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Effect of Variation in Tillage Systems on Maize (*Zea mays* L.) Establishment and Grain Yield in a Semi-Arid Tropical Climate

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ABSTRACT

On-farm experiments were designed to investigate the response of maize establishment and grain yield to variation in tillage systems. The tillage treatments included arara ploughing followed by zig-zag harrowing and arara ridging (T1); emcot ploughing followed by zig-zag harrowing and emcot ridging (T2); mouldboard ploughing followed by disc harrowing and mouldboard ridging (T3); disc ploughing followed by disc harrowing and disc ridging (T4); manual ridging (T5). Generally, shallow (0-15.0 cm) tilled plots of T1 showed lower root lengths and root length densities than deep (0.28.0 cm) tilled plots of T4. However, there was higher soil penetration resistance (PR) in T1 than in T4. Increased PR in the range of 4.0 – 4.5 MPa decreased plant height (Hp), leaf area index (LAI), and maize grain yield (Yg). Reductions in Yg in the range of 35 – 50% can be expected for a reduction in soil moisture contents from 24.2 – 15.7%, w/w. Tillage treatment significantly (P<0.01) affected Yg. However, there were no significant differences at P<0.05 in the emergence rate index (ERI), LAI and Yg for the interactions of nitrogen levels × planting methods × tillage treatments.

Keywords: Leaf area index, Soil penetration resistance, Tillage systems.

INTRODUCTION

Maize (*Zea mays* L.) is a major food and cash crop for small-scale farmers in Nigeria. A rapid increase in population in the country and subsequently higher food demands make mechanized agriculture viable. However, the recent increase in the mechanization of agriculture and intensive tillage operations are the main causes of soil compaction in northern Nigeria. The weights of wheeled tractors used vary from 2 to 5 t coupled with various implements for land cultivation.

Previous researchers (Lipiec *et al*., 1991; Oussible *et al*., 1992; Håkansson and Reeder, 1994) reported that the response of soil physical properties to soil compaction is manifested in an increase in bulk density, a decrease in total porosity, air permeability, plant-available water and crop yield. Soil compaction adversely affects soil structure, reduces crop production, increases runoff and erosion, and accelerates potential pollution of surface water by organic wastes and agro-chemicals applied. Therefore, knowledge of soil compaction is increasingly important in agriculture and for environmental protection (Assouline, 2002). Studies have also shown that changes in pore size distribution due to soil compaction resulted in a lower water infiltration rate (Yusuf and Yiljep, 2000; Yusuf, 2001) and slow down the downward growth of roots with restricted root systems to the upper part of the soil profile (Black and Hartge, 1986). Field experiments were conducted by Laboski *et al*. (1998) to determine if soil strength and/or available water could be the factors limiting maize rooting depth on an irrigated fine sandy soil. They found that a compacted soil layer confined roots almost entirely to the top 0.06m of soil because it had high soil

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strength and bulk density; the compacted layer, in turn, retained more water for maize use. Despite the considerable amount of research done elsewhere which shows the negative effects of wheel-induced soil compaction on crop yield (Negi *et al*., 1981; Heberle and Vach, 1992), very limited work has been done to investigate the effect of soil compaction on maize production in Nigeria. Greater knowledge of the effects of various tillage systems on crop establishment and yield is needed to assess the contribution of these tillage systems to sustainable land use and management, soil water and air retention characteristics, water and nutrient use efficiencies and crop production. The purpose of this study was to evaluate the response of maize establishment and yield to the variation in tillage systems.

MATERIALS AND METHODS

The work was established at Samaru ($11^o11'$N, $07^o38'$E and 685m above sea level). The soil (Typic Haplustalf) is free draining with a hydraulic conductivity of 0.8 to 1.5 cm h^{-1} within the cultivated soil layer, low in cation exchange capacity (C.E.C.), organic matter and nitrogen (Heathcote and Stockinger, 1970).

Two methods, manual (P1) and mechanical (P2) were used in planting maize. The planter used for mechanical planting was equipped with a narrow knife opener (14 mm thick) and a coulter disc. Four nitrogen rates: (no nitrogen (N1), 40 kg N ha^{-1} (N2), 80 kg N ha^{-1} (N3) and 120 kg N ha^{-1} (4)), were investigated. The study was laid out as a strip-split plot design (Gomez and Gomez, 1984). Each plot size was 5.0 m long and 4.0 m wide. An area of 0.35 ha was used each year. The treatments were applied to the same plots during the 3-year (1997-1999) on-farm study. Tillage treatments in this study were: arara ploughing followed by zig-zag harrowing and arara ridging (T1); emcot ploughing followed by zig-zag harrowing and emcot ridging (T2); mouldboard ploughing followed by disc harrowing and mouldboard ridging (T3); disc ploughing followed by disc harrowing and disc ridging (T4) and manual ridging (T5).

At the beginning of each year, soil cores were collected randomly with rectangular sampler (70mm x 115mm) from each plot. Soil samples were taken to a depth of 30 cm for determination of soil particle-size analysis which was carried out using the pipette method. Organic matter content was determined by combustion (Gee and Bauder, 1986). Soil moisture content was determined gravimetrically after drying in an oven at 105 ^{o}C for 24 hours. Soil bulk density was determined at sowing using a volume core (15 cores at 50-mm diameter and 30-mm high each) method (Black and Hartge, 1986). Penetration resistance was measured with a cone type ring penetrometer of 12.8-mm cone diameter and 30^o angle of the cone (Anderson *et al*., 1980) at depths of 5-cm increments from the surface down to a depth of 30 cm. Twenty random penetrations were made in each plot and depth. Soil shear strength was also determined at the site with a 33-mm diameter, 50-mm high shear-vane at sowing and emergence of seedlings as described by Ball and O'Sullivan, (1987). The depths to the centre of the vane were 50 mm at sowing and 60 mm an emergence. The germination of seeds and emergence of seedlings were monitored after planting and records were maintained on seedling emergence starting on the day of their initial emergence and continued until full emergence. The time required for the total establishment percentage of seeds sown was noted and emergence rate index (ERI) was calculated as follows (Lõpez and Arrue, 1997):

$$ERI=\sum_{i=1}^{n}\frac{(d_i\,p_i)}{p} \qquad (1$$

Where d_i is the number of days after sowing, p_i is the number of plants emerged from the last counting of emerged plants.

Five 10-cm diameter core samples were obtained from planted plots to a soil depth of 50-cm. Each of the core samples was cut into sections and air dried. The total length of roots was measured (Newman, 1966).

Root samples were taken with auger when the crop was fully developed. Root length density (RLD) was calculated by multiplying root length by the average bulk density of each depth (Meterechera and Mloza-Banda, 1997). Plant height was measured 60 days after planting and leaf area duration (LAD) of the plant was obtained as:

$$LAD = \int_{t1}^{t2} Adt \quad (2$$

Where:

A is the leaf area over a time period from t_1 to t_2. Leaf area was determined daily on the field with a planimeter (Li-Cor Model 3100) throughout the period t_1 to t_2. In each year of this study (1997-1999), t_1 and t_2 are 60 and 90 days after planting, respectively. The mean leaf area (Ã) over the time period t_1 to t_2 was calculated as:

$$\tilde{A} = \frac{1}{t_2 - t_1} \int_{t1}^{t2} Adt \quad (3$$

From equations 2 and 3, the leaf area index (LAI) was determined on the field as (Watson, 1952):

$$LAI = \frac{\text{Total leaf area}}{\text{Total land area}} \quad (4$$

Pest and weed controls were performed according to general local practices and recommendations. To compare the effects of variation in tillage systems within each cropping season, analysis of variance (ANOVA) was used. Differences among the treatments and their interactions were tested with an orthogonal contrast test to assess their significance (SAS, 1985).

RESULTS AND DISCUSSION

Cropping season precipitation from May to August of 1024 mm per annum was near the 20-year (long-term) average of 1014 mm at Samaru. Although the total precipitation was similar in the three cropping seasons, its distribution varied widely. The poor rainfall distribution in 1997, particularly from May to July, stressed the crop during seedling emergence and grain fill. Much of the rainfall (41%) occurred late in August, 1997. In contrast, rainfall was evenly distributed in 1998 and 1999. The mean monthly temperature of 29.5 ^oC didn't vary much from the 20-year (long-term) average of 29.7 ^oC.

The soil of the experimental site was coarse-textured with a low fertility status. Results of particle size analysis of the soil are shown in Table 1. The organic matter content of the soil varied from 1.1 to 2.4% while the field capacity varied from 25.0 to 28.4 $cm^3\ cm^{-3}$. The highest organic matter content of 2.4% was obtained on the plots that were not well drained. An increase in soil moisture content resulted in a reduction of soil stability because of low quantities of clay and organic matter. The minimum

Table 1. Some soil properties (0-30cm depth) across the field at Samaru, Nigeria.

Property	N [b]	Mean	Minimum	Maximum
Particle size analysis:				
Sand (%, w/w)	15	67	65	70
Silt (%, w/w)	15	15	14	17
Clay (%, w/w)	15	18	16	19
Other characteristics:				
Organic matter (%)	15	1.9	1.1	2.4
Porosity (%)	15	29.4	28.7	30.1
Bulk density (g cm^{-3})	15	1.5	1.4	1.6
Field capacity ($cm^3\ cm^{-3}$)	15	26.8	25.0	28.4
Atterberg limits (g per 100g) [a]				
Plastic limit	15	23	18	25
Liquid limit	15	36	30	40
Plastic index	15	13	12	15

[a] (British Standard 1377, 1975).
[b] Number of spots randomly sampled.

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moisture content at which the soil will flow under its own weight (liquid limit) ranged between 30 and 40 g/100g. The minimum moisture content at which the soil may be rolled into a thread 3 mm in diameter without breaking up (plastic limit) ranged between 18 to 25 g/100g. The soil can be described as having a low to intermediate plasticity.

The distribution of crop roots in the soil profile of the five tillage treatments are shown in Table 2. Although few roots of the crop were observed to have penetrated beyond 30 cm, most roots resided above the 30 cm soil depth. The longer the root length, the more the root length density. Root length of 24.0 cm produced the root length density of 0.4cm cm^{-3} under T1 treatment while root length of 40.0 cm produced the root length density of 0.9 cm cm^{-3} under T4 treatment in 1997. Shallow (0-15.0 cm) tilled plots of T1 showed low root length and root length density as compared with deep (0-28.0 cm) tilled plots of T4 (Table 2). These results emphasise the importance of deep tillage in seedbed preparation for maize production. There was higher soil penetration resistance in shallow (0-15.0 cm) tilled plots of T1 which restricted root growth further than in deep (0-28.0 cm) tilled plots of T4. The tillage depths of 18 cm in T2, 26 cm in T3 and 25 cm in T5 resulted into root length densities of 0.5, 0.7 and 0.6 cm cm^{-3}, respectively, in 1997 (Table 2). Similar results were obtained in 1998 and 1999. However, tillage treatments did not significantly ($P<0.05$) influence the root length densities during the three years of the study. An increase in soil

Table 2. Tillage depth, root length and root length density as affected by tillage treatment at Samaru, Nigeria.

Cropping season	Tillage treatment	Root depth (cm)	Root length (cm)	Root length density (cm cm^{-3})
1997	T1	15±3	24±1	0.4±0.03
	T2	18±3	30±3	0.5±0.01
	T3	26±2	37±4	0.7±0.01
	T4	27±4	40±5	0.9±0.01
	T5	25±2	45±2	0.6±0.02
	LSD (0.05)[a]	*	**	ns
	CV (%)	3.7	5.1	0.05
1998	T1	15±2	25±3	0.4±0.02
	T2	18±2	28±2	0.4±0.02
	T3	26±4	35±2	0.6±0.01
	T4	28±3	41±1	0.8±0.01
	T5	24±1	37±1	0.6±0.01
	LSD (0.05)	*	*	ns
	CV (%)	3.1	6.8	0.07
1999	T1	16±1	26±3	0.4±0.02
	T2	19±1	28±2	0.5±0.03
	T3	25±2	34±2	0.6±0.03
	T4	28±1	43±3	0.8±0.01
	T5	25±2	40±2	0.5±0.01
	LSD (0.05)	*	*	ns
	CV (%)	4.4	4.9	0.08

[a] ns: Not significant, * and ** significantly different at $P<0.05$ and 0.01, respectively. Values are means of fifteen replicates ± standard deviation and CV represents coefficients of variation. T1 = arara ploughing followed by zig-zag harrowing and arara ridging, T2 = emcot ploughing followed by zig-zag harrowing and emcot ridging, T3 = mouldboard ploughing followed by disc harrowing and mouldboard ridging, T4 = disc ploughing followed by disc harrowing and disc ridging; T5 = manual ridging.

penetration resistance resulted in a decrease in plant height, leaf area index and maize grain yield (Table 3) during the three years of the study. This result is consistent with the findings of Campbell *et al*. (1986) and Dickson *et al*. (1992) who found that high soil compaction decreased crop yield. Reduction in soil moisture content of 15.7%, w/w in 1997 to 14.8%, w/w in 1999 increased penetration resistance from 4.3 MPa to 4.5 MPa under T1 treatment. Increased penetration resistance from 3.1 MPa in T5 to 4.3 MPa in T1 reduced soil moisture, sowing depth, plant height, leaf area index and crop yield from 19.4%, w/w to 15.7%, w/w, 2.3 cm to 2.0 cm, 167 cm to 152 cm, 4.2 to 3.1 and 3.4 t ha^{-1} to 2.5 t ha^{-1}, respectively in 1997 (Table 3). Thus, at a shallower tillage depth (15.0 cm) under T1 treatment, the lower soil moisture of 15.7%, w/w could be expected than in T4 treatment with tillage depth of 27.0 cm and soil moisture content of 24.2%, w/w. Total maize grain yield reduction in the vicinity of 35 to 50% was caused by a reduction in soil moisture contents from 15.7 to 24.2%, w/w. Increased soil moisture content from 15.7 to 24.2%, w/w enhanced plant height, leaf area index and maize grain yield. Similar results were obtained in 1998 and 1999.

Tillage treatment of T4 provided adequate seed soil contact which, according to Singh *et al*. (1985) and Rainbow (1994), is a prerequisite for rapid seedling emergence and good crop stand establishment as it provides a route through which soil moisture can enter a seed. There were consistent trends in maize grain yield with regards to tillage treatments. The highest maize grain of 5.4 t ha^{-1} was obtained in 1998 under T4 treatments, while the lowest maize grain yield of 2.4 t ha^{-1} was obtained under T1 treatment in 1997. Tillage effects on maize grain yield from 1997 to 1999 were in the order of T4>T3>T2>T5>T1.

Table 3. Tillage treatment effects on maize performance at Samaru, Nigeria.

Cropping season	Variable [b]							
	Tillage treatment	PR (MPa)	SM (%,w/w)	BD (Mgm^{-3})	Sd (cm)	Hp (cm)	LAI	Yg (t ha^{-1})
	T1	4.3	15.7	1.7	2.0	152	3.1	2.5
	T2	4.0	16.0	1.5	2.2	160	4.0	3.6
	T3	2.8	22.0	1.4	2.1	173	4.0	4.8
1997	T4	2.0	24.2	1.5	2.4	166	5.3	5.2
	T5	3.1	19.4	1.6	2.3	167	4.2	3.4
	LSD (0.05)[a]	*	*	ns	ns	*	**	**
	T1	4.2	15.1	1.5	2.1	160	3.0	2.6
	T2	4.1	17.3	1.6	2.2	161	4.5	3.7
	T3	2.5	21.2	1.3	2.4	170	5.0	4.7
1998	T4	2.3	23.7	1.4	2.4	172	5.2	5.4
	T5	3.4	20.0	1.7	2.3	164	3.0	3.4
	LSD (0.05)	*	*	ns	ns	*	**	**
	T1	4.5	14.8	1.5	2.0	164	3.3	3.2
	T2	4.5	18.1	1.5	2.2	169	4.5	3.9
	T3	2.2	20.7	1.4	2.4	174	4.8	4.9
1999	T4	2.0	24.1	1.5	2.3	175	5.0	5.3
	T5	3.0	19.0	1.3	2.3	168	3.7	3.5
	LSD (0.05)	*	*	ns	ns	*	**	**

[a] ns:Not significant, * and ** significantly different at $P<0.05$ and 0.01, respectively.

[b] PR, penetration resistance; SM, Soil moisture content; BD, soil bulk density; Sd, sowing depth; Hp, plant height; LAI leaf area index; Yg, maize grain yield. Values are means of fifteen replicates ± standard deviation and CV represents coefficients of variation. T1 = arara ploughing followed by zig-zag harrowing and arara ridging, T2 = emcot ploughing followed by zig-zag harrowing and emcot ridging, T3 = mouldboard ploughing followed by disc harrowing and mouldboard ridging, T4 = disc ploughing followed by disc harrowing and disc ridging; T5 = manual ridging.

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Tillage treatment significantly (P<0.01) affected the soil shear strength, emergence rate index, leaf area index and maize grain yield (Table 4). However, the interactive effects of nitrogen level × tillage treatment × planting method had no significant effect on the emergence rate index, leaf area index and maize grain yield. In the 3-year study, there were no significant differences at P<0.05 in emergence rate index and leaf area index for the different nitrogen levels tested. Tillage systems of T3 and T4 and ridge tillage (T5) to 25- 28 cm tillage depth (Table 2) resulted in greater plant height, leaf area index and maize grain yield (Table 3) than the tillage systems of T1 and T2. The depth of water penetration and wetter soil, both in the top soil and subsoil of T3, T4 and T5, resulted in more intensive root length density (Table 2). Soil moisture and nutrient transmission and storage pores created by tillage systems (T3, T4 and T5) in the soil type (Typic Haplustalf) investigated might be more stable with enhanced soil structure than in other tillage systems (T1 and T2) and, hence, facilitated deeper root systems and greater root length density. Significant yield differences between the years, planting methods and tillage systems (Table 4) occurred with maize grain yields from T3 and T4 outyielding T1 and T2 in Typic Haplustalf. However, there was little yield difference between T2 and T5 (Table 3) throughout the 3-year study because of close tillage and seeding depths (Tables 2 and 3). The greater depth of soil moisture penetration associated with deep tillage may be of significance in that it represents a very active storage pool of the nitrogen fertilizer applied. The nutrient (nitrogen) becomes available for plant uptake, growth and grain yield. Low depths of tillage and low nitrogen rates resulted in lower crop yields than equivalent rates applied to deep tilled plots. When nitrogen

Table 4. Combined analysis of variance of tillage effect on maize grain yield at Samaru, Nigeria.

Source of variation	Df	Variable[b]				
		SS	SS	ERI	LAI	Yg
		At sowing	At emergence			
		Mean squares and significant of F [a]				
Replication	3	246.662	242.043	69.621	265.871	10.942
Years (Y)	2	6.804*	22.135**	1.168ns	0.558ns	14.637**
Reps (R)	6	23.034	93.672	4.636	0.789	1.376
Nitrogen (N)	3	64.040**	2.185ns	0.810ns	2.421ns	0.256ns
Y × N	6	8.962**	1.449ns	0.081ns	0.105ns	0.031ns
Reps (Y × N)	27	5.961	0.919	0.140	0.121	0.017
Tillage (T)	4	5870.479**	4242.799**	37.583**	25.483**	37.038**
N × T	12	26.709**	1.823*	0.082ns	0.038ns	0.009ns
Y × T	8	12.509**	57.631**	1.829ns	0.158ns	1.201ns
Y × N × T	24	5.786**	0.688ns	0.067ns	0.033ns	0.193ns
Reps (Y × N × T)	144	8.867	8.347	0.595	0.209	0.249
Planting (P)	1	59.925**	12.578**	40.542**	13.872**	9.344**
N × P	3	5.971**	1.412ns	0.146ns	0.040ns	0.024ns
T × P	4	24.347**	1.492ns	1.056ns	0.080ns	0.129ns
Y × P	2	16.047**	0.186ns	13.238**	0.137ns	1.274ns
N × T × P	12	1.662ns	1.237ns	0.100ns	0.031ns	0.021ns
Y × T × P	8	3.648**	0.465ns	0.351ns	0.032ns	0.598ns
Y ×N × T × P	30	1.312ns	0.910ns	0.111ns	0.023ns	0.020ns
Error	180	5.692	0.910	0.215	0.044	0.137
Total	479					

[a] *,** significantly different at P<0.05 and 0.01, respectively; ns : Not significant.
[b] SS, soil shear strength; ERI, emergence rate index; LAI, leaf area index; Yg, maize grain yield.

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availability in the soil is low, the microbial biomass out competes the crop for the nitrogen and yields are reduced (Rice and Smith, 1983). Furthermore, the tendency for nitrogen fertilizer to accumulate at the soil surface and the buildup of nitrogen in shallow tilled soils is high indicating a decrease in the availability of organic nitrogen to micro organisms with soil depth.

CONCLUSIONS

The trends observed during the three years of this study showed that adverse conditions during seedling emergence and grain fill affected the maize grain yield (Yg). Also, soil moisture content and sowing depth influenced the emergence rate index (ERI), leaf area index (LAI) and early plant growth. Total Yg reduction in the range of 39.0-50.0% can be expected in the soil moisture content reduction from 24.2–15.7%, w/w. A penetration resistance (PR) of 4.0 - 4.5 MPa reduced maize yield because of restriction of rooting depth and water supply while a PR of 2.0-3.4 MPa enhanced maize grain yield. Deep (0-28.0 cm) tilled plots showed higher root lengths and root length densities than shallow (0-15.0 cm) tilled plots. Tillage treatment significantly ($P<0.01$) affected the ERL, LAI and Yg in the order of T4>T3>T2>T5>T1. The depth of water penetration, the wetter soil, both in the top soil and sub soil of T3, T4, and T5 resulted into a deeper root length, more intensive root length density and the nutrient (nitrogen) becomes more available for plant uptake, growth and grain yield. Use of T4 is a good option for the enhancement of ERI, LAI and Yg by reducing excessive soil compaction, providing adequate seed-soil contact and soil moisture availability.

REFERENCES

1. Anderson, G., Pidgeon, J.G., Spencer, H.B. and Parks, R. 1980. A New Hand-held Recording Penetrometer for Soil Studies. *J. Soil Sci*., **31:** 279-296.
2. Assouline, S. 2002. Modelling Soil Compaction under Uniaxial Compression. *Soil Sci. Soc. Am. J*., **66:** 1784-1787.
3. Ball, B.C. and O'Sullivan, M.F. 1987. Cultivation and Nitrogen Requirements for Drilled and Broadcast Winter Barley on a Surface Water Gley (Gleysol). *Soil Tillage Res.*, **9:**103-122.
4. Black, G.R. and Hartge, K.K. 1986. Bulk Density. In: "*Methods of soil analysis. Part 1.*" (Ed.) Klute, A. Agronomy Monographs No. 9, 2nd edition, American Society of Agronomy and Soil Society, Madison, WI, PP. 463-478.
5. Bristish Standard 1377. 1975. *Methods of Testing Soils for Civil Engineering*. British Standards Institution, London. 134 pp.
6. Campbell, D.J., Dickson, J.W., Bell, B.C. and Hunter, R. 1986. Controlled Seedbed Traffic after Ploughing or Direct Drilling under Winter Barley in Scotland, 1982-1984. *Soil Till. Res*., **8:**3-28.
7. Dickson, J.W., Campbell, D.J. and Ritchie, R.M. 1992. Zero and Conventional Traffic Systems for Potato in Scotland, 1987-1989. *Soil Till. Res*., **24:**397-419.
8. Gee, G.W. and Bauder, J.W. 1986. Particle-size Analysis. In: "*Methods of soil analysis: Part 1. Physical and Mineralogical Methods*" (Ed.) Kline, A. Agronomy 9. American Society of Agronomy and Soil Society, W.I., pp. 383-411.
9. Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. 2nd edition. John Wiley and Sons, New York, pp. 154-167.
10. Håkansson, I. and Reeder, R.C. 1994. Subsoil Compaction by Vehicles with High Axle Load-extent Persistence and Crop Response. *Soil Till. Res*., **29:**277-304.
11. Heathcote, R.G. and Stockinger, K.R. 1970. Soil Fertility under Continuous Cultivation in Northern Nigeria. II. Response to Fertilizers in the Absence of Organic Manures. *Expl. Agric*., **6:** 345-350.
12. Heberle, J. and Vach, M. 1992. Effect of Soil Compaction and Nitrogen Fertilization on the Productivity of Spring Barley and Oats. *Fragmenta Agron*., **1:**102-115.
13. Laboski, C.A.M., Dowdy, R.H., Allmaras, R.R. and Lamb, J.A. 1998. Soil Strength and Water Content Influences in Maize Root Distribution in a Sandy Soil. *Plant and Soil*, **203:**239-247.

14. Lipiec, J., Håkansson, I., Tarkiewicz, S. and Kossowski, J. 1991. Soil Physical Properties and Growth of Spring Barley Related to the Degree of Compactness of Two Soils. *Soil Till. Res*. **19:**307-317.
15. Lõpez, M.V. and Arrue, J.L. 1997. Growth, Yield and Water Use Efficiency of Winter Barley in Response to Conservation Tillage in a Semi-arid Region of Spain., *Soil Till. Res*., **44:** 35-54.
16. Meterechera, S.A. and Mloza-Banda, H.R. 1997. Soil Penetration Resistance, Root Growth and Yield of Maize as Influenced by Tillage System on Ridges in Malaysia. *Soil Till. Res*., **41:**13-23.
17. Newman, E.I. 1966. A method of Estimating the Rotal Root Length of Root in a Sample. *J. Appl. Ecol*. **3:** 139-145.
18. Negi, S., McKyes, E., Raghavan, V.G. and Taylor, F. 1981. Relationships of Field Traffic and Tillage to Corn Yields and Soil Properties. *J. Terramech*., **18:**81-90.
19. Oussible, M., Crookston, R.K. and Larson, W.E. 1992. Subsurface Compaction Reduces the Root and Shoot Growth and Grain Yield of Wheat. *Agron. J*. **84:**34-38.
20. Rainbow, R. 1994. Presswheels Improve Production. *Farm Ahead*, **8:**41-44.
21. Rice, C.W. and Smith, M.S. 1983. Nitrification of Fertilizer and Mineralized Ammonium in No-till and Ploughed Soil. *Soil Sci. Soc. Am. J*. **44:** 1125-1129.
22. Singh, N.T., Aggarwal, G.C. and Woodhead, T. 1985. Physical Aspects of the Root and Seed-environment in Lowland Soils. In: "*Soil Physics and Rice*." International Rice Research Institute, Los Banos, Phillippines, pp. 367-382.
23. SAS Institute Inc., 1985. *SAS Users Institute Inc*. Cary, NC, PP. 433-506.
24. Watson, D.J. 1952. The Physiological Basis of Variation in Yield. *Adv. Agron*., **41:**101-145.
25. Yusuf, D.D. 2001. Deep Ploughing Effects on Irrigation Intake, Bulk Density and Soil Compaction on a Slowly Permeable Soil in Northern Nigeria. *Nigerian J. Eng*., 19(1):22-26.
26. Yusuf, D.D. and Yiljep, Y.D. 2000. Appropriate Multi-purpose Tillage Machinery for Cereal Crop Production in a Sub-Saharan Africa. *Savanna J. Agr. Mechanization*, **2(1):** 49-51.

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اثرسیستمهای مختلف خاک ورزی بر رشد و میزان محصول ذرت در اقلیم حاره‌ای نیمه خشک

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چکیده

آزمایشات مزرعه‌ای برای بررسی اثر سیستمهای مختلف خاکورزی بر رشد و میزان محصول ذرت طراحی گردید. تیمارهای خاک ورزی شامل شخم آرارا قبل ازچنگک زیگزاگ و نواری (تیمار اول)، شخم امکات قبل از چنگک زیگزاگ و امکات نواری (تیمار دوم)، شخم باخیش قبل ازچنگک بادیسک و شخم با خیش نواری (تیمار سوم)، شخم با دیسک قبل از چنگک با دیسک و دیسک نواری (تیمار چهارم)، شخم نواری دستی (تیمار پنجم) بودند. به طور کلی، در کرتهای با شخم سطحی (صفر تا ۱۵ سانتی متر) از تیمار اول، طول ریشه و دانسیته طول ریشه در مقایسه با کرتهای با شخم عمیق تر (صفر تا ۲۸

سانتی متر) ازتیمار چهارم کمتر بود. در هر صورت، مقاومت به نفوذ بیشتری در تیمار اول در مقایسه با تیمار چهارم وجود داشت. افزایش مقاومت خاک در محدوده ۴ تا ۴/۵ مگاپاسکال سبب کاهش ارتفاع گیاه، کاهش شاخص سطح برگ و کاهش میزان محصول ذرت گردید. علت کاهش میزان محصول به میزان ۳۵ تا ۵۰ درصد می تواند به علت کاهش میزان رطوبت از ۲۴/۲ به ۱۵/۷ درصد وزنی باشد. تیمار خاکورزی به صورت معنی داری (P<0.01) بر میزان محصول موثر بود. در هر صورت، تفاوت معنی داری در سطح ۵ درصد در اثرات متقابل سطوح نیتروژن، روشهای کشت و تیمارهای خاکورزی بر نسبت جوانه زنی، شاخص سطح برگ و میزان محصول در وجود نداشت.

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