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The effect of four types of tillage operations on soil moisture and morphology and performance of three varieties of cotton

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ABSTRACT

Golestan Province is located in Northern Iran and is one of the cotton-rich provinces of the country. This region used to have the highest cotton cultivation, but recently the cultivated area has significantly decreased to the point of oblivion due to such factors as long growth period, high cost, and being uneconomical. Another strategic product of Golestan Province is wheat, which due to its fibrous root can be alternately cultivated with cotton. Cultivating two strategic products in the same year and in the same field is important both for the agriculturist and for the province in terms of food supply, employment, and textile raw materials. No-till farming—i.e. sowing in undisturbed soil and in wheat straw residue—allows the agriculturist to cultivate cotton shortly after harvesting wheat. Another benefit of no-till farming is the reduced growth period. This method is the best solution for increasing the cultivated area and income of farmers. The present research examines the effect of four types of tillage operations on the performance of three varieties of cotton in a split-plot design in randomized complete block design in the Cotton Research Institute of Hashemabad Agricultural Station. The results of three years of experiment suggest the significance of performance and performance components, where low-till cultivation leads to 695.8, 227.8, and 129.5 kg/ha increase in yield compared to disk, chisel/disk, and moldboard/disk treatments. Also the number of bolls has increased at the 99% confidence interval, while increase in boll size has not been significant. Further, morphological measurements showed that plant height significantly changed, while the number of monopodial and sympodial branches did not change significantly. Finally, the results show that no-till system increases soil's water storage capacity.

Keywords: Cotton, No-till farming, Morphology, Performance, Soil moisture

INTRODUCTION

Cotton production and related industries are among the most important sources of employment and income for different countries around the world. This product is an essential raw material in textile and oil press industries in many countries. Cotton-cultivated area in Iran was previously 224 hectares, and in that time cotton was mainly cultivated in Golestan, Mazandaran, Khorasan, Fars, Markazi, and Mugan Plain, and Golestan Province had the highest cotton cultivation with 65 ha [9, 15]. In 2010, the total cotton-cultivated area was 91019 ha in Iran and 8243 ha in Golestan Province. Cotton is a flowering dicotyledonous plant of the family Malvaceae, genera Hibiscus, and genus Gossypium. Genus Gossypium was named by Linneaus in 1753, and by 1947 only 20 species of this genus were identified. Cotton grows annually in cold and temperate regions and perennially in warm regions [12]. Cotton requires a growing season of more than 150 days [13]. It not only provides fiber for the textile industry, but is also an oilseed whose cake can be fed to cattle [8]. There are few revolutions in agriculture that occur in any one lifetime. For thousands of years tillage and agriculture were synonymous, and it was difficult to think of growing plants without tillage or without controlling weeds. However, with the advent of modern herbicides, cultivation without tillage became a reality. No-till farming consists of planting crops in unprepared soil with at least 30% mulch cover [24]. To prevent soil erosion and runoff, at least 30% of soil surface must be covered with residue after planting the next crop (USDA-NRCS). Repeated intensive tillage on soils in the tropics and subtropics leads to soil loss, reduction in soil nutrients and organic matter (including soil organisms), release of soil carbon to atmosphere, undesirable changes in soil structure, and reduced water infiltration and moisture-holding capacity. Conservation tillage has greater impacts on erosion rates than on runoff and infiltration [11]. Long-term agricultural sustainability, maintaining soil health, and agricultural productivity entail preventing nutrient depletion due to constant plowing [14]. In order to maintain and improve soil fertility and achieve a sustainable agriculture in the tropics and subtropics, it is necessary to stop mechanical soil preparation and keep a permanent cover of the soil. At the same time adequate quantities of plant residues should be added to the system (more than 6 t/ha/year of dry matter in semi-arid climates and more than 10 t/ha/year of dry matter in humid climate) [7]. Field studies carried out in India from 2002–2003 through 2004–2005 have shown that seed cotton yield significantly increase in the reduced tillage (RT) system as compared to the conventional tillage (CT) system. The tillage-species interaction has also been significant. Averaged over years, Asiatic G. Arboreum produced 8% less seed cotton with treatment RT2 than with CT. Upland, G. hirsutum produced 118–134 kg/ha additional seed cotton on the RT than with CT [4]. Smith (1995) found that subsoiling provided significant improvement over disk-harrow tillage, where average yield increases were 14.7 and 8.2% in the non-irrigated and irrigated environments respectively. However, another study showed that crop yield was not affected by tillage systems [1]. Bauer and Frederick (2005) studied how the soil type that the crop is grown on and the tillage practices used to produce the crop affect fiber properties at specific locations within the crop canopy. They found that fibers at specific positions within the canopy differ in length and in micronaire between conventional and conservation tillage when rainfall was limiting during boll development. They also found that the range of micronaire values within the canopy was greater on the soil that was more susceptible to drought. Nyakatawa (2001) showed that no-till and mulch-till systems with cover cropping and poultry litter can reduce soil erosion and as well increase cotton growth and lint yields, thus improving sustainability of cotton soils in the southeastern USA. A study showed that, among tillage practices, deep plowing significantly increased pooled seed cotton yield (15.22 q/ha), boll weight, number of bolls/plant, and plant height as compared to reduced preparatory tillage (11.34 q/ha) [16]. Ishaq (2001), Pettigrew and Pettigrew (2001), and (2002) also reported poorer performance in no-till as compared to conventional tillage. Daniel (1999) found that cotton yield and quality were not affected by tillage systems. One of the effects of plant residue management and conservation tillage on the soil is increased water storage capacity of the soil. Depending on the weather conditions and soil type, no-till farming can increase soil water, which is due to increased soil permeability and reduced evaporation with sufficient crop residue [20]. Others have also reported the positive effect of conservation tillage with crop residue in preventing soil erosion and increasing soil permeability [3, 5, 6]. In sum, conservation tillage and crop residue can be effective for increasing cotton yield and reducing production costs. Many studies have shown that no-till management can reduce costs and improve performance compared to conventional tillage [23, 18].

MATERIALS AND METHODS

To examine the effects of tillage systems on performance, morphology, and soil moisture of three varieties of cotton in Gorgan, a three-year experiment (2009-2011) was conducted in Hashemabad Station which is affiliated with Cotton Research Institute of Iran (CRII). The studied field had been under wheat cultivation in the previous year, and seedbed preparation was done at four levels including conventional tillage, chisel, disk, and no-tillage after wheat harvest. During seedbed preparation, 100 kg/ha phosphate and 100 kg/ha nitrogen were applied to the soil. The experiment was done in a split plot arrangement in randomized complete block design and in four replications. The distance between the rows was 80 cm, and the distance between plots and between blocks was considered to be 3 and 5 m respectively. Seeds were disinfected before being planted and were sowed with a seed planter able to plant in untilled soil. Weeding was done in the three-leaf stage and at 20 days age. After the second weeding, thinning was performed in two dates before the five-leaf stage so that the distance between shrubs would reach 20 cm. special pesticides and herbicides were used when necessary.

To determine soil moisture, samples were taken from the soil 48 hours after irrigation from 30 and 60 cm depths. After weighting the sampled soils on a digital scale with an accuracy of 0.01 g, the samples were placed in an oven at 100° C for 24 hours. Soil moisture was obtained after weighting the dry samples. With the opening of bolls, five shrubs were harvested from each plot and their morphology and performance (e.g. number of bolls and boll weights) were evaluated. Finally, boll performance was compared by harvesting two rows from each plot. The data was analyzed suing SAS software and mean attributes were compared at 1% and 5% levels using Duncan's multiple range test. Moreover, Excel was used for drawing diagrams.

RESULTS

Morphology, performance, and performance components

Statistical analyses indicate the significance of performance between tillage treatments and varieties at the 1% level (Table 1). Considering the table, there is a significant difference in terms of number of bolls, but no significant difference can be observed for the weight of 10 bolls. Boll weight is one of the fixed attributes of the studied varieties. Morphological measurements show that shrub height decreases with reduced tillage, while the number of bolls and overall crop performance increases. The number of monopodial and sympodial branches was not affected by tillage systems.

Table 1. Mean squares of shrub height, number of monopodial and sympodial branches, number of bolls per plant, boll weight, and overall performance of the treatments in the period 2009-2011

Treatment	df	Shrub Height	Number of Monopodial Branches	Number of Sympodial Branches	Number of Bolls per Plant	Weight of 10 Bolls in a Plant	Performance (kg/ha)
Year	2	320.10^{NS}	45.84**	480.57**	2462.51**	7125.87**	110887174.3**
Replication	8	1384.43**	1.20**	16.63^{NS}	25.09^{NS}	37.73^{NS}	908359.2**
Tillage	3	21.54^{NS}	1.06^{NS}	6.41^{NS}	64.03*	101.83^{NS}	3004725.4*
Tillage × Year	6	376.08*	0.37^{NS}	8.92^{NS}	177.29^{NS}	12.33^{N}	1358545.6**
Variety	2	1752.64**	1.21^{NS}	2.07^{NS}	571.19^{NS}	46.87^{NS}	1237237.3*
Year × Variety	4	150.36^{NS}	1.91^{NS}	9.46^{NS}	251.65**	727.62**	1297033.1*
Variety × Tillage	6	155.57^{NS}	0.78*	10.44^{NS}	18.98^{NS}	15.69^{NS}	370151.5^{NS}
Year × Tillage × Variety	12	124.73^{NS}	1.21^{NS}	3.87^{NS}	44.53^{NS}	58.06^{NS}	575078.7*

Notes: *,** significant at 1% and 5% levels; ^{NS} not significant

The effect of year on all treatments has been significant at 95% CI. Performance and performance components have been better in 2010 than the other two years. Based on meteorological investigations, precipitation and temperature in 2010 were less than 2009 and more than 2011. Cotton is a sun plant and has better performance in sunny weather. Mean precipitation and temperature in the years 2009-2011 are provided in Table 3. As can be seen in Table 2, difference in shrub height between conventional tillage and no-tillage systems is 1.95 cm, and this difference is 22.18 cm between varieties. Mean performance and performance components have been more in no-tillage than in conventional tillage, where differences in performance, number of bolls, and weight of 10 bolls are 695,4.91, and 3.33 respectively.

Table 2 . Comparing mean shrub height, monopodial and sympodial branches, number of bolls, boll weight, and performance of all tillage treatments across the period 2009-2011

Treatment	Shrub Height	Number of Monopodial Branches	Number of Sympodial Branches	Boll Weight	Number of Bolls	Performance (kg/ha)
No-Tillage	105.79a	2.58a	11.49a	37.7a	22.33a	2172.8a
Disk	106.63a	2.52a	10.58a	34.69ab	21.18a	2043.3a
Chisel/Disk	106.82a	2.33a	10.79a	34.53ab	21.18a	1944.9a
Moldboard/Disk	107.76a	2.18a	10.42a	32.79b	19.00b	1477.0b
Varieties						
Shirpan	111.89a	2.56	11.11a	35.7a	24.57a	2027.6a
Armaghan	108.66a	2.39a	10.86a	34.95a	20.84b	1978.5a
B-557	89.71b	2.25a	10.68a	33.66a	17.36c	1715.7b

Different varieties have significantly different performance and height (Table 1), with Shirpan having the highest performance and height (Table 2), while B-557 has a lower performance. No significant difference is observed between varieties and tillage systems, that is, different tillage operations on different varieties have had similar effects. However, these effects have become significant at the 1% level by adding year to the interaction; i.e. weather conditions affect tillage system, and no-tillage farming is most desirable in warmer weather and with less precipitation.

Table 3. Mean precipitation, minimum temperature, and maximum temperature in the period 2009-2011

Year	Precipitation	Minimum Temperature	Maximum Temperature
2009	648.5	7.767	31.07
2010	360.3	8.283	31.86
2011	710	6.9	29.67

Source: Statistics from Hashemabad Synoptical Station, Gorgan

Soil moisture

Measurement of soil moisture in 0-30 cm and 30-60 cm depths show that relative moisture varies across treatments. This difference is greater in 0-30 cm than 30-60 cm. Analysis of variance of the data related to soil moisture indicates that there is no significant different between treatments in 0-30 cm and 30-60 cm depths. Figures 1 and 2 respectively display soil moisture at 0-30 cm in 2009 and 2010.

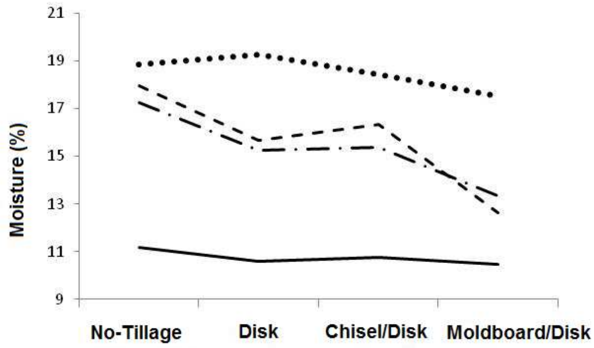

Figure 1. Percentage of soil moisture at 0-30 cm depth across tillage treatments (2009)

As shown in the above figure, at all measurement dates the highest moisture level is observed in the no-tillage treatment and the lowest moisture level is observed in the moldboard/disk treatment. A similar condition can be seen in Figure 2. At 0-30 cm depth, the highest moisture level belongs to the no-tillage treatment, while the lowest moisture level belongs to the moldboard/disk treatment. In other words, in both 2009 and 2010 soil treated with no-tillage has stored higher levels of moisture. The reason for such a difference in moisture can be attributed to the residual cover that prevents direct exposure to sunlight. Moreover, higher moisture levels in the no-tillage treatment may a one of the reasons for the better performance of this treatment.

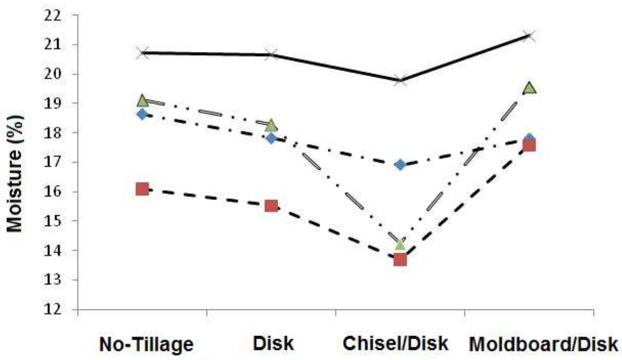

Figure 2 .Percentage of soil moisture at 0-30 cm depth across tillage treatments (2010)

CONCLUSION

The results of the experiments suggest significant differences between tillage treatments in performance and number of bolls. This significant difference must be considered in light of weather conditions which is a determinant for tillage systems. Warmer weather conditions with sufficient precipitation are more desirable for cotton cultivation and for the no-tillage system. More rainy days and less sunny hours reduce the effect of low-tillage system. Significant difference in the performance of tillage systems in the three-year period on the one hand and benefits such as reducing fuel consumption, saving time, maintaining soil nutrients, and reducing costs on the other make no-tillage systems a useful alternative for reviving cotton cultivation in Golestan Province. Increased water storage capacity of the soil is another advantage of using no-tillage farming. Considering the essential role of water for cultivation, especially cotton cultivation, increased water storage capacity due to crop residue cover can protect plants against evapotranspiration.

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