SCREENING OF VETIVER NEW VARIETY, KARNATAKA AND ITS SYSTEMATIC APPLICATION ON HIGHWAY

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Abstract: The vetiver eco-engineering has been applied for protection and stabilization of highway slopes for 10 full years in China. However, the coverage and effects of vetiver in slope stabilization projects of highways are still far from satisfied due to its native imperfectness, such as too high plant height, and withering brown appearance in winter. Currently, the demand for the landscape of highways is becoming higher and higher in China. Therefore it is necessary and even urgent to find better new varieties in order to keep vetiver's vitality on highway. Since 1999, we collected 12 vetiver varieties (or ecotypes) from abroad and home, and then investigated in detail their growth, development and phenology through strict plot experiments for the above purpose. As a result, Karnataka, the variety introduced from India, assumed the best comprehensive performance among the 12 varieties. This is because: 1) it did not ear or flower and, therefore, assumed the shortest plant height; 2) its tiller forming speed was ranked as the second, up to 18.5 times/yr; 3) it hardly became brown in winter; 4) its root length was almost identical with the commonest variety, Sunshine; moreover it had more fibrous roots with diameter < 1 mm, which would be beneficial to increasing root tensile strength; and 5) it produced culm-branches from the lateral buds of the mature culm, which could be used as new reproductive materials to germinate new seedlings. Thereby, the Karnataka variety is regarded as the most excellent one among the 12 varieties, and can be used as an alternative of the commonest variety, Sunshine.

In order to testify the above observed results and also to disseminate the Karnataka vetiver, the South China Botanical Garden first introduced it to the Guangzhou Peifeng Environmental Protection Co. Ltd. Then, the company set up a vetiver nursery of 10 ha mainly using Karnataka variety in 2004. Thereafter, the company conducted a large-scale vetiver project for slope protection of the Zhanjiang-Chongqing Highway using the new variety from April to November 2005. The project covered a total area of over 90,000 m^2 with over 1 million clumps of vetiver seedlings. Through meticulous preparation and design, scientific operation, and careful management, the project won a huge success. It not only changed the ecological landscape of the highway distinctly, but also effectively protected the highway from slope erosion or landslide. On the contrary, some slopes without the protection of vetiver or with the protection of other bio-measures suffered from severe erosion or even landslide under scour of storms in the second quarter of 2006. At present, the vetiver new variety, Karnataka, is being given more and more attentions by various circles of Chinese society, including the China Central Television (CCTV). It can be affirmative that a new round of climax for vetiver's dissemination and application will probably occur in China soon once CCTV broadcasts the special report on vetiver.

Keywords: vetiver variety, Karnataka ecotype, slope stabilization for highway, ecological landscape

1 Introduction

In the past 10 years, China's highway construction has made a huge progress. Taking Guangdong an example, the driven mileage of highways has been up to 2900 km in the

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province by the end of 2005, increased by 1050 km or 56.8% compared with the year 2002. However, the construction and maintenance of highways has become more and more expensive. This is because many newly built highways go through mountain regions, which not only dig up mountains and excavate tunnels for their construction, but also must conduct steep slope stabilization work, usually using the “hard method” (Fig. 1). As a result, the construction fee for highway has been up to RMB 40,000,000~50,000,000 Yuan/km (about US$5,000,000~6,200,000/km) in Guangdong. Hence, cost reduction has been an important issue for highway departments and also been their greatest concern. In addition, the “hard method” forms permanent “earth scar” without any ecologic benefits; furthermore, these “earth scars” would probably produce bigger disasters to highway and to nearby areas once burst by rainwater. Therefore, the “soft method”, e.g. eco-engineering, is becoming increasingly attractive.

The Vetiver System is just such a technique or “soft method” that can not only effectively abate construction fees of highways, especially those with steep slope stabilization projects, but also bring a huge ecological benefit. So, the Vetiver Eco-engineering Technique has been highly regarded around the world for the purpose of highway slope stabilization. In China, since it was successfully applied first for this purpose in Guangzhou a decade ago, the technique has produced a huge influence on highway departments of China and given a deep impression on them due to its miraculous effects for slope stabilization.

Fig. 1 A section of highway and its huge “scar” being constructed in northern hilly region of Guangdong

Fig. 2 A panorama of vetiver common variety in winter of Guangzhou, southmost Mainland China (23° 9′ N)

However, the application of vetiver on highways is still restricted to great extent. This is because: 1) today, the demand for highway’s landscape is becoming higher and higher in China, while vetiver grows too high, up to over 2 m after it flowers; as a result the vetiver landscape on highway slopes does not look very good; and 2) vetiver is not tolerant to cold, becoming brown in winter, even if in south China (Fig. 2), which not only results in poorer landscape, but also increases the possibility of catching fire in winter. Thereby, it is necessary and even urgent to look for new vetiver variety that is shorter and greener in order to gain better application of vetiver on highway.

1 Screening of the Vetiver New Variety, Karnataka

1.1 Materials for screening new variety

The tested materials consisted of 12 varieties (or ecotypes) of vetiver grass (Table 1). Among them variety #1-10 were collected from five countries and regarded as good ones in the locality. The ten varieties were first introduced into an experimental nursery in the US for a period of time, and then sent to us in July 1999. The delivery lasted ten days (28 July to 7 August) in the hot summer, yet some slips of each variety survived. This indicates that vetiver really has a strong vitality and can tolerate high temperature and long period without water. Their survivals, however, showed a big difference, varying from 17 to 91%, indicating that they were different in relation to the ability to tolerate high temperature and drought (Xia and Liu, 2003).

Table 1 List of vetiver varieties and their performance at the time of introduction

No.	Variety	Origin	Tiller number at planting	Tiller number at 15 days after planting	Survival rate (%)
1	Capitol	USA	6	1	17
2	Huffman	USA	5	3	60
3	Sunshine	USA	3	1	33
4	Lilongwe	Malawi	11	10	91
5	Zomba	Malawi	7	5	71
6	Kandy	Sri Lanka	4	2	50
7	Karnataka	India	3	2	67
8	Malaysia	Malaysia	5	2	40
9	Parit Buntar	Malaysia	3	2	67
10	Sabak Bernam	Malaysia	7	2	29
11	Domesticated	Guangdong, China	-	-	-
12	Wild	Guangdong, China	-	-	-

Variety #11, ‘Domesticated’, introduced from abroad in 1950s, is being widely cultivated in China for the purpose of erosion control and ecological restoration. The DNA fingerprinting conducted reveals that it is the same genotype as the most extensively cultivated variety around the world, i.e. ‘Sunshine’ (variety #3) (Adams *et al.*, 1998). As it had been cultivated for nearly 50 years, therefore some changes in physiological, ecological or morphological features probably might have taken place. Variety #12 (‘Wild’) was sampled from the wild vetiver community of Wuchuan County, Guangdong Province. The community, lying in a wetland near the sea, has existed for hundreds of years; no one knows its initial origin. Furthermore, the vetiver growing in this community has distinct disparities with the widely cultivated variety (‘Domesticated’) in the aspects of morphological characteristics and ecological features. Because of the above reasons, it was named ‘Wild’ variety, which presents a striking contrast to the ‘Domesticated’ one (Xia and Ao, 1998).

1.2 Plant height and tiller forming capacity of different varieties

After the above vetiver varieties (No. 1-10) were introduced from USA for 15 months, the experiment for growth of plant height and tiller forming capacity was conducted. 4 clumps for each variety and 3 tillers for each clump were planted at the spacing 40 cm×50 cm. Prior to planting, all slips were cut to 30 cm high. After 12 months of growth, different varieties produced tangible differences regarding plant height (Table 2). The tallest variety was ‘Huffman’, whose average height was 288 cm, and the tallest plant was up to 305 cm whereas the shortest variety was ‘Karnataka’, whose average height was only 176 cm, and the shortest plant was only 170 cm. Thus the difference in height between the shortest and tallest plants was 135 cm. Karnataka is much shorter than other 11 varieties (Table 2).

As to the tiller number, they were all 3 tillers for each clumps at planting; one year later however, they also produced a huge difference. The variety yielding the most number of tillers was ‘Kandy’, which yielded 66.8 tillers per clump; followed by Karnataka, up to 55.8 tillers per clump. That is to say, Karnataka assumed a tillering rate of 18.6 for one year. The variety yielding the fewest number of tillers was ‘Zomba’, with only 24.5 tillers per clump. Thus, a large difference of 42 tillers between them exists as shown in Table 2. So, ‘Kandy’ is undoubtedly far better than all other varieties, while ‘Karnataka’ and ‘Domesticated’ ranked second, and ‘Zomba’ the poorest with regard to tiller formation.

Table 2 Comparison of the plant height and accumulative tiller number of 12 vetiver varieties

No.	Variety	Height at planting (cm)	Height one year later (cm)	Tiller number per clump at planting	Tiller number per clump one year later	Tillering rate*
1	Capitol	30	259	3	44.5	14.8
2	Huffman	30	288	3	41.8	13.9
3	Sunshine	30	271	3	43.5	14.5
4	Lilongwe	30	246	3	34.0	11.3
5	Zomba	30	251	3	24.5	8.2
6	Kandy	30	235	3	66.8	22.3
7	Karnataka	30	176	3	55.8	18.6
8	Malaysia	30	211	3	37.3	12.4
9	Parit Buntar	30	273	3	47.5	15.8
10	Sabak Burnam	30	265	3	49.0	16.3
11	Domesticated	30	271	3	52.3	17.4
12	Wild	30	274	3	40.0	13.3

*Tillering rate = Tiller number one year later / Tiller number at planting

1.3 Blooming situation and growth of roots of different varieties

In this experiment, the variety that came into bloom first was ‘Zomba’, followed by ‘Wild’, ‘Sabak Bernam’, ‘Lilongwe’, ‘Kandy’, ‘Sunshine’, ‘Domesticated’, ‘Malaysia’, ‘Parit Buntar’, ‘Huffman’, and ‘Capitol’. Their first bloom occurred on 9, 12, 18, 21, 23, 30 August, 1, 8, 8, 17, and 25 September, respectively; the maximum difference was 46 days. Karnataka, however, did not bloom at all from beginning to end. Since the main inflorescence stalk of vetiver is about 50-70 cm long, so the radical reason that ‘Karnataka’ remained the shortest (Table 2) was because it did not grow out any inflorescence stalks (Table 3). It is worth noticing that the ‘Karnataka’ variety did not bloom, but kept on growing reproductively during this period, too, by producing culm-branches from the lateral buds of the culm. A single mature culm may produce 3-9 such culm-branches, and a clump may produce around 30-40 culm-branches, each 40-50 cm in length. It is just the reason that Karnataka produces culm-branches, it is relatively greener in the winter while other varieties turned brown of varying shades (Fig. 3). What’s more, these culm-branches can be used as new propagules after they become mature; the survival rate can be up to over 90% using them as seedlings.

Blooming rate is referred to as percentage of number of tillers with inflorescences to total number of tillers. Obviously, it is also an index for evaluating the disparity among different varieties. Maybe it is more precise to compare the blooming rates of different varieties than number of inflorescences. For example, the inflorescence number of ‘Kandy’ variety was 7, about 1/6-1/3 of other varieties, but its blooming rate 2.6%, only 1/10-1/5 of other varieties (Table 3), which was due to its far more total number of tillers than those of other varieties (Table 2).

Fig. 3 The Karnataka variety is always greener and shorter than the Sunshine variety no matter in what season, winter (Left) or summer (Right)

Table 3 Performance of shoots and roots for 12 different varieties of vetiver

No.	Variety	Total inflorescence number	Blooming rate (%)	Root weight per tiller (g DW/tiller)	Root amount with diameter <1 mm to the total root amount (%)
1	Capitol	13	7.3	0.87	50
2	Huffman	16	9.6	0.82	60
3	Sunshine	24	13.8	0.88	60
4	Lilongwe	19	14.0	1.25	20
5	Zomba	21	21.4	1.44	30
6	Kandy	7	2.6	0.77	40
7	Karnataka	0	0	0.42	80
8	Malaysia	16	10.7	0.51	70
9	Parit Buntar	22	11.6	0.97	60
10	Sabak Burnam	30	15.3	0.58	70
11	Domesticated	26	12.4	0.57	40
12	Wild	35	21.9	0.39	30

If vetiver had no massive roots, its ecological effectiveness would be weakened dramatically. Therefore, it is necessary to inspect the growth of roots when screening excellent varieties. Due to this reason, another experiment was designed to investigate the growth of vetiver roots. One year after planting, vetiver roots were dug up from the soil surface to 60 cm deep and then weighted. As a result, there was a large difference of the biomass of roots within 60 cm soil depth among different varieties (Table 3). The variety with the least root biomass was ‘Wild’, and that with the most root biomass was ‘Zomba’, in spite of the fact the latter had the poorest tillering ability. The root biomass of Karnataka was ranked as penultimate, but the root amount with diameter <1 mm was up to 80% of the total, the highest among the 12 varieties. It has been well testified that the higher the proportion of thin roots is, especially those with diameter < 1 mm, the stronger the root tensile strength is (Hengchaovanich, 1998; Nilaweera and Nutalaya, 1999; Bischetti *et al.*, 2005). Therefore, it can be inferred that the Karnataka variety may have stronger root tensile strength than other varieties and, therefore, might stabilize slopes more firmly.

In addition, in order to get to know the length of Karnataka roots, we built 2 cement boxes with a volume of 2 m high×0.8 m long×0.6 m wide for each one to observe the growth of roots. Two vetiver varieties, Sunshine and Karnataka, were planted equally in

each box, 2 clumps for each variety (Fig. 4). One year later, vetiver roots were dug up and measured. As a result, the roots of Sunshine were up to 2.44 m and those of Karnataka up to 2.25 m. There was no significant difference between them both (Fig. 5).

Fig. 4 Cement growing boxes used to investigate the growth of vetiver roots

Fig. 5 The roots of Karnataka and Sunshine one year after planting, up to 2.25 m and 2.34 m, respectively

1.4 Comprehensive evaluation to the growing performance of vetiver varieties

It can be seen from the foregoing discussion that various varieties of vetiver present distinct differences regarding their growing performance. Each variety has its own advantages and disadvantages. No one variety performs the best in all aspects. In order to screen out the best variety on the whole, 12 varieties are divided into 12 grades, and each grade endowed with 1 point. This means that the best variety in a certain aspect is given 12 points, and the poorest one given 1 point. The ones with same performance are given a mean value. Then, the accumulative scores for each variety could be figured out (Table 4). The variety obtaining the highest scores is obviously the best one. As a result, the Karnataka variety ranks first, which is beneficial mainly from its non-blooming and low stature resulted from non-blooming. Domesticated and Sunshine belong to the same genotype and their scores are quite close, indicating that the former has produced quite few changes even after 50 years of being introduced into China. Regarding the ‘Wild’ variety, the main reason that it scores the lowest scores is, no doubt, associated with its prior long-term waterlogged habitat (Xia and Ao, 1998). It is well known that the waterlogged environment is disadvantageous to root growth and tiller formation of vetiver. Although the ‘Wild’ plants had grown in our nursery for two years before conducting the observation, they still did not obtain the identical or similar growing features with the ‘Domesticated’ or other varieties (Table 4).

2 Systemic Application of the Karnataka Variety on Highway

Through the above experiment up to 4 years, the Karnataka is evaluated as the best one among the 12 vetiver varieties in terms of the situation of growth and development. Then, how is the pracitcal situation? Obviously it is indispensable to apply it in practical projects in order to verify the correctness of the experimental result.

Table 4 A comprehensive evaluation for the 12 varieties of vetiver

No.	Variety	Plant height	Total number of tiller	Tillering rate	Blooming rate	A*	B*	Total score	Rank
1	Capitol	5	5	4	3	8	6	31	9
2	Huffman	1	6	6	10	7	8	38	7
3	Sunshine	6	7	8.5	8	9	8	46.5	4
4	Lilongwe	9	2	2	5	11	1	30	10
5	Zomba	8	1	1	1	12	2.5	25	11
6	Kandy	10	12	12	11	6	4.5	55.5	2
7	Karnataka	12	11	11	12	2	12	60	1
8	Malaysia	11	3	3	4	3	10.5	34.5	8
9	Parit Buntar	3	9	8.5	9	10	8	47.5	3
10	Sabak Burnam	7	8	7	6	5	10.5	43.5	5
11	Domesticated	4	10	10	7	4	4.5	39.5	6
12	Wild	2	4	5	2	1	2.5	17.5	12

* A is the mean root weight per tiller, and B is the percentage of roots with diameter <1 mm to the total root amount

2.1 Persuading the company to use the Karnataka variety

In March 2004, a new company named the Guangzhou Peifeng Environmental Protection Co. Ltd. was founded in Guangzhou. After getting to know that the company will be engaged in ecological and environmental protection mainly using the vetiver technique, Dr. Hanping Xia immediately contacted the company, zealously introducing the new variety Karnataka to it. Mr. Bing Lin, the boss of the company, is a smart, honest, and up-and-coming entrepreneur. He is very keen to new things and new techniques. After hearing Xia's introduction to the new variety, he immediately promised to introduce it to be the main vetiver seedlings of his company. Very soon, the company established 2 vetiver nurseries with a total area of 10 ha (Fig. 6) in 2004 under the auspices of China Ministry of Water Resources, Guangdong Provincial Department of Water Resources, and other pertinent departments, in which over 80% of vetiver seedlings were Karnataka variety.

Fig. 6 The vetiver nursery of the Peifeng company. Left: a scutcheon at the entrance of the vetiver nursery; Right: a large patch of Karnataka seedlings growing lushly in the nursery

2.2 Persuading the highway construction department to apply the Karnataka variety

After preparing for enough short seedlings, we started to take action for its application from the end of 2004. First of all, we came to Zhanjiang, the most southwest city of Guangdong Province. It is nearly 500 km away from Zhangjiang to Guangzhou, the capital of the province. The reason that we came Zhanjiang was because there was a highway from

Zhangjiang to Chongqi, the largest city of southwest China, was under construction. The beginning section of the highway lied in Guangdong, 73 km long, was demanded very high by the provincial government with regard to its slope protection and landscape construction projects; as a result, in the first design vetiver was not considered by the highway construction company due to its above-mentioned defects, such as too high at mature period, and becoming brown in winter. After meeting the leaders of the highway construction company, we did our utmost to persuade them to accept the vetiver new variety using large quantity of data and photos. Eventually, they were persuaded, approving us to try it first on one slope with an area of 8000 m^2.

2.3 Construction of vetiver projects

As soon as the highway construction company approved our new design, the Peifeng company immediately took action to conduct the project in the beginning of April 2005. However, there are lots of adverse factors in this region influencing operation of projects and efficiency of vetiver for slope protection. Soils in here are extremely infertile kaolin and lateritic red earth, highly acidic (pH 4-5) and severely short of organic matter, <0.3% in newly dug subsoil. Therefore, soil is quite adverse to plant growth. Furthermore, it is rainy season from April through September, and the rainfall in this period accounts for 80% of the whole year (1600-1700 mm) due to concentrative storms. In order to guarantee to win success, the company took the most secure measures, including raising seedlings with polybags in advance, digging up contour ditches, applying enough basal manure, and replanting seedlings in time (Fig. 7). 10~15 days after the project was over, vetiver began to become green and grow; only 40~60 days later, vetiver hedgerows began to form, and furthermore many other grass species naturally grew out of soil due to the protection of vetiver; as a result, the originally barren embankment slope was completely covered and stabilized by vetiver and these naturally growing grasses (Fig. 8).

Fig. 7 The first vetiver project conducted on the highway with the new variety, Karnataka
Left: preparation of ploybag vetiver seedlings
Right: level ditches and basal manure applied prior to planting vetiver

Due to the miraculous efficiency of vetiver and good landscape formed by Karnataka variety, the first project gave the highway construction company a very deep impression. What's more, the earnestness, carefulness and specialized level of the Peifeng company deeply moved the leaders of highway construction company. And then they made a decision at once to change the original design to adopt the vetiver eco-engineering of Karnataka variety on a large scale. Thus the vetiver projects were immediately conducted along the 73 km Guangdong section of the highway, lasting over 8 months, from April through November. Altogether more than 1 million clumps (3~5 tillers per clump) of vetiver were planted and covered more than 90,000 m^2 of slopes and cuts. Among them,

there are 5 large-scale upper cuts above the highway surface, covering 35,000 m^2, and 4 large-scale embankment slopes below the highway surface, covering about 34,000 m^2 (Fig. 9). Apart from these, there are also dozens of small-scale slopes, drainage ditches, and wasteland along the both sides of the highway covered by vetiver, which account for over 21,000 m^2 (Fig. 10).

Fig. 8 Left: vetiver began to become green 10~15 days after being planted; Right: vetiver hedgerows began to form and the slope was completely covered by vetiver and other naturally growing grasses about 2 months after planting

Fig. 9 Left: a upper cut covered and stabilized by hedgerows of Karnataka vetiver Right: a wonderful vista composed of the highway itself and vetiver hedge-belt rounding it

Fig. 10 Left: vetiver planted along drainage ditches also grew well despite of water logging; Right: Karnataka vetiver grown on the wasteland along both sides of the highway and grazed by animals due to delicious culms and leaves

Of the 9 executed large-scale slopes and cuts, the largest one is an upper slope, or a cut, nearly 16,000 m^2, which is worthy of mention. The soil dup up from the slope is extremely infertile kaolin and, furthermore, local places of the slope is quite steep, up to over 60° . Vetiver was planted in the end of August 2005 (Fig 11). Due to meticulous execution and strengthened management, vetiver began to cover the slope two months later, and the ecological landscape of the whole slope has completely changed 8 months later. The huge cut not only has become stable, but beautiful and wonderful as well owing to the miraculous effects of Karnataka vetiver (Fig. 12).

Fig. 11 The largest vetiver project with the area of about 16,000 m^2
Left: parts of the panorama prior to planting vetiver. The white parts are all kaolin
Right: the landscape that vetiver was just planted on the slope

Fig.12 The landscape of the largest cut after Karnataka vetiver was planted for two months (left) and for eight months (right)

3 Effect and Influence

After these projects were finished, their ecological effects began to gradually exhibit out on the Zhanjian-Chongqing highway. First of all, the section in Guangdong Province assumes greener and more beautiful landscape than other highways and other sections with the common vetiver variety. Secondly, the slopes protected by Karnataka vetiver are all stable and intact, without any erosion or landslide; on the contrary, some places or sections without vetiver protection or with other bio-measures protection have produced clear erosion and even landslide (Fig. 13). In the second quarter of 2006, especially in May and in the first 10 days of June there was a clearly overmuch rainfall in whole Guangdong, almost as twice as the mean of the same period in the past 30 years. As a result many highways were destroyed due to successive storms; so were some sections of the

Zhangjiang-Chongqing highway protected by other bio-measures. However, as narrated above, all slopes and cuts covered by Karnataka vetiver along this highway are strongly fortified. After inspecting and comparing damaged and undamaged spots, the highway construction company was very pleasantly surprised at the miraculous effectiveness of the new variety, and they felicitated themselves on correct selection of bio-measure.

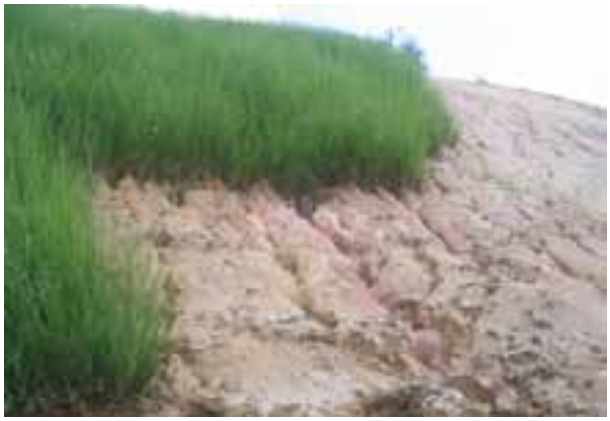

Fig.13 A contrast for erosion control and slope stabilization with or without Karnataka vetiver

Fig. 14 In the end of May the China Central Television (CCTV) gave a special interview and shoot to the new variety, Karnataka and the vetiver projects conducted with it

To our surprise, the China Central Television (CCTV), the most authoritative news agency in China, actually got to know the application of the new vetiver variety Karnataka, and then immediately allocated a journalist team of 3 persons to gave a special shoot and interview to the new variety and our recent work in the end of May (Fig. 14). As early as the year 2000, CCTV ever made a special report to vetiver. After the special program was broadcasted to the whole China, we received multitudes of repercussions coming from various places of the country. Later on, a climax disseminating and using vetiver took place in China. Therefore, we believe that the second climax special for vetiver will appear very soon at the scope of the whole country as soon as the newly finished program is broadcasted by CCTV. As a matter of fact, at present we are receiving more and more consultations inquiring about the vetiver new variety. So, we are assured that the vetiver eco-engineering, especially the use of new variety Karnataka, will exhibit more and more wonderful future.

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A Brief Introduction to the First Author

Dr. Hanping Xia, a restoration ecologist, is working at the South China Botanical Garden, Chinese Academy of Sciences. Since 1991, he has been engaged in a wide range of R&D on the Vetiver System for the purpose of erosion control and polluted environment mitigation. He creatively initiated “the Vetiver Eco-engineering” from his working experience of many years and has advocated over 10 enterprises to run vetiver market in China. So far he has one monograph and over 40 academic papers in this aspect published. He won the first “Vetiver Champion” and “The Kind of Thailand Vetiver Award” at ICV-3. He also won two second prizes awarded by The Vetiver Network in 1998.