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Crop rotation with no-till methods in cotton production of Uzbekistan

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Abstract

Many soils of Uzbekistan have low water and nutrient holding capacity because of their sandy texture, low organic matter concentrations and degradation caused by long years of cotton monoculture. Conservation tillage production systems have the potential to increase the productivity of these soils by increasing soil humus and nitrogen content. As practiced conservation tillage helped to lessen N leaching losses, holding more of these elements within the topsoil as well as increase crop productivity. Conventional tillage cotton/wheat/maize crop rotation has resulted very low humus and nitrogen content in soil by degreasing crop yield. Therefore, the effects of tillage, and crop rotation were examined on growth and yield of crops in three cotton-based rotation systems, (i) cotton/wheat/maize, (ii) cotton/wheat/sorghum and (iii) cotton/wheat/soybean, in Tashkent region in middle east of Uzbekistan. This obtained result suggests that no tillage with inserting legumes in crop rotation is able to improve soil quality and plant productivity.

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Introduction

The problem of soil degradation is confounded by the drying off of the Aral Sea, and susceptibility to wind erosion of the vast territories of the former seabed. Annually 43 million tons of salts are blown out of the Aral Sea basin and spread on 1.5 - 2.0 million km^2 causing considerable damage to neighbouring agricultural regions. Humus content in soil decreased over the last decades by 30-40%. The humus content of plow layer had declined by 20 to 45% due to accelerated erosion. Soils with low or very low humus content have occupied about 40% of the total irrigated area of Uzbekistan (Qushimov et al., 2007).
Many years of monoculture with ploughing and disking have intensively degraded soil physical, chemical and biological properties. Surface crusting and subsurface (plough pan) compaction, low organic matter contents and low biological activity (absence of earthworms) are clear symptoms of this process (Egamberdiev, 2007). Nowadays in Uzbekistan exists cotton – wheat crop rotation which is not a good choice for agricultural management practices. It is vitally important to introduce some legume crops in this crop rotation system to prevent further degradation of soil. Studies revealed that there is a strong demand to use a conservative agriculture in Uzbekistan's harsh soil-climatic conditions.
Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits and high and sustained production levels while preserving the environment (Franzluebbers et al., 2006). CA is based on the enhancement of natural biological processes above and below ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum

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level and in a way and quantity that does not disrupt or interfere with biological processes (Aziz et al., 2011; McGrath and Zhang, 2003; Aziz et al., 2009).

The monitoring process provided information showing that CA practices implemented on the field of experimental station saved water (increased water availability and reduced number of irrigations); improved soil quality (soil humus, N, P and K content); reduced machinery use; and maintained or increased yields. In that study crop yields under conservation tillage were generally only equal, and often slightly inferior, compared to the conventional tillage treatments. This situation offered the opportunity to monitor soil impacts from six years of continuous conservation tillage. The results reported here are based on soil samples collected in the spring of 2005 before beginning to 2010 fall the end of this research in selected areas within that study. The objective of this research was to characterize and compare the soil physical and chemical properties of cotton based conventional and no till methods crop rotation systems that incorporated crop productivity in a long-term (6 year) experiment in typical serozem soil of Tashkent region.

Material and Methods

Data were collected during 2005-2010 of a tillage experiment on a typical serozem soil at Tashkent State Agrarian University's Experimental Station in Urtachirchik district, Tashkent region. Two tillage systems, conventional tillage and no-tillage, have been maintained since the beginning of the study. At the beginning and the end of the researches, soil samples from fields under no-till and conventional tillage cotton, wheat and soybean were collected for analysis. Soil and crop monitoring no-till and conventional tillage fields included soil bulk density and total porosity, compaction, humus content, visual soil assessment, germination and development of rotated crops.

Soil is typical serozem (1 % organic matter, 0.6 mg N 100 g^{-1} soil; 3.0 mg P 100 g^{-1}; 12 mg K 100 g^{-1}; 6 mg Mg 100 g^{-1} soil; pH 7.4) having a calcic horizon within 50 cm of the surface. The orchic horizon is low in organic matter. The climate is continental with mean annual rainfall is about 200 mm. The total nitrogen content, N, was determined by the Kjeldahl method. The molybdenum blue method was used to determine the total phosphorus content, P, in soil. Potassium, K, was determined using the Flame Photometric Method (Riehm, 1985). Soil pH-value was measured by means of an electrometer. Soil particle distribution was determined using natrium phosphate. Plant seeds were obtained from the Tashkent University of Agriculture.

Fertilization and irrigation was supplied on as equal amount on each of the plots. All cotton plots were fertilized at 200 kg N, 150 kg P and 100 kg ha^{-1}, followed crop winter wheat were fertilized total 150 kg N ha^{-1} in spring, and next crop (maize, sorghum or soybean) were fertilized 100 kg N ha^{-1}. Soil analysis was used to determine P and K needs. All N, P and K fertilizers were applied to the surface of plots one to two days before planting, and incorporated in CT plots only. Cotton yield was determined by hand harvesting and weighing all whole cotton bolls from each plot. Twenty to thirty bolls were randomly picked from each plot to determine shelled cotton weight. The kernel yield was determined in proportion to the whole boll yield of each plot and expressed at 15% moisture equivalent. Statistical analysis was carried out using the MIXED procedure of SAS (Littell et al., 1996; SAS Inst. 1990) including analysis as repeated measures for years. Unless otherwise indicated, all significant differences are given at $P \leq 0.05$. The experiment was laid out as a split plot design with three replications. Conventional-till (CT) and no-till (NT) were main plots. The CT consisted of a 30 cm deep chisel plowing followed by one to two diskings to a depth 15 cm and a subsequent disking to 1 cm to smooth the seed bed. The only soil disturbance in NT was a coulter disk for planting. NT treatments have continued on the same plots since the fall of 2005. Each plot was 10 m wide and 60 m long. The cropping system consisted of cotton (*Gossypium hirsutum* L.), winter wheat (*Triticum aestivum* L.) and soybean (*Glycine max* L.) from mid-summer to mid fall next year on one set of the plots. This was a two-year rotation and had a moderate level of crop residue returned. A cotton based crop rotation intensity system was cotton planted in Aprel and harvested in September - October followed by winter wheat planted in October and harvested for grain in June, next crop (maize, sorghum or soybean) planted after harvesting wheat in summer. Wheat straw was left in the field in no till experiment and a summer cover crop soybean planted in June and harvested in October. The wheat and soybeans were grown in 90 cm wide rows as cotton and planted with a new model of till equipment that incorporate the residues and till the soil in a very narrow strip (a few centimetre wide) for placement of seed and fertilizers.

Results

Introduction of winter wheat on large irrigated areas after harvesting cotton showed that the combination of the cotton–wheat soybean- rotation with no-tillage was superior to intensively tilled cotton monoculture in maintaining soil quality. Trials showed that sowing soybean into wheat stubble could also minimize erosion and reduce pesticide and nutrient runoff. These trials showed that no-tillage cotton-wheat-soybean rotations could increase soil humus content in irrigated lands more than intensively-tilled C/W/M or minimum-tilled continuous C/W/S rotation. Lowest crop yields and profitability occurred with intensively-tilled continuous cotton. Cover crops represent another important CA practice. Studies have shown that cover crops and plant residues positively influence soil quality: lower soil bulk density; increased soil moisture, biological activity and soil fertility. Deep-rooted cover crops can help reduce the impact of soil compaction.

Double cropping also plays an important role in conservation agriculture weed management as it covers the land surface with a crop canopy, rather than leaving it in weedy fallow. The greatest benefit from crop rotation comes when crops grown in sequence are from totally different families. Table 1 provides an example of the type of response to crop rotation that is possible.

Table 1. Cotton yield response to rotation

	Rotation	Tillage methods	Cotton yields, t/ha		
			(2005–06)	(2007–08)	(2009–10)
1	Cotton–wheat-maize	Conventional tillage	2.78	2.56	2.10
2	Cotton–wheat –sorghum	Conservative tillage	2.47	2.51	2.30
3	Cotton–wheat–soybean	Conservative tillage	3.35	2.65	3.15

The fibrous root systems of cereal and legume crops are excellent for building soil structure. Studies have shown that the benefits of including wheat, and especially wheat plus soybean, may persist beyond just the following year. Double cropped soybean after wheat resulted in yield increases of cotton 0.57; 0.09; 1.05 t/ha according to growing seasons. On the contrary sorghum grown after wheat resulted in decrease of cotton yield by -0.31; -0.05; 0.2 (Table 1). During the summer, after harvesting winter wheat, intermediate crops were planted under zero tillage with direct seeding. Yields obtained from the intermediate crops were at the same level as the conventional ones (Data was not shown). In some cases, CA intermediate crop yields were higher because it was planted earlier without wasting time in land preparation.

Cover crops can also perform a number of other functions, a very important one of which is salinity control in salinated fields of Uzbekistan (Qushimov et al., 2007). The soils should never be left bare and, ideally, there should always be a crop growing to avoid evaporation and replace it with transpiration. Soil covered with cover crops conserved soil moisture for a long time, and cotton growth was better than with conventional management (Islam, 2006). Many scientists documented that crop type and intensity also play an important role in increasing soil quality. The effects of cropping choices on soil physical properties are also often related to increases in soil organic matters (Ghidey and Alberts, 1999). Furthermore, the contribution to SOM concentration is determined by the incorporation of new organic matter in the coarse fraction and the reduction of mineralisation processes in the finest ones (Oue´draogo et al., 2005). Experiences from northern Kazakhstan (Suleimenov, 2008) and north-western Uzbekistan (Egamberdiev, 2007) have shown that adjusted resource-conserving technologies (RCT) can serve as an excellent strategy for improving land and water management, and increase crop productivity, while being economically profitable. RCTs include an array of practices, including no-till and minimum tillage approaches, crop residue retention and crop and rotation diversification.

Table 2. Soil bulk density by soil, crop rotation, and sample depth

	Crop rotation / Soil depth cm	Soil Bulk Density ($g.cm^{-3}$)				Humus content, %			
		before		after		before		after	
		0-30	30-50	0-30	30-50	0-30	30-50	0-30	30-50
1	Cotton–wheat-maize	1.444	1.580	1.467	1.665	0.991	0.872	0.981	0.861
2	Cotton–wheat-sorghum	1.439	1.581	1.469	1.669	0.995	0.869	0.964	0.822
3	Cotton–wheat–soybean	1.441	1.583	1.427	1.643	0.995	0.867	1.112	0.912

Table 3. Agrochemical characteristics of soil.

	Crop rotation / Soil depth cm	Total Soil N (%)				Total Soil P (%)			
		before		after		before		after	
		0-30	30-50	0-30	30-50	0-30	30-50	0-30	30-50
1	Cotton–wheat-maize	0.124	0.116	0.119	0.105	0.139	0.168	0.128	0.153
2	Cotton–wheat-sorghum	0.123	0.114	0.104	0.099	0.144	0.165	0.115	0.135
3	Cotton–wheat–soybean	0.126	0.113	0.138	0.127	0.142	0.161	0.159	0.195

The humus content increased significantly after soybean was inserted in crop rotation with CA management practices (Table 3). The soil humus content increased by 5.9 % in cotton/wheat/soybean rotation but decreased in cotton/wheat/maize rotation by 4.5 % compare cotton/ wheat rotation. On the contrary, the soil bulk density decreased significantly in cotton/wheat/soybean rotation compare others. Cotton/wheat/sorghum rotation had very poor humus content and soil bulk density parameters. It was observed that the soil bulk density and humus concentrations mostly depended on crop rotation and tillage system (Tables 2, 3). Also, there was significant difference in N, and P concentrations between tillage system and crop rotations. On average, the N and P concentrations in cotton/wheat/soybean rotation were 21-27.5 % higher than cotton/wheat/maize rotation, respectively. Soils under cotton/wheat/sorghum rotation had a slightly higher soil bulk density 0.2% and 4.5 % lower soil humus content compared with cotton/wheat/maize rotation.

The positive and significant relationship crop rotation with legume suggests that no till can be used as a sensitive and early indicator of changes in the availability of soil humus content especially the active organic pool (Landgraf and Klose, 2002; Islam and Weil, 2000; Islam, 2006). Since crop rotation and organic matter are typically related to each other (Tables 1 and 2), a significant decrease in organic matter probably intensifies the adverse effects of soil degradation (Alvaro-Fuentes et al., 2009).

Recent findings in northwestern Uzbekistan (Egamberdiev, 2007) showed particularly an increase in soil organic matter, improvements in soil structure and greater soil moisture holding capacities for fields with residues without losing yield of winter wheat, sunflower and maize. Furthermore, relay-planting or intercropping systems have shown great potential to significantly increase the system’s productivity for various crop combinations including cotton + mung beans and maize + legumes. Modern agriculture has prospered and become dependent on cheap fossil fuels. Fossil fuels are used to power mechanized traction for tillage, cultivation, spraying and harvest, but also for pumping irrigation water, powering dryers and transport of agricultural products and inputs. In precisely leveled fields, water flows quicker and uniformly across the no-tilled fields compared to the plowed fields resulting saving of water and energy required for pumping water. Fertilizer use efficiency also increases because the nitrogen and phosphorus inputs drilled with the no-till equipment rather than broadcast as in conventionally tilled wheat or cotton plots will not be lost to the atmosphere (Rochestera et al., 2001). No-tillage is an appropriate technology to achieve more efficient energy use in agriculture. In no-tillage, crops are planted in just one pass of the tractor powered seeder/planter.

Conservation agriculture (CA) practices are based on the necessity that soil is permanently covered and crops are sown through this cover with minimal soil disturbance. Specialized no till machinery has been developed and is today widely available. Tractor mounted equipment offers many different designs from cutting discs, rotary turbo-system fitted with chisel opener tines that penetrate the mulch and open the soil for seed and fertilizer to other innovative systems such as strip till equipments that incorporate the residues and till the soil in a very narrow strip (a few centimeter wide) for placement of seed and fertilizers.

Double cropping could increase grain and forage production and reduce the overall cost of production. By eliminating ploughing and preparation, the no tillage system reduced the period without a crop while retaining soil moisture and also reduced runoff, soil erosion and evaporation. These factors are essential given the intensive cultivation characteristics of a multi-cropping system.

Discussion

In conclusion, crop rotation with legumes especially cotton/wheat/soybean in our study in no till condition significantly improved soil chemical properties and organic matter content. A significantly higher concentration of N and P with an associated decrease in soil bulk density suggests that crop rotation in no tillage associated legumes were responsible for soil fertility and subsequently exerting adverse effects on soil restoration. It may be possible to increase soil N and P content by organic amendments to soil and thus this may be a useful management of irrigated land for cotton production.

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