# Conserving Soil Fertility and Sustaining Crop Performance Via Soil Tillage Systems and Crop Rotation

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## ABSTRACT

**Crop rotation / tillage impact on status of plant nutrients, crop production and soil properties was studied under North Sinai conditions, Egypt. The study assessed crop rotation (rice/clover (Berseem) / wheat/ soybean/ wheat (summers 2016 to 2018) under no tillage (NT) and conventional tillage (CT) systems and implications of crop and soil performance. CT revealed more positive implications over NT in few cases. Contents of available nutrients in soil after harvest were greater after legumes. Contents of Fe, Mn and Zn in soil after crop harvest showed increases with CT than NT Rotation cropping maintained similar levels after legume crop especially compared to cereals crop. Crop productivity was in some cases higher CT than NT although NT increased plant chlorophyll, protein and proline.**

**Keywords: Legumes, No-Tillage, Cereal crops, Soil nutrients, Crop rotation**

## INTRODUCTION

Crop rotation and tillage system are major agricultural practices in sustainable farming. A proper crop rotation provides increased yields, nutrient uptake and soil available nutrients simultaneously with decreased pest and weed infection, as well as avoiding soil erosion. In some soils , no tillage may be beneficial with regard to conservation of soil structure (Machado et al., 2015) . Balanced crop rotation can improve soil structure and augment nutrient availability in soils besides attaining increased crop production (Shaalan et al., 2014; Dogan et al., 2008; Baumhardt and Anderson, 2006; Montemurro and Maiorana, 2008). Havlin et al. (1990) mentioned that adequate crop rotation involving alfalfa enriched soil with organic matter at considerable rates of up to 5 Mg $ha^{-1}$. Combination of legumes and non-legumes and green manures can cause increased yields and improve soil fertility (Tosti et al., 2014 and Tribouillois et al., 2016). Riedill et al. (1998) applied a crop rotation involving cereals and legumes and noticed increased contents of total and available N. Legume residues can increase N , soil fertility (Sharma and Behera 2008) , improves soil pH (Hickman, 2002), and soil water / nutrient availability (Niu et al., 2017). Chan et al. (2008) reported that uptake of plant nutrients and soil structure depends on soil organic matter. Curtin et al. (2000) and Mc Conkey et al. (2012) reported that organic matter decomposition was promoted by conventional tillage more than no-tillage. Hickman (2002) reported that no tillage increased soil organic matter contents compared with conventional tillage, but conventional tillage increased available K. Maillard et al. (2018) noted that tillage increased mineralization of nutrients. Irfan et al. (2013) reported that physical, chemical and biological properties of soil were all improved with no tillage Eck and Jones (1992) and Mitchell et al. (2017) applied no tillage over 15 years and obtained increases in soil aggregation, water infiltration, organic matter and nitrogen. Baumhardt et al. (2017) studied the effect of long term conventional tillage versus no tillage during over a rotation of wheat-sorghum-fallow and grown on a clay loam soil and crop performance. They found that available soil water for 1.8 m profile averaged 194mm for no tillage compared with 166 mm for conventional tillage. Vetsch and Randall (2004) reported leaf chlorophyll was highly correlated to maize grain yield. De Vita et al. (2007) obtained grater wheat grain yield and protein content under conventional tillage than no tillage. Crop residues were reported to be grater under no tillage than conventional tillage (Blanco-Canqui and Lai, 2009). Gentile et al. (2009) reported that the combine use of organic residues left by crops help in decreasing N loss from the soil/plant systems.

The main objective of the present work was to compare the no tillage and the conventional tillage applied over a rotation of rice (*Orza sativa*) / clover "Berseem" (*Trifolium alexandrinum*) / wheat (*Triticum aestivum) /* soybeans (*Glycine max*) / wheat grown on a loamy sand soil at El-Quntra Shark, Ismailia, Egypt.

## MATERIALS AND METHODS

### Experiment location and site description:

Field experiments were carried out in a farm at El-Quntra Shark, Ismailia (30.85° N 32.31° E), Egypt, for two years from summer 2016 up to summer 2018 over rotations of rice (*Orza sativa*) / clover "Berseem" (*Trifolium alexandrinum*) / wheat (*Triticum aestivum) /* soybeans (*Glycine max*) / wheat on a sandy loam soil in

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at El-Quntra Shark, Ismailia, Egypt. Conventional tillage (CT) and no-tillage (NT) were applied. The main soil properties (Table 1) were determined according to methods cited in Klute (1986) and Page et al., (1982). Plant materials were analyzed for N P, K ,Fe, Mn and Zn contents using methods cited by Cottenie et al. (1982) while protein content was calculated by multiplying grain N content by 6.25 (FAO, 2003).

Usual agricultural practices were implemented except for the tillage. One set of rotation was subjected under conventional tillage (CT) while the other was under no tillage (NT). At the stare soil was ploughed then leveled using lazar technique. The filed drains were at a distance of 10 m between each other with a depth of 90cm. Fertilizer nutrients were applied at rates (as kg element per ha) as follows N : 240 for rice , 180 for wheat, 48 for soybeans (as urea ; 640 g N $kg^{-1}$) , P 210 kg P $ha^{-1}$ as ordinary superphosphate before rice planting (as ordinary superphosphate 68 g P $kg^{-1}$) while K was at 150 kg K $ha^{-1}$ (in 2 equal splits doses "21 and 45 days" after rice planting as K-Sulfate 400 g K $kg^{-1}$).

Rice was planted on 25$^{th}$ of April 2016, followed by clover (fahl) on the 10$^{th}$ of September 2016 which stayed up to 25$^{th}$ November 2016, followed by wheat on the 30$^{th}$ of November 2016, followed by soybean on the 10$^{th}$ May 2017 then followed by wheat on 30$^{th}$ November 2017. In case of NT treatment, at end of season of each crop, plant residues of 15-cm stems over soil surface were left on the soil and the following crop was sown without tillage. On the other hand, for CT treatment soil was tilled after harvest of each crop. Irrigation was done using water of El-Salam Canal (Agricultural drainage water mixed with Nile water at a 1:1 ratio). Table 2 shows the main properties of the water.

**Table 1. The main physical and chemical properties of soil of the experiment site**

| Curses sand (%) | Fine sand ( %) | Silt (%) | Clay (%) | Soil texture* | Organic matter ($gkg^{-1}$) | $CaCO_3$ ($gkg^{-1}$) |
|---|---|---|---|---|---|---|
| 7.93 | 75.88 | 5.22 | 10.97 | Sandy Loam | 5.8 | 86.4 |

| pH (1:2:5) | EC ($dS\ m^{-1}$) | Soluble cations (mmolc $L^{-1}$) | | | | Soluble anions (mmolc $L^{-1}$)** | | |
|---|---|---|---|---|---|---|---|---|
| | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO^{-}_3$ | $Cl^{-}$ | $SO^{--}_4$ |
| 8.07 | 13.5 | 15.4 | 24.9 | 94.1 | 0.8 | 7.6 | 85.6 | 78.0 |

| Available macronutrients (mg $kg^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|
| N | P | K | Fe | Mn | Zn | Cu |
| 36.9 | 3.5 | 185.3 | 1.7 | 2.5 | 0.7 | 0.1 |

*Texture according to the International Soil Texture Triangle (Moeys 2016).

**Table 2. Main properties of irrigation water (El-Salam Canal, Ismailia)**

| Parameter | Season | April | September | November |
|---|---|---|---|---|
| pH | **2016** | 8.02 | 8.04 | 7.98 |
| | **2018** | 8.00 | 8.03 | 7.99 |
| EC | **2016** | 1.25 | 1.55 | 1.36 |
| | **2018** | 1.43 | 1.69 | 1.40 |
| $NO^{-}_3$-N | **2016** | 18.62 | 20.47 | 17.62 |
| | **2018** | 22.64 | 23.19 | 19.55 |
| $NH^{-}_4$-N | **2016** | 9.14 | 10.98 | 9.72 |
| | **2018** | 12.47 | 9.37 | 10.39 |
| K | **2016** | 10.95 | 8.14 | 7.93 |
| | **2018** | 12.48 | 12.94 | 9.13 |
| Fe | **2016** | 1.46 | 1.68 | 1.77 |
| | **2018** | 1.50 | 1.88 | 1.85 |
| Mn | **2016** | 0.97 | 0.80 | 0.65 |
| | **2018** | 0.83 | 0.98 | 0.73 |
| Zn | **2016** | 0.57 | 0.60 | 0.55 |
| | **2018** | 0.66 | 0.67 | 0.58 |

**Statistical analysis**

The experimental design was randomized complete block design with 3 replicates. The data collected were statistically analyzed using analysis of variance (ANOVA) according to the procedures outlined by Snedecor and Chochran (1967). To compare treatment means L.S.D at 5% level of significance was used according to Steel and Torrie (1980). All statistical analysis was performed by using MSTAT-C (1989) statistical software.

## RESULTS AND DISCUSSION

**Yields**

The CT treatments showed slight, but not statistically significant, increase in productivity as well as in contents of chlorophyll, proline or protein (Table 3). Baumhardt et al. (2017) reported that NT may reduce evapotranspiration which affect plant leaf area and biomass that leads to greater yield potential, Alarcon et al. (2018) reported that tillage system caused no effect of legume yields. Al-Kaisi et al. (2016) mentioned that soybean yield were higher with CT system which they attributed to cold early spring under which conditions the NT system would cause slow seed germination and seedling emergence (Botta et al., 2010). There may be greater soil organic matter which would improve soil aggregation and high yield by NT (Franzluebbers, 2002; Yang et al., 2013; Yeboah et al., 2016).

Productivity in terms of grain yields for grain crops followed the pattern of rice> wheat > soy bean (Table 3). Pedersen and Lauer (2004) and Shahzad et al. (2016) reported that crop rotation has important implication for increase the crop productivity.

**Nutrients uptake by planrs**

Table 4 presented the nutrients uptake by different plants; legumes are of special interest in organic crop rotations. Therefore, legume crops in rotations improve N, P and K uptake by crops, particularly in soybean and clover c. N'Dayegamiye et al. (2015) reported that legume crops in the rotation can provide a direct. There were increases in N, P and K in wheat crop than in rice crop. Lower Fe, Mn and Zn wheat, soybean and continuous wheat. Wei et al. (2006) which reported that uptake of Fe, Mn and Zn were greater in clover and lowest with wheat.

**Soil pH, EC and available nutrients after harvest**

Table 5 shows Soil pH, Ec and available NPK, and Table 6 shows available micronutrients after harvest. Treatment of CT pH showed pH in the rice and clover soils being 7.91 to 7.92 respectively. However pH values were 8.21, 8.11, and 8.12 after wheat, soybean and wheat respectively. Available N increased to 46.35 mg $kg^{-1}$ after tillage compared with 36.89 before cultivation. Long term cropping can degrade soil fertility (Wei et al., (2006). Legume crops residues contribute to organic N and after mineralization N increases in soil (Chu et al., 2004). Increased soil N occurred in NT as well as CT .Soil P values were increased compared with before cultivation. Among the nutrients deficiency of P in soil has an adverse impact of legume production as it is required enhanced N fixation (Rotaru and Sinclair 2009).

**Table 3. Grain and straw yield, total chlorophyll, proline and protein content in in No-tillage (NT) and conventional tillage (CT) systems**

| Field crop | Grain Yield (Ton/h) | | Dry straw (Ton/h) | | Total Chlorophyll (mg/g) | | Proline (µg/g) | | Protein (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NT | CT | NT | CT | NT | CT | NT | CT | NT | CT |
| Rice | 8.98 Aa | 9.02 Aa | 10.30 Ba | 10.46 Ba | 3.59 Aa | 3.61 Aa | 22.36 BCa | 22.14 Ba | 8.34 Ca | 8.74 Ca |
| Clover | - | - | 16.44 Aa | 17.59 Aa | 4.25 Aa | 4.33 Aa | - | - | - | - |
| Wheat | 3.33 Ba | 3.36 Ba | 5.97 BCa | 6.10 BCa | 3.22 Aa | 3.28 Aa | 25.74 ABa | 24.99 ABa | 11.67 BCa | 11.96 BCa |
| Soybean | 1.85 Ba | 1.90 Ba | 4.56 Ca | 4.56 Ca | 4.66 Aa | 4.72 Aa | 22.63 BCa | 21.69 BCa | 22.19 Aa | 22.50 Aa |
| Wheat | 3.70 Ba | 3.74 Ba | 6.25 BCa | 6.31 BCa | 3.35 Aa | 3.42 Aa | 27.14 Aa | 27.36 Aa | 12.25 Ba | 12.36 Ba |

*Capital letters represented the significant different among different crop rotation and small letters represented the significant different among the tillage system.

**Table 4. Nutrients uptake in grains under different crop rotation treatments except clover in straw and no-tillage (NT) and conventional tillage (CT) systems**

| Nutrients | N Uptake | | P Uptake | | K Uptake | | Fe Uptake | | Mn Uptake | | Zn Uptake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crop | NT | CT | NT | CT | NT | CT | NT | CT | NT | CT | NT | CT |
| **Rice** | 83.23 Aa | 87.25 Aa | 13.77 Aa | 16.65 Ca | 133.7 Aa | 138.3 Aa | 5471.4 Ca | 5582.7 Ba | 3462.9 Ba | 3609.9 Ba | 2244.3 Aa | 2353.4 Aa |
| **Clover** | 183.1 Aa | 186.6 Aa | 25.83 Aa | 33.29 Aa | 138.5 Aa | 159.0 Aa | 3329.2 Ea | 3491.6 Ca | 2635.8 Ca | 2805.7 Ca | 1572.8 Ca | 1613.5 Ca |
| **Wheat** | 116.5 Aa | 119.4 Aa | 18.37 Aa | 18.37 Ca | 140.1 Aa | 141.2 Aa | 6319.7 Ba | 6473.6 Aa | 4496.7 Aa | 4540.3 Aa | 1836.2 Bb | 1925.8 Ba |
| **Soybean** | 203.8 Aa | 206.6 Aa | 25.83 Aa | 25.83 Ba | 159.6 Aa | 160.7 Aa | 6460.4 Aa | 6652.7 Aa | 4355.5 Aa | 4541.5 Aa | 2108.9 Aa | 2181.2 Aa |
| **Wheat** | 122.3 Aa | 123.4 Aa | 18.94 Aa | 21.24 BCa | 146.9 Aa | 149.2 Aa | 5113.8 Da | 5197.6 Ba | 4604.6 Aa | 4618.9 Aa | 1600.3 Ca | 1691.6 Ca |

*Capital letters represented the significant different among different crop rotation and small letters represented the significant different among the tillage system.

**Table 5. pH, EC and macronutrients content in the experimental site after harvest in No-tillage (NT) and conventional tillage (CT) systems**

| Field crop | pH (1:2.5) | | EC ($dSm^{-1}$) | | Macronutrients ($mg\ kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | N | | P | | K | |
| | NT | CT | NT | CT | NT | CT | NT | CT | NT | CT |
| Rice | 7.91 | 8.01 | 11.10 | 8.21 | 38.02 Eb | 41.25 Aa | 3.57 Aa | 3.72 Aa | 188.3 Ca | 192.4 Ca |
| Clover | 7.92 | 7.82 | 7.00 | 7.09 | 42.77 Ba | 44.29 Aa | 3.98 Aa | 4.50 Aa | 203.6 Ba | 207.1 Ba |
| Wheat | 8.21 | 8.16 | 8.10 | 6.38 | 42.32 Ca | 42.98 Aa | 3.94 Aa | 4.88 Aa | 201.4 Ba | 205.2 Ba |
| Soybean | 8.11 | 8.12 | 7.00 | 6.75 | 44.33 Aa | 44.07 Aa | 4.06 Aa | 4.15 Aa | 209.6 Ab | 214.1 Aa |
| Wheat | 8.13 | 8.11 | 7.30 | 6.85 | 41.37 Da | 46.35 Aa | 3.91 Aa | 4.46 Aa | 205.6 ABa | 207.0 Ba |

*Capital letters represented the significant different among different crop rotation and small letters represented the significant different among the tillage system.

**Table 6. Micronutrients content in the experimental site after harvest in No-tillage (NT) and tillage (T) systems**

| Field crop | Micronutrients ($mg\ kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Fe | | Mn | | Zn | |
| | NT | T | NT | T | NT | T |
| Rice | 1.71 Ba | 1.79 Ca | 2.62 Ba | 2.65 Ba | 0.71 Ba | 0.72 Ba |
| Clover | 1.85 Aa | 1.99 Aa | 2.77 Aa | 2.81 Aa | 0.75 ABa | 0.86 Aa |
| Wheat | 1.90 Aa | 1.91 Ba | 2.71 ABa | 2.78 Aa | 0.74 ABa | 0.83 Aa |
| Soybean | 1.86 Aa | 1.98 Aa | 2.77 Aa | 2.76 Aa | 0.78 ABa | 0.86 Aa |
| Wheat | 1.84 Aa | 1.86 Ba | 2.70 ABa | 2.76 Aa | 0.83 Aa | 0.83 Aa |

*Capital letters represented the significant different among different crop rotation and small letters represented the significant different among the tillage system.

Deficiency of P in soil directly affects roots growth, photosynthesis, sugar translocation which in turn directly or indirectly disturbs N-fixation (Martin-Rueda et al., 2007). Soil K was increased particularly after soybeans. Soon and Arshad (1996) reported the K was decreased by cropping systems. Long term studies by Jonston (1969) Hickman (2002) noted little change in K after more than 100 years of cultivation of no K fertilization.

Contents of Fe, Mn and Zn in soil after crop harvest shows increases in the CT than the NT systems. Rotation cropping maintained similar levels after legume crop especially compared to cereals crop. Hickman, (2002) found that reduced tillage resulted increased Fe, Mn and Zn. While, Martin-Rueda etal. (2007) found that minimum tillage leads to higher Fe, Mn and Zn in the upper layer soil.

## CONCLUSION

Crop rotation is a critical feature of all sustainable cropping systems because it provides the principal mechanism for building healthy soils, a major way to control pests along with a variety of other benefits. Crops productivity was rather higher under conventional tillage system compared with the NT system. Legumes increased N, P and K availability by crop. Higher Fe, Mn and Zn were obtained by clover wheat soybeans than rice.

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## الملخص العربي

## المحافظة علي خصوبة التربة وكفاءة المحاصيل من خلال إدارة نظم حرث التربة وإستخدام الدورات الزراعية

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تأثير الدورات الزراعية / نظم الحراثة علي حالة التغذية في النبات، وإنتاجية المحاصيل وخصائص التربة كان هو الهدف الرئيسي من إجراء الدراسة التي تمت شمال سيناء، مصر. حيث قيمت الدراسة تأثير تناوب المحاصيل الأرز / البرسيم / القمح / فول الصويا / القمح (صيف ٢٠١٦ حتى ٢٠١٨) تحت نظام عدم وجود حراثة (NT) ونظام الحراثة التقليدية (CT)، علي أداء وكفاءة المحاصيل وكذلك خصائص التربة.

أظهرت النتائج بعض السمات الإيجابة لنظام الحراثة التقليدية (CT) عنه في نظم عدم الحراثة (NT) في بعض الحالات تحت التجربة المقامة. حيث كان محتوى المغذيات النباتية في التربة بعد الحصاد أكبر بعد حصاد المحاصيل البقولية. هذا بلإضافة إلي زيادة في محتوى كلا من الحديد (Fe) والمنجنيز (Mn) في التربة بعد حصاد المحصول البقولي تحت نظم الحراثة التقليدية (CT) عنه تحت نظم عد الحراثة (NT) والتي حافظت علي نفس المستويات بعد حصاد المحاصيل البقولية مقارنة بمحاصيل الحبوب. بالنسبة لإنتاجية المحاصيل كانت أعلى، في بعض الحالات، تحت نظم الحراثة التقليديه (CT) عنه تحت نظام عد الحراثة (NT)، بالرغم من زيادة محتوى الكلوروفيل في النبات، البروتين وكذلك البرولين عند إستخدام نظام عدم الحراث (NT).

**الكلمات الدالة:** البقوليات، اللاحراثة، محاصيل الحبوب، مغذيات التربة، الدورة الزراعية.