Research & Reviews

ISSN: 2319-9857

Research and Reviews: Journal of Agriculture and Allied Sciences

Effects of Conventional Tillage on Some Soil Properties, Root Growth and Seed Emergence

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Research Article

Received: 27/03/2013
Revised: 30/03/2013
Accepted: 08/04/2013

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Keywords: soil, root growth, seed, conventional tillage

ABSTRACT

The experiment work was carried out at Akure, latitude 7, 5' and longitude 5, 10' E in the rain forest zone of Nigeria on soil type classified as alfisol. Maize was used as the indicator crop. Soil parameters measured included bulk density, moisture retention, soil temperature, porosity aggregate stability and soil shear strength while crop parameters measured include root length and number of main roots, and crop emergence. The tillage treatment used included zero tillage (ZT), one ploughing (PL), one ploughing followed by harrowing (PH) and ploughing, harrowing and ridging in sequence (PHR). All operations are single pass. The result provided enough evidence that the soil structural condition as modified during tillage, affects the soil physical properties and some crop properties. The effects of cultivation on the soil temperature, moisture retention appear insignificant at the 95% confidence interval, but the soil density was significantly altered by the tillage treatment used. Experimental results of all measured data established the superiority of one disc ploughing over the other treatments. ANOVA results indicated that most of the physical properties are statistically significant at 95 % confidence level except soil density and the mean weight diameter (MWD) by dry and wet sieving. Analysis of results also revealed that shear strength of the soil decreased with tillage treatments. It was found that emergence was earliest in treatment three and lowest in treatment four, decreasing directly with increasing soil strength. Similarly, result of statistical analysis showed that total emergence was not significant although the emergence force exerted by seedling was significantly affected by tillage. It decreased from a maximum of 10.63kN at the zero tillage plots to 8.85kN for plots ploughed, harrowed and ridged. Values recorded for other treatments are 9.22 kN for disc ploughing and 8.96 kN for one disc ploughing followed by disc harrowing. The least root system both in number and length was observed on the zero tillage plots.

INTRODUCTION

In the middle ages it was though that plants survived on the minute soil particles and that the more finely soil was divided the more of such soil particles will be absorbed by plant roots [15]. Later developments have proved that plants actually depend on the release of adequate amounts of plant nutrients in the soil and the availability of these nutrients is regulated by some factors which include soil composition and management practices.

Land preparation methods using various implements or a combination of tillage techniques have proved to be largely successfully in that they have resulted in continuous high yields and weed control. When soil was worked manually and with work bulls, there was no time and energy to over-till the soil. But due to the ease of mechanical cultivation, many farmers erroneously believe that since tillage is good it cannot be overdone. On the contrary, it is now known that overworking the soil may results in excessive pulverization of soil particles thus making the soil easily erodible. It can lead to tillage pan as a result of frequent wheel traffic and also results in waste of time and fuel. All these consequences directly or indirectly lead to increase cost of production.

Economic pressure due to high operational cost and capital outlay on Tractors and implements is now forcing a review of these conventional systems of cultivation which are now considered over elaborate. The question now arises; what is the minimum tillage treatment that can be applied to produce a particular crop on a particular farm without a reduction in growth and yield characteristics at the same time protect the soil from the undesirable characteristics of continuous tillage? It now seems obvious that the greatest chance of increasing the benefits to cost ratio in the field lies not so much in the expectation of obtaining a greater yield from new or a more elaborate tillage method but more in the possibility of maintaining the same high yields while simplifying and economizing tillage operations [6].

The main objectives of this study are to determine the amount of soil manipulation that will produce specific soil physical characteristics using given soil parameters and to determine the level at which tillage will be considered enough or over elaborate as well as to predict the emergence force exerted by the growing seedling under different tillage system.

Review of Literature

Soil cultivation has reached its present stage of development due to the experience by trial and error of local farmers than the work of researchers. Hillel [6] reported that the major aims of soil tillage investigation is to define the optimum soil physical environment required to satisfy a give purpose or combination of uses, plant needs, mechanization needs and soil and water needs. A way to this is to take detailed measurements of soil physical properties such as texture, structure and relief. The problem is that these characteristics only provide little information since they bear no direct significant relationship with crop growth. Therefore, Reece (1970) recommended the evaluation of tillage in terms of change that they may bring about in the physical properties of soil that are directly involved in plant growth. These properties include: Soil temperature, aeration, impedance to roots and soil moisture (infiltration, drainage, evaporation and conductivity). Spoor (1975) also found that soil physical environment may be studied by plant assessment which involves identification of plant factors which respond to changes in cultivation; root development, time for shoot emergence and internal stress.

Conventional tillage practices for maize planting in the rain forest belt of Nigeria includes one or two passes of disc ploughing, harrowing with a disc harrow. Ridges are normally made if the crop is to be inter-cropped with cassava or to be irrigated.

Effect of Tillage on Soil Physical Properties

Different tillage practices affect soils in a variety of ways depending on their stability and moisture level. The most critical of these properties often changed by cultivation is the soil structure. The soil structure also influence water movement, heat transfer, aeration, bulk density and porosity [2]. Spoor [29] enumerated the ways that soil structure is affected by tillage namely; Formation and disintegration of soil aggregates, changes in clod size distribution, rearranging soil particles by inversions or loosing and transformation of the soils surface

Sing and Colvin [28] proposed that if the soil conditions associated with a good tilt can be optimized, tilth will be adequate for crop growth. However, experiments by Brady [3] showed that tillage effects appear to be favourable for plant on the short-term basis only, on the long term, the breakdown of soil organic matter in tillage results in unpleasant consequences of runoff and compaction due to traffic, growth of plough pans and reduction in aggregate stability. Baver et al [1] noted that such zones of compaction apparently move closer to the surface as the number of tillage operation increase. His observation on a number of seedbed profiles indicated that from 50-70% of the soil loosened by disc ploughing operation was recompacted by subsequent disc harrowing. Kohnke [10] recommended that minimum tillage is required for medium-coarse textured soils with a good humus content which can enhance the retention of a favourable structure for a long time. For soil rich in clay and silt, more frequent and elaborate tillage is recommended because of its tendency to "run together" and inhibit the passage of water and air.

Douglas and Zoufa [5] in a study at Ibadan, Onne and PortHarcourt reported that the effect of different tillage implements and practices on the soil water content vary according to soil type. In the test at Ibadan, Alfisols, the tilled plots had the highest water content, though differences were far from being significant. This trend was repeated on the PortHarcourt soils (Ultisols- sandy loams). At Onne the rotavator and mouldboard plough contained significant higher amounts of soil water than the disk ploughed soil. The study concluded that in general intensive tillage practices which compacts the soil leave little or no soil volume for accumulating soil water. Kowal and Kassam [12] also reported that as part of tillage system to improve water retention in the soil surface, a system of tied ridges was developed but this did not prove to be very economical and effective in the sandy soils of Northern Nigeria.

Maurya and Lal emphasized that the resistance to root development is a function of the shear strength exerted by the soil while the shear strength itself is affected by soil moisture potential and bulk density. Baver et al [1] noted that water availability plays an important role in determining the magnitude of the cohesion component as it affects the distance between particles and the attractive forces associated with air water menisci.

Evaluation of soil Structural Changes resulting from tillage operations

Although Koorevaar et al. [11] opined that it is nearly impossible to measure soil structure directly, Kepner et al. [9] named three aspects of final soil condition may be of interest; the degree of soil breakdown, segregation of clod sizes in relation to depth and uniformity of mixing throughout the tilled depth. The most frequency studied is the degrees of soil break-up. Biswas and Mukherjee [2] grouped various methods of evaluating soil structure into direct and indirect methods. The indirect method involves the evaluation of Size distribution of aggregation through dry or wet sieving, stability of aggregates and the study of soil properties which are due to soil structure.

According to Kepner et al. [9] the Mean weight diameter (MWD) or pulverization modulus is a quantitative assessment of such performance into a single characteristic parameter so that it might be correlated with other factors. De boodt, et al. in singh has shown that changes in the MWD are correlated with crop yield when other conditions are uniform.

Effect of tillage on Root growth and seed emergence

In order for individual roots to elongate at daily rates of 6-8 cm, the soil must be warm, fertile, moist, well aerated and the shoot system must have ample temperature and light for food production. Notwithstanding, the optimum root system is not always the largest, it is that which ensures the provision of water, nutrients and hormones by root to the shoot leading to the maximum production of economically important tissues [24]. Root growth outside these requirements as it exists in some elaborate tillage system might actually be superficial, resulting in wastage of the products of photosynthesis especially in less favourable field condition of drought. Root growth and the soil bulk density measurement have been reported to be negatively correlated [25]. Trouse [30] reported that in loose soils with a density of 1.0g/m^3, root grows rapidly. Soils compressed by 0.35 g/cm^3 can reduce elongation rates to about tenth of their capacity. According to Hongwen et al. [8] long-term Conventional Tillage and straw removal resulted in poor soil structure and low productivity. Mean soil bulk density in No-till soil residue cover (NTSC) was 1.5% less than in conventional Tillage (CT) and capillary porosity 3.2% greater.

MATERIALS AND METHODS

The study was conducted at the University Teaching and research Farm in Akure. The soil is classified as Alfisoil [18]. Soil textural class analysis from samples taken randomly from the 12 plots indicated that the soil is composed of 71.0-82.2% of sand, 6.5-8.9% of silt, 9.5-19.0% of clay classified in the range of sandy loam to loamy sand.

The experimental design was a completely randomized block for each tillage treatment with three replicates each, making a total of 12 plots. Plots are 4.75m in length and 3.25m in breath with a 50m – row border round the perimeter of each plot on the length and breadth side of to allow for stopping and turning of tractor. Tillage operations were done according to the treatment (table 1) used. All operations are single pass. Treated maize seeds were manually planted in singles at 5cm depth, and at a spacing of 75 x 25cm. Planting depth was controlled with painted mark on planting pegs at 5cm. Gramozone was sprayed for weed control on the Zero tillage treatments. Treatments were assigned randomly to the blocks and independent randomization was done for each block.

A 65Hp MF tractor was used for all tillage operations. Ploughing was done with a 3 furrow mounted disc plough. Harrowing was with a mounted tandem disc harrow with alternate serrated and plain edged discs. Ridging was carried out with a two row disc ridger, the furrow haven been adjusted to produce a spacing of 0.75m.

Measurement of Physical Properties

Soil Temperature was measured with a soil probe. Readings were taken at 5cm, 10cm as recommended by Kohnke [10] with three replicates each from each depth, randomly selected per plot in the 8hrs and 16hrs. Readings were started as soon as tillage treatments were completed and seeds planted because effect of temperature is most critical during the germination and seedlings stage Lal [13].

The speedy moisture meter model Mc 320 which has been previously calibrated with the gravimetric method was used for the determination of percentage moisture in situ per plot. Kohnke [10] noted that this method is recommended as an approximation for most fieldwork with accuracy within 5% on most materials.

To determine the size distribution of soil aggregates from the tillage treatment, dry sieving method of aggregate analysis was used and the results expressed as the mean weight diameter (MWD) as described in Singh [27]. Seven size rages of sieves 0.425, 0.85, 2.00, 2.36mm 3.35 6.7mm, 9.5mm were used. Three replicates of each treatment were done and mean values obtained. 200g and 400g of soil per replicate were used for the dry and wet sieving respectively. The MMD is defined by the following equation:

ISSN: 2319-9857

$$MWD = \Sigma X_i W_i \quad .... (1)$$

Where, Xi = Mean diameter of any particular size range of aggregates in a fraction and Wi = weight of aggregates in that size range, as a fraction of the total dry weight of sample analysed.

Bulk density measurements were taken with core cylindrical samplers of 166 cm^3. Samples are taken from two depths of the soil profile 0-10cm, 10-20cm. Two replicates were taken per plot. For seedling emergence force, wet density was also determined. Three replicates of samples for determination of the soil shear strength were collected per plot in a 3.8 cm core cutter having a 60mm x 60mm x 60mm cross section, for the shear box from 0-10cm soil depth and tested with Residual direct shear box machine and normal stress of $5kN/m^2$, $1-kN/m^2$, $20kN/m^2$, $30kN/m^2$ and a load ring of 0,0009kN/div.

Measurement of the Crop Parameters

Four seedlings per plot were randomly and carefully selected and dug up in 20cm circular diameter root cage for root length determination. The samples were soaked in water overnight and washed to ensure complete removal of soil and then dried. The length of each root and the

Table 1: Tillage Treatments.

	Operations	Designation
1.	Zero Tillage (ZT)	T1
2.	Ploughing (PL)	T2
3.	Ploughing, Harrowing (PH)	T3
4.	Ploughing, Harrowing & Ridging (PHR)	T4

total number of main roots were measured and recorded. The numbers of seedlings germinating from the plots were physically counted daily and recorded while the force exerted by seedling was calculated from the mathematical relationship used by Sheikh et al. (1978):

$$F = \mu'' D (2CL \tan (45^\circ + 2\theta) + WL/2 - \tan^2 (45^\circ + 20) \quad ....(2)$$

F	=	force exerted by seedling (gms)
μ	=	Coefficient of friction between seedling and soil (assume 0.25)
D	=	Mean stem diameter of seedling (cm)
L	=	Depth of planting (cm)
C	=	Cohesion of soil (gms/cm^3)
θ	=	Angle of internal friction of soil in degree
W	=	Wet density of soil (gms/cm^3)

RESULTS AND DISCUSSION

Result of the physical characteristics obtained are quite variable, while the soil moisture and soil temperature did not show a significant influence of tillage treatments which support earlier results by Ojeniyi [17] and Ojeniyi and Dexter [19], the soil density was significantly altered by tillage (Table 2). Result of the soil moisture retention also shows that average percentage of soil moisture fall within a maximum range of 9.59% in T4 and minimum of 8.61% for T1. T2 and T3 have 8.9% and 9.92% respectively. Result of the analysis of variance for this parameter at $P< 0.05$ indicated that there is no much difference between plots. This insignificant result is contrary to the results of Ojeniyi [17] but it compares with Ojeniyi [18] which suggested that the larger the macro-porosity (>8 mm) as in zero tillage, the smaller the soil water content because voids larger than 8mm are responsible for water loss in tilled soils. The results might be due to the packing of organic matter on the plots before planting, which left very little organic matter to serve as mulch thus supporting the view that the more the micro-porosity as with more tillage the better the water conservation when there is no surface mulch.

Temperature readings taken in the morning show in table 2 showed results which are equal to or higher than that at the 5cm except for treatment four.

Comparatively the readings in the evenings with mean values of 34.22 °C, 35.14 °C, 34.38 °C, 35.14 °C for ZT, PL, PH and PHR at the 5cm depth and 33.05 °C, 33.36 °C, 33.26 °C, 34.64 °C at the 10cm depth. Soil Temperature is generally lower at the 10cm in the evening. The no-till

Table 2: Soil Physical Properties.

Treatment	Soil temperature (C). 8.00 hrs		Dry Density g/cm3		Soil Moisture (%)
	5cm	10cm	0-10cm	10-20cm	0-10cm
ZT	25.59	25.79	1.40	1.48	8.60
PL	25.52	25.53	1.24	1.33	8.90
PH	25.76	25.89	1.25	1.47	9.22
PHR	25.62	256.53	1.31	1.32	9.59

plots presented the lowest value of soil temperature probably because of undisturbed organic matter which reduces the impact of direct solar radiation on the top soils.

The soil density (dry basis) for 0 – 10cm soil depth shows that the zero tillage plots are denser than others, averaging 1.40g/cm^3 obviously because with time the particles have been naturally consolidated. This is followed by treatment four with 1.31 g/cm3, treatments three and two at 1.25 g/cm3 and 1.24 g/cm3 respectively. The apparent significantly high density of treatment four is probably die to the finer particles that are broken down and pushed into existing macro-pores thus clogging them apart from this, the result is consistent with Oyelade and Aduba [20]. The inconsistent and insignificant result of density on treatment at the 10-20cm depth might be due to the inability of maintaining a constant depth of operation during tillage. However, the no-till plots are still denser, at 1.48 g/cm3 than the others treatments. Predictably all treatments are denser in the 10 – 20 cm depth. This may be due to the reduction in the soil organic matter content at the depth or possibly the tillage pan formation effect reported by Baver et al [1].

The evaluation of the effects of tillage treatment on soil structure by using data from dry sieving experiment (Table 3) revealed an average MWD of 6.54mm for T1, 6.18mm for T2, 4.79mm T3 and 4.81mm for T4. These results are significant at the 95% confidence interval. It showed that the tillage implements used did influenced the breakdown of the soil clods into smaller units with the exception of Treatment four which showed a marginally higher value than the preceding treatment. This might probably be due to the fact that ridging operation is more of an aggregate forming operation than the preceding operations which are for inversion and disintegration.

During wet sieving results recorded also showed that soil aggregates were broken down by the action of water to 2.99mm for treatment one and 2.36mm, 1.81 and 1.81 for T2, T3 and T4 respectively. This shows that tillage intensity contributes to the formation of water stable aggregates of smaller MWD than the zero tillage.

To determine the degree of stability of soil in the different tillage treatments, a ratio of wet/dry sieving was used. Although the result of the ANOVA was not significant at the 5% level. The values of F calculated is 1.231 against F critical of 4.346. This indicates that the differences within the treatments are small. Higher values of stability ratio as in T_1, signifies the better stability against destructive forces of rain or wind erosion, suggesting that, with more cultivation, stability is reduce as reported by Vakali [31]. This is probably due to the weakening of bonding between soil mineral particles found out by Chan [4] or the disintegration of soil organic matter that enhances aggregate formation.

Table 3: Stability index of tillage techniques

Treatment	MWD (Wet Sieving)	MWD (Dry Sieving)	Stability Index
1	2.99	6.54	0.471
2	2.36	6.18	0.384
3	1.81	4.79	0.379
4	1.81	4. 81	0.388

Crop Parameters

ANOVA results of the root measurements taken showed that P 0.05 both for the mean number of roots developed per treatment and the mean root length of measured roots. The maximum number of main roots developed are 13, 18, 13 and 14 for the T1, T2, T3 and T4. The minimum number of roots are 7, 8, 8 and 9 for the same treatments respectively. Treatment two developed an average of 12.4 main roots (Table 4) followed by treatment four which is 10.4 in number. Treatments one and three recorded root numbers that were marginally fewer than treatment four. This result seems not to follow any clear pattern with tillage intensity as found out in Ojeniyi [18].

The mean root length of the treatment three with two tillage operations is 12.98 cm followed by 11.57 cm on the treatment with one tillage operation and 11.03cm for treatment Four. The Zero tillage recorded the least developed average root length and the number of roots developed, with 8.75 cm long roots on average. This can be due to the influence of the soil density on the root elongation confirming the negative correlation between these two parameters as reported by previous researchers. Such root system may eventually fail to meet the demand of crops. The result was not able to predict accurately the critical density at which the root growth is limited.

Effect of Soil Shear Strength

Result of the direct soil shear box test revealed that soil strength is highest in the uncultivated soil. The soil shear strength decreases directly with tillage in treatments two, and four. The third and fourth tillage treatments being the ones with the least shear strength. The predictive values on table 5 were got from the linear regression analysis for the shear tests according to coulombs law which was used to model the shear test data. The regression statistic on table 5 showed that a high positive correlation exists between the normal stress and the shear stress for all treatments except treatment four. Values of R are 0.76 for T1 and 0.92,

Table 4: Crop Parameters.

Treatment	Mean Root length (cm)	No of roots (No)
ZT	8.79	10.00
PL	11.57	12.44
PH	12.98	10.00
PHR	11.03	10.44

0.78, 0.39 for T2, T3 and T4 respectively. The standard errors obtained are 2.71, for T1, 1.22 for T2, 2.51 and 7.66 for T3 and T4. The analysis of variance also showed that these results are significant at the 95% confidence interval. Although, Hillel [7] remarked that the effect of soil strength on seedlings depends not only on the crust strength but also on extraneous factors like, the size of seedlings, vigour of seedlings

Table 5: Model of Soil Shear Strength.

Treatment	Angle of Internal Friction (θ°)	Cohesion C (kN/m^2)	Model
ZT	16.86	23.31	$y = 0.3032X + 23.315$
PL	15.7	21.15	$y = 0.2813x + 21.147$
PH	17.36	16.81	$y = 0.2969x + 16.808$
PHR	17.36	16.65	$y = 0.312x + 16.651$

Emergence of Seedlings

The result of experiment showed that the emergence was higher after five days in T3 (table 6). This is probably due to better contract of seed with soil and moisture resulting from the production of smaller mean void size by tillage treatments. In T3 a maximum of 72.58% of seeds have emerged at the fifth day. This result also shows that denser tilths restrict emergence in T4 and T1. Treatment two has 63.56%, followed by 45.1% in T4. This pattern was not followed by the actual emergence after seven days as all treatments show appreciable emergence of over 85% of seeds. Seedlings emerged in the order 26, 25, 24, 66 and 24, seedling for T2, T1, T3 and T4 out of the 28 observation units. Although, the ANOVA for the actual emergence shows that this result is not significant at $\alpha = 0.05$ similar to results in Mari, et al [14] and Papworth [21].

The emergence force calculated using data from various physical and crop parameters extracted into table 6. The force was lowest in treatment four and increase directly with less tillage. Average values are 10.63kN, 9.22KN, 8.96KN for T1, T2, T3 and T4. Result of the analysis of variance for these is significant at the 95% confidence interval.

A multiple linear regression model was fitted for each of the treatments with emergence Force as the dependent variable and other physical and crop parameter as the independent variable. Such parameters are: Cohesion (C), Angle of a internal frication (θ), Wet

Table 6: Emergence Force Exerted by Seedlings.

Treatment	Wet Density W (g/ cm³)	Angle of Internal Friction (θ°)	Cohesion C (kN/ m²)	Total emergence (No)	Emergence Force. F (kN)
ZT	1.63	16.86	23.31	25.00	10.63
PL	1.44	15.7	21.15	26.00	9.22
PH	1.42	17.36	16.81	24.66	8.96
PHR	1.54	17.36	16.65	24.00	8.85

density (W), Mean weight diameter (D), Root length (RL) and Root number (RN) for each treatment. The models are:

F_1= – 11.98 + 0.05C + 0.25 + 1.39W + 0.62D + 0.15RL + .0016RN…………………(6)
F_2 = – 5.62 + 0.23C – 0.850 + 5.56W + 0.93D + 0.11RL + 0.0015RN……………….(7)
F_3 = 1.90 – 0.019C – 0.0690 – 0.34 + 0.17D – 0.031RL + 0.031RN…………………(8)
F_4 = – 42.82 + 2.21C – 1.520 + 28.05W – 4.22D + 1.14RL – 0.14RN……………….(9)

Result indicated that a good fit exists between the variables. Both the correlation coefficient (R) and the coefficient of determination (R2) are very high for the individual treatment. They are 0.84 for T1 0.83 for T2, 0.88 for T3 and 0.96 for T4. The R are 0.92, 0.91, 0.92 and 0.98 for the same treatments. The standards errors were also low, indicating that there are common factors between the relationships. These results indicate that the independent variables are accurate parameters for the prediction of the emergence force exerted by the maize seedling and vice versa.

CONCLUSION AND RECOMMENDATION

The research gave enough evidence that the soil structural condition as modified during tillage, affected the soil physical properties and seed emergence. The influence of cultivation on the soil temperature, moisture retention is not considerable. But the soil density was significantly altered by the tillage treatments used. These findings, agrees with previous works reported by Chan [4]. No obvious advantage has been found for ridging operation of its use in the study, although there may be advantages in erosion prevention and improvement in water conservation otherwise it might be considered superfluous for cultivation of Maize. The experiments have also shown that intensive cultivation decreases the aggregate stability of the soil tested in the different tillage treatments. This suggests serious harmful consequences to the uncovered soil during the rainy season.

Seed emergence was earlier on the treatments with reduced tillage and no tillage. The emergence force was found to increase directly with soil strength from a minimum value of 8.85 kN in T4 to a maximum of 10.63 kN in T1. This might be responsible for the decrease in stands with less tillage relative to the third and fourth treatments in the study that has been corroborated in reports by Phillips and Phillips [22]. For these reasons, a higher seed rate might be recommended as tillage is reduced to make up for the short fall and to guarantee maximum stands. The number of main roots and the average length of the roots sampled in the experiment were also significantly affected by treatments and both showed the superiority of a single pass disc ploughing operation. The experiment was not able to determine the critical soil strength that might completely hinder the growth of the seedlings. It is difficult to statistically say one tillage technique is the optimum, considering the general influence of all parameters measured but it is recommended that one ploughing is adequate for the growth of maize planted under similar condition of this test. This is adequate to satisfy the demands of the crops, soil conservation and mechanization. From the experiment, the no-till system is not advantageous except there is adequate mulch cover over seedling to improve soil moisture conservation, also a more frequent supply of either organic or inorganic fertilizer might be required to compensate for the inability of the root system to penetrate deeper and denser tilth in search for fresh nutrients. Problem of environmental hazard of herbicides and difficulty in mechanization are also strong points against zero tillage. From the result it is evident that the red uced shear strength and emergence force obtained with more tillage operations was not translated to increase in the crop parameters studied.

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