Available online at www.sciencedirect.com
ScienceDirect
Soil & Tillage Research 96 (2007) 6–18
Soil & Tillage Research
www.elsevier.com/locate/still

# Effects of vetiver grass (*Vetiveria nigritana*) strips, vetiver grass mulch and an organomineral fertilizer on soil, water and nutrient losses and maize (*Zea mays*, L) yields

O. Babalola *, S.O. Oshunsanya, K. Are

*Department of Agronomy, University of Ibadan, Ibadan, Nigeria*

Received 15 August 2006; received in revised form 26 January 2007; accepted 10 February 2007

**Abstract**

Soil erosion remains a serious problem on most agricultural fields especially in the humid tropics. Experiments were conducted between 2003 and 2005 to test the efficiency and efficacy of using vetiver grass strip (VGS), vetiver grass mulch (VGM) and an agronomic practice of using an organomineral fertilizer (OMF) capable of improving soil structure and a control, as treatments, on soil and water conservation and improvement of maize yields. The treatments, in three replicates, were laid out in a randomized complete block design on 7% runoff plots on an Alfisol in the sub humid region of Southern Nigeria. Soil physical conditions were significantly best under VGM plots and least under VGS plots. Nevertheless, runoff and soil loss were generally in the increasing order of VGS, VGM and OMF. Although mean runoff and soil loss on VGS plots were 36.6% and 28% of the value of the control plot in 2003, when 2 tonnes/ha of vetiver grass mulch was applied to the control plot in 2004, these values were increased to 61.5% and 48.4%, respectively indicating a significant reduction of runoff and soil loss on the mulched plots. Vetiver grass mulch (VGM) at 6 tonnes/ha was more effective than VGS plots in reducing runoff than soil loss. Whereas mean runoff for VGM, VGS and OMF plots were 28.67, 38.44 and 42.44 mm, respectively, the corresponding mean soil losses at 6 tonnes/ha were 980.5 kg/ha, 389 kg/ha and 1251 kg/ha, respectively. Mean soil losses were 629 kg/ha and 591.5 kg/ha higher on VGM than VGS plots at 4 tonnes/ha and 6 tonnes/ha, respectively. Mean $No_3$-N levels of runoff water on the VGS plots were 40.4% and 65.6% of the levels of the OMF and the control plots, respectively over 2003 and 2004. Nutrient loads of eroded sediments were highest for OMF plots and least for VGS plots. Carbon, Nitrogen and P contents of eroded sediments were 22–23.5%, 12–35.9%, and 20.6–37.6% lower on VGS plots than other treatments.

The significant beneficial effect of OMF in producing the highest yields was dwarfed by the potential danger of water pollution by nutrient loads in the absence of a soil erosion control measure. Although the differences were not significant, grain yields on VGM plots were 4% and 47.4% higher than on VGS plots when 4 and 6 tonnes/ha of grass mulch were applied.


*Keywords:* Vetiver; Strips; Mulch; Soil loss; Runoff; Nutrient losses; Crop yields

## 1. Introduction

Soil erosion remains the major source of land degradation on sloppy lands in most tropical regions of the world. High rainfall erosivity, high soil erodibility and the undulating topography combine to impact negatively on the landscape. This is particularly true of Nigeria where sheet erosion is widespread (Babalola et al., 2000). Although gully erosion is also widespread, it is particularly worse in the southern parts of the country where land instability is the result of deep loose sands on steep slopes in an area with very high rainfall

* Corresponding author. Tel.: +234 23087027.
*E-mail address:* profobabalola@yahoo.com (O. Babalola).

0167-1987/$ – see front matter 
doi:10.1016/j.still.2007.02.008

(2000 mm or more per annum). Both physical and biological measures of erosion control such as contouring, zero or minimum tillage, soil mulching, terracing, alley-cropping, agroforestry, crop rotation, bunding and tied-ridging have been used to varying degrees and successes in Nigeria, depending on localities (Lal, 1981; Aina, 1989). The limitations of each method in terms of costs, adaptability and effectiveness determine the level and degree of adoption by farmers.

The use of vetiver grass strips as a cheap, efficient and sustainable means of soil and water conservation is at its infancy in the Nigerian environment and indeed in many countries of the world. A vetiver grass strip is a vegetative barrier or a hedge of grass which is placed preferably along the contour, perpendicular to the direction of water flow in the field in order to trap sediments, reduce runoff velocity and encourage water infiltration. The stiff foliage of the grass and the dense but porous nature of the hedge formed by the strip makes vetiver grass strip suitable to perform the function (Grimshaw, 1993). Recent experiments using vetiver grass strips have demonstrated locally their efficiency in curtailing soil erosion and improving crop yield. Indeed soil loss was reduced by about 70%, runoff by about 130% and maize grain yield was increased by almost 50%, when vetiver grass strips were built at 20 m surface intervals when compared to a control (Babalola et al., 2003). Similar reports elsewhere (Kon and Lim, 1991; Wang Zisong, 1991; Laing and Ruppenthal, 1991; Grimshaw, 1993; Xia et al., 1996; Hu et al., 1997; Levan Du and Truong, 2003) have demonstrated the same kind of beneficial effects albeit to varying degrees. For instance, Xia et al. (1996) and Hu et al. (1997) reported a decrease in surface runoff of 32.7–59.7% and a decrease in soil loss of 63.7–92.7%.

In many of these reports, vetiver grass strips were compared with either no vetiver grass treatments or other soil conservation measures such as contour hedges of Leuceana, graded earthen bund, stone barriers, lemon grass and contour cultivation. Little or no reports have compared vetiver grass strips with mulching. A large quantity of mulch material in the form of vetiver grass clippings is produced as prunnings when vetiver grass strip is used for soil erosion control. The use of the grass necessitates at least two prunnings during the growth of a maize crop. Few reports have discussed the mulching and manurial potentials of vetiver grass clippings. Chen et al. (1994) and Lu and Zhong (1997) applied vetiver grass clippings as mulch at the base of orchard trees and reported some improvement in the chemical and physical properties of the soil. Report on the use of the prunnings for controlling soil and water loss is few or hard to find.

Table 1
Proximate analysis for the organomineral fertilizer (OMF)

| Nutrient element | Value |
|---|---|
| Total nitrogen (%) | 2.58 |
| Available P (Bray P1) | 1.08 |
| Exchangeable K (%) | 0.68 |
| Calcium (%) | 0.08 |
| Sodium (%) | 0.68 |
| Zinc (mg/kg) | 712.70 |
| Manganese (mg/kg) | 55.30 |
| Iron (mg/kg) | 6153.40 |
| Copper (mg/kg) | 257.40 |

*Source*: Soil Analytical Laboratory, Department of Agronomy, University of Ibadan, Nigeria (2002).

Any practice that improves soil structure will also enhance water entry into the soil and reduce runoff amount and velocity. Preliminary studies have indicated that the incorporation into the soil of a locally manufactured organomineral fertilizer (called pacesetter) is such a practice (Omueti et al., 2000). The product is a compost of cowdung and city waste fortified with mineral nutrients (Table 1). The organic material is at least 80%. Not only is it capable of improving soil structure but can also enhance quick and adequate vegetal soil coverage. Vegetative cover breaks the impact of raindrops on the soil surface, enhances water entry into the soil and thus reduce runoff and soil erosion.

An experiment was therefore carried out to (i) determine the effectiveness of vetiver grass strip vis a vis the use of vetiver grass prunnings or clippings as mulch and the use of a locally manufactured organomineral fertilizer on soil and water conservation and improvement of maize yield and (ii) to determine their effects on the nutrient loads of eroded sediments and runoff water.

## 2. Materials and methods

The experiment was conducted at the Teaching and Research Farm of the University of Ibadan (7°24′N 3°54′E) in Nigeria. The site has a mean altitude of 180–210 m above sea level. The rainfall pattern is biomodal and averages 1230 mm per annum. Rainfall peaks occur in June and September. There are 175 total wet days in the 6 years. There are two cropping seasons; an early season runs from March/April to August and late season, from mid-August to October/November. Annual temperatures range from a high of 31.2 °C to

Table 2
Sequence of treatments (T) imposed during the study period

| Year | Season | Treatments | | |
|---|---|---|---|---|
| | | T1 | T2 | T3 |
| 2003 | Early | VGS | OMF | Control |
| 2003 | Late | VGS | OMF | Control |
| 2004 | Early | VGS | OMF | VGM (2 tonnes/ha) |
| 2004 | Late | VGS | OMF | VGM (2 tonnes/ha) |
| 2005 | Early | VGS | OMF | VGM (4 tonnes/ha) |
| 2005 | Late | VGS | OMF | VGM (6 tonnes/ha) |

VGS is vetiver grass strip, OMF is organomineral fertilizer, VGM is vetiver grass mulch.

a low of 21.3 °C. Ibadan has a percentage sunshine that ranges between 16% in August to 59% in February and December with an average of 44%. The soil of the area is an Alfisol of the order Oxic Paleustalf according to the USDA classification. It is classified locally as Iwo series (Smyth and Montgomery, 1962).

Three treatments each were imposed on a 7% slope during the early and late growing seasons of 2003, 2004 and 2005 (Table 2) on runoff plots measuring 40 m long and 3 m wide. The runoff plots were demarcated by earthen bunds about 10 cm high. In 2003, the treatments were (i) vetiver grass strip established at surface intervals of 10 m, (ii) the application of locally manufactured organomineral fertilizer (OMF) called Pacesetter (Table 1) which was intimately and uniformly mixed with the surface (0–10 cm) soil at a rate of 2 tonnes/ha and (iii) a control, without any intervention. In establishing a vetiver grass strip, shallow trenches, about 2.5 cm wide and 15 cm deep and 3 m long, were dug at 10 m intervals on the runoff plot perpendicular to the direction of water flow. At each location, vetiver grass slips (a planting unit with shoot and roots largely intact) were detached from clumps of grass (whose roots were presoaked in water) collected from a nearby nursery and were planted at 10 cm spacings. There were about 30 slips per strip. The roots were covered up with top soil and irrigated periodically to encourage good establishment. Vetiver grass strips were planted in August 2002 and were adequately established in the early growing season of 2003 by March/April. In the second year, 2004, the same treatments were imposed except that 2 tonnes/ha of vetiver grass clippings as mulch were applied to the control plots in order to investigate the ameliorative effect of mulch on the soil properties and soil erosion. In the third year, 2005, 4 tonnes/ha of vetiver grass clippings were applied to the mulched plots in the early growing season and 6 tonnes/ha in the late growing season. The fertilized plots received 2 tonnes/ha of OMF only during the early growing seasons in each year. Inorganic fertilizer, as urea, was applied at the rate of 100 kgN/ha to all the plots in order to boost the crop growth on the already rundown soils in the late season of 2005. Thus, vetiver grass clippings as mulch were steadily increased at the rates of 2, 4 and 6 tonnes/ha on the initial control plots. Each treatment was replicated thrice and laid out in a randomized complete block design.

Some physical properties of the soil on the experimental site were determined using soil samples collected from a representative soil profile on the site (Table 3). Particle size analysis, saturated hydraulic conductivity and bulk density were determined using bulk and core samples as described by Smith and Mullins (1991).

White maize, variety ACR95TZEE Comp. 4C3, was used as a test crop planted at spacing of 90 cm × 30 cm for six growing seasons in 2003, 2004 and 2005. When in the early season of 2003 the vetiver strips were fairly well established, soil and runoff water collecting devices were installed at the bottom of each plot using two oil drums, 90 cm, high and 58 cm wide per plot as runoff collector. The two drums were connected such that an overflow from the first drum ran into the second drum. A divisor was introduced such that one-third of the runoff and soil loss from each plot was collected first into a trough and then into the drum (Fig. 1). Soil losses were estimated from the soil collected in the trough and also from sediments in the runoff water. First, the wet

Table 3
Effect of vetiver grass strip (VGS), organomineral vetiver (OMF) and vetiver grass mulch (VGM) on some soil properties after six growing seasons as determined in the late season of 2005

| Treatment | Bulk density ($g/cm^3$) | Carbon (%) | MWD (mm) | Equilibrium infiltration rate (cm/h) | Kostiakov's infiltration model | |
|---|---|---|---|---|---|---|
| | | | | | $c$ | $\alpha$ |
| VGS | 1.47 | 1.68 | 1.097 | 18.6 | 1.62 | 0.652 |
| OMF | 1.49 | 2.31 | 1.061 | 31.2 | 2.24 | 0.743 |
| VGM | 1.37 | 1.75 | 1.478 | 49. 8 | 2.58 | 0.849 |
| LSD (0.051) | 0.18* | 0.50* | 1.026* | 24.6* | 1.03 | 0.280 |

MWD is the mean weight of aggregates (*indicates significant difference at the 5% level).

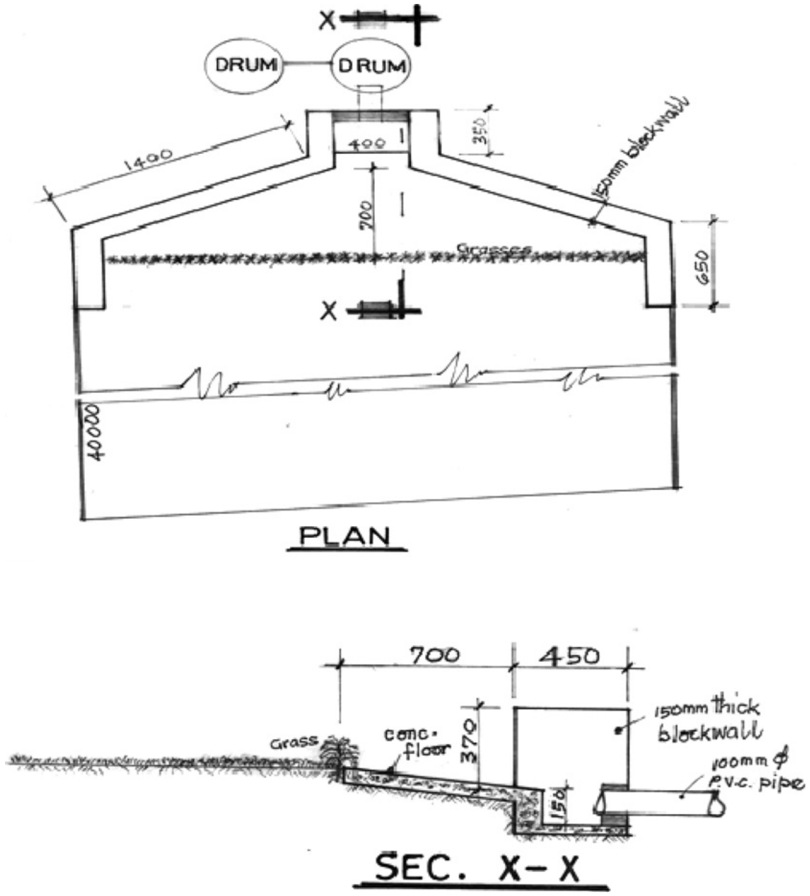


Fig. 1. Sketch of erosion site.

soil in the trough was collected and weighed. The moisture content of the soil was determined gravimetrically using a small sample and the value obtained was used in converting the wet weight of eroded soil to oven dry weights. Also, an aliquot of 100 ml of soil suspension in the drum, after thorough stirring, was oven-dried to determine the dry matter content. This was used to compute the total sediment loss in the drum or drums. Although the aliquot was taken from the main drum, the sediment yield was calculated using the total volume of suspension in the two drums with the assumption that the concentration of the suspension was similar in the two drums, although this may not be so. The addition of the latter to the weight of oven dry soil in the trough gave an estimate of the total soil loss from each runoff plot. Volume of runoff water was estimated from the height of water in each drum and later converted to depth (mm) of water. An aliquot of 100 ml of the soil suspension was collected for $NO_3$-N analysis from the main drum. Eroded soils were analysed for organic carbon, total nitrogen, phosphorus, the base elements and the micronutrient elements from samples collected in 2003 and 2004 using standard methods as described by Bartels et al. (1996). Soil loss and runoff data were collected after every major storm over six growing seasons in 2003, 2004 and 2005.

Infiltration rate was measured using the double ring infiltrometer as described by Smith and Mullins (1991). The inner and outer rings were 30 and 50 cm in diameter, respectively. The rings were 30 cm high and were inserted 15 cm deep into the soil to leave another 15 cm above the ground surface. The soil surface was covered with grass mulch during measurements. Infiltration runs were carried out for 2 h after the late growing season of 2005 at distances of 25 m from the top of the plot. The infiltration data were analyzed according to Kostiakov (1932) model. Ten core samples, 0–5 cm depth, were collected within each 5 m intervals down the slope. These were bulked and subjected to aggregate size analyses using a nest of sieves in a modified Yoder's technique (Kemper and Rosenau, 1986) and mean weight diameter of the soil aggregates (MWD) was estimated from the equation:

$$\mathrm{MWD} = \sum X_i w_i$$

where $X$ represents the mean diameter of the soil aggregates on each sieve and $w_i$ is the mass fraction of the aggregates on each sieve.

Yield and yield parameters were estimated from the three inner rows of plants. Plant heights on each plot, as an index of vegetal soil cover, were determined at the silking stages using measuring tapes. Statistical analysis were carried out using ANOVA to test levels of significance due to treatments (Gomez and Gomez, 1984).

## 3. Results and discussion

The soil of the experimental site has a loamy sand texture with a pH of 6.0 and an organic carbon content of 1.5–1.8%. The mean soil bulk density ranged from 1.62 g/cm$^3$ at the surface to 1.80 g/cm$^3$ at a depth of 30–35 cm. Soil porosity thus ranged between 0.33 and 0.42. Mean saturated hydraulic conductivity values ($K$s) ranged from 8.46 cm/h at a depth of 45–60 cm to 0.82 cm/h at almost a metre depth with a mean value of 4.18 cm/h at the soil surface. Gravel concentration is high ranging from 35% at the surface to about 45% at a depth of 30–45 and 45–60 cm. Other chemical properties include total nitrogen (5.88 kg$^{-1}$) available phosphorus (16.48 mg/kg) 9 and exchangeable potassium (5.7 Cmol/kg).

Table 3 shows some specific physical characteristics of the soil amenable to changes by the treatments imposed. At the end of six growing seasons, treatments influenced significantly the mean soil bulk density, %C, and equilibrium infiltration rate. On the vetiver grass mulched plots (VGM), the bulk density was the least, the mean weight diameter of aggregates (MWD)' and equilibrium infiltration rates were the highest. Fig. 2 shows the infiltration runs as influenced by treatments when 6 tonnes of vetiver grass mulch was imposed. The $c$ and $\alpha$ coefficients of the Kositiakov's infiltration equation (Kostiakov, 1932) were in the order VGM > OMF > VGS. These data show that soil physical conditions were best on the VGM plots and least on the VGS plots as exemplified by the data on the infiltration characteristics of the soil. The mean weight diameters of soil aggregates were virtually the same for OMF and VGS plots.

## 4. Runoff and soil loss

Runoff was significantly influenced by treatments and was generally in the decreasing order of Vetiver grass strip (VGS), OMF and the control in the 2003 growing seasons (Fig. 3). Mean runoff on VGS plots were 36.6% of the control and 50% of the OMF plots. However in 2004, when 2 tonnes/ha of mulch was applied on the control plot, mean runoff were 19.08 mm, 42.38 mm and 32.23 mm for VGS, OMF and VGM plots, respectively. Although runoff and soil loss were higher on the control plots than OMF plots in the early growing season of 2003, the reverse was the case in 2004 when mulch was applied.

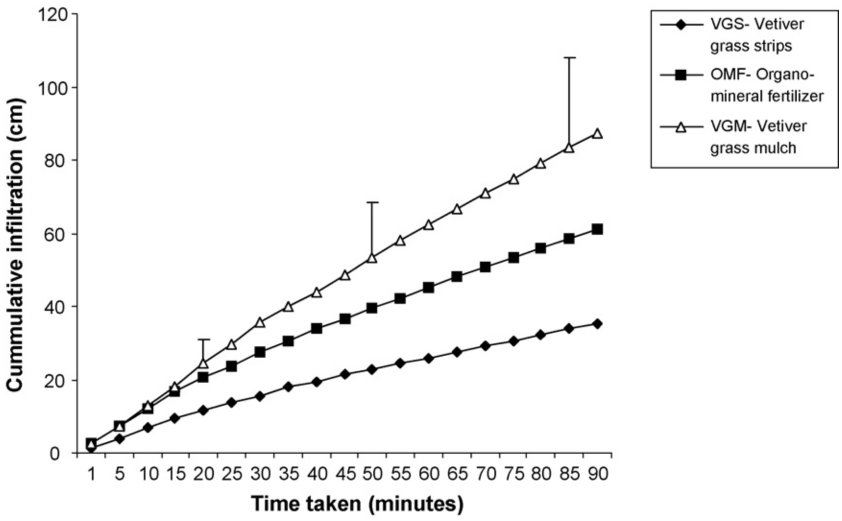


Fig. 2. Effect of vetiver grass mulch (VGM), vetiver grass strip (VGS) and an organo-mineral fertilizer (OMF) on the infiltration of water into an Alfisol in Ibadan.

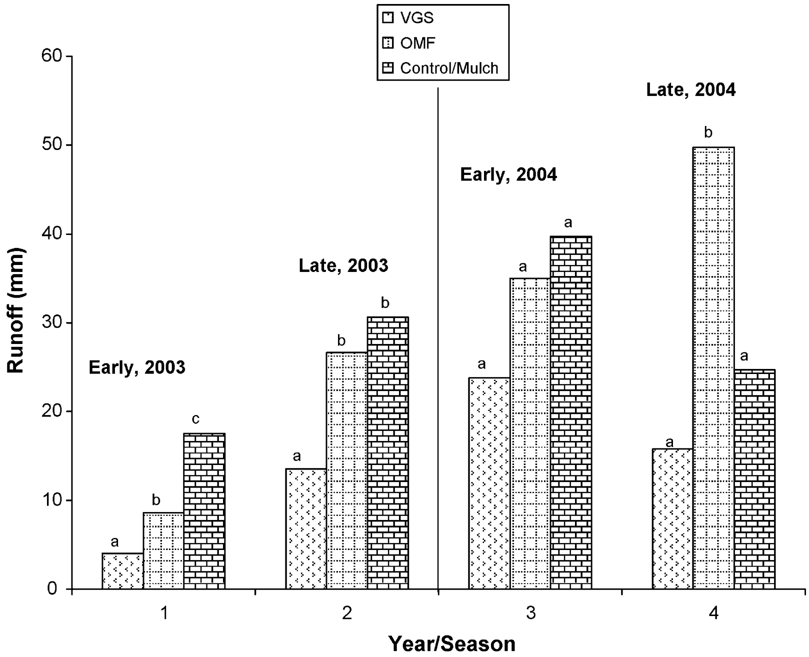


Fig. 3. Effect of vetiver grass strip (VGS), an organomineral fertilizer (OMF), mulch and a control on runoff from 40 m long runoff plots planted to maize during the early and late growing seasons of 2003 and 2004.

Soil loss was also significantly influenced by treatment and followed the same pattern as runoff during the 2003 growing seasons (Fig. 4). Mean soil losses were 252.4 kg/ha, 400.17 kg/ha and 732.64 kg/ha, respectively for VGS, OMF and the control. With the application of mulch to the control plots in 2004, soil loss values were 359.7 kg/ha, 950.7 kg/ha and 741.1 kg/ha for VGS, OMF and VGM, respectively.

Thus VGS was more effective in reducing runoff and soil loss than other treatments. Indeed mean runoff and soil loss on the mulched (VGM) plots were 61.5% and 48.4%, respectively of the values on the VGS plots. It is therefore concluded that (i) VGS was more effective than OMF and VGM in terms of runoff and soil loss and (ii) that VGM was more effective in reducing runoff than soil loss.

Although runoff and soil loss were higher on VGM plots than OMF plots in the early growing season of 2004, the reverse was the case in the late growing season at which time another dose of grass mulch was applied suggesting an increasing ameliorative effect of mulch on the soil conditions on the control plot.

In 2005, 4 tonnes/ha of mulch applied in the early season did not change the pattern of runoff and soil loss in that they were still in the increasing order of VGS, mulch (VGM) and OMF plots (Fig. 5). However when 6 tonnes of mulch were applied in the late season of 2005, the runoff pattern changed. Indeed, runoff was in the increasing order of vetiver grass mulch (VGM), vetiver grass strip (VGS) and OMF. Although the differences were not significant, mulched plots (VGM) reduced runoff by 34.1% over vetiver grass strip (VGS).

This demonstrates clearly that although the use of vetiver grass strip and vetiver grass clippings are beneficial in reducing runoff, the mulch effect was better only when 6 tonnes/ha of mulch was applied. This corroborates earlier report (Lal, 1986) that 6 tonnes of crop residue was optimum for the control of soil erosion. Whereas when 2 and 4 tonnes/ha of grass mulch were applied, the mulching effect were no longer physically apparent on the soil surface at the end of the growing season because much decomposition had taken place, this was not so when 6 tonnes/ha of mulch was applied as the mulch was still quite evident on the soil surface when crops were being harvested. It is worthy of note that with 4 and 6 tonnes of vetiver grass clippings per hectare, soil losses were on the average 629.2 kg/ha and 591.5 kg/ha lower on the VGS plots than the VGM (mulched) plots, respectively. This demonstrates that vetiver grass ''standing'', as in a strip, was more effective than vetiver grass ''prostrate'' as in a mulch in controlling soil loss. From the standpoint of soil and water conservation, vetiver grass strip and vetiver grass mulch should be combined for maximum efficiency. These conclusions can be attributed to the higher infiltration characteristics and better physical

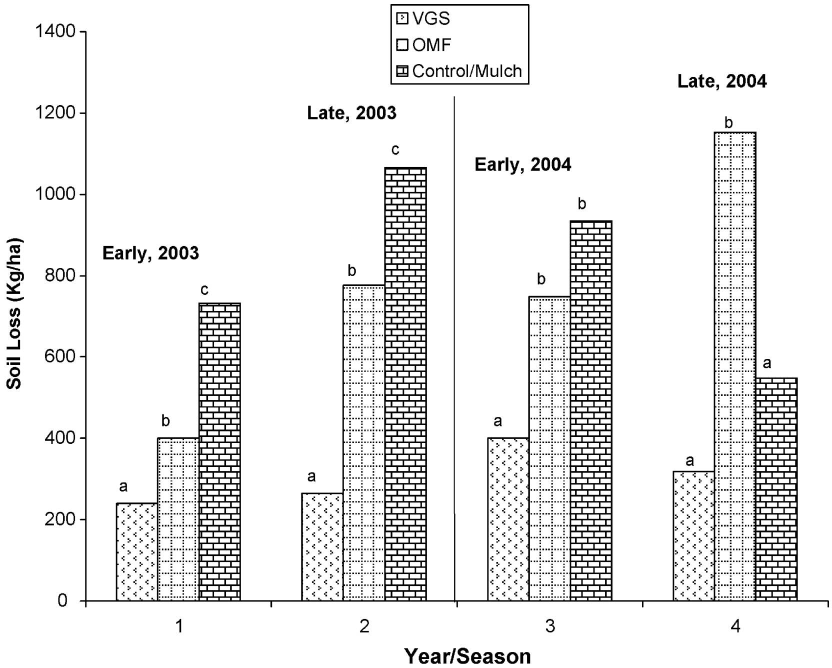


Fig. 4. Effect of vetiver grass strip (VGS), an organomineral fertilizer (OMF), Mulch and a control on soil loss from runoff plots planted to maize during the early and late growing seasons of 2003 and 2004. Control plots received mulch application in 2004. Note that bars within each season having the same letter are not significantly different a.

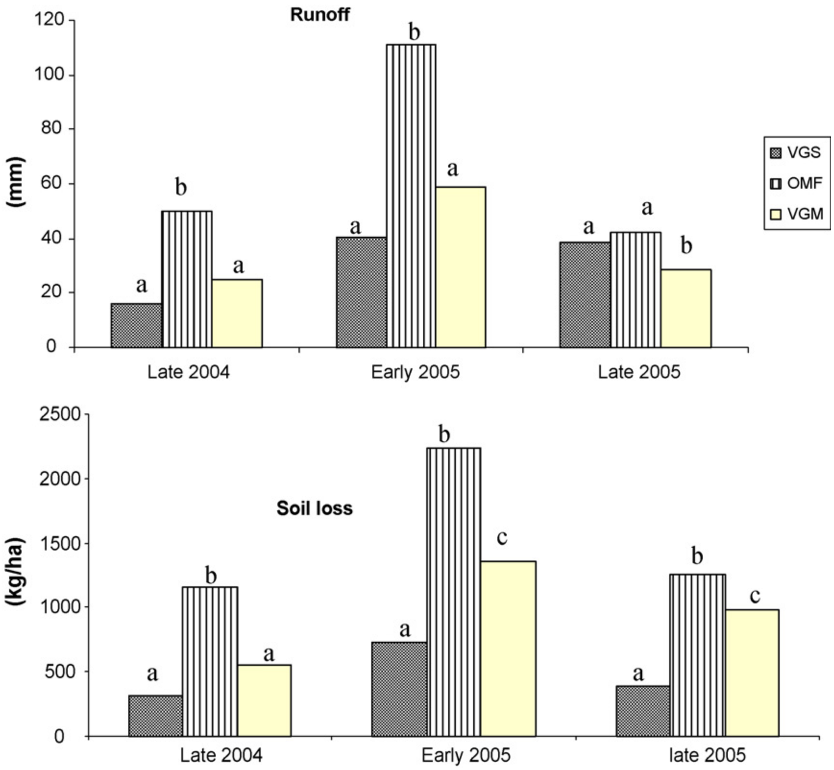


Fig. 5. Effect of vetiver grass strips (VGS), organomineral fertilizer (OMF) and vetiver grass clippings as mulch (VGM) on runoff and soil loss. (Mulch rates were 2, 4 and 6 tonnes/ha for late 2004, early and late 2005 growing seasons, respectively.) Bars within each season having the same letter are not significantly different at the 5% level.

conditions of the soil at high rates of mulch application which perhaps surpassed the effect of the "standing" vetiver grass in reducing runoff velocity, spreading out runoff water and allowing more water infiltration into the soil. The $c$ and $\alpha$ coefficients of the Kostiakov's equation (Table 3) were 59.2% and 30.2%, respectively higher on VGM plots than VGS plots. (The higher the $c$ and $\alpha$ coefficients, the higher is the initial water intake rate and the stability of soil structure, respectively). Similarly, the standing effect of the vetiver grass perhaps outweighed the better soil physical conditions on the OMF plots (Table 3). Here also the $c$ and $\alpha$ coefficients were 36.6% and 14.0% higher for OMF plots than VGS plots.

### 4.1. Plant height

Maize plant height under OMF plots were significantly different from other treatments only during the early growing seasons in 2003 and 2004 when the organomineral fertilizer was applied (Fig. 6). In the late season of 2003, there was no significant residual effect of OMF application since organomineral fertilizer was applied once a year during the early growing season. It is worthy of note that in the late season of 2004 when vetiver grass clippings as mulch was applied on the control plots at the rate of 2 tonnes/ha, there were no significant differences among the treatments. Indeed, mean plant heights were 172.6 cm, 174.4 cm and 163.6 cm for VGS, OMF and VGM (mulched) plots, respectively. On all the plots, mean plant heights were higher in 2004 than 2003 in accordance with increase in rainfall amount. The percent increases of plant heights in 2004 over 2003 plant heights were 1.52, 0.90 and 2.06 for VGS, OMF and VGM, (mulched) plots, respectively. The highest value for the grass mulched (VGM) plots suggests a definite ameliorative effect on the properties of the hitherto control but now mulched plots. In the late season of 2005 when 6 tonnes of grass clippings were applied as mulch, and 100 kg/(N ha) as urea was applied to all the plots, the plants were highest on the mulched plots. Indeed the mean plant heights were 159.1 cm, 154.2 cm and 153.6 cm for mulched, VGM, VGS and OMF plots, respectively, although the 345 differences were insignificant.

### 4.2. Maize grain yield

Maize yield differences were due to a combination of water availability and fertility status of the soil as induced by treatments. Fig. 7 demonstrates the definite beneficial and significant effect of OMF on yield

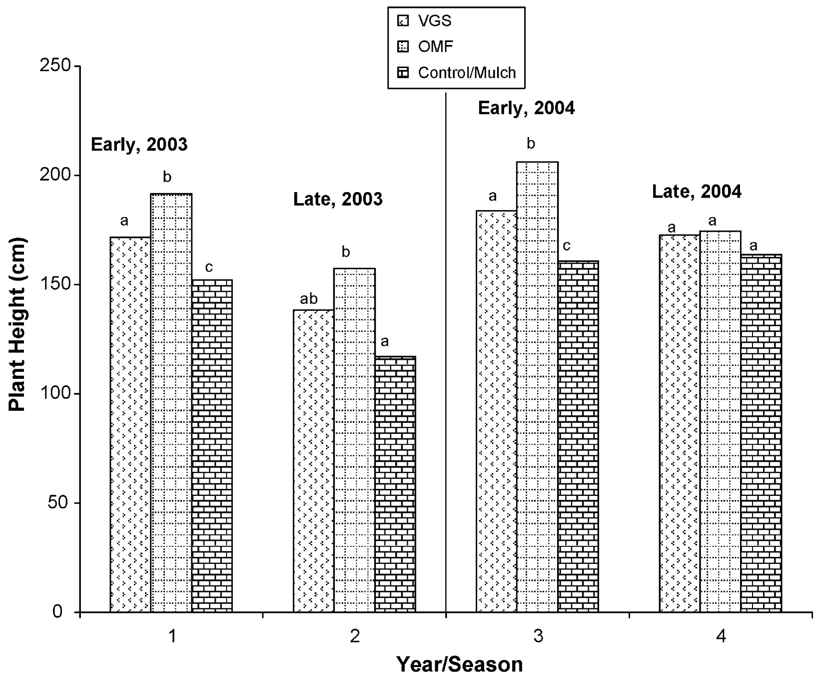


Fig. 6. Effect of vetiver grass strip (VGS), an organomineral fertilizer (OMF), mulch and a control on maize plant height during the early and late growing seasons of 2003 and 2004. Control plots received mulch application in 2004. Note that bars within each season having the same letter are not significantly different at $a = 0.05$.

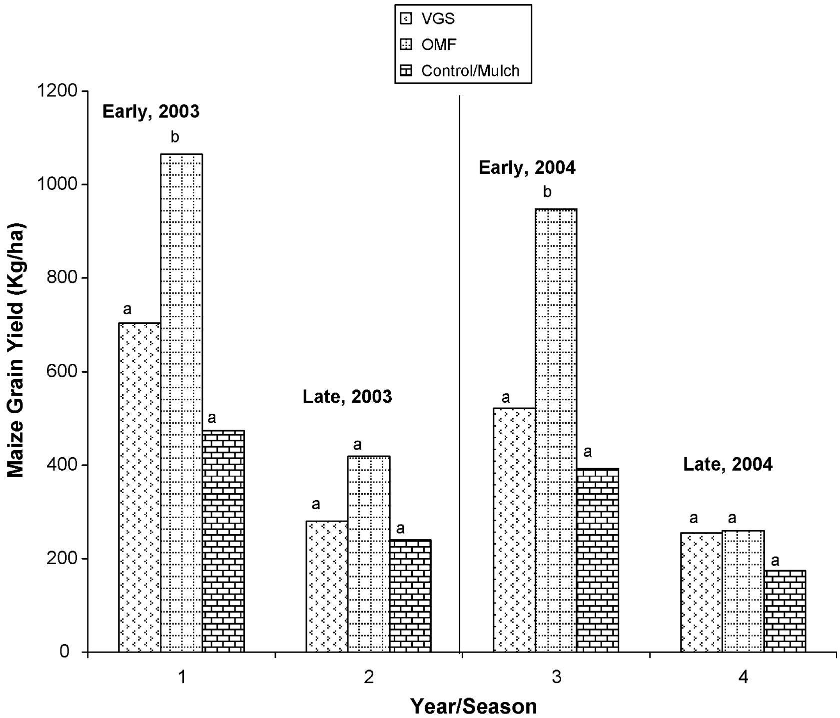


Fig. 7. Effect of vetiver grass strip (VGS), an organomineral fertilizer (OMF) and a control on maize grain yield from 40 m long runoff plots planted to maize during the early and late growing seasons of 2003 and 2004. Note that bars within each season having the same letter are not significantly different at $a = 0.05$.

compared with other treatments. Grain yield was in the decreasing order of OMF, VGS and control. Late season yields of maize in 2003 and 2004 were adversely affected because of erratic rains at the time of planting in 2003 which led to poor seedling establishment and in 2004, a sudden cessation of rains at the flowering stage of the crops. Maize grain yield under vetiver grass strips (VGS) was about 67% higher than under the control and about 66% of the yield on OMF plots in the early season of 2003. In the early season of 2004 when 2 tonnes/ha of vetiver grass clippings were applied as mulch on the control plots, maize grain yield on VGS was 75% higher than the mulched control plots and 55% of the grain yield on OMF plots. There were no significant

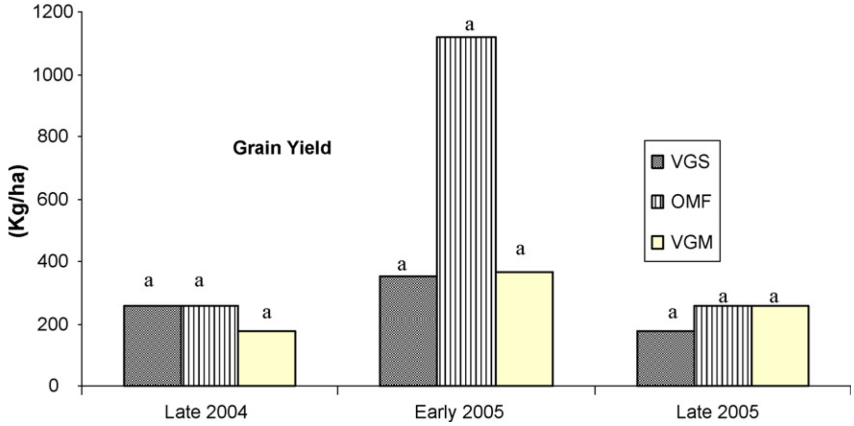


Fig. 8. Effect of vetiver grass strips (VGS), organomineral fertilizer (OMF) and vetiver grass clippings as mulch (VGM) on the grain yield of maize. (Mulch rates were 2, 4 and 6 tonnes/ha for late 2004, early and late 2005 growing seasons, respectively.) Bars within each season having the same letter are not significantly different at the 5% level.

differences in grain yield due to treatments in 2004 perhaps due to a sudden cessation of rain and the subsequent severe drought stress.

In the 2005 seasons, despite the applications of 4 and 6 tonnes/ha of vetiver grass clippings as mulch, the more beneficial effect of organomineral fertilizer on grain yield was apparent. Indeed the highest yields were obtained on OMF plots (Fig. 8). Although the differences were not significant, grain yields on mulched plots were 4% and 47.4% higher than on vetiver grass strips (VGS) when 4 and 6 tonnes/ha of mulch were applied, respectively. This supports the findings of Chen et al. (1994) and Lu and Zhong (1997) of the beneficial manurial effect of vetiver grass prunings even though *Vetiveria zizanioides* was used in their experiment as opposed to *Vetiveria nigritana* used in this study. Lu and Zhong (1997) reported that the addition of vetiver clippings to the soil as manure resulted in the production of 2790 kg/ha and 2280 kg/ha of corn seed which was an increase of 34.8% and 10.1% when compared with 2070 kg/ha yield from a control.

### 4.3. Nitrate-nitrogen levels in runoff water

Fig. 9 shows that $No_3$-N in runoff water was the least for the VGS and the highest for OMF plots during the 2003 and 2004 growing seasons. The values varied from 3.32 ppm for OMF plots in the early season of 2003 to 0.18 ppm in the early season of 2004 on VGS plots. Mean losses of $No_3$-N over the four growing seasons were 0.59 ppm, 1.46 ppm and 0.90 ppm for VGS, OMF and Control/Mulch, respectively. These differences were significant at the 5% level. The highest amount of $No_3$-N recorded on fertilized plots was not surprising

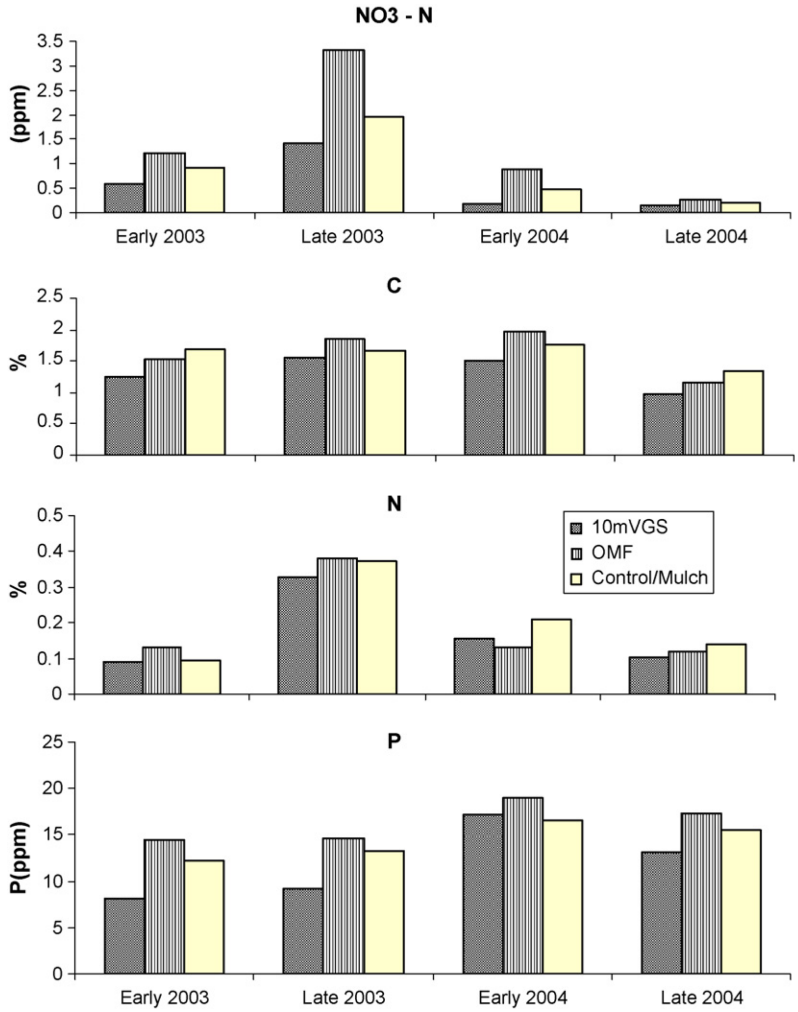


Fig. 9. Effect of vetiver grass strips (VGS) organomineral fertilizer (OMF) and a control/mulch on nitrate levels in runoff water and carbon, nitrogen and phosphorus contents of eroded soils during the growing seasons in 2003 and 2004. The differences displayed were not significant at the 5% level.

Table 4
Mean values of nutrient contents in eroded sediments over two growing seasons in 2003 as influenced by vetiver grass strip (VGS) and organomineral fertilizer (OMF) and a control

| Treatments | C (%) | N (%) | P (ppm) | Ca (Cmol/kg) | Mg (Cmol/kg) | K (Cmol/kg) | Na (Cmol/kg) | Fe (ppm) | Zn (ppm) | Cu (ppm) | Mn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VGS | 1.403 | 0.208 | 8.66 | 1.80 | 2.33 | 4.70 | 2.54 | 400 | 104 | 20.37 | 294 |
| OMF | 1.689 | 0.256 | 14.56 | 1.93 | 2.71 | 6.01 | 2.58 | 365 | 116 | 21.8 | 288 |
| Control | 1.669 | 0.233 | 12.69 | 1.86 | 2.95 | 5.69 | 1.94 | 291 | 114 | 19.4 | 285 |
| LSD (0.05) | 0.31 | 0.07 | 6.23 | 1.09 | 1.08 | 2.25 | 0.97 | 176.8 | 54 | 10.9 | 114 |

and demonstrates that as beneficial as it is to apply fertilizer for increased crop yield, the absence of a soil erosion control intervention may enhance the negative side effect of possible pollution of water bodies. Indeed VGS kept back 147.5% and 52.5% more $No_3$-N than OMF and the control/mulched plots, respectively.

### *4.4. Nutrients loss in sediments*

The vulnerability of fertilizer application to severe losses and its control are demonstrated by the data in Fig. 9 and Tables 4 and 5.

### *4.5. Carbon*

There were no significant differences in the carbon content of eroded soils among the treatments (Fig. 9). The mean carbon contents for the four growing seasons (2003 and 2004) were 1.32%, 1.63% and 1.61% for VGS, OMF and control/mulch, respectively. The corresponding mean C contents in 2003 of 1.40%, 1.69% and 1.79% and 1.24%, 1.56% and 1.55% in 2004 did not suggest any contributive effect of grass mulch on carbon content of the eroded soils.

### *4.6. Nitrogen*

Mean N content of eroded soils were 0.168, 0.191 and 0.204% for VGS, OMF and control/mulch, respectively over the four growing seasons. N contents for 2003 averaged 0.208, 0.257 and 0.233% for VGS, OMF and control plots, respectively. In 2004 when 2 tonnes of vetiver grass mulch were applied on the control plots, the values were 0.129, 0.126 and 0.175% for VGS, OMF and vetiver grass mulched (VGM) plots, respectively (Tables 4 and 5). The N content of the eroded soils on the VGS plots was 12% lower than the control plots in 2003. In 2004, the N content of the eroded soils on VGS plots was 35.9% lower than for the mulched plots. This suggests a contributive effect of N from the vetiver grass clippings to the eroded sediments and supports the findings that vetiver grass enhances the nitrogen status of soils (Chen et al., 1994; Lu and Zhong, 1997).

### *4.7. Phosphorus*

Phosphorus levels in eroded sediments on all treatments throughout the four growing seasons in 2003 and 2004 ranged from 8.08 ppm on vetiver strip plots to 19.05 ppm on OMF plots (Tables 4 and 5). The mean P contents were 11.90 ppm, 16.37 ppm and 14.36 ppm for VGS, OMF and control/mulch treatments, respectively. For the early 2003 growing seasons, mean P levels were 8.67 ppm, 14.56 ppm and 12.7 ppm, respectively. With the application of 2 tonnes/ha of mulch on the control plots in 2004, the mean P contents were 15.15 ppm, 18.17 ppm and 16.03 ppm for VGS, OMF and mulched plots respectively. Whereas P levels on the control plot was 46.5% higher than the vetiver plots (VGS) in 2003, the figure was reduced to 5.8% when mulch was applied demonstrating a positive beneficial influence of mulch on P contents of the eroded soils.

Table 5
Mean values of nutrient loads in eroded sediments over two growing seasons in 2004 as influenced by vetiver grass strip (VGS), organomineral fertilizer (OMF) and vetiver grass mulch (VGM). (*indicates significant difference at the 5% level)

| Treatments | C (%) | N (%) | P (ppm) | Ca (Cmol/kg) | Mg (Cmol/kg) | K (Cmol/kg) | Na (Cmol/kg) | Fe (ppm) | Zn (ppm) | Cu (ppm) | Mn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VGS | 1.24 | 0.129 | 15.19 | 2.56 | 2.24 | 0.70 | 0.88 | 122 | 56 | 9.65 | 232 |
| OMF | 1.56 | 0.126 | 18.17 | 3.82 | 2.68 | 1.35 | 0.96 | 188 | 72 | 13.12 | 235 |
| Mulched | 1.56 | 0.175 | 16.03 | 3.12 | 2.44 | 0.86 | 0.81 | 114 | 85 | 18.40 | 173 |
| LSD (0.05) | 0.31* | 0.06 | 5.34 | 1.42 | 1.31 | 4.02 | 0.46 | 47.71 | 46.9 | 8.76 | 149 |

### 4.8. Bases (Ca, Mg, K, Na)

The treatments did not significantly affect the nutrient loads in eroded sediments. In the 2003 growing seasons, the mean contents of the Ca, Mg and K in eroded sediments were the least for VGS plots. There were only slight differences between the values for OMF and control plots.

In the 2004 growing seasons when 2 tonnes/ha of vetiver grass mulch was applied to the control, the general trend was not altered significantly (Table 5). The total base contents of the sediments on the VGS plots were 15.0% lower than the mulched plots.

### 4.9. Micronutrients (Fe, Cu, Zn and Mn)

Micronutrient losses from the fertilized (OMF) plots were not significantly different from losses on the vetiver grass strip (VGS) plot and mulched or control plots (Tables 4 and 5). Fe, Zn and Cu contents were lower under VGS plots than the mulched plots (Table 5). Mean losses of micronutrients in 2004 growing seasons were 22.0% and 5.0% lower under VGS plots than OMF and mulched plots, respectively.

## 5. Conclusions

Soil physical conditions in terms of soil bulk density, soil organic matter and the infiltration characteristics of the soil were significantly affected by organomineral fertilizer, vetiver grass strip and vetiver grass mulch. The conditions were best under high mulch rates and least under vetiver grass strip plots. Nevertheless, runoff and soil loss generally, and the nutrient loads of eroded sediments were the least for vetiver grass strip plot and the highest for the organomineral plots. Vetiver grass mulch was more effective in reducing runoff than soil loss only at a mulch rate of 6 tonnes/ha. The significant beneficial effect of organomineral fertilizer in producing the highest maize yields was dwarfed by the potential danger of water pollution by higher nutrient loads in eroded sediments in the absence of a soil erosion control measure. Grain yields were higher on vetiver grass mulched plots than vetiver grass strip plots at 4 and 6 tonnes/ha of grass application of vetiver grass clippings. For maximum benefits, vetiver grass strip and vetiver grass mulch should be combined in the field from the standpoint of soil, water and nutrient conservation and improved crop yields. Large quantities of vetiver grass clippings from prunings make this possible.

## Acknowledgements

This study is part of the work carried out by the senior author from funds provided to him as the occupant of the First Bank (Nig Plc) Professorial Chair in Agronomy at the University of Ibadan, Nigeria, during the period 2002 to 2005.

## References

Aina, P.O., 1989. Soil erosion problems in Nigeria: issues and perspectives of soil management for conservation. In: Babalola, O. (Ed.), Proceedings of the 17th Annual Conference of the Soil Society of Nigeria, Nsukka, Anambra State, Nigeria, pp. 6–63.

Babalola, O., Zagal, E., Ogunsola, O., 2000. Physical conditions and degradation of Nigerian soils. In: Babalola, O. (Ed.), Proceedings of the 26th Annual Conference of the Soil Science Society of Nigeria. Soil Science Society of Nigeria, Ibadan, Nigeria pp. 96–507, 111.

Babalola, O., Jimba, S.C., Maduako, O., Dada, A.O., 2003. Use of vetiver grass strips for soil and water conservation in Nigeria. In: Truong, P., Xia, H.P. (Eds.), Proceedings of the Third International Conference on Vetiver and Exhibition: Vetiver and Water, Guangzhou, China, October. China Agriculture Press, Beijing, pp. 293–299.

Bartels, J.M., Bigham, J.M., Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnson, C.T. Sumner, M.E., 1996. Madison, USA, Soil Science Society of America, 1390 pp.

Chen, K., Hu, G.Q., Yao, H.M., 1994. Ecological effects of vetiver in an orange orchard on sloping land. Acta Ecol. Sinca 14 (3), 249–254.

Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures for Agricultural Research, 2nd ed. John Wiley & Sons, New York, 680 pp.

Grimshaw, R.G., 1993. The Role of Vetiver Grass in Sustaining Agricultural Productivity. Asia Technical Department. The World Bank, Washington D.C., USA.

Hu, J.Y., Xie, H.X., Zhou, C.W., 1997. Research on vetiver for red soil development. Agroforestry Today 5 (3).

Kemper, W.D., Rosenau, R.C., 1986. Aggregate stability and size distribution. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Properties. A.S.A. Monograph. No. 9, Madison, WI, pp. 425–442.

Kon, K.F., Lim, F.W., 1991. Vetiver research in Malaysia. Some preliminary results on soil loss, runoff and yield. Newsletter of the vetiver information network. ASTAG, World Bank, No. 5.

Kostiakov, A.N., 1932. On the dynamics of the coefficient of water percolation in soils and on the necessity of studying it from a dynamic point of view for purpose of amelioration. In: Trans. VIth International Congress Soil Science. pp. 17–21.

Laing, D.R., Ruppenthal, M., 1991. Vetiver News Letter No. 8 June 1992. Asia Technical Department. The World Bank, Washington, DC.

Lal, R., 1981. Soil erosion on alfisols in Western Nigeria. VI. Effects of erosion on experimental plots. Geoderma 25, 215–230.

Lal, R., 1986. Soil surface management in the tropics for intensive land use and high and sustained production. Adv. Soil Sci. 5, 1–106.

Levan Du, Truong, P., 2003. Vetiver grass system for erosion control on severe acid sulfate soil in southern Vietnam. In: Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China, pp. 284–292.

Lu, S.L., Zhong, J.Y., 1997. Vetiver applications on red soil in hilly areas. ACTA Agriculture Jiangxi 9 (4).

Omueti, J.A.I., Sridar, M.K.C., Adeoye, G.O., Bamiro, O., Fadare, D.A., 2000. In: Akorada, M.O. (Ed.), Organic fertilizer use in Nigeria: Our Experience. Agronomy in Nigeria, pp. 208–215.

Smith, K.A., Mullins, C.E., 1991. Soil Analysis: Physical Methods. Marcel Dekker, New York, 620 pp.

Smyth, A.J., Montgomery, R.F., 1962. Soils and Land Use in Central Western Nigeria. Government Printer, Ibadan, 265 pp.

Wang Zisong, 1991. The experiments and popularization of vetiver grass, Nanping Prefecture, Fujian Province China. Newsletter of the Vetiver Information Network ASTAG World Bank No. 5 March, 1991. In: Grimshaw, R.G., Helfer Larisa (Eds.), Vetiver grass: soil and water conservation, Land Rehabilitation and Embarkment Stabilization. A collection of papers.

Xia, H.P., Ao, H.X., He, D.Q., 1996. The function of vetiver on soil amelioration and water and soil conservation. Tropical Geography 16 (3), 265–270.