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Vetiver Seedlings Multiplication in Rice Husk Amended Soil and Crops Performance on Erosion-Prone Hillside under Vetiver Buffer Strips

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ABSTRACT

Vetiver buffer strips hold back soil on cultivated hillsides. A major constraint in their adoption is the low availability of seedlings for the establishment of buffer strips. Two experiments were conducted. In the first, vetiver grass strip spacing (VGSS) at 5, 15, 25 m and farmers' practice (FP) (no soil conservation measures used) were established as treatments on erosion plots sited on a cultivated hillside with a view to identifying the VGSS that would best increase crop yields. In the second experiment, 0, 25, 33.33, 41.67 and 50 $t.ha^{-1}$ of rice husk were applied as soil organic nutrient enhancer to identify the rice husk rate that would maximize vetiver seedling multiplication on degraded soil. A traditional crop mixture of maize and cassava was introduced on mounds. Maize grain yield was significantly influenced by VGSS and FP. Maize yields were 18.7, 8.7 and 11.6% higher on VGSS at 5, 15 and 25 m, respectively than on the FP plot. Maize dry matter accumulation between the VGSS and FP plots were significantly different. Fresh cassava tuber yields were significantly influenced by VGSS. Fresh cassava tuber yields were; 36.6, 12.2 and 13.2% higher on the VGSS at 5, 15, and 25 m, respectively, than on FP. The significant beneficial effect of VGSS in increasing crop yields on the cultivated hillside was evident. The farmer's field soil used for the vetiver multiplication was degraded having a sand fraction of 886 $g.kg^{-1}$ of soil and a clay fraction of 40 $g.kg^{-1}$. The soil was naturally very low in calcium and effective cation exchange capacity, low in organic carbon, nitrogen, magnesium and sodium and medium in potassium. Plant nutrient analysis of the rice husk used in amending the soil showed that it was high in available phosphorus and potassium, and medium in organic carbon and nitrogen. Vetiver tillers increased with the application rate of rice husk. A rice husk rate at 33.33 $t.ha^{-1}$ could be the optimum rate of application as there was no significant tiller increase beyond this rate.

Keywords: hillside, vetiver grass strips, erosion studies, crop yields, soil enhancement

INTRODUCTION

Oku (2011) noted that in the humid forest zone of Nigeria, population pressure and the uneven distribution of income and land have forced small holder farmers to cultivate steep hillside land not suitable for crop cultivation so that forested hillsides are increasingly being cut down and burnt for farming activities. The direct consequence has been accelerated soil erosion

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resulting in low crop yields and therefore low income returns which has spread across the humid forest zone in Nigeria, leaving behind a trail of poverty, hunger and mass migration of youths from rural to urban centers as it becomes increasingly difficult to earn a living and sustain the family by cultivating the soil Oku (2011).

It is common to hear farmers in this region complain that after three to four years of clearing the forest on the hillsides for farming activities, their crop yields on these sites have declined to low levels (Hellin, 2003). Erosion of the surface soil leads to the exposure of the more gravelly soil layer, which in turn makes working the soil difficult (Salako, 2004). It is difficult to farm on the hillside as there is no stable platform for cultivation, particularly where there are no barriers to prevent runoff and also hold the eroded soil from the upper slope. In the absence of protective barriers, the heavily erosive tropical storms detach soil particles, transport them down to the bottom of the slope and deposit the sediments in streams, rivers and the valley bottom leaving behind degraded upland hillsides. Farmers do not cultivate these hillsides by choice but as the only means of generating income for their families' upkeep and to enable their children to attend school. Hillside farming will not only continue but is expected to expand in the foreseeable future since land availability is finite and the population is growing steadily (Juo and Thurow, 1998). On the other hand, traditional cropping systems in most developing countries such as Nigeria do not apply soil and water conservation methods on steep agricultural land (FAO, 1990). In addition, the fact that there have been only a few studies on conservation practices for hillside farming does not mean that this land is not being used or cultivated (Juo and Thurow, 1998).

Accelerated soil erosion and declining crop yields constitute major challenges in the effort to reduce poverty and hunger and achieve food security in the developing countries of the world. A vetiver grass system for erosion control has had successes on agricultural farmlands prone to erosion (Truong, 1993; Inthapan and Boonchee, 2000; Phien and Tam, 2003). Even in situations where the steep slope limits the introduction of engineering structures and soil, water and plant nutrient losses continue uncontrolled, vetiver grass buffer strips can be used without constraint (Truong, 1993; Grimshaw and Larisa, 1995; Oku, 2011). Success in erosion control should translate into increased crop yields as a result of the reduction in eroded soil and plant nutrients, improved infiltration and improved water economy within the plant rooting zone as a result of the reduction in surface water runoff. In Fiji, when vetiver was first used, Truong and Baker (1998) reported up to 55% improvement in the sugar yield. In Vietnam, Phien and Tam (2003) reported that yields in plots with vetiver hedgerows increased by 15–39%. Although still in its infancy worldwide, the reported use of vetiver grass strips is more common in Asia than other parts of the world. On gentle slopes (less than 7%), crop yields were increased by a range from 11 to 26% for cowpea and about 50% for maize under vetiver management (Babalola *et al*., 2003). Vetiver grass grows in Nigeria but its potential for soil and water conservation and improved crop yields has not been fully realized, let alone quantified (Babalola *et al*., 2003; Randev, 1995).

In the humid forest zone of Nigeria, the rains are very erosive; the soils are easily detached and the topography is characterized by hilly steep land on which small holder farmers cultivate their crops (Oku, 2011). According to Grimshaw and Larisa (1995), in some countries there is a maximum acceptable slope for cultivation ranging from 12% (parts of central Africa), 25% (the Philippines) and 30% (Ethiopia), up to 34% (Israel). However, cultivators of hillsides and steep land do not observe these slope limits and it is difficult for governments even in these countries to limit cultivation above the maximum prescribed figure in the face of land scarcity and population pressure. Removing farmers from these slopes in regions where there is no alternative flatter land available for resettlement will mean relocating millions of people and their families.

On the other hand, the productivity of hilly land can be maintained for the sustained use of rural people and their families by introducing cheap, effective, user-friendly vetiver buffer strip technology that retains soil for crop production on the erosion-prone, steep agricultural land. Farmers in the study area practice mixed farming, with the International Institute of Tropical Agriculture (IITA) noting that cropping with cassava was the most common crop in the tropics using mainly rainfall agriculture which is common in the humid tropics (IITA, 2004). Mixed cropping reflects a better utilization of environmental resources and also gives higher gross returns per unit area of land (Olukosi *et al*., 1991; IITA, 2004). The use of vetiver grass strip spacing (VGSS) to support sustainable crop yields is yet to be adopted by farmers in this region. Therefore, this first study was set up to assess the growth and yield of maize and cassava, a traditional crop mixture under different VGSS on a steep hillside (45%) in order to quantify its impact on crop yield on steep slopes in the humid forest zone of Nigeria.

Additionally, although vetiver (*Vetivera nigritana)* is known in Nigeria, its potential for soil and water conservation has not been recognized. The use of vetiver buffer grass strips for soil and water conservation in Nigeria is still in its infancy; Jimba and Adedeji (2003) reported that the rapid use of vetiver buffer strips for soil and water conservation is constrained by the very low availability of planting materials in nurseries for prospective users. One of the major constraints to the multiplication of vetiver in nurseries is that soils in the humid tropics consist predominantly of sand and are very low in native soil nutrients (EI-Ashry and Ram 1987). Murwira (2003) mentioned low nutrient holding, high acidity and low organic matter as constraints of soils that were responsible for low productivity. One striking feature of the soil on the study site is its inherent low fertility which is expressed in low levels of organic carbon (Table 1). Fertile soil would enhance vetiver seedling multiplication in the nursery but the scarcity or non-availability of inorganic fertilizer in the third world is a great impediment to achieving this. It was suggested that increasing soil fertility and productivity is possible with the recycling of rice husk back to the soil as organic manure in areas where rice is grown extensively (Essoka *et al*., 2004). Sobulo and Aduayi (1990) had stated that the future of fertilizer use in agriculture will depend on the development of organic material which will provide the required nutrients, enhance the soil organic matter content and water holding capacity, and improve soil physical property. The most limiting nutrients in the soils of the humid tropical zone of Sub-saharan Africa are nitrogen and phosphorus (Mokunge, 1979). Rice husk is an agro-industrial waste that is high in phosphorus (Essoka *et al*., 2004).

Rice husk is readily available in large quantities from rice mills that abound in the rice-producing areas of Nigeria. The mammoth piles of rice husk around the mills and at dumps throughout the landscape constitute a serious environmental nuisance as the rice mills owners burn the husk as a waste reduction technique thereby compounding the pollution effects of the heaps. Therefore, the objectives of the second study were threefold: 1) to determine the growth and response of vetiver to soils treated with rice husk; 2) to determine the maximum rate of husk that would maximize vetiver tiller production; and 3) to evolve a method of disposing of the rice husk by recycling the husk to maintain soil productivity.

MATERIALS AND METHODS

Experimental site

The studies were conducted on steep agricultural land (45%) within the Faculty of Agriculture and Forestry, Cross River University of Technology, Nigeria ($6^{o}8'$ N, $8^{o}20'$ E). The experimental location has a tropical climate and the rainy season starts in April while the dry season starts from late October each year. The rainfall pattern is bi-modal with peaks in June and September; the mean annual rainfall of the area ranges from 2,250 to 2,500 mm and the mean annual temperature is 29 ^{o}C (CRADP, 1992). The soil is underlain by cretaceous sandstones and shale of the Eze-Aku group of the southeastern Benue Trough with the soil classified as an Inceptisol (Cross River State Ministry of Agriculture and Natural Resources, 1989). The soil at the experimental site was randomly sampled to a depth of 30 cm, samples were bulked and a composite sample obtained for pre-experimental routine laboratory analysis. The bulked sample was air dried, passed through a 2 mm sieve and analyzed for particle size distribution and some chemical properties. Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Soil pH was determined in 1:2 soil:water ratio with a Benchtop ORP pH meter. The Walkey and Black wet oxidation method (Allison, 1965) was used to determine the content as explained by organic carbon. The micro-Kjeldhal method of Bremner and Mulvaney (1982) was used for nitrogen determination. The methods of Bray and Kurtz (1945) and Riley and Murphy (1962) were used to determine available phosphorus. The contents of exchangeable cations (Ca, Mg, K and Na) were determined using the method of Chapman (1965). The effective cation exchange capacity (ECEC) was determined by summing up the total exchangeable bases and exchangeable acidity (IITA, 1979). Base saturation was calculated by dividing the total exchangeable bases by ECEC and finding the percentage (IITA, 1979).

Experiment one

The experiment was conducted during 2010 and 2011. The treatments involved three different distances of vetiver grass strip spacing (VGSS) (5, 15 and 25 m) and the conventional farmers' practice (FP) (no soil protection measure is applied). These treatments were laid out in three blocks in a complete randomized block design. There were twelve erosion plots, with each measuring 50 m long and 3 m wide (150 m^2) that were normally used for cropping (Oku, 2011). The treatments were imposed on the erosion plots. Mounding, the predominant traditional tillage system in the study area, was used. Mounds were made 100 × 100 cm. Three cassava cuttings of a local variety were planted per mound giving a total population of 30,000 plants.ha^{-1}. Maize (Oba Super II hybrid variety) was planted at the rate of three seeds per hole at the base of each mound. The maize seedlings were thinned to two per mound one week after emergence, leaving a total maize population of 20,000 plants.ha^{-1}. Compound fertilizer (NPK 15:15:15) was applied to only maize at 5 cm depth and at a 10–15 cm radius from the plant at the rate of 300 kg.ha^{-1} three weeks after planting (WAP). Weeding was done with a hoe at 3, 8 and 24 WAP. Maize yield measurements were collected at harvest (103 days after planting). Harvested maize seeds were dried, weighed and grain yield data adjusted to 14% moisture content. Maize dry matter accumulation was determined by oven drying samples at 65 ^{o}C to a constant weight. Cassava tubers were harvested seven months after planting. The fresh tuber weight per plant was measured. The data obtained were subjected to analysis of variance (ANOVA) and the means that showed significant differences were separated by least significant differences, as described by Gomez and Gomez (1984). Pre-experimental soil sampling was done by randomly collecting samples from 0–30 cm depth. The samples were air dried and passed through a 2 mm sieve for routine soil physico-chemical analysis.

Experiment two

The rice husk was ploughed and harrowed into the soil three weeks before the planting of vetiver to allow time for mineralization of the rice husk. Treatments consisted of rice husk at rates of : 0 t.ha^{-1} (control); and 25, 33.33, 41.67 and 50 t.ha^{-1}.

Each experimental unit (plot) measured 4 × 4 m. Each treatment had four blocks and was laid out in a complete randomized block design. Planting material (5 mth old) was obtained from the vetiver nursery at the Department of Agronomy, Cross River University of Technology, Nigeria. The vetiver splits were cut with a 20 cm top and roots were cut at 30 cm and two tillers (splits) per stand were planted at a spacing of 20 × 30 cm based on the prescription for good establishment of vetiver grass in the humid tropics (Jimba and Adedeji, 2003). The vetiver was planted in July 2008 when there was regular rainfall. Weeding was done at 4 and 8 WAP. Plant heights were assessed at 2, 4, 6, 8, 10 and 12 WAP, when the number of tillers and dry matter accumulation of the root, shoot and total plant were also assessed. From 12–16 wk, vetiver is sufficiently mature for field establishment (Jimba and Adedeji, 2003). At 12 WAP, a count of the number of tillers produced per hill was carried out. Vetiver plants were randomly selected and gently dug out for dry matter accumulation determination. The dry matter accumulation of root and shoots was determined by oven drying at 65°C to a constant weight. The dry matter accumulation was computed on per plant basis. Data obtained were subjected to ANOVA as specified by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Experimental sites

Table 1 shows the native fertility of the soil used for both studies and the chemical nutrient contents of rice husk. Particle size analysis of the soil shows a preponderance of sand (more than 80%). The coarse texture of the soil implies low stability, low specific surface area and as a result, low cation exchange capacity. The low clay content (less than 4%) means low ability of the soil to retain nutrient and added nutrient in the form of fertilizer (Idoga *et al*., 2006). The low silt content has been reported by Ahn (1979) as typical of West African soils. The soil was acidic (pH 5.3–6.5), low both in organic carbon (less than 15 $g.kg^{-1}$) and total nitrogen (less than 1.0 $g.kg^{-1}$) content. The low organic carbon content of the soil implies low aggregate stability of the soil. This low stability makes the soil susceptible to degradation, particularly when the hillside has

Table 1 Some physico-chemical properties of the soil used for the experiment (sampled at 0–30 cm).

Soil property	Amount
Sand ($g.kg^{-1}$)	886
Silt ($g.kg^{-1}$)	74
Clay ($g.kg^{-1}$)	40
Soil pH H_2O (2:1 water:soil)	5.62
Total nitrogen (%)	0.05
Organic carbon (%)	0.54
Available phosphorus ($mg.kg^{-1}$)	11.75
Exchangeable Bases	
Calcium ($cmol.kg^{-1}$)	1.4
Magnesium ($cmol.kg^{-1}$)	0.8
Potassium ($cmol.kg^{-1}$)	0.36
Sodium ($cmol.kg^{-1}$)	0.11
Exchangeable acidity ($cmol.kg^{-1}$)	0.16
Base saturation (%)	94.3
Effective cation exchange capacity ($cmol.kg^{-1}$)	2.83

been cleared of vegetation and made vulnerable to agents of degradation like water erosion. Based on Holland *et al*. (1989), the soil was very low in calcium (less than 5 $cmol.kg^{-1}$), medium in potassium (0.3–0.6 $cmol.kg^{-1}$), low in magnesium (0.3–1.0 $cmol.kg^{-1}$) and very low in cation exchange capacity (less than 5 $cmol.kg^{-1}$), while available phosphorus was high (> 10.0 $mg.kg^{-1}$).

Experiment one

There were significant differences among the maize grain yields of the different VGSS and FP (Table 2). The maize grain yield with the VGSS at 5 m was 18.1% higher than for FP and it was 8.7 and 11.6% higher on VGSS at 15 m and 25 m, respectively, than for FP. The significant differences in maize yield reported on the mounds in the current study is different from the 5 m and 10 m VGSS and no vetiver plots reported by Babalola *et al*. (2003) in Ibadan, western Nigeria. However, the study in western Nigerian was on a gentle slope (less than 7 %). The dry matter accumulation

Table 2 Effects of different vetiver grass strip spacing on maize grain yield and some crop parameters on steep land (45% slope).

Vetiver grass strip spacing (m)	Range	Mean
	Maize grain yield ($t.ha^{-1}$)	
5	10.34–10.64	10.52±0.57
15	8.90–9.81	9.43±1.38
25	9.37–10.05	9.74±1.23
Farmers' practice	8.31–8.83	8.61± 0.95
LSD (*P* = 0.05)		0.7
	Dry matter (stover) yield per plant (g)	
5	67.70–76-00	70.78±1.61
15	54.38–59.52	56.23±1.01
25	57.83–68.00	61.55±1.98
Farmers' practice	44.07–45.96	44.99±0.33
LSD (*P* = 0.05)		5.09
	Maize height at tarselling (cm)	
5	138.21–157.18	145.37±3.64
15	139.11–148.43	144.35±1.68
25	121.36–143.88	132.17±3.99
Farmers' practice	105.13–145.03	129.71±7.60
LSD (*P* = 0.05)		NS
	Number of leaves/maize plant	
5	12.19–12.30	12.26±0.02
15	11.42–12.43	11.85±0.18
25	10.76–12.66	11.66±0.34
Farmers' practice	11.69–12.71	11.98–0.23
LSD (*P* = 0.05)		NS

LSD = Least significant difference; NS = Not significant.

(Table 2) was 36.4, 19.9 and 26.9% significantly higher on the VGSS at 5, 15 and 25 m, respectively, than on the FP plot. The maize height at tarselling and the number of leaves per maize plant were not significantly influenced by the different VGSS and FP treatments(Table 2). The maize plant heights were 10.7, 10.1 and 1.8% higher on 5, 15 and 25 m VGSS plots, respectively, than for FP.

The fresh cassava tuber yields were significantly influenced by VGSS and FP (Table 3). The fresh cassava tuber yields were: 36.6, 21.2 and 13.25% significantly higher on VGSS at 5, 15 and 25 m plots, respectively, than on the FP plot. Increases in the yield of crops under the influence of vetiver grass buffer strips on agricultural farmland have been reported elsewhere (Truong, 1993; Inthapan and Boonchee, 2000; Phiem and Tam, 2003). A similar increase in the yield of cassava under VGSS at 10 m on a 7% slope was reported in Ibadan, Western Nigeria (Babalola *et al*., 2003).

Experiment two

Rice husk was high in available phosphorus and potassium but low in organic carbon and total nitrogen (Table 4). Different rates of rice husk (organic fertilizer) did not impact on plant height at 2, 6 and 12 WAP (Table 5). However, there was a significant difference in plant height at 8 and 10 WAP. Vetiver tiller multiplication under different rates of rice husk was significantly different. However, tiller multiplication under plots with 33.33, 41.67 and 50 t.ha^{-1} of rice husk was not significantly different (Table 6). Vetiver tillers produced under natural soil fertility (rice husk applied at 0 t.ha^{-1}) produced the lowest number of tillers. Tiller multiplication was 40, 47 and 50% significantly higher on application plots of 33.33, 41.67 and 50 t.ha^{-1}, respectively, than on the control plots (0 t.ha^{-1} of rice husk). Although tiller multiplication on the plots with rice husk applied at 25 t.ha^{-1} was 25% higher than the control plots, the difference was not significant.

The effects of different rates of rice husk application on the shoot and total plant dry matter accumulation are shown in Table 7. The vetiver grass dry matter accumulation from the application of rice husk at 0.t ha^{-1}, (control) was significantly different from plots where rice husk was applied at 33.33, 41.67 and 50 t.ha^{-1}. The total plant dry

Table 3 Effects of different vetiver grass strip spacing on fresh cassava tuber yield on steep land (45% slope).

	Fresh tuber yield/plant (kg)	
Vetiver grass strip spacing (m)	Range	Mean
5	1.40–1.71	1.58±0.06
15	1.19–1.32	1.27±0.03
25	1.06–1.22	1.16±0.03
Farmers' practice	0.98–1.05	1.00±0.01
LSD (P = 0.05)		0.24
	Fresh tuber yield (t.ha^{-1})	
5	42.00–51.60	47.50±1.75
15	35.70–39.60	38.20±0.77
25	31.80–36.60	34.70±0.90
Farmers' practice	29.40–31.50	30.10±0.43
LSD (P = 0.05)		5.82

LSD = Least significant difference.

matter accumulation on plots with rice husk applied at 25 $t.ha^{-1}$ was 29% higher than on the control plot. This was however not significant. The tiller multiplication under rice husk application rates of 33.33, 41.67 and 50 $t.ha^{-1}$ were 49, 55 and 56%, respectively, higher than on the FP (control plots). Although tiller production, and the root, shoot and total plant dry matter accumulation increased with increased rice husk rates, the tiller production was not significant when the rate of 33.33 $t\ ha^{-1}$ was exceeded.

Table 4 Nutrient/chemical properties of rice husk.

Rice husk property	Amount
pH	6.1
Organic carbon ($g.kg^{-1}$)	320
Total nitrogen ($g.kg^{-1}$)	2.72
Available phosphorus ($mg.kg^{-1}$)	99.12
Calcium ($cmol.kg^{-1}$)	0.4
Potassium ($cmol.kg^{-1}$)	1.02
Sodium ($cmol.kg^{-1}$)	0.11
Exchangeable acidity ($cmol.kg^{-1}$)	4.48
Base saturation (%)	32
Effective cation exchange ($cmol.kg^{-1}$)	6.61

Table 5 Effect of different rates of rice husk on plant height (cm) of vetiver grass in the nursery.

Rice husk	Weeks after planting					
($t.ha^{-1}$)	2	4	6	8	10	12
0 (control)	37.92	67.67	84.21	103.33	129.08	157.83
25	46.91	79.63	90.92	107.83	135.83	151.02
33.33	45.08	74.63	94.25	122.23	141.63	166.58
41.67	49.74	75.07	93.40	131.83	154.33	196.67
50	52.91	76.73	93.44	143.40	167.75	203.08
LSD (P = 0.05)	NS	NS	NS	11.16	23.54	NS

LSD = Least significant difference; NS = Not significant

Table 6 Effect of different application rates of rice husk on tiller production at 12 weeks after planting.

Rice husk	Number of tillers	
($t.ha^{-1}$)	Tiller/planted split	$Tiller.ha^{-1}$ ($\times 10^4$)
0 (control)	9	112.5
25	12	150.0
33.33	15	187.5
41.67	17	212.5
50	18	225.0
LSD (P = 0.05)	5	

LSD = Least significant difference.

Table 7 Effect of different application rates of rice husk on dry matter yield of vetiver grass at 12 weeks.

Rice husk ($t.ha^{-1}$)	Dry matter yield		
	Root ($g.plant^{-1}$)	Shoot ($g.plant^{-1}$)	Total plant ($g.plant^{-1}$)
0 (control)	26.78	42.55	69.33
25	39.22	59.00	98.22
33.33	53.67	83.78	137.45
41.67	58.33	97.22	155.55
50	63.11	94.89	158.00
LSD ($P = 0.05$)	31	41	31

LSD = Least significant difference.

CONCLUSION

The increasing need for cropland has prompted farmers to cultivate more and more marginal lands (such as steep hillsides). The cultivation of hillsides will continue even in the foreseeable future with its attendant low crop yield as farmers do not have the choice to farm better land since land is a finite resource and the population is growing steadily. Vetiver buffer strips across steep agricultural land can be used for erosion control. The use of vetiver buffer strips in this study significantly increased maize and cassava yields in the traditional crop mixture on a steep hillside in the humid forest zone of Nigeria. Vetiver grass strip spacing at 5 m gave the best significant crop yield and is recommended for farmers cultivating hillsides for the protection of the hillside and the sustainability and maximization of crop yields. Rice husk used as a soil nutrient enhancer significantly encouraged vetiver tillers to multiply. Rice husk, being of organic origin, acts as a source and sink for nutrients. Recycling rice husk to the soil could be a way of building up the little or non-existent soil organic matter of tropical soil, increasing soil productivity and improving crop yield instead of allowing the mountains of organic waste (rice husk) to adversely effect surface and underground ecosystems.

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