphologic properties on the performance of a cotton picker machine.

This study was carried out at the Hashemabad Cotton Research Station in Gorgan. This station is located in north of Iran at 36° 51' N latitude and 54° 16' E longitude at the south-east corner of the Caspian Sea and its height from sea level is 13.3 meters. This station has a Mediterranean climate with relatively mild winters and dry summers.

Five Iranian cotton verities Golestan, Armaghan, Kashmar, Sajedi and Khorshid were planted over an area of 2000 m^2 in May 22 and harvested in Oct 5, 2017.

Defoliation is a preparation for harvesting cotton that is accomplished by applying chemicals which induce plants to form abscission layers causing the petiole to detach from the stem [19]. The defoliation chemicals do not kill the plants, and re-growth of the plants commonly occurs until cold weather stops plant growth [20]. Twenty days before harvesting, defoliator was sprayed in the field and the percentage of leaves dropped was calculated for each cotton varieties.

Before harvesting, the height of each of the cotton plant varieties, number and length of sympodial and monopodial branches were measured in 15 replicates.

Boll weight was calculated based on the average of 30 boll weights for each cotton cultivar.

For studying the effects of boll dimensions, maximum diameter and boll height, 10 bolls of each variety were measured when the bolls crack and start to opening.

After harvesting, numbers of carpel in boll and bracts angle were measured 45 times in each variety. For measuring the bracts angle, a picture was taken from the boll without seed cotton and by help of analyses image the angles between wall carpel were measured (Fig. 1).

Fig. 1 Bracts angle measurement method

The experimental field was harvested by cotton picker John Deere 9920 model, at 4.24 km/h forward speed.

For calculating the performance of the cotton picker in the field before harvesting, based on the number of open bolls and boll weight, the amount of seed cotton was estimated in five meters for each variety.

For evaluating the performance of the cotton picker in the experimental field, after harvesting by JD9920, the percentages of seed cotton remaining inside of open bolls, on the cotton plants and on the ground were calculated based on the amount of seed cotton in five meters. The data were analyzed using SAS and XLSTAT software.

III. Results and Discussion

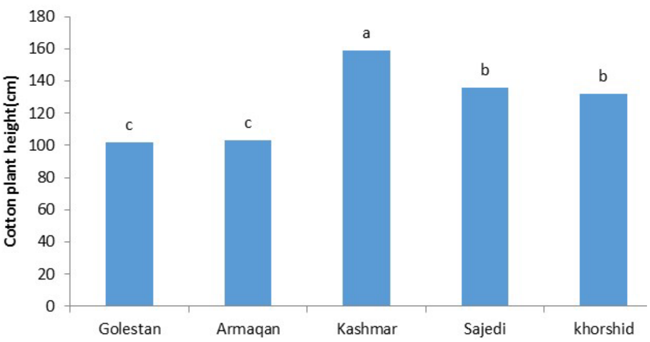

Fig. 2 Comparison of plant height in different cultivars

Analysis of variances indicated that plant heights in cotton cultivars were significantly different (Fig. 2). According to Fig. 2, Kashmar cultivar had the highest plant height and Golestan and Armaghane had the lowest plant height.

Table I shows that Kashmar has the shortest sympodial length. It also indicates that Khorshid has the highest boll size while the smallest boll diameter belongs to the Golestan cultivar.

TABLE I
Comparison of Some Morphological Properties in Different Cotton Varieties (cm)

Cotton varieties	Sympodial length	Monopodial length	Boll diameter	Boll height
Golestan	17.43 A	62.03 A	3.12 C	3.65 B
Armaghan	17.83 A	66.63 A	3.13 C	3.62 B
Kashmar	10.72 C	76.15 A	3.30 B	3.71 B
Sajedi	16.47 AB	61.97 A	2.83 D	3.67 B
Khorshid	14.33 B	79.00 A	3.72 A	4.22 A

Similar letters indicate no significant difference in each column.

As Table I shows, although Khorshid has the highest boll size (diameter and height), it has the lowest boll weight and seed cotton weight (Table II).

All properties indicated in Tables I-III have significant differences in cotton varieties, except of monopodial length.

TABLE II
Comparison of Boll Properties and Seed Cotton Weight in Different Varieties

Cotton varieties	Number of carpel	Bracts angle (º)	Boll weight (g)	Cotton weight (g/m^2)
Golestan	4.17 D	120.2 A	5.49 A	281.98 A
Armaghan	4.29 CD	104. 8 D	5.11 AB	227.99 B
Kashmar	4.44 AB	110.3 C	5.55 A	225.62 B
Sajedi	4.39 BC	116.8 B	4.95 B	259.77 A
Khorshid	4.55 A	112.2 C	4.76 B	219.56 B

Similar letters indicate no significant difference in each column.

After machine harvesting, the percentages of seed cotton remaining inside of open bolls, on the cotton plants and on the ground showed that, Khorshid and Golestan had the most and the least seed cotton on the ground, respectively. Also, Khorshid had the maximum seed cotton on plants after harvesting. Thus, it can be concluded that Khorshid showed the weakest performance of the cotton picker (Fig. 3) among other cotton cultivars.

TABLE III
Seed Cotton Remained after Harvesting inside of Open Bolls, on Cotton Plants and on the Ground (g/m^2)

Cotton varieties	In open boll	On plant	On the ground
Golestan	1.48 B	0.14 B	0.72 B
Armaghan	2.12 A	0.16B	0.84 B
Kashmar	1.73 AB	0.16 B	0.83 B
Sajedi	1.70 B	0.16 B	0.78 B
Khorshid	1.53 B	0.23 A	1.83 A

Similar letters indicate no significant difference in each column.

As Fig. 3 indicates, the best cotton picker performance belongs to Golestan with minimal residue in open bolls and on the plant after harvesting (Table III). There are no significant differences in cotton picker performance among of Armaghan, Kashmar and Sajedi (Fig. 3).

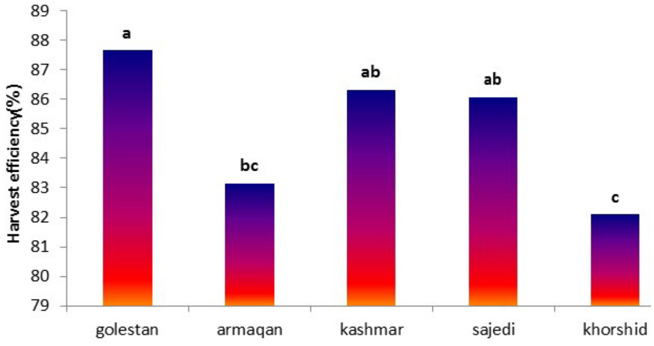

Fig. 3 Cotton picker performance in different cotton cultivars (Similar letters indicate no significant difference in each column)

Principal Component Analysis (PCA) was used to analyze the studied traits on harvesting machine performance. Fig. 4 is PCA scatter plot for 13 cotton and harvester performance properties.

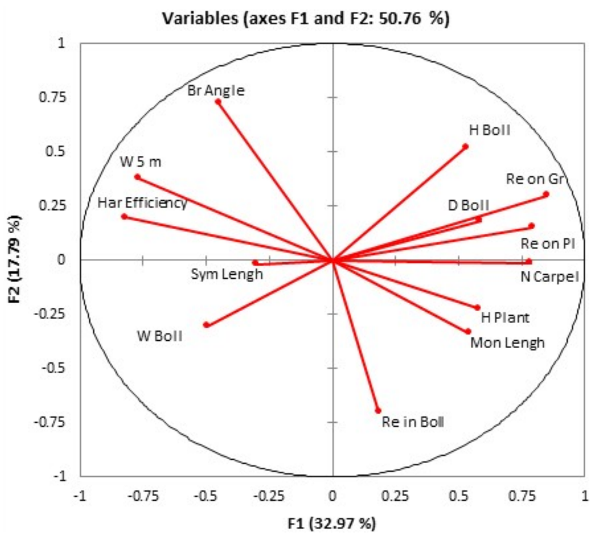

Fig. 4 Scatter plot of cotton properties in PCA

The PCA analyses showed that at 50.76% probability, the harvest picker efficiency (Har Efficiency) is affected by the bracts angle, seed cotton weight (W 5 m) positively, and by boll dimeter (D Boll) and boll height (H Boll), the number of carpel (N Carpel) and the height of cotton plant (H plant) negatively.

The seed cotton remains after harvesting in the plant (Re on Pl) and on the ground (Re on Gr) in PCA scatter plot were in the same zone with boll dimensions and number of carpels. In the other words, the seed cotton remains in the plant and on the ground affected strongly by boll diameter and after that affected by boll height and number of carpel positively, e.g. Khorshid had the biggest boll diameter and the maximum seed cotton on the ground while Golestan with the smallest boll diameter had the minimum seed cotton on the ground (see Tables I and III). As Fig. 4 indicates, the seed cotton remained in open boll (Re in Boll) has not been affected by these properties.

The harvest picker efficiency was affected negatively and strongly by the factors of height of cotton plant and monopodial length (Fig. 4). Thus, the results of the study conclude that cotton varieties such as Khorshid are not suitable for cotton picker harvest due to the greater plant height and monopodial length. While, varieties like Golestan with larger bract angle, smaller height and diameter boll were harvested better by picker compared to the other cotton varieties.

IV. Conclusion

Based on research conducted on five different cotton cultivars, it can be concluded that the performance of the cotton picker machine is not only related to machine settings but also to the morphological characteristics of the cotton varieties.

Some cotton properties such as bract angle, boll diameter, boll height and number of carpels, affected the performance of the spindle type cotton picker and consequently, resulted in increases or decreases in harvest efficiency. Therefore, it is recommended to breeders pay more attention to these morphological properties when selecting suitable cotton cultivars.

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