Vetiver System for Agriculture Development

Reviewer

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Abstract: Early in 1988, less than a year after it was introduced as a pilot experiment in the red earth area in South China, Vetiver had attracted wide attention for its "magical" characteristics, such as its wide adaptability and rapid growth. At that time, many agricultural officers, scientists and technicians as well as some farmers were involved in research, experimentation, application and promotion of Vetiver. During the past 15 years, the Vetiver System (VS) has been applied widely in agricultural sectors including sustainable agriculture development; soil and water conservation in orchards, in tea gardens and on sloping farmland; ecological and environmental improvement of farmland; moisture retention by mulching with Vetiver leaves and stems to avoid drought; increased crop production; soil fertility by using leaves and straw for manure; environmental protection; windbreaks to prevent shifting sands from invading farmland; livestock production; fodder production by using the tender leaves and straw for cattle and sheep feed; and rural economic development by using Vetiver straw to culture edible fungi such as Jew's ear (*Auricularia auricula-judae)*.
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1 VETIVER SYSTEMS FOR SOIL AND WATER CONSERVATION IN ORCHARDS, TEA GARDENS AND ON SLOPING FARMLAND

1.1 In China

Vetiver Systems applications in agriculture for soil and water conservation with orchards, tea gardens and sloping farming fields is very important. Technicians in the experimental group of the first phase of the Red Earth Development Program in Jiangxi and Fujian Provinces first introduced Vetiver plants as pilot experiments in agriculture development in 1989. At that time the Jiangxi Red Earth Program Office introduced 10,000 kg of Vetiver by planting on farmland in 6 counties (Guixi, Jinxi, Linchuan, Dongxiang, Chongren and Jinxian) and a research institute (Jiangxi Provincial Institute of Red Earth) within the development area. Altogether the Vetiver protected more than 200 ha of fields.

At the same time, the Fujian Red Earth Program introduced another 30,000 kg of Vetiver plants. These were planted in 29 tea gardens and orchards distributed in 7 counties in that province and protected more than 130 ha of fields as well. All experimental Vetiver plants were planted according to the technical rules listed in the *Green Book* (the Vetiver field handbook). In the fields involved, Vetiver was planted on the contour, with 2 m between contour lines. In addition, some farmers planted additional lines around their own fields to protect their crops with a Vetiver hedge.

Due to a shortage of Vetiver planting material, only 2-3 slips of Vetiver were planted in a clump at each hole with holes at 20 cm intervals. When planted, a small quantity of phosphorus or composite fertilizer was also applied. A year later, the plants had formed hedges with a 75% density. After the third year of establishment, these thick hedges provided excellent soil and water conservation conditions by intercepting runoff as well as trapping eroded silt and soil.

According to experimental results from standard runoff fields set up in Jiangxi and Guangdong Provinces (Table 1), silt interception increased with the Vetiver hedges compared to a control with no hedges revealing a decrease in surface runoff of 32.7%-59.7%, while soil erosion was reduced by 63.7%-92.7% (Hu *et al*., 1997; Xia *et al*., 1996).

Table 1 Effects of vetiver hedges on water and soil conservation[a]

Field Sites	Annual Rainfall (mm)	Treat-ment	Surface Runoff			Eroded Soil		
			Total (mm)	Decrease (mm)	Decrease (%)	Total (kg/m^2)	Decrease (kg/m^2)	Decrease (%)
Yonghe Town, Xingning City, Guangdong Province	1931.8	Control	1015.8			14.53		
		Vetiver Hedge	409.1	606.7	59.7	1.06	13.47	92.7
Sixia Small Catchment, Chongren County, Jiangxi Province	1766.0	Control	223			3.36		
		Vetiver Hedge[b]	151	72	32.7	1.22	2.14	63.7
		Level Terrace	170	53	23.8	1.67	1.69	50.3

[a] Figures were averaged from measurements in 1993 and 1994. Vetiver was planted in 1992. Observation area for each treatment was 100 m^2

[b] Vetiver hedges were established on 6^0 slopes

A stationary observation in Renshou County, Sichuan Province, set up by the Soil and Fertilizer Division of the Agriculture and Animal Husbandry Department of that province, showed that 2 cm of silt was intercepted in front of the Vetiver hedge in the first year of its establishment, and 5 cm of silt was observed in the second year at the same site. Meanwhile, very evident eroded rills were seen at locations without Vetiver hedge protection. These observations showed Vetiver's excellent results in soil conservation.

In a different experiment in Yonghe Town, Xingning City, Guangdong Province, with Vetiver hedges present, soil moisture content during the rainy season increased 20.3% and 4.1% at soil depths of 0-20 cm and 20-40 cm, respectively, when compared to a control (Table 2) (Xia *et al.*, 1996). More importantly though, larger corresponding figures of 42.1% and 13.3% were recorded during the dry season. At the Soil Conservation Station in the same city, increases of 39.9% and 7.6% were recorded with Vetiver hedges in the dry season at 0-20 cm and 20-40 cm depths, respectively. This illustrated the positive effects of Vetiver grass on maintaining soil moisture during times of stress.

Since 1993, Vetiver technology has been further disseminated to counties and cities involved in the Second Phase of the Red Earth Development Program in Jiangxi, Fujian, Hunan and Zhejiang Provinces as well as Guangxi Autonomous Region. These areas are all found in South China's Soil and Water

Conservation Program. For example, in Jiangxi Province alone, Vetiver contour hedges, with an accumulated area of over 20,000 ha, controlled all 43 small catchments on farms involved in the program distributed throughout 19 counties. These played an important role in controlling soil and water losses in the early stages of this phase of the Red Earth Development Program. Promoted by the China Vetiver Network (CVN), Vetiver Systems were disseminated to 16 provinces and regions in South China in 1998, with an estimated 200,000 ha planted.

Table 2 Increase of soil moisture content due to vetiver

Experimental Sites[a]	Observation Season	Treatment	Depth: 0-20 cm		Depth: 20-40 cm	
			% Moisture	Increase (% Increase)	% Moisture	Increase (% Increase)
Yonghe Town	Dry	Control	15.74		19.29	
		Vetiver Area	22.37	6.63 (42.1%)	21.86	2.57 (13.3%)
	Rainy	Control	22.47		25.31	
		Vetiver Area	27.03	4.56 (20.3%)	26.36	1.05 (4.1%)
Soil Conservation Station	Dry	Control	16.3		14.50	
	Dry	Vetiver Area	22.8	6.5 (39.9%)	15.60	1.1 (7.6%)

[a] Both sites are located in Xingning City, Guangdong Province.

Moreover, a Vetiver System, with an area of nearly 80 ha, was established during the implementation period of the "China Vetiver and Agroforestry Program" led by Prof. Xu Liyu, of the Nanjing Institute of the Chinese Academy of Soil Sciences. On slopes in the Dabie Mountains, chestnuts, tea gardens, and mulberry farms located in Yuexi County, Anhui Province and Yingshan County, Hubei Province, were planted with Vetiver in 2002 and 2003. As the Vetiver hedges fill out, their effects on conserving soil and moisture as well as on ensuring continuous high yields of tea and fruits will become evident. Because of the favorable results to date, the project has been broadened through training and extension programs to include the whole of the Dabie Mountain region.

1.2 In Other Countries

In Nigeria a study was conducted at the University of Ibadan, over three growing seasons to assess

(i) the effectiveness of vetiver grass on soil and water loss,
(ii) soil moisture retention and,
(iii) crop yields.

Vetiver strips were established on 6% slopes at a surface interval of 20 m on erosion plots measuring 40 m x 3 m each. Plots with and without vetiver strips constituted the treatment and control, respectively. The plots, laid bare in the first season to determine the maximum efficiency of the vetiver strips, were sown to cowpea in the second season and maize in the third season when actual runoff and soil loss from each plot were determined using soil and water collecting devices at the end of each plot. Results showed that first vetiver strip on the slope accumulated 98% more soil than lower vetiver strips in the first year. Vetiver strips increased cowpea seed and stover yields by 11.1% and 20.6%, respectively and increased soil moisture storage by a range of 1.9% to 50.1% at various soil depths. Maize yield increased by 50%. Soil loss and runoff water were 70% and 130% higher on non-vetiver plots than vetiver plots. Eroded soils on non-vetiver plots were consistently richer in nutrient contents than on vetiver plots. Nitrogen use efficiency was enhanced by about 40% (Babalola *et al*., 2003).

Cassava is a crop that induces high rate of soil erosion, especially if grown in sloping sandy soils. The joint research of the Centro Internacional de Agricultura Tropical, the Department of Agriculture, and Kasetsart University in Thailand revealed that planting methods or planting system adjustment could reduce soil erosion. Each method has certain advantages and disadvantages. While some methods give extra income, some others need more management or high investment; thus it was not certain whether or not the farmers would adopt any of these methods. During the first phase (1994-98) of the Project, two pilot sites were selected in Nakhon Ratchasima and Sa Kaeo provinces. Farmer Participatory Research trials on methods to reduce soil erosion were conducted for three consecutive years. After narrowing down the number of suitable options, farmers in both sites finally selected and adopted the contour strip cropping of cassava with vetiver hedgerows. They planted vetiver hedgerows of a total length of 17 km in the first year.

In the second phase of the Project (1999-2003), a total of 18 villages in 14 districts in eight provinces were participating in the Project There were 622 farmers participated in the Project, andvetiver hedgerows were grown for a total length of 111 km in the cassava fields (Somsak Suriyo and Wilawan Vongkasem, 2003).

2 VETIVER MULCH TO IMPROVE SOIL MOISTURE AND FARM ECOLOGICAL ENVIRONMENT

In China, Vetiver grass (mainly hedges for soil conservation) planted between fruit trees, tea trees and other crop lines must be pruned several times every year. The first pruning occurs at the end of February when the dead leaves and stems that dried out during the winter are removed. Then, from the middle or latter part of June to the middle part of September another 3-4 prunings must take place. The pruned leaves and stems are usually used *in situ* as mulch materials to help resist drought or cold injury to fruit trees, tea bushes and other crops. The mulch is usually placed at the base of the tree, bush or crop or buried in the soil while fertilizing. Farmers have adopted this practice to increase yields as it helps retain soil moisture, lowers soil temperature and resists drought in the summer, while facilitating resistance to cold in the winter.

Chen *et al.* (1994), conducted a trial in an experimental citrus orchard located on Xiaohuashan Hill, a hill of red earth soils in Linchuan County, Jiangxi Province (28.0°N, 116.5°E, 50m above sea level). Orchard surface soils without Vetiver were compared to those with Vetiver planting and mulching. Results showed that the ecological environment of the orchard with Vetiver planting and mulching (the mulch consisted of pruned Vetiver leaves and stems placed on the soil surface at the base of and under the tree crowns) had greatly improved. On mid-summer days, the average temperature measured at the middle of the tree crowns (Table 3) decreased by 2.8_; relative humidity increased 4.3%; illumination intensity decreased 18.6 klux; and daily mean temperature, daily maximum temperature, and diurnal temperature range on the surface soil at the base of the tree decreased by 5.1_, 19.1_ and 20.8_, respectively. Meanwhile daily minimum temperature increased by 1.7_, daily inter root mean soil temperature decreased by 1.7_, and soil moisture increased by 2.8%. This illustrated that Vetiver improved the microclimate of the citrus orchard located on sloping red earth land. Especially during the mid-summer dry season with its high temperatures, the soil temperature was greatly lowered, while soil moisture maintained acceptable levels.

Hu *et al*. (1997) conducted another experiment on a low hill in a citrus orchard, located at the Jiangxi Provincial Institute of Red Earth in which soil moisture capacities under different treatments were compared. The treatments were as follows: 1) the base of citrus trees were mulched with 12 kg of dry

Vetiver grass; 2) the base of citrus trees were mulched with the same amount of dry rice straw; and 3) there was no mulch applied (control).

Table 3 Effects of vetiver planting on microclimate improvement in a citrus orchard on red earth sloped land

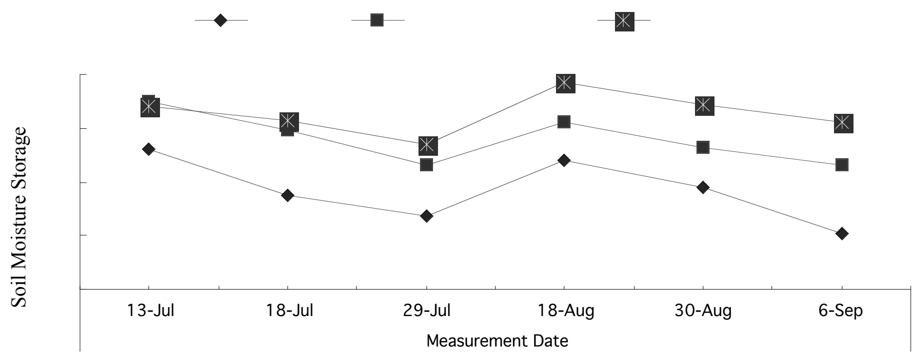
Treatment	Daily Mean Temp. (in tree crown) °C	Daily Mean Relative Humidity %	Daily Illumination Intensity k lux	Temperature of Surface Soil at the Base of the Tree: Daily Mean °C	Daily Max. °C	Daily Min. °C	Diurnal Range °C	Soil in Grass Roots: Daily Mean Temp. °C	Moist. Content %
Control	29.3	59.2	57.2	33.8	58.6	22.5	36.1	29.2	17.4
Vetiver	26.5	63.5	38.6	28.7	39.5	24.2	15.3	27.5	20.2

Results showed that, the daily mean soil moisture evapotranspiration from 0-60 cm observed on the first treatment of dry Vetiver grass at the 5th day and 16th day during a continuous fine-weather period were 1.4 mm and 1.1 mm, respectively. That is to say, at the 16th day during a continuous fine-weather dry period in mid-summer, soil within 0-60 cm depth in the Vetiver mulch treatment contained 4.5% and 17.9% more moisture than that in the rice straw mulch treatment and the control treatment, respectively (Fig.1). Moreover, the differences were greater at the end of the Autumn-drought days. On 6 September, in the middle of the Autumn-drought period, there was 10.3% and 27.8% more moisture retained in soils with Vetiver mulch compared to the rice straw mulch treatment and the control treatment, respectively. As a result the Vetiver mulch increased the farmland's drought endurance capability by 6-10 days (Fig.1).

3 VETIVER CLIPPINGS TO IMPROVE SOIL FERTILITY AND CROP YIELD

Vetiver grass hedges established in orchards, in tea gardens and on sloped farmland have to be pruned 3-4 times per year and can yield 8-15 kg/m of fresh vegetation. Annual yields of fresh Vetiver plant material can reach 58-100 t/ha along with 24 t/ha of root material. According to the Jiangxi Provincial Institute of Red Earth, in 1 kg of dry Vetiver leaves and stems there are 422 g of C, 17.4 g of N, 0.5 g of P_2O_5, and 7.5 g of K_2O. Meanwhile, 1 kg of dry Vetiver roots contains 402 g of C, 2.1 g N, 0.6 g P_2O_5, and 5.8 g K_2O. Thus, Vetiver pruning used as mulch or manure can effectively improve soil fertility leading to increased crop production.

Fig. 1 Dry season soil moisture change, soil depth 0-60 cm, in a citrus orchard using various mulches



Lu and Zhong (1997) at the Jiangxi Provincial Institute of Red Earth conducted a 3-year stationary experiment in which cut Vetiver chips were applied to the soil as manure to improve fertility. In this experiment, 4.5 t and 2.25 t of dry Vetiver leaves and stems were applied on 2 farmland sites. Results

(Table 4) showed that soil total porosity, organic C, total N, total P_2O_5 as well as available N and available P_2O_5 on treated farmland increased while soil specific weight decreased. This resulted in production of 2790 kg/ha and 2280 kg/ha of experimental corn seed, which was an increase of 34.8% and 10.1%, respectively, when compared with 2070 kg/ha yield from a control.

Table 4 Effects of vetiver clippings on soil physical features and chemical characteristics of red earth farmland

Treatment	Specific Weight[a] (mg/cm^3)	Total Porosity[a] (%)	Organic C[a] (g/kg)	Total Component[a] (g/kg)			Available Component[a] (g/kg)		
				N	P_2O_5	K_2O	N	P_2O_5	K_2O
Vetiver[b]	-0.03	+1.0	8.24	1.07	0.51	15.13	168	16.8	75.0
Vetiver[c]	-0.04	+1.3	8.26	1.08	0.51	15.12	173	15.3	77.5
Rice straw[c]	-0.09	+3.0	7.6	1.03	0.48	14.86	120	14.1	73.8
Control	+0.14	-5.0	7.97	1.05	0.50	15.26	163	13.5	75.0

[a]Values for specific weight and total porosity were derived by taking the differences between measurements before and after the experiment (i.e., after the third harvest), while other measurements were recorded at the end of the experiment; [b]applied 4.5 t/ha of dry straw ; [c]applied 2.25 t/ha of dry straw

Similar results were found in an experiment conducted by Chen *et al.* (1994), at Nanjing University of Agriculture, in which Vetiver grass was planted in a citrus orchard on red earth sloped land and then applied as a mulch material at the base of the trees. In this experiment, when compared to an untreated case, soil physical features and chemical characteristics in the treated cases improved. As shown in Table 5 the soil specific weight dropped by 0.09 mg/cm^3, soil porosity increased by 3.8%, and the pH value went up 0.65 (meaning acidity decreased). In addition, there were increases in the following: organic matter (OM) 4.60 g/kg, total N 0.29 g/kg, hydrolytic N 17 mg/kg, available P 2.4 mg/kg and available K 51 mg/kg. Meanwhile micronutrients also increased by the following amounts: Ca 274 mg/kg, Mg 21.85 mg/kg, Fe 18.27 mg/kg, Mn 1.59 mg/kg, Zn 1.90 mg/kg, Cu 0.32 mg/kg, B 0.04 mg/kg and Mo 0.01 mg/kg. Finally, total soil amino acid content increased by 57.44 mg/kg. The experiment indicated that Vetiver planted in a citrus orchard on red earth sloped land could help increase citrus yields due to improvement of the soil physical features and chemical composition. It was also noted that conditions for citrus flowering and fruiting were enhanced. For example, the increase in pH and OM meant an increase in soil nutrient availability and an improvement in ability of the citrus root system to assimilate them.

4 APPLICATIONS AS WINDBREAK ON FARMS, STABILISATION OF SHIFTING SAND, AND RIVERS AND PONDS EMBANKMENTS ON COASTAL ZONE

4.1 In China

Key attributes of Vetiver grass are its drought resistance, its ability to grow on infertile soils and its deep and thick root system allowing wide adaptability. Therefore, technicians in Fujian and Jiangxi Provinces planted Vetiver as a fast growing windbreak hedge to fix shifting sands and to stabilize seacoast embankments, riverbanks and pond dikes, with beneficial results.

In March 1994 the Soil Conservation Office of Fuzhou City, Fujian Province established Vetiver hedge windbreaks for their Jojoba (pronounced hohoba) oil crop garden in Daping Village, Zhonglou Township, Pingtan County. The 0.44 ha garden of sandy soil, comprised of mainly shifting sands (90%), had an annual mean wind velocity of 8.4 m/s with a prevailing northerly wind. In total the hedges were over 800 m long and arranged at 6-8 m intervals. This was parallel to the Jojoba lines and perpendicular to the prevailing wind direction. These hedges filled out the same year the Vetiver was planted and after 1 year had long, thick leaves and stems. By the end of the second year, these lush hedges which were over 2 m high, had already become powerful natural windbreaks arresting the shifting sands and protecting the Jojoba garden. The result was a high yield of oil. Measurements on the sheltered (leeward) side of the hedges showed that wind speed was greatly diminished by the hedges (Zhang, 1996). The closer the measurement was to the hedges the greater the decrease in wind speed. For example, 5 m from the hedge, the wind speed decreased 58.8% while 2 m away from the hedge the wind speed decreased 79.4%.

Table 5 Effects of vetiver clippings on improvement of soil physical and chemical properties for red earth soils in a citrus orchard

Treatment	Specific Weight (mg/cm^2)	Porosity (%)	pH	OM	Total N (g/kg)	Hydrolytic N	Available P (mg/kg)	Available K	
Control	1.35	48.6	4.70	10.30	0.54	47	7.0	24	
Vetiver	1.26	52.4	5.35	14.90	0.83	64	9.4	75	
	Total Amino Acid (mg/kg)	Ca (mg/kg)	Mg	Fe	Mn	Zn	Cu	B	Mo
Control	254.75	252	70.36	14.37	3.85	1.15	0.75	0.10	0.04
Vetiver	312.19	526	92.21	32.64	5.44	3.05	1.07	0.14	0.05

In March 1995, over 2000 m of Vetiver hedges were set up along the banks of the Pan River, the Liushui seacoast and a few ponds. These hedges also had positive effects on soil conservation and minimization of silt in the runoff in the same year as planting. Measurements indicated that, in the winter of the first year of hedge planting, up to 7.5 kg of silt was intercepted by a 1 m long section of the hedge; while in the second year the figure increased to 17.0 kg. Moreover, embankments were tightly bound and stabilized by the powerful Vetiver root system, preventing collapse from strong winds and waves. As an example, there were over 200 cases of collapsed embankments without the Vetiver hedge protection after a powerful typhoon hit on 31 July 1996. By contrast, in the same storm the embankments stabilized by Vetiver hedges were not destroyed at all. As a result, in the spring of 1997 local fishermen planted 1740 m of Vetiver hedges on a voluntary basis around all of their ponds.

4.2 In Other Countries

Farmers in Central Coastal Vietnam are regularly confronted with flood or storm related damage, and have to spend much of their time and money to restore badly damaged structures. The measures they used are not effective enough (e.g. stabilisation of dykes by local grass, which are easily uprooted by flood, or small waves) or of short-term measures such as blocking sand dune flow by sand dikes, which themselves are poorly stabilised due to lack of vegetation cover. Technical support, when available, has its own problems. Local civil engineers are used to more expensive hard solutions such as rocks and cement, even these solutions are not always effective or durable. Agro-forestry projects focus on tree planting but it is expensive to implement and slow in growth. Trees are effective for wind erosion control but they give little protection against neither water erosion nor trapping sand eroded by heavy rainfall.A vetiver trial and demonstration project was initiated in 2001. The results were outstanding, vetiver planting on coastal sand dunes has stabilized the dunes and stream banks within one year and both local farmers and engineers now adopted VS as their preferred option for sand dune and road batter stabilisation, stream bank erosion control and fishpond stabilisation (Tran tan Van *et al*., 2003).

In southern Vietnam the banks of drainage and irrigation channels in the acid sulfate soil (ASS) region of are highly erodible due to the weak or no physical structure and the extremely acidic chemical conditions. With these soil properties, most plants cannot survive; especially during dry season hence erosion is a severe and results in costly repairs. Vetiver grass has been used successfully for erosion control in drainage channels on ASS in Queensland, Australia. Therefore a primary trial on the effect of lime on the survival and growth of vetiver was tested on the drain system on a State farm near Ho Chi

Minh City in September 2001, to determine the effectiveness of vetiver grass hedges on dike/bank erosion control. Results to date indicate that on severe ASS (pH between 2.5 and 3.0), vetiver grass can survive and grow only with lime application, which provides high survival and growth rates, the minimum lime rate needed for that soil was about 100g CaO/linear meter row. At that rate of application, vetiver grass established and grew well; soil loss caused by erosion on bank was reduced from 400-750 tons/ha/4months to only 50-100 tons/ha/4 months with vetiver grass hedges. Vetiver grass stopped growing during dry season, but it recovered well just after rainfall of about 20 mm. Concentrations of some toxic elements such as Al, Fe, and SO_4 in vetiver grass were very high, much higher than those species considered tolerant to ASS. Moreover these concentrations tend to increase as the plant matures. These high contents indicate the level of these elements could be reduced in both surface runoff and deep drain water, thus reducing the contamination of canal water. However the long term survival of vetiver on these soil are not known once its root system passed through the lime surface zone. As these drainage system are also used for irrigation and transportation, if successful the vetiver system will provide a very cost effective method of bank stabilisation as well as improving water quality in these channels (Le van Du and Truong, 2003).

5 FRESH VETIVER CLIPPINGS AS FODDER FOR CATTLE AND SHEEP

5.1 In China

Both the Soil and Fertilizer Division of the Agriculture and Animal Husbandry Department in Sichuan Province and the Jiangxi Provincial Red Earth Development General Company conducted an analysis of nutrient values on Vetiver as a fodder. Nutrient levels were compared for Vetiver at 65 days and then again at 215 days (Table 6, Soil and Fertilizer Department of the Agricultural Bureau of Sichuan Province, 1992).

Table 6 Protein and amino acid content in vetiver leaves and stems

Content of vetiver leaves and stems (%)	Number of Growing Days	
	215	65
Water	60.4	69.7
Lignin (Dry)	9.33	10.07
Lignin (Fresh)	3.69	3.05
Raw Protein (Dry)	8.94	11.0
Raw Protein (Fresh)	2.75	3.33
Asparaginie Acid	0.32	1.00
Threonine	0.17	0.19
Serine	0.13	0.32
Glutamic Acid	0.55	2.61
Blycine	0.22	5.13
Alanine	0.35	2.64
Cystine	0.06	0.21
Valine	0.27	0.70
Methionine	0.04	0.04
Iso Leucine	0.19	0.27
Leucine	0.30	0.73
Tyrosine	0.11	0.06
Phenylalanine	0.21	0.45
Lysine	0.22	0.59
Amonia	0.16	0.17
Histidine	0.07	0.14
Arginine	0.18	1.23
Proline	0.12	3.25

In addition, a comparison of protein content (Table 7) showed that fresh and tender Vetiver stems and leaves (at 65 days) was higher than alfalfa, clover, sweet potato vine and rice straw but slightly lower than that of Chinese milk vetch (*Astragalus sinicus*). Although protein content in dry Vetiver (at 65 and 215 days) was lower than alfalfa, it was higher than that in corn silage and other common winter fodders such as rice straw and wild oat straw. Moreover, the methionine content of Vetiver was almost the same as other fodders, while the lysine content was much higher (Soil and Fertilizer Department of the Agricultural Bureau of Sichuan Province, 1992). These measurements indicated that tender Vetiver grass clippings were suitable as fodder for cattle, sheep, pigs, rabbits, and fish. Also with cattle and sheep, Vetiver seemed very palatable.

Hu *et al*. (1997) found that different sources and tenderness of Vetiver grass revealed differences in content (Table 8). The degree of tenderness was important as experiments at the Jiangxi Provincial Institute of Red Earth showed that cattle could be fed entirely on tender Vetiver grass when it was a half-month old, but only 90.9% when it was one-month old. Meanwhile, large numbers of fish could eat feed that was 59-71% Vetiver if the grass was a half-month old, but with one-month old grass this was reduced to 44-56%. This meant that the more tender the Vetiver clippings the better the feed. The older grass with joints was not as suitable as the younger shoots when used as fodder.

Table 7 Nutrient content of vetiver and some common fodder types

Component / Fodder Type	Protein (Fresh) (%)	Protein (Dry) (%)	Lysine (%)	Methionine (%)
Vetiver grass (65 Days)	3.30	11.00	0.59	0.04
Vetiver grass (215 Days)	2.75	6.94	0.23	0.04
Alfalfa	3.20	12.00	0.25	0.07
Comfrey (start of flowering)	3.10	22.30	0.15	0.04
Clover	2.30	13.30	0.18	0.06
Sweet Potato Vine	2.10	18.30	--	0.22
Chinese Milk Vetch	3.50	17.00	--	--
Rice Straw	2.90	3.40	--	--
Corn Stem Silage (Mature)	--	5.31	--	--
Corn Stem Silage (Waxen Mature)	--	6.32	--	--
Wild Oat Straw	--	4.50	--	--

The dynamic state of nutrient contents of Vetiver grass was studied in Guangdong. Grass samples were collected and analyzed in different plant condition, season, growth stage and mowing time. The results showed that nutrient contents of Vetiver grass were correlated highly to growth season stage and soil condition. Vetiver grass passing through winter showed lower nutritive value than those growing in other season. Vetiver grass growing in sand showed lower nutritive value than those growing in soil. Nutrient contents reach the highest level in the tillering stage and then decrease in the jointing stage. Vetiver grass that grew in pig farm waste showed higher contents of CP, carotene and lutein, relatively lower contents of Ash, Ca, Fe, Cu Mn and Zn, and maintained normal contents with other nutrients especially contents of Pb, As and Cd, which indicated Vetiver grass that grew in pig farm waste was still a promising feed resource for ruminant (Liu *et al*., 2003a).

In Guangdong, the digestibilities of nutrient contents of Vetiver grass in Dongshan goat were determined by the typical method of total-faeces-collection. The results showed that digestibility of DM, CP, EE, CF, Ca, TP and NFE (nitrogen free extractor) in Vetiver grass hay was 46.09%, 23.15%, 28.79_, 46.44_, 61_, 66.6_ and 36.25_ respectively. One kilogram dry matter of Vetiver grass hay can provide 13.4g of digestible CP, 4.17g of EE and 1.47 Mcal of DE, which indicated that Vetiver grass would be a promising resource of goat feed (Liu *et al*., 2003b).

Table 8 Content of vetiver grass with different sources and tenderness

Sources of Vetiver	Tenderness	Water (%)	Raw Protein (%)	Raw Fat (%)	Raw Fiber (%)	Raw Ash (%)	N-free Extract (%)
Indian	Tender	3.25	7.31	1.97	34.53	4.76	48.18
	Less tender	3.19	6.00	1.86	35.76	4.79	48.40
Fujianese	Tender	3.24	6.76	1.28	36.24	4.07	48.41
	Less tender	3.14	5.89	1.19	18.36	3.83	47.60
Rice straw	Old	3.25	4.59	1.46	32.37	17.14	41.33

Thus Vetiver's advantages of fast growth, drought-resistance, and ability to grow on infertile soils renders it useful for soil conservation, and for developing animal husbandry by stall feeding animals when the young and tender shoots are used.

5.1 In Other Countries

In Australia, very high protein and digestibility values in vetiver irrigated with high N and P industrial effluent. Table 9 shows that the digestible energy of vetiver is much higher the those of Rhodes grass and Kikuyu (Smeal *et al*., 2003).

Table 9 Nutritional values of vetiver, Rhodes and Kikuyu grasses

Analytes	Units	Vetiver grass			Rhodes	Kikuyu
		Young	Mature	Old	Mature	Mature
Energy (Ruminant)	kCal/kg	522	706	969	563	391
Digestibility	%	51	50	-	44	47
Protein	%	13.1	7.93	6.66	9.89	17.9
Fat	%	3.05	1.30	1.40	1.11	2.56
Calcium	%	0.33	0.24	0.31	0.35	0.33
Magnesium	%	0.19	0.13	0.16	0.13	0.19
Sodium	%	0.12	0.16	0.14	0.16	0.11
Potassium	%	1.51	1.36	1.48	1.61	2.84
Phosphorus	%	0.12	0.06	0.10	0.11	0.43
Iron	mg/kg	186	99	81.40	110	109
Copper	mg/kg	16.5	4.0	10.90	7.23	4.51
Manganese	mg/kg	637	532	348	326	52.4
Zinc	mg/kg	26.5	17.5	27.80	40.3	34.1

6 VETIVER POWDER FOR GROWING EDIBLE FUNGI

An experiment conducted by Lin Zhanxi of the Fungi-Grass Research Center at Fujian Agricultural University, indicated that Vetiver was a high quality grass material for culturing edible fungi (Zhang, 1996). They successfully used Vetiver leaves and stems as a raw material to raise many kinds of edible fungi, including *Lentinula edodes* (Shiitake, Black forest, Black, Oak Shiitake, Black forest mushroom), *Auricularia polytricha* (Cloud ear, Tree ear, Wood ear, hairy Jew's ear), *Auricularia auricula* (Black ear, Wood ear, Jew's ear, *Pleurotus ostreatus* (Tree Oyster, Oyster, White oyster, Gray oyster, Oyster mushroom), *Pleurotus abalones* (Abalone, Abalone mushroom), *Pleurotus pulmonarius (sajor-caju)* (Phoenix oyster, phoenix-tail mushroom), *Pleurotus spp.*, *Flammulina velutipes* (Enoki, Winter, Velvet stem, Golden, Snow puff, Winter mushroom), G*anoderma lucidum* (Ling-Zhi, Reishi, Glossy ganoderma), *Hericium erinaceus* (Lion's mane, Monkeyhead, Bear's head), *(Dictyophora indusiata* (Bamboo sprouts, Collared stinkhorn, Stinkhorn mushroom), (*Pholiota nameko* (Nameko, Nameko mushroom) and others. In cultivating edible fungi, Vetiver presented high biotransformation rates of about 80% for *Lentinula edodes* and up to 100% for both *Pleurotus ostreatus* and *Auricularia polytricha*.

Information summarized from various sources showed that, in the second year of planting, Vetiver planted as a net on soils of medium or higher fertility could produce 60-100 t/ha of dry grass. That is to say, with a biotransformation rate of 80%, a single hectare of Vetiver was able to raise 48-80 t of fresh mushrooms, valued at 19,000-32,000 Yuan (about $2290-$3855) at the present market price. At the same time, the hyphal rich waste material remaining after fungi raising qualified as feed that was good for livestock, poultry, and pond fish. In addition, Vetiver hedges could be pruned 2-3 times and their clippings could still be used for edible fungi production. This meant not only more biomass for fodder, but also a thicker hedge for soil conservation. Therefore, Vetiver grass with its multiple uses was ideal in helping to increase farmer's income and for promoting rural economic development.

7 PEST CONTROL

Van den Berg *et al.* (2003) presented a very comprehensive literature review on insect pest and the effect of vetiver on companion crops.

7.1 In China

Stem borers and termites seem to be the most commonly reported pests of vetiver grass. Paddy stem borers (*Chilo* spp.) have been reported to infest culms and midribs of leaves wherever vetiver grass was planted in Southern China. An interesting observation was that although the levels of mortality amongst stem borer larvae were high no pupae were ever found inside plants. In the worst case, the borer damaged approximately 39 % of grass stems but no pupae were found (Xinbao, 1992), indicating that no larvae survived in the plants. Zisong (1991) in China reported that stem borers attacked a vetiver grass hedge planted in a tea plantation and that on average of 1.5 to 6 % of individual tillers was killed.

Shangwen (1999) recorded 102 insect species that occurred on vetiver plants during two seasons of vetiver production in China. Among these he distinguished 13 species as leaf eaters, four as sucking insects and 19 as herbivores on spikes, stems and roots of plants. Many of these species could be identified as general herbivores (such as grass hoppers). Sixty four percent of the insect species observed on vetiver was identified as visitors or natural enemies of other insects. These observations showed that insect biodiversity in vetiver could actually be high. An interesting observation made by Shangwen (1999) was that population densities of many of the herbivorous insects on vetiver was low and that they did not do any apparent damage to plants

7.2 In Other Countries

Research in South Africa has shown the benefits that Vetiver may have in controlling insect pests. Vetiver grass is highly preferred for oviposition by moths of the lepidopterous stem borer *Chilo partellus*, a serious pest of maize, rice and other grain crops in Asia and throughout East and Southern Africa, where it can cause yield losses of up to 58% in maize. These observations prompted more detailed research on stem borer/Vetiver grass interactions. Studies were therefore conducted to determine the relative oviposition preference of gravid female moths for Vetiver grass and maize, and to determine the suitability of Vetiver grass for larval survival. Results showed that, although there was a highly significant oviposition preference compared to maize, *C. partellus* moths preferred to lay eggs on vetiver grass as compared to maize. Of the total number of eggs, only 18 % were laid on maize. Vetiver plants received an average of 544 eggs each while maize plants received only 119 eggs (Fig. 2). Larval survival on grasses was low compared to that of maize. On average there was 63.0%, 2.8% and 0% larval survival on maize, Napier and vetiver grass respectively, a distinct show of 100% mortality of larvae on vetiver grass. These results corroborate those of the studies above with an indication that *C. partellus* prefers vetiver grass for oviposition with subsequent insignificant rates of larval survival (Fig. 3). Thus, Vetiver has potential as a trap crop component of an overall “push-pull” strategy to concentrate oviposition away from the maize crop and reduce subsequent population development (Van den Berg *et al.*, 2003).

8 CONCLUSION

From the information presented above, it is clear that when appropriately applied Vetiver System is a very effective, low cost, simple and ‘green’ method of soil and water conservation that will improve crop yield without chemical and minimal energy input.

The future role of VS in improving forestry and agricultural production will most likely lies in the protection of crops from insect pests as shown by Van den Berg *et al.* (2003) at this Conference.

Fig. 2 Mean number of eggs per plant laid by *Chilo partellus* moths with maize and vetiver plants under laboratory conditions (Bars indicate Standard Error)

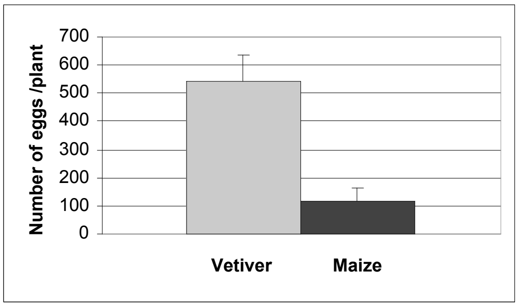
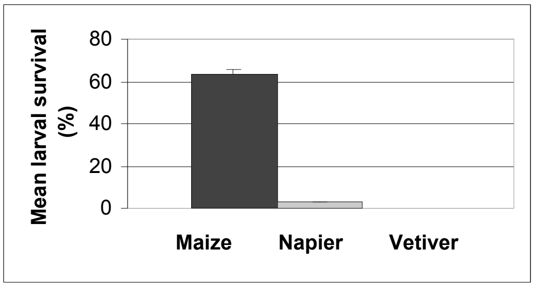


Fig. 3 Percentage survival of *Chilo partellus* larvae on maize, vetiver and Napier grass, 28 days after egg hatch (Bar indicates Standard error)



References

Babalola O, Jimba SC, Maduakolam O, *et al*. 2003. Use of vetiver grass for soil and water conservation in Nigeria**.** Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Chen K, Hu GQ, Yao HM, *et al*. 1994. Ecological effects of vetiver in an orange orchard on sloping red soil land. Acta Ecologica Sinica, 14(3): 249-254

Chen LJ. 1998. Analysis of vetiver on field bridge stabilization. In: Xu LY (ed.), Vetiver Research and Development. China Agriculture ScienTech Press, Beijing

Hu JY, Xie HX, and Zhou CW. 1997. Research on vetiver for red soil development. Agroforestry Today 5(3)

Le van Du, and Truong P. 2003. Vetiver System for erosion control on drainage and irrigation channels on severe acid sulfate soil in Southern Vietnam. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Liu PX, Lin YC, Luo FH, *et al*. 2003a. Dynamic state of nutrient contents of vetiver grass. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Liu PX, Lin YC, Luo FH, *et al*. 2003b. Study on digestibility of nutrient contents of vetiver grass. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Lu SL, and Zhong JY. 1997. Vetiver applications on red soils in hilly areas. ACTA Agriculture Jiangxi, 9(4)

Shangwen C. 1999. Insects on vetiver hedges. The Vetiver Newsletter, 23

Smeal C, Hackett M, and Truong P. 2003. Vetiver System for industrial wastewater treatment in Queensland, Australia. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Soil and Fertilizer Department of the Agricultural Bureau of Sichuan Province. 1992. Summary on vetiver planting and demonstrations in Sichuan Province. China Vetiver Information Network Newsletter, No.10

Somsak Suriyo, and Wilawan Vongkasem. 2003. The use of vetiver for soil erosion prevention in Cassava Fields in Thailand. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Tran tan Van, Pinners E, and Truong P. 2003. Coastal dune stabilisation in Central Vietnam. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Van den Berg J, Midega C, Wadhams LJ, *et al*. 2003. Can Vetiver grass be used to manage insect pests on crops? Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Xia HP, Ao HX, He DQ, *et al*. 1996. The Function of Vetiver on Soil Amelioration and Water and Soil Conservation. Tropical Geography, 16(3): 265-270

Xinbao Z. 1992. Vetiver grass in P.R. China. Vetiver Newsletter, Number 8: 8-11

Zhang J. 1996. Planting and utilization of vetiver on coastal dune land. Water and Soil Conservation of Fujian Province, 96(1)

Zisong W. 1991. Excerpts from the experiments and popularization of vetiver grass, Nanpang Prefecture, Fujian Province, China. Vetiver Newsletter, Number 6: 23-26