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Effect of Soil Tillage and Maize-grass Intercropping Followed by Grass Management on Soil Properties and Yield of Rainfed Maize

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ABSTRACT

This study was conducted in Indonesia during dry season to determine the effect of preceding tillage and maize-grass intercropping in the preceding wet season followed by the management of grasses in the succeeding dry season on soil properties and yield of rainfed maize. During the preceding wet season, maize was intercropped with clump grass, lemon grass and elephant grass under three tillage methods (conventional tillage, deep tillage & no tillage). During dry season, grass rows were slashed in one half of killed in the other half and plots occupied by preceding sole maize combined with conventional tillage as a control. Maize was grown alone with the recommended population. Soil properties, growth and yield of maize were recorded. Soil bulk density and organic C were lowest in control, while soil porosity was opposite. Preceding plots occupied by maize intercropped with either clump grass (4.66 kg plot^{-1}), elephant grass (5.96 kg plot^{-1}) or lemon grass (6.26 kg plot^{-1}) grown under conventional tillage and killing grasses at land preparation gave a significantly higher yield than control (4.91 kg plot^{-1}). Deep tillage also gave similar yield increases, but required special machinery for land preparation.

Key Words: Tillage; Maize-grass intercropping; Grass management; Soil properties; Rainfed maize yield

INTRODUCTION

In Lampung province, Sumatra Island, Indonesia, maize is grown through out the year and the production is heavily dependent upon the water availability during the growing period. During the wet season, rainfall is well distributed and mean grain yield is about 3 t/ha, while during the dry season, yields is drastically reduced with an average yield of 1 t/ha (Swastika *et al.,* 2004). Soil moisture deficit resulted from very low occasional rainfall and poor distribution has been recognized as the main cause of yield reduction in this province (Maamun *et al.,* 1999; Swastika *et al*., 2004). Maize is extremely sensitive to soil moisture deficit (Roygard *et al.,* 2002; Kefale & Ranamukhaarachchi, 2004) and thus reducing grain yield under water stress.

Lack of rainfall and inaccessibility to water during critical growth periods affect growth and development and grain yield of maize (Verplance *et al.,* 1988). Chopart and Vauclin (1990) reported that crop yield estimates are mainly correlated with soil moisture. Begg and Turner (1976) reported that the grain yield of maize depended upon growth stage, deficiency level and environmental changes during drought. Even a minor drought stress during specific physiological stages can substantially reduce maize yields (Boyer & McPerson, 1975; Begg & Turner, 1976; McWilliams, 2003). McWilliams (2003) observed that four days of visible wilting just before tasseling reduced maize yield by 10 - 25% and four days of visible wilting between the boot stage (only a week prior to tasseling) and the milk stage reduced yield by 50%. During reproductive stages, maize yield losses occur due to drought and its effects decrease towards physiological maturity (McWilliams, 2003; Kefale & Ranamukhaarachchi, 2004), which shows the extent of vulnerability of maize to drought (NeSmith & Ritchie, 1992; Roygard *et al.,* 2002).

There has been an introduction of conservation farming and tillage methods for alleviating moisture stress, yet low yields continue to appear in the dry season (Njihia, 1988; Scopel *et al*., 2000). Several water conservation methods for preventing evaporation from soil surface have been reported: mulching (Unger & Parker, 1976; Verplance *et al.,* 1988; Steiner, 1989), deep tillage (FAO, 1987), use of different tillage methods at different dates of initial seedbed preparation (Njihia, 1988), different tillage practices and types of mulch (Iqbal, 1998), combination of mulching, deep tillage, counter farming and ridging (Habitu & Mahoo, 2002), no tillage (Soza *et al.,* 2000) and both minimum tillage and no tillage in combination with mulch (Rosegrant *et al*., 2002). Furthermore, timing and duration of cropping season can greatly influence soil water storage (Sinclair, 1988; Unger *et al.,* 1998; Allmaras *et al.,* 1998).

However, suitable management, crop selection and sequencing are important needs for increasing crop yield through efficient use of water (El Mejahed, 1998; Rusan, 1998) and soil productivity (Rusan, 1998). Many researchers have reported that methods could increase soil moisture availability for next season to be explored (Bouwer, 1988; Unger & Howell, 1999; Acquaah, 2002) and integrated for increasing and sustaining maize yield in dry land conditions (Maraux, 1998).

An alternative strategy to develop deep soil layer by growing selected deep rooted grasses capable of producing high root biomass was tested in the wet season, assuming these roots improve physical properties thus enhancing hydraulic properties and moisture retention (Ahadiyat & Ranamukhaarachchi, 2007). This was due to the fact that grasses are known to produce deep roots and heavy root biomass (Prihar *et al.,* 2000). Therefore, the study was conducted with the objectives to quantify the effect of preceding tillage and cropping pattern to compare the effect of the management of intercropped grasses of the preceding and to evaluate the impact of these methods on soil properties, growth and yield of rainfed maize yield in the succeeding dry season.

MATERIALS AND METHODS

This study was conducted in Metro Kibang sub-district of Lampung province, Indonesia, in the dry season from May–August 2006, which is mainly occupied by rainfed maize-maize cropping pattern. The topography of the study area is flat with an approximate slope of 0 - 5%. The latitude, longitude and altitude of this site are 5^0 11'S, 105^0 18'E and 83 m above sea level (MASL), respectively. The soil texture is sandy clay loam with friable consistency and pH of 5.17.

In the preceding wet season, factorial combinations of three tillage methods as main plot [viz. no tillage, conventional tillage (20 cm depth) and deep tillage (30 cm depth)] and four cropping patterns [viz. sole maize (Hybrid BISI-9), maize + lemon grass (*Cymbopogon citratus* (D.C.) Stapf), maize + clump grass (*Vetiveria zizanioides* (L.) Nash) and maize + elephant grass (*Pennisetum purpureum* Schum)] as sub plot were used in a split plot design with three replicates. In the succeeding dry season, management of grass rows (grasses were slashed & killed with glyphosate) as sub sub-plot were imposed on each subplot. There were 18 treatment combinations and one control (sole maize grown under conventional tillage as per farmers practice). Effective plot size was 3 m x 7.5 m (22.5 m^2) in each sub sub-plot.

In the preceding wet season, land was plowed once, harrowed twice, levelled and ridges were prepared using a tractor with disk plow in plots of both conventional and deep tillage. Ridge and furrow method with ridges of 15 cm high and with the distance of 75 cm was used for both conventional and deep tillage plots. In no-tillage plots, glyphosate [36% N-(phosphonomethyl) glycine] was applied at the rate of 480 a.i., g/L to destroy weeds. In the succeeding dry season, plots were manually plowed using a hoe to adequately incorporate grasses and ridges and furrows were restored as had in the wet season. Grasses in a half of the plots were killed and slashed in the other half, on a random basis. Three maize seeds were dibbled on ridges in each planting hill with an intra-row spacing of 25 cm. Excess seedlings were thinned out to one plant per hill at 2 weeks after emergence and maintained the same plant population.

Each plot was given N, P and K at the rate of 65, 28 and 14 kg/ha, respectively using urea (46% N), triple super phosphate (19.8% P) and muriate of potash (50% K), respectively as a basal dressing, seven days after sowing. At second top dressing 65 kg/ha of urea was applied 6 weeks after sowing. There were no pest and diseases observed during growing period. Weeds were manually controlled every 3 weeks until silking.

At the end harvesting, soil samples were taken from selected furrows in each plot to a depth of 0 - 30, 30 - 70 and 70 - 100 cm using an open-end soil probe. Soil pH of these samples was determined by Electrometric method using soil to water ratio of 1:2.5 and pH meter (Model EIL 7045/46 of Kent Scientific, USA). Soil organic carbon (SOC) content was determined the upper of 30 cm soil profile using Walkely and Black method (Nelson & Sommers, 1982). For bulk density, soil samples were taken using a core sampler at 0 - 30, 30 - 70 and 70 - 100 cm depths and oven dried at 105^oC for a period of 24 - 48 h until two consecutive weight readings remained unchanged and soil bulk density was computed (Blake & Hartge, 1986). Soil porosity (E) was computed by $E = 1- (\rho_b/\rho_p)$, where ρ_b is the bulk density of soils and ρ_p is the particle density (Lal & Shukla, 2004).

Plant height, leaf area, root dry weight, root length, vertical and lateral root distance, above ground dry matter and yield components of maize were recorded from 4 consecutive maize plants in a randomly selected single row located in the middle. Plant height was measured at tasseling stage from the ground level up to the collar of the flag leaf (Flint-Garcia *et al*., 2003). Leaf area was estimated by using leaf length and breadth (McKee, 1964) at tasseling stage and leaf area index (LAI) was computed (Watson, 1947).

Root samples were taken at harvest. Vertical and lateral root distance was recorded from one randomly selected plant in each plot and by digging a trench around the selected plant. The plant was then uprooted, soils washed out and roots separated. The roots were first air dried and later oven-dried at 80^0C and dry weight was recorded when consecutive weight reading taken at six hourly intervals remained unchanged. Root length was determined using root intersection method (Bohm, 1979).

At harvest, grain yield and yield components (Laffite, 1994) i.e., number of kernels per ear and 100-kernel weight were recorded. Total kernel weight per plot was converted to yield per hectare at 15% moisture content. Above ground dry matter was determined (Lorens *et al*., 1987) and harvest index computed (Black & Watson, 1960).

Analysis of Variance procedure was adopted for all the data (Steel & Torrie, 1980). Tillage method, intercropping pattern and grass management were analyzed and interaction effects were compared using Fisher's Protected LSD method.

RESULTS

In the presentation of results tillage and cropping pattern referred to the treatments adopted in the preceding wet season, while grass management refers to the management of grass rows of the intercrops by killing or slashing adopted at land preparation in the beginning of the dry season for growing maize as a sole crop.

Weather conditions. The dry season received an average of 98 mm/month. Rainfall intensity was higher during mid May – mid June than other months and there was zero mm in mid June to mid July and in late July to mid August (harvest time). Relative humidity and temperature minimum and maximum ranged from 60 - 70%, 16 - 20^{0}C and 30 - 33^{0}C, respectively. These data confirmed that water deficit and unfavorable conditions were prevalent during the dry season.

Soil Parameters

Soil pH. Soil pH in the experimental site was 5.17 and 5.16 at 0 - 30 and 30 - 70 cm profiles, respectively and hence the soils were slightly acidic (Landon, 1991). However, there was no liming applied as many farmers in the area confirmed that yield increases resulting from liming were inadequate to compensate for the cost of liming. Therefore, crop productivity under inherent conditions was assessed.

Organic C. The soil organic C was 0.77% in the preceding control plots. Organic C content increased, which ranged from 0.90 % in maize + elephant grass to 2.02% in maize + lemon grass under conventionally tilled plots followed by killing grasses, which were significantly different. Meanwhile, in all grass slashed plots organic C content ranged from 1.07% in maize + elephant grass under conventional tillage to 2.48% in maize + elephant grass under deep tillage, Slashing significantly increased organic C in soils due to continued root biomass compared to killing (Fig. 1).

Bulk density. The cropping patterns and tillage methods in the preceding wet season as well as grass management at land preparation for control in the succeeding dry season had no significant effect on bulk density at 0 - 30 cm and 70 - 100 cm soil profiles, but in the profile 30 - 70 cm, control plots (1.52 g/cm^3) had a significantly lower bulk density than maize + elephant grass cropping pattern (1.71 g/cm^3). Among the three intercrops, maize + lemon grass had the lowest bulk density (1.59 g/cm^3), which was non-significantly higher than maize + clump grass intercropping (1.66 g/cm^3). Maize + elephant grass intercrop had the highest bulk density (1.71 g/cm^3) and it was significantly greater than the other two cropping patterns. However, bulk density increased towards 70 - 100 cm depth (Fig. 2).

Porosity. Soil porosity was not significantly different among the treatments in the 0 - 30 cm and 70 - 100 cm profiles compared to control plots. Similar to bulk density, there was a significant interaction between tillage methods and cropping pattern for soil porosity, which significantly increased in maize + clump grass and maize + lemon grass intercropped plots compared to maize + elephant grass plots. In the 0 - 30 cm layer, the soil porosity ranged from 38.1% to 39.4% (Fig. 3).

Soil moisture. The soil moisture content (SMC) varied due to experimental treatments. At tasseling, there was a significant interaction between cropping pattern and grass management for SMC at 30 - 70 cm depth (Fig. 4). Control plots had the lower SMC than maize grass intercrops followed by managing grasses except in maize + elephant grass followed by slashing, while maize + clump grass grown plots followed by both killing and slashing grasses and maize + elephant grass plots followed by killing grasses had significantly greater SMC. At 3 weeks after silking (WAS), a similar interaction was observed for SMC at 70 - 100 cm profile. Significantly highest SMC were observed in maize + lemon grass intercropped plots followed by killing and slashing grasses and in maize + elephant grass followed by slashing, but others remained insignificant (Fig. 5). At harvest, a three way interaction was found for SMC at 30 - 70 cm depth. In general, SMC was greater when the grasses were killed than slashed. Maize + elephant grass intercrop grown with deep tillage followed by killing grasses had the highest SMC (Fig. 6). However, maize + clump grass in all tillage methods and maize + lemon grass under conventional and deep tillage followed by slashing and killing grasses, respectively had higher SMC compared to control. At 70 - 100 cm soil profile, there was a greater SMC in deep tillage combined with killing grasses at harvest (Fig. 7).

Root systems. There were significant interactions among tillage and cropping pattern in the preceding season followed by grass management on lateral and vertical root distance, total root length and root dry weight.

Lateral root distance. Lateral root distance was highest in plots occupied by maize + clump grass (26.6 cm) with no tillage followed by killing grasses and maize + lemon grass with deep tillage followed by slashing grasses had the second highest (24.6 cm) (Table I). There was a reduction in lateral root distance with deep tillage and conventional tillage compared to no tilled plots. In general, maize had a higher lateral root distance when grass rows were killed than slashed, except in the deep tilled plots.

Vertical root distance. Vertical root distance was greater in all three intercrops in conventional tillage than sole maize except in maize + lemon grass followed by killing grasses (Table I). In other tillage and grass management methods, the vertical root distance remained unchanged or decreased compared to control. Vertical root distance significantly increased with slashing than killing in all intercrops.

Fig. 1. Organic C as influenced by preceding cropping patterns and tillage methods followed by grass row management

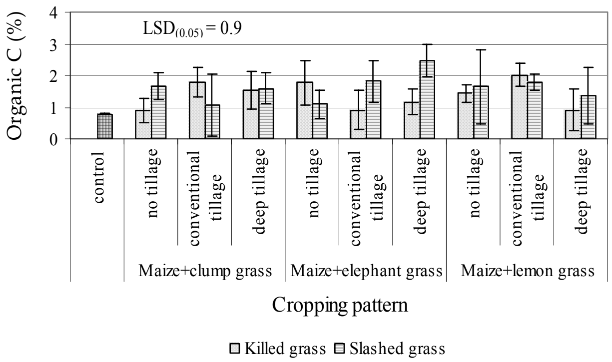


Fig. 2. Bulk density as influenced by preceding cropping patterns

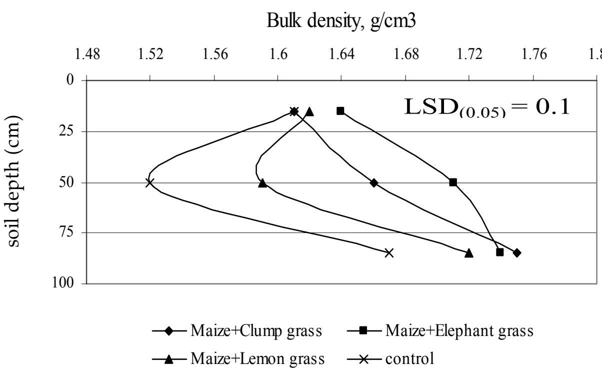
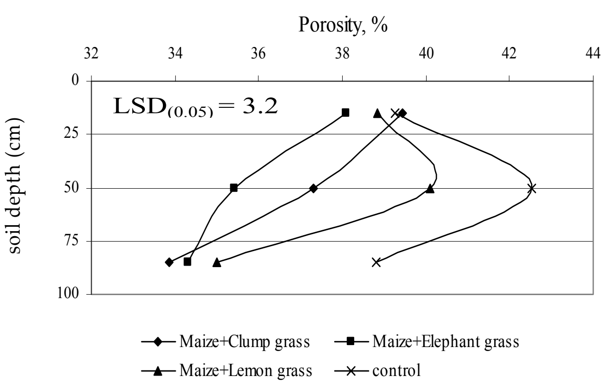


Fig. 3. Porosity as influenced by preceding cropping patterns



Root length. The total root length of maize in control plots was 2517 cm and its ranged from 1474 cm in maize + elephant grass followed by killing grasses to 3123 cm under both slashing and killing regardless of the method of tillage (Table I). Thus, a significant interaction among preceding season cropping pattern, tillage and grass management showed that plots occupied by maize + clump grass followed by killing grasses and maize + lemon grass

Fig. 4. Soil moisture at tasseling as influenced by preceding cropping pattern followed by grass row management at 30 - 70 cm soil depth

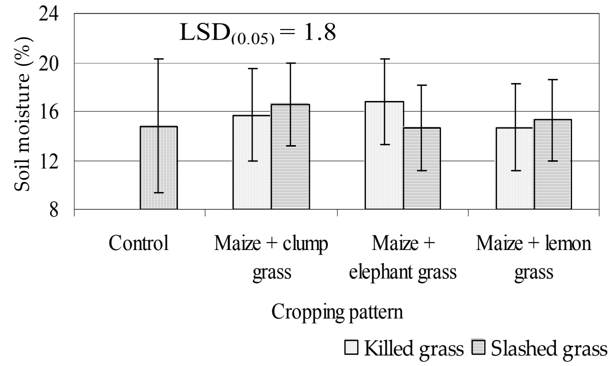


Fig. 5. Soil moisture at 3 weeks after tasseling as influenced by preceding cropping patterns followed by grass row management at 70-100 cm soil profile

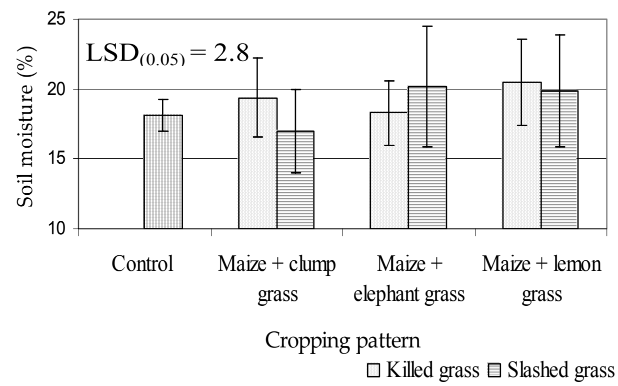
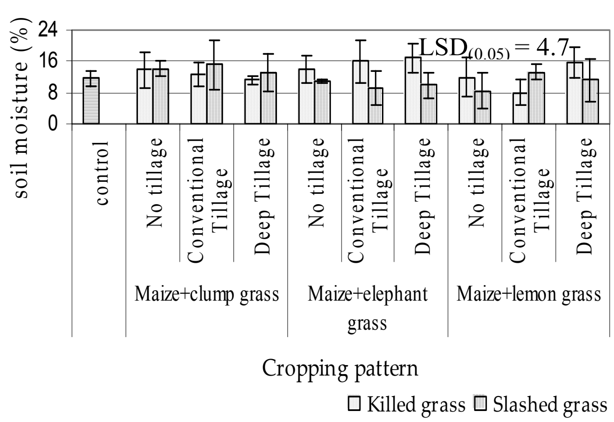


Fig. 6. Soil moisture at harvest as influenced by preceding tillage method x cropping pattern followed by grass row management at 30-70 cm soil depth



followed by slashing grasses, both with conventional tillage and maize + elephant grass followed by slashing grass in no tillage in the preceding wet season had significantly higher total root length (> 3.0 m) compared to control and other

Table I. Root systems as influenced by preceding tillage method and cropping pattern followed by grass management

		Lateral root distance (cm)		Vertical root distance (cm)		Root length (cm)		Root dry weight (kg plot^{-1})	
Tillage method	Cropping pattern	Killed grass	Slashed grass	Killed grass	Slashed grass	Killed grass	Slashed grass	Killed grass	Slashed grass
Control		22.9 ± 3.1		25.60±2.9		2517 ± 641		1.7 ± 0.18	
No tillage	Maize+clump grass	26.6 ± 2.4	18.3 ± 2.5	21.8 ± 1.9	26.6 ± 3.6	2738 ± 565	2288 ± 455	0.9 ± 0.05	0.9 ± 0.14
	Maize+elephant grass	19.6 ± 1.9	20.7 ± 2.5	23.0 ± 2.8	27.0 ± 2.2	2016 ± 132	3056 ± 388	0.8 ± 0.09	0.9 ± 0.09
	Maize+lemon grass	21.0 ± 4.6	19.6 ± 2.4	22.6 ± 1.3	26.5 ± 3.4	2155 ± 696	1725 ± 411	0.7 ± 0.09	0.8 ± 0.16
Conventional Tillage	Maize+clump grass	22.4 ± 3.1	18.8 ± 3.6	27.5 ± 3.5	29.9 ± 1.5	3123 ± 494	2082 ± 564	3.2 ± 0.18	2.3 ± 0.32
	Maize+elephant grass	21.1 ± 2.4	18.4 ± 2.4	29.8 ± 2.8	30.0 ± 1.7	2819 ± 362	2116 ± 309	2.3 ± 0.45	1.8 ± 0.18
	Maize+lemon grass	16.7 ± 1.3	20.9 ± 3.1	22.1 ± 3.1	31.1 ± 2.6	2157 ± 602	3108 ± 1046	2.0 ± 0.11	3.5 ± 0.11
Deep Tillage	Maize+clump grass	20.8 ± 3.6	19.3 ± 3.0	24.5 ± 1.6	27.0 ± 3.0	2576 ± 394	2357 ± 347	3.2 ± 0.34	2.0 ± 0.05
	Maize+elephant grass	14.5 ±2.0	21.0 ± 2.6	24.4 ± 2.4	26.9 ± 3.0	1474 ± 393	2777 ± 508	1.3 ± 0.05	2.6 ± 0.18
	Maize+lemon grass	19.0 ± 2.3	24.6 ± 4.7	24.2 ± 1.2	26.0 ± 4.1	2284 ± 339	2808 ± 203	1.8 ± 0.34	2.5 ± 0.25
LSD (0.05)		2.60		3.26		551.47		0.25	

combinations in the succeeding dry season.

Root dry weight. Root dry weight was significantly greater in plots occupied by all intercrops except in no tillage plots and maize + elephant grass with deep tillage plots than control (1.7 kg plot^{-1}) (Table I). The highest root dry weight was in plots occupied by maize + lemon grass intercrops under conventional tillage (3.5 kg plot^{-1}) and maize + clump grass under conventional and deep tillage had the second highest (3.2 kg plot^{-1}) but with significantly a lower root dry weight. Grass management had a significant effect on root dry weight. In maize lemon grass plots followed by slashing, under conventional tillage root dry weight was significantly greater than others but no significantly different with maize + clump grass plots followed by killing grasses except in previously no tillage plots. In previous no tillage plots, intercrops and grass management had lower root dry weight than other combinations treatment.

Growth Characteristics of Maize

Plant height. There was a significant effect of only grass management on plant height and no effect of both tillage and intercropping (Fig. 8). Plots occupied by control had a plant height of 147.4 cm, where as of 154.0 cm in maize + grass intercrops followed by killing grasses compared to slashed (144.8 cm) and the difference was significantly greater.

Leaf area index (LAI). Intercropping with grasses in preceding wet season followed by grass management showed a significant interaction on LAI (Fig. 9). The highest LAI was in both plots occupied by maize + clump grass followed by slashing grasses (3.80) and maize + elephant grass followed by killing grasses (3.81), which were significantly greater than in the plots occupied by the rest of the treatment combinations and control (3.60).

Above ground dry matter. There was a significant effect of tillage and maize + grass cropping pattern followed by grass management in the succeeding dry season on above-ground dry matter of maize. In maize + grass intercrops, above-ground dry matter ranged from 7.4 kg plot^{-1} in maize + elephant grass under conventional tillage plots followed by slashing grasses to 19.8 kg plot^{-1} in maize + elephant grass under deep tillage followed by killing grasses (Table II).

Fig. 7. Soil moisture at harvest as influenced by preceding tillage method followed by grass row management at 70-100 cm soil depth

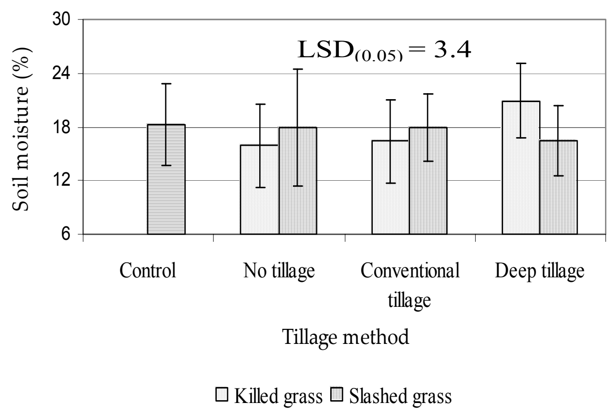
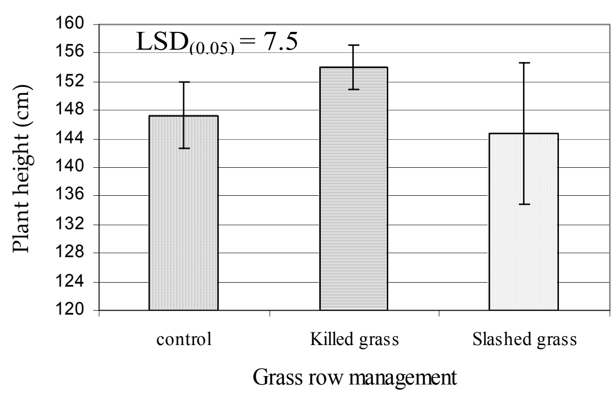


Fig. 8. Plant height as influenced by grass row management



Yield and Yield Components

Number of kernels per cob. Control had 407.3 kernels per cob (Table II). There was an interaction among tillage, cropping pattern and grass row management for kernel number per cob. Maize + elephant grass under no tillage followed by slashing of grasses gave the highest kernel number per plant, but was not significantly different from

Table II. Above ground dry matter, no. of kernels and grain yield as influenced by preceding tillage method and cropping pattern followed by grass management

		Above ground dry matter (kg plot^{-1})		No. of kernels		Grain yield (kg plot^{-1})	
Tillage method	Cropping pattern	Killed grass	Slashed grass	Killed grass	Slashed grass	Killed grass	Slashed grass
Control		14.8 ± 1.8		407.3 ± 51.4		4.91 ± 1.56	
No tillage	Maize+clump grass	17.6 ± 0.7	16.4 ± 2.7	364.3 ± 81.6	249.7 ± 29.3	6.19 ± 0.90	5.15 ± 0.45
	Maize+elephant grass	14.9 ± 1.6	16.0 ± 1.6	298.0 ± 46.0	413.7 ± 16.2	4.66 ± 0.68	4.91 ± 0.68
	Maize+lemon grass	12.6 ± 1.8	15.5 ± 2.7	289.0 ± 50.5	292.0 ± 65.3	5.15 ± 0.90	3.85 ± 1.56
Conventional	Maize+clump grass	15.3 ± 1.8	15.1 ± 1.4	387.3 ± 63.0	356.0 ± 30.5	5.60 ± 1.56	4.77 ± 1.35
Tillage	Maize+elephant grass	14.6 ± 1.8	7.4 ± 1.6	288.0 ± 83.9	236.7 ± 39.5	5.96 ± 0.90	3.35 ± 0.23
	Maize+lemon grass	13.3 ± 2.7	11.5 ± 2.9	286.0 ± 39.6	297.7 ± 83.6	6.26 ± 0.23	4.46 ± 0.45
Deep Tillage	Maize+clump grass	12.4 ± 1.8	15.5 ± 1.8	303.7 ± 88.2	298.0 ± 33.7	4.59 ± 0.56	5.96 ± 0.90
	Maize+elephant grass	19.8 ± 2.9	14.4 ± 2.9	252.0 ± 28.2	355.0 ± 20.3	6.12 ± 0.90	5.29 ± 0.45
	Maize+lemon grass	12.6 ± 1.3	12.6 ± 0.9	291.3 ± 32..2	322.3 ± 9.0	5.38 ± 1.56	6.39 ± 0.90
LSD (0.05)		2.68		77.76		0.86	

Fig. 9. Leaf area index as influenced by preceding cropping pattern

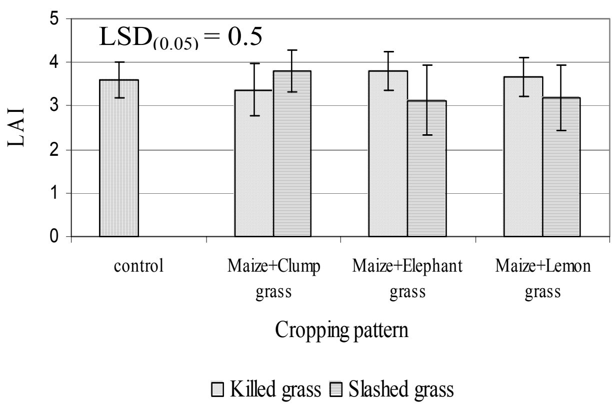
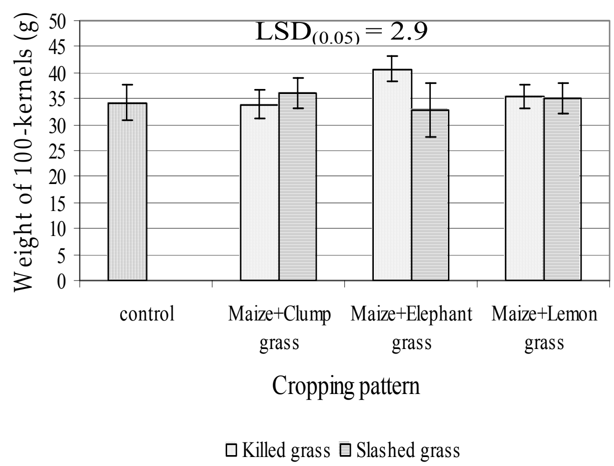


Fig. 10. Weight of 100-kernels as influenced by preceding tillage method and cropping pattern followed by grass row management



the maize sole crop. In all other cases, kernel number per cob was lower than control.

100-Kernel weight. There was a two-way interaction between cropping pattern and management of grass rows for 100-kernel weight. 100-kernel weight of succeeding maize increased in plots associated with maize + elephant grass plots in the preceding season followed by killing grass compared to slashing grass and in other treatments it remained unchanged (Fig. 10).

Grain yield. There was a three-ways interaction among tillage and cropping pattern in the preceding wet season and grass management in the succeeding dry season on grain yield. The highest grain yield (6.39 kg plot^{-1}) was produced in plots occupied by maize + lemon grass under deep tillage followed by slashing grasses and which was significantly greater than the yield produced in control plots (4.91 kg plot^{-1}) and other cropping patterns (Fig. 11). Killing the grass rows significantly increased maize yields in all intercrops compared to slashing in all tillage methods except in maize + elephant grass intercrop in no tillage and maize + clump grass in deep tillage. Results showed that higher grain yields during dry season could be increased with the use of growing maize and selected grasses as intercrops in the preceding season followed by killing grasses rows and growing maize as rainfed crop in the succeeding dry season.

Harvest index (HI). There was significant effect of maize + grass intercropping on HI. Maize grown in plots of intercrop in the preceding wet season had a significantly higher HI than control (0.34) (Fig. 12). There was a significant interaction between tillage in the preceding wet season and grass management at the beginning of dry season for HI. Conventional tillage with killed grasses and deep tillage with slashed grasses had significantly greater HI (0.42) than the rest and no tillage with slashed grasses had a lowest HI (0.29) (Fig. 13).

DISCUSSION

Preceding cropping pattern had significant effects on soil bulk density and porosity at 30 - 70 cm depth of soil profile. Control had the lowest bulk density and in turns the highest porosity than others (Fig. 2 & 3). Maize + grass intercrops increased bulk density and decreased porosity. Similar observations were also made by other researchers when the grasses were planted as intercrops (Obi, 1999; Imhoff *et al.*, 2000). Kuchenbuch and Ingram (2004) and Hasan (2000) reported that increase in bulk density reduced

Fig. 11. Grain yield as influenced by preceding tillage method and cropping pattern followed by grass row management

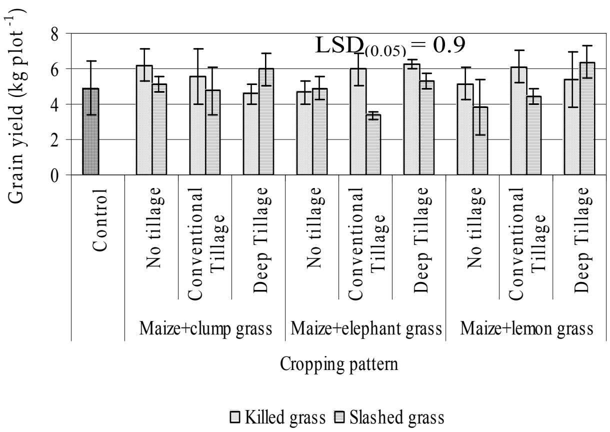
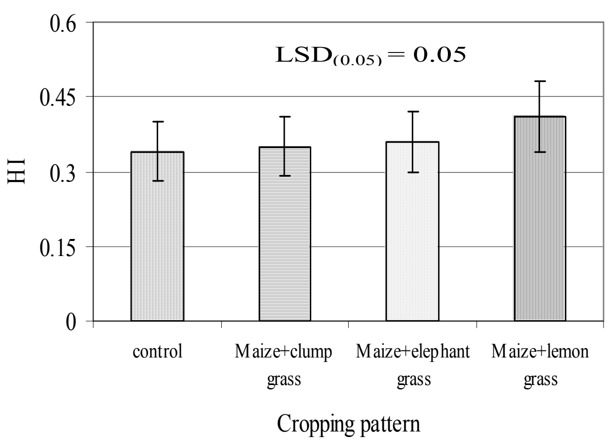


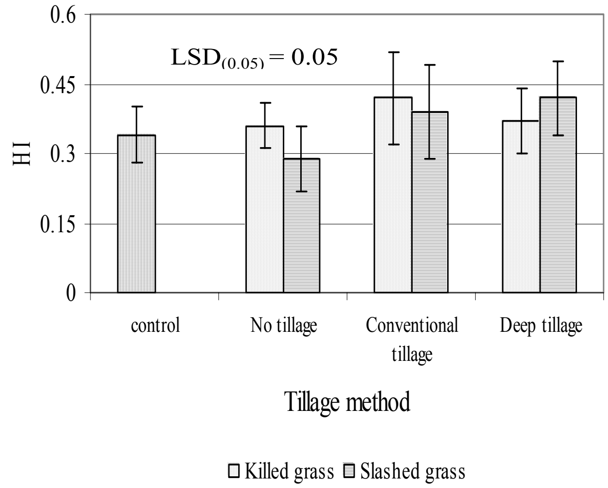
Fig. 12. Harvest index as influenced by preceding cropping pattern



both root growth and total root length. Maize in no tillage intercropped with elephant grass and conventional tillage intercropped with clump grass followed by killing grass and lemon grass followed by slashing grass increased root length. This confirms the possibility of exploring deeper soils in the presence of selected grasses grown in the previous season.

Intercropping maize with grasses in preceding wet season followed by management of grasses compared to control increased soil organic C (SOC) (Fig. 1). Tillage mixes up plant residues throughout the plough layer, which generally increases the rate of decomposition of organic matter (Magcale-Macandog *et al*., 1998) and SOC content (Ahmad *et al.,* 2006; Jantalia *et al.,* 2006) this was possible only down to 30 cm with depth ploughing. Plot occupied by maize + elephant grass had higher SOC than others. Obi (1999) too reported the ability of elephant grass to produce high amount of organic materials and hence improving SOC. Grasses with dense root systems are capable of forming large, stable and continuous pores in the soil profile

Fig. 13. Harvest index as influenced by preceding tillage method followed by grass row management



thus reducing bulk density (Prihar *et al*., 2000). Organic C was higher in plots when grasses were slashed, which may be due to continues production of roots (Fig. 1). However, in the current study, there was a slight increase in soil bulk density despite increasing SOC in the soil profile, which could only be attributed to inhibition of microorganism by herbicide inhibiting decomposition of organic matter as reported by Schnitzer and Khan (1978).

Vertical root distance was significantly greater in conventionally tilled plots occupied by maize + grasses intercrops followed by grasses slashed compared to other tillage method and control except in conventional tillage plots occupied by maize + lemon grass (Table I). As the grasses remained alive with slashing, deep root growth of maize could be a way of avoiding the root competition for nutrient and water between the two species in the succeeding dry season. Roots were limited to a depth of 30 cm. This could be attributed to Al toxicity (Khan *et al*., 2001). As reported by many researchers, root apex is the critical site sensitive for Al (Ryan *et al.*, 1993; Hairiah *et al.,* 2000) and higher Al content inhibits root growth by inhibiting root cell division (Horst *et al*., 1997; Jayasundara *et al.*, 1998) However, Kramer and Boyer (1995) and Hairiah *et al.* (2000) reported that in acid soil, the plants avoid Al toxicity and its adverse effects by reducing deep root growth.

Tillage and cropping pattern in the preceding wet season followed by grass management in the succeeding dry season had significant effect on plant growth. Plant height was greater when the grasses were killed than slashed (Fig. 8). LAI significantly increased in maize + clump grass and maize + elephant grass intercrops followed by slashing and killing grasses, respectively compared to control (Fig. 9). Above-ground dry matter remained unchanged in all tillage and grass management practices plots of maize + lemon grass, maize + clump grass except in deep tillage plots followed by killed grass and maize + elephant grass except in conventional tillage plots followed by slashing (Table II). Both plant growth and LAI showed that maize was not subject to water stress even though it was grown in the succeeding dry season. This may be attributed to modified soil environment rather than deep root growth thus providing better opportunities for roots to acquire water and other nutrients from the soil profile around 30 cm. This shows a fact that it may not be the depth of soil explored by roots per se is needed to enhance water uptake, but an interface between deep and shallow soils, where roots could extract water upon it is released to upper soil profiles from the deeper layers when the soil moisture gradient is developed in the dry seasons. The significantly greater SMC at 30 - 70 cm depth in plots of maize + elephant grass followed by killing grasses confirmed this fact (Fig. 4 & 6). The SOC and porosity increased in plots of maize + lemon grass followed by slashing and killing grasses and in maize + elephant grass followed by slashing, but in other treatments both parameters remained insignificant (Fig. 1 & 3). Yield and yield components in the current study showed promising results compared to past yield records in the area (Swastika *et al*., 2004). Despite number of kernels in maize + grass intercrops decreased, weight of 100-kernels was higher in plots occupied by maize + elephant grass intercrops followed by killing grasses (Fig. 10). Grain yield was higher in conventionally and deep tilled plots occupied by maize + grass intercrops followed by killing grasses than control, no drastic variations maize + grass intercrops (Fig. 11). Harvest index (HI) was slightly higher in preceding maize + lemon grass intercropped plots (Fig. 12) and in conventional and deep tillage plots with killing and slashing grasses (Fig. 13), respectively which was due to lower biomass. Kirungu *et al*. (2000) reported that stover of the previous sole cropped maize had no significant effects on growth of maize. However, grasses intercropped with maize in preceding wet season improved the SOC for succeeding crops. Although soil characteristics did not significantly vary among cropping pattern, tillage or grass management, even minor changes of physical properties such as soil bulk density, porosity, hydraulic conductivity, water holding capacity etc., in the soil profile could create an interface for storage and exchange of water between roots zone and deeper soil layers and it would then be adequate for the maize to develop a few sizeable roots to that thin profile and acquire its water requirement and supporting its normal growth and activities. This would provide the opportunity for maize to perform in the succeeding dry season and produce satisfactory yields as shown in the current study.

CONCLUSION

This study showed that tillage and intercropping maize with grasses in the preceding wet season followed by killing grasses after harvest improved soil physical properties enhancing the accessibility to moisture and yield of maize grown in the succeeding dry season. Maize + lemon grass intercrops under deep tillage plots followed by slashing grass gave the highest grain yields In general all maize + grass intercrops with the grasses killed at land preparation performed better than sole maize occupied plots. Therefore, maize + grass intercropping in the wet season followed by killing the grasses at land preparation in the succeeding dry season could help the farmers to raise maize yields and accrue associated benefits.

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