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QUANTIFYING SOIL TILTH FOR WHEAT AND *Faba bean* CROPS USING TILTH INDEX

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ABSTRACT

One of the factors critical to seed germination and plant development is good tilth. This study was conducted to calculate the tilth index (T1) under different tillage practices and two crops, wheat and faba bean in order to determine the optimum tilth index value for maximum yield of wheat and faba bean crops. Tillage practices applied were traditional tillage by different chisel ploughing passes {two (P2), four (P4), six (P6) and eight passes (P8)} and moldboard plough (Pm). Tilth index was calculated following the model suggested by Singh *et al*., (1992). Five soil physical properties, soil bulk density, cone index, aggregate uniformity coefficient organic matter content, and plasticity index were determined for each tillage system to quantify (T1) according to the model. The calculated values of the tilth index were varied with tillage practices. The tilth index increased as ploughing passes increased. Tilth index increased from 0.52 to 0.67 under (P2) and (P8), respectively. However, the highest value was obtained with the moldboard plough (0.71).Yield of wheat and Faba bean also varied according to the tillage practices and to the (TI) values. The highest yield of wheat was obtained with (Pm) treatment which corresponds to (TI) value of 0.71, while *Faba bean* yield increased with (P6) treatment which corresponds to (TI) value of 0.59.It is concluded that the tilth index can be used to describe the physical conditions of the soil and as an indicator for the most effective tillage practices that achieve the maximum yield for a certain crop.

Key words*: Faba bean yield, soil physical properties, tilth index, wheat yield.*

1. INTRODUCTION

Tillage plays an important part in the preparation of the seed bed for germination and plant growth. Soil physical conditions following tillage may vary according to tillage systems applied. De Costa *et al.* (1997), stated that one of the most influential technical factors on the outcome of a crop is the tillage method since it changes both the physical properties and moisture content of the soil. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). Tilth has been viewed as a qualitative term describing the physical state of soil in terms of ease of tillage, seed bed preparation, seedling emergence and root growth (Brady, 1984 and Plaster, 1985). Karlen *et al.* (1990) defined soil tilth as the physical conditions of a soil described by its bulk density, porosity, structure, roughness, and aggregate characteristics as related to water, nutrient, heat, impedance to seedling emergence and root penetration. They also added that plant growth can be used as an indicator of soil tilth because it integrates the effects of crop, soil, and microenvironment.

Tapela and Colvin, (2002) stated that the tilth or soil condition resulting from the use of different tillage tools depends on both the type of implement used and the soil condition when tillage occurs. They also indicated that benefits of tillage are well known, but the proper tillage needed to achieve optimum soil conditions is not well understood. Cruse and Colvin (1989), however, reported that some tillage is needed but excessive tillage may not be helpful. They also added that unnecessary tillage operations not only consume energy needlessly, but can aggravate soil erosion, and reduce long term production capabilities. Tapela and Colvin (1998) reported that if tillage results and soil conditions were quantifiable, it would be easier to determine the amount of tillage necessary to achieve an optimal yield level.

Schafer *et al.* (1985) reported that quantification of soil tilth may help in evolving custom-prescribed tillage. Gupta (1986) used a single composite physical index to quantify soil tilth as a product of the rating of eight physical properties included soil depth, bulk density, infiltration rate or apparent hydraulic conductivity, available water storage capacity, organic matter content, non-capillary pore space, water table depth and slope. Singh, (1991) believed that if soil properties were optimized; the tilth then would also be optimum. He also added that to identify the tillage practice that produce adequate tilth for the maximum yield production, the tilth index is a good quantitative value that can be used to describe soil conditions that relate to plant growth.

Singh and Colvin (1992) stated that there is a need for a quantitative understanding of soil tilth to help scientists, engineers, and farmers for better understand how to manage soil. They developed the tilth index as a multiplicative combination of tilth coefficients for soil parameters of bulk density, cone index, aggregates uniformity coefficient, organic matter and plasticity index.

Tilth index (TI) has been used to describe soil conditions ranging from 0.0 for worst to 1.0 for best soil conditions as related to crop production. It can be used for tillage management to avoid unnecessary tillage operations beyond an optimum tilth. A value of (TI) between 0.8 and 1.0 was found optimal for crop production, (Singh *et al.*, 1992). They suggested that the relations could be used over a variety of soil and climatic conditions and management practices, after further testing.

Abou Youssef (2005) found that tilth indices of individual soils ranged from 0.507 for no-tillage to 0.852 for moldboard tillage. He also found a strong correlation between (TI) and yield of soybean under different tillage systems. Tripathi *et al.* (2005) reported that wheat yield increased linearly with increasing (TI) from 0.75 to 0.89.

2. MATERIALS AND METHODS

2.1. Experimental details

This experiment was conducted at the Agriculture experimental and Research Station, Faculty of Agriculture, Cairo University. Five tillage treatments were used *i.e.*, chisel ploughing by two (P2), four (P4), six (P6) and eight (P8) passes and the moldboard ploughing (Pm). The experimental design was a randomized complete block design with three replicates. The plot size was 100 m^2 (5 x 20 m). Wheat (*Triticum aestivum* L.), c.v. Sds1 and faba bean (*Vicia faba* L.), c.v. Giza3 were planted on Nov.26, 2006. Wheat was sown in rows at a distance of 15 cm between rows. Faba bean was sown at a distance of 30 cm between rows and 25 cm apart. Fertilizers were applied according to the recommended doses of the Ministry of Agriculture. Some physical characteristics of the experimental soil were determined and given in Table (1). Soil physical properties measured for the determination of the (TI) were: bulk density (BD) according to Klute, (1986) using the core method, soil penetration resistance (CI) by using the penetrologger with a cone type of 1 cm^2 and an angle of 60º, organic matter (OM) by the modified Walkley and Black method (Page *et al.*, 1982), aggregate uniformity coefficient (AUC) according to Jumikis, (1962) and the plasticity index (PI) according to Liu and Evett, (1990). Soil samples were taken after the establishment of the tillage practices from the 0-15cm soil depth for the measurements of the previous soil properties. Grain yield of each crop was recorded after harvesting.

Table (1): Some physical and chemical characteristics of the experimental soil site.

Soil depth (cm)	Particle size distribution (%)			Texture class	ECe ($dS.m^{-1}$)	pH
	Sand	Silt	Clay			
0-20	41.6	36.8	21.6	Loam	1.23	7.62
20-40	45.8	30.5	23.7	Loam	1.42	7.84

2.2. Tilth index calculation

Tilth index was calculated for each tillage treatment using the model developed by Singh *et al.* (1992). The model utilizes bulk density, cone index, organic matter content, aggregate uniformity coefficient and plasticity index as parameters for calculating tilth index. According to the model, the tilth index is a multiplicative combination of tilth coefficients expressed as: $TI = CF_1 \times CF_2 \ldots \times CFn$

Where, TI is the tilth index ($0.0 \leq TI \leq 1.0$), CF the tilth coefficient and n is the number of soil properties used for calculation of the tilth index.

The equations used to calculate tilth coefficients for each soil property according to the model of Singh *et al.* (1992) are as follows:

$$CF\ (BD) = -1.5 + 3.87\ BD - 1.5\ BD^2$$
$$CF\ (CI) = 1.012 - 0.002\ CI - 0.01\ CI^2$$
$$CF\ (OM) = 0.59 + 0.122\ OM - 0.008\ OM^2$$
$$CF\ (AUC) = 0.35 + 0.245\ AUC - 0.023\ AUC^2$$
$$CF\ (PI) = 1.02 + 0.0009\ PI - 0.00016\ PI^2$$

The non-limiting and critical values of tilth coefficients, assigned by Singh *et al.* (1992), for the soil properties are given in Table (2).

Table (2): The non-limiting and critical values of tilth coefficients (CF) for each soil property.

Soil properties	**Non-limiting values of CF**	**Critical values of CF**
Bulk density, BD (g.cm-3)	1.0 for BD ≤ 1.3 g.cm-3	1.3 ≤ BD ≤ 2.1 g.cm-3
Cone index, CI (MPa)	1.0 for CI ≤ 1.0 MPa	1.0 ≤ CI ≤ 10 MPa
Organic matter, OM (%)	1.0 for O.M ≥ 5%	1.0 % ≤ OM ≤ 5%
Aggregate uniformity coefficient, AUC	1.0 for AUC ≥ 5	2.0 ≤ AUC ≤ 5
Plasticity index, PI (%)	1.0 for PI ≤ 15%	15.0 % ≤ PI ≤ 40 %

3. RESULTS AND DISCUSSION

3.1. Soil physical properties

Soil physical properties and the (AUC) of the different tillage treatments are shown in Table (3 and 4) and Fig.(1).It is observed that bulk density (BD) and penetration resistance (PR) values were decreased as ploughing passes increased. The lowest values were obtained under (P8) treatment while the highest values were recorded under (P2) treatment. The decrease of soil bulk density after tillage may be due to the break down of soil compaction and the increase of the soil pore spaces (Taieb, 1998). Soil penetration resistance varied with the tillage treatments as a result of the changes in soil bulk density. Many researchers reported greater bulk density and soil penetration resistance in no-till compared with moldboard plow and chisel plow during the early and mid season corn growth (Vyn and Raimbault, 1993 and Cassel *et al.,* 1995). The moldboard plough decreased (BD) and (PR) as compared to chisel plough by two, four and six passes. The difference in (BD) and in (PR) between (P2) and (P4) was not significant. However, the differences between both (P2) and (P4) and the other tillage treatments were significant. The changes of soil organic matter content (OM) among treatments were small. Plasticity index (PI) is related to texture and does not change with management practices; therefore the tilth coefficient for plasticity was the same for all tillage treatments. Aggregate size distributions were expressed in terms of the aggregate uniformity coefficient (AUC), which is the ratio of D_{60} to D_{10} where D_{60} and D_{10} are the diameters, at which 60% and 10% of the soil mass is finer, respectively, (Hillel, 1982, Wray, 1986). Singh *et al.*(1992) reported that any soil with an aggregate uniformity coefficient greater than or

Table (3): Effect of tillage treatments on bulk density, penetration resistance, organic matter and plasticity index.

Tillage treat.	**Bulk density ($g.cm^{-3}$)**	**Penetration resistance (MPa)**	**Organic matter (%)**	**Plasticity index**
P2	1.46	2.15	1.89	21.52
P4	1.42	1.96	1.82	
P6	1.32	1.46	1.68	
P8	1.23	1.01	1.43	
Pm	1.27	1.29	1.75	
L.S.D. 0.05	0.056	0.209	0.109	

Table (4): Effect of tillage treatments on aggregate size distribution.

Tillage treat.		**Aggregate size distribution (%)**				
	4.0-2.0 (mm)	**2.0-0.85 (mm)**	**0.85-0.42 (mm)**	**0.42-0.25 (mm)**	**<0.25 (mm)**	**AUC**
P2	**6.84**	**8.49**	**13.28**	**15.63**	**55.76**	**2.01**
P4	**10.83**	**8.79**	**11.51**	**16.13**	**52.74**	**2.12**
P6	**16.94**	**19.10**	**17.51**	**18.24**	**28.21**	**2.41**
P8	**9.73**	**22.05**	**19.84**	**9.14**	**39.24**	**3.49**
Pm	**12.75**	**28.74**	**20.15**	**12.45**	**25.91**	**3.75**

equal to five was considered to be non-limiting, and one with a value less than or equal to two was considered unusable by plants.

faba bean yield showed a significant difference between (P6) and all other treatments. These results indicate that wheat crop under either the

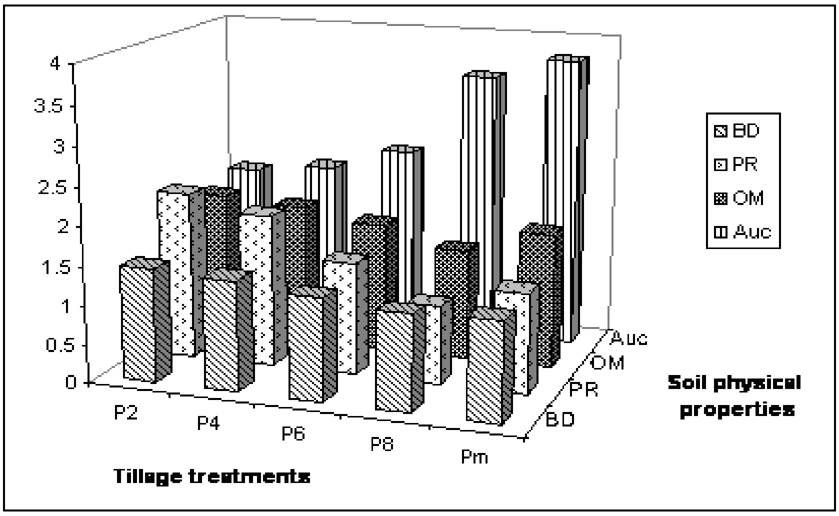

Fig . (1): Soil physical properties as affected by tillage treatments.

3.2. Tillage and crop performance

Grain yield of wheat and faba bean are presented in Table (5). The response of wheat and faba bean yield is varied with the applied tillage practices. The highest grain yield of wheat was obtained with (Pm) followed by (P8), (P6), (P4) and (P2), respectively. While, the highest grain yield of faba bean was obtained with (P6)

Table (5): Tilth index and yield of wheat and faba bean as affected by the tillage treatments.

Tillage treat.	Yield (kg/fed.)		Tilth Index
	Wheat	Faba bean	
P2	1410.75	816.92	0.52
P4	1496.15	921.74	0.55
P6	1896.41	1203.68	0.59
P8	2250.32	1026.52	0.67
Pm	2375.82	1068.95	0.71
L.S.D. 0.05	164.87	47.72	0.049

followed by (Pm), (P8), (P4) and (P2), respectively. The lowest grain yield of both wheat and faba bean were obtained with (P2) treatment which showed a poor soil physical properties that influenced both wheat and faba bean crops. The differences in wheat and faba bean yields among treatments were obtained. Wheat yield show no significant difference between (P8) and (Pm), while the differences between them and the other treatments were significant. On the other hand, moldboard plough or chisel plough (by eight passes) obtained the maximum yield, while faba bean obtained its maximum yield with chisel plough (by six passes).

3.3. Tilth index (TI)

Effect of tillage practices on (TI) is presented in Table (5). The (TI) is varying with the applied tillage treatment. (TI) ranges between 0.52 and 0.71. According to the model of Singh *et al.*, (1992) it is proposed that a tilth index in the range of 0.8 to is optimal for crop production and that one less than 0.50 is poor. In the current study the highest (TI) value is obtained with moldboard plough. Singh *et al.*, (1992), Tapela and Colvin, (1998) and Abou Yuossef, (2005) found that (TI) for moldboard plough system was higher than chisel plow system. No significant difference however, was found between the (TI) values of (Pm) and (P8). The lowest (TI) value was obtained with (P2). Data show that the highest grain yield of wheat was associated with the maximum (TI) value of (0.71) obtained with (Pm). While, the highest grains yield of faba bean was associated with (TI) value of (0.59) which obtained with (P6) treatment. These results indicate that wheat yield increased as (TI) increased, while faba bean yield decreased as (TI) increased. Wheat yield matches well with (TI) while faba bean yield did not match well with the (TI). This trend may be due to the nature of faba bean roots. The relationships between (TI) and yields of wheat and faba bean were performed. A second order (quadratic) type shows a highly significant correlation between (TI) and the yield of wheat, while the correlation with faba bean yield was much lower.

Y (wheat) = -6129+21040 (TI)-12760 $(TI)^2$ R2=0.983

Y (faba bean) = -9049+32100 (TI)-25240 $(TI)^2$ R2=0.708

Conclusion

Soil physical properties such as bulk density, penetration resistance and soil aggregates changed by the applied tillage system. The tilth index based upon these physical properties can determine the proper tillage method that improves these soil properties. These soil properties can affect root growth, root distributions and in turn influence crop growth and crop yield. In the current study the studied tillage practices influenced the wheat and *Faba bean* yields; moldboard plough followed by chisel plough, by eight passes, had the highest yield of wheat, while the highest yield of faba bean was obtained with chisel plough by six passes followed by moldboard plough. The yield of wheat increased as tilth index increased, while the yield of faba bean increased as tilth index increased to a certain value and decreased as tilth index increased. These results indicate that the energy require for the tillage of Faba bean crop can be saved. Tilth index should be calculated for different soil types, soil tillage practices and different crops. From its value it can be optimize the tillage practices needed for the maximum yield of the crop. Tilth index can also help in reducing labor and energy required for the management and this could lead to a reduction in production costs.

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قياس كفاءة حرث التربة لمحصولى القمح والفول بأستخدام دليل الحرث

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ملخص

يستخدم دليل الحرث لوصف حالة بناء التربة و تأثير عمليات الخدمة على الخواص الطبيعية للتربة. أجريت تجربة حقلية لتقييم تأثير بعض عمليات الخدمة على قيم دليل الحرث و إنتاجية محصولى القمح والفول البلدى.تم دراسة تأثير اختلاف مشاوير الحرث بأستخدام المحراث الحفار(مرتين- أربعة – ستة - ثمانية مشاوير) وأيضا بإتباع نظام الحرث بأستخدام المحراث القلاب و ذلك لحساب قيم دليل الحرث تحت نظم خدمة مختلفة و لتحديد القيمة المقابلة لأعلى محصول لكل من القمح و الفول البلدى. و قد تم تقدير كل من الكثافة الظاهرية و مقاومة التربة للاختراق و كمية المادة العضوية و معامل تجانس التجمعات الأرضية و أيضا دليل المرونة للتربة تحت الدراسة حيث أستخدمت فى حساب دليل الحرث.

أظهرت النتائج :

1- اختلاف تأثيرعمليات الحرث على إنتاجية محصولى القمح و الفول البلدى. فقد تم الحصول على أعلى محصول عند أستخدام المحراث القلاب و عند أستخدام المحراث الحفار بثمانية مشاوير فى حالة القمح وستة مشاوير فى حالة الفول البلدى.و كان أقل محصول لكل من القمح و الفول البلدى هو عند الحرث بالمحراث الحفاربأثنين و أربعة مشاوير فقط.

2- تأثرت قيم دليل الحرث بأختلاف معاملة الخدمة حيث كانت أعلى قيمة محسوبة له هى عند أستخدام المحراث القلاب ثم قلت قيمتة عند أستخدام المحراث الحفار.تراوحت القيم من 0.52 لمعاملة الحرث بمشوارين إلى 0.71 للمعاملة بالمحراث القلاب.

3- هناك زيادة فى محصول القمح مع زيادة قيمة دليل الحرث ,بينما لم يتبع الفول البلدى هذا الاتجاة.

4- وجد ان هناك أرتباط عالى المعنوية بين دليل الحرث ومحصول القمح وبينه وبين محصول الفول البلدى مع أنخفاض المعنوية قليلا فى حالة الفول البلدى بالمقارنة بمحصول القمح.

توضح هذة الدراسة أن لدليل الحراثة أهمية فى تحديد عمليات الخدمة المناسبة و التى تعطى أعلى محصول عند استخدامها.

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