Study on Screening for Better Ecotypes of Vetiver Grass

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Abstract: An observation for growth and development of 12 ecotypes of vetiver grass (*Vetiveria zizanioides*) collected from China and abroad was conducted. The results showed that 'Karnataka' from India grew shortest because it did not flower; and 'Kandy' sampled from Sri Lanka yielded the most tillers and the second fewest number of inflorescences next to 'Karnataka'. As to growth and development of roots, 'Wild' from Guangdong, China, produced the lowest root biomass and 'Zomba' from Malawi the highest; 'Lilongwe' assumed lowest and 'Karnataka' highest with regard to the percentage of root quantity with diameter <1 mm to total root amount. Regarding the plant appearance, 'Karnataka' seemed to be greener than the other ecotypes, especially in their young stage; but it produced culm-branches from the lateral buds of the culm when it grew up, which bent the mother plants and therefore gave a negative influence on its appearance. On the whole, Karnataka performed best, Kandy second, and Wild collected from a natural vetiver community of Guangdong, China worst with reference to their growth and development, but research on their ecological benefits, such as erosion control and pollution mitigation, remained to be further conducted.

Key words: *Vetiveria zizanioides* (L) Nash, ecotype, introduction and cultivation, ecotype selection, biodiversity

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1 INTRODUCTION

Vetiveria zizanioides (L.) Nash, a perennial native to tropical regions, is an excellent grass in the aspect of water and soil conservation due to its unique characteristics, such as massive and deep roots, stiff stalk and dense hedgerows. In the process of vetiver's dissemination and application for erosion control, it is found to have a strong resistance to such adverse conditions as infertility, strong acidity or alkalinity, organic pollutants and heavy metals. This makes it an excellent plant in the aspects of environmental amelioration and ecological restoration. Since vetiver has so many fine qualities, it has been spread and used in over 100 countries and regions of the tropics and subtropics so far. The vast majority of the applications and utilizations win success (National Research Council, 1993; Truong and Baker, 1998; Xia *et al.*, 1998; Narong and Barang, 2002).

As early as the 1950s, vetiver was introduced into China, mainly in to Guangdong, from India and Indonesia to be utilized as aromatic plant. However, due to the high cost of cultivation and extraction, plus low quality oil, the oil processing industry using vetiver in China ceased several years later and afterwards the once-cultivated vetiver became a wild grass (Xia, 1997; Xia and Ao, 1998). In the 1980s, the "wild" grass abandoned nearly 30 years was re-utilized after the vetiver technique for soil and water conservation was introduced into China. However, during the process of vetiver dissemination and application, its performance was found not to be very perfect. The prominent problems are: 1) it grows too high, often up to 2 m or so and even up to about 2.5 m after flowering; and 2) it becomes brown in winter, which makes its appearance and landscape become less appealing. Cutting has been testified to make vetiver keep green and become short, but it is time- and labor- consuming to frequently cut vetiver hedgerows; furthermore some are planted on steep slopes to stabilize them or planted in wetlands to treat wastewater, as a result it is very difficult to conduct the cutting work in such habitats. It is obvious, therefore, that these shortcomings of vetiver must be overcome first in order to spread the technique quickly throughout south China. That is to say that shorter and greener new varieties must be first found or screened out.

At present, there are lots of ecotypes of vetiver. Since vetiver has been introduced by many countries for the purpose of oil extraction for hundreds of years, as a result it has gradually formed dozens of ecotypes with different morphologies or physiological or ecological features after a long-term of adaptation and domestication. For example, over 20 ecotypes of vetiver were exhibited at ICV-1 held in 1996. However, they have been very poorly documented to comparatively investigate these ecotypes or screen excellent ecotypes from them (Kaveeta *et al.*, 2002). In China, no any new ecotype has been found except the above-mentioned one introduced from abroad in 1950s and a wild one naturally distributed in Wuchuan, Guangdong Province; and no any work has been conducted with regard to comparison of different vetiver ecotypes, either. It is well known that it is a very important work to screen excellent varieties regarding species introduction and cultivation. Considering these reasons, this paper hopes to screen the excellent ecotypes, from the 12 observed ecotypes, that can normally grow, are shorter than the common ecotypes and even keep green all year round in South China.

2 MATERIALS AND METHODS

2.1 Materials

The materials consisted of bare root clumps of 12 ecotypes of vetiver grass (Table 1). Among them ecotype # 1–10 were collected from five countries and regarded as good ones in the locality. The ten ecotypes were first introduced into an experimental nursery in the US by Mr. Mark Dafforn and Dr. Robert P. Adams for a period of time and then sent to the author in July 1999. The delivery lasted ten days (28 July to 7 August) in the hot summer, yet some clumps of each ecotype 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.

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

No.	Ecotype	Origin	Tillers number at planting	Tillers 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	-	-	-

Ecotype # 11, 'Domesticated' was introduced from abroad in 1950s; it was widely cultivated in China. The DNA fingerprinting reveals that it is the same genotype as the most extensively cultivated variety around the world, i.e. 'Sunshine' (Ecotype No.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. Ecotype # 12 ('Wild') was sampled from the wild vetiver community of Wuchuan County, Guangdong Province. The community, lying in the wetland near the sea, has existed for hundreds of years; no one knows its origin. Furthermore, the vetiver of 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' ecotype, which presents a striking contrast to the 'Domesticated' one.

2.2 Experimental Methods

The 10 introduced ecotypes multiplied themselves up enough for the experiment after one-year growth in the nursery of SCIB. Thus, they and the two local ecotypes, domesticated and wild, were dug up and then planted again, at the same time, to conduct the field plot experiment.

The experiment was designed and conducted on 9th October 2000 and divided into 2 groups in a randomized block design. The first group, 4 clumps for each ecotype and 3 tillers for each clump, was used to observe the aerial parts. Prior to being planted, the shoots were cut to 30 cm and roots to 5 cm. Vetiver clumps were planted with a large spacing of 50 cm _ 70 cm to ensure enough space for their normal growth without mutual influence. All treatments and duplicates were cultivated and managed with identical conditions. After planting was over, observation was carried out once each month, which contained plant height, plant pattern, numbers of tillers and inflorescences. In here, the plant height is referred to as the absolute height value at the situation of pulling leaves, culms or inflorescence stalks upward, not to as its natural height. The second group was used to observe roots. The pre-treatment to seedlings before planting, planting spacing, and maintenance after planting were identical to the first group, but only 3 clumps for each treatment (or ecotype). One later, the tillering number was investigated for the second group and then roots were investigated. The method used was digging up all roots within 60 cm depth, then washing away soils, cutting off the roots, washing all attached soil and particles with tap water. Thereafter, the roots were aired to dryness and weighed; and then roots with diameter < 1 mm and with > 1mm were divided, and then weighed respectively.

3 RESULTS AND DISCUSSION

3.1 Plant Height as a Measure of Growth of Different Ecotypes

The growth rate of the 12 vetiver ecotypes tested is shown in Fig.1. Prior to planting in October 2000, all clumps were cut to 30 cm high. After 14 months of growth, different ecotypes produced tangible differences regarding plant height. At the last measurement, the tallest ecotype was 'Huffman', whose average height was 291 cm and the tallest clump was up to 305 cm high whereas the shortest ecotype was 'Karnataka', whose average height was only 178 cm and the shortest clump was only 170 cm. Thus the difference in height between the shortest and tallest clumps was 135 cm (305_170) and between the shortest and tallest ecotypes was 113 cm (291_178). Actually, their height revealed only a little difference during vegetative stage of growth. For example, at June observation, the tallest ecotype ('Capitol') averaged 197 cm, while the shortest ('Zomba'), 153 cm, only a 44 cm disparity between them. It can be seen, therefore, that a huge difference of plant height results mainly from reproductive growth. It is interesting that the height of most ecotypes was shorter in February than in last December. This is because vetiver leaf tips were frozen to death in cold winter; as a result the majority of them became a little shorter after winter. In addition, during the whole period of investigation, especially in the early growth phase, the leaves of 'Karnataka' ecotype seemed to be greener than those of other ecotypes. Among them 'Lilongwe' had the lightest leaf color and the leave colors of ten other ecotypes were between 'Karnataka' and 'Lilongwe'. It was very difficult to differentiate the colors of different ecotypes with naked eyes.

Fig.1 Comparison of the plant height of 12 vetiver ecotypes in the process of 14-month growth

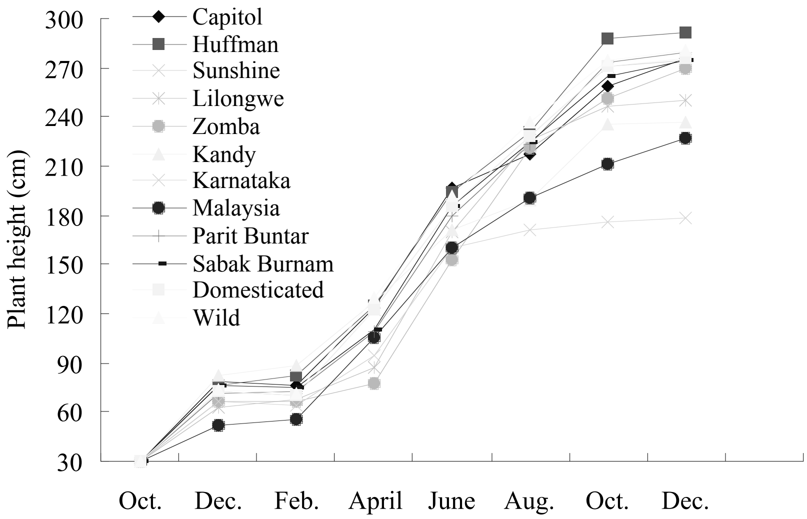

Table 2_Accumulative tiller number per clump of different ecotypes during the growing period*

No.	Ecotype	Oct.	Dec.	Feb.	April	June	Aug.	Oct.	Dec.
1	Capitol	3	3.5bc	7.5abcd	14.3cd	21.8cde	33.8cde	44.5bcd	51.0cdef
			(1.19)	(1.94)	(2.66)	(2.84)	(4.19)	(4.66)	(4.67)
2	Huffman	3	3.3bc	5.3bcd	10.8cd	18.5de	30.8cde	41.8bcd	56.5bcde
			(0.63)	(1.31)	(2.17)	(3.07)	(4.82)	(4.17)	(2.53)
3	Sunshine	3	3.8abc	7.0abcd	14.5bcd	22.0cde	36.5cd	43.5bcd	59.0bcde
			(0.48)	(0.58)	(1.26)	(1.87)	(3.30)	(4.99)	(6.94)
4	Lilongwe	3	3.5bc	5.8bcd	13.5cd	21.0cde	30.5cde	34.0de	39.5fg
			(0.50)	(0.25)	(1.32)	(1.73)	(2.47)	(2.08)	(3.29)
5	Zomba	3	2.3c	4.3d	10.0d	15.3e	20.0e	24.5e	31.5g
			(0.48)	(0.63)	(0.58)	(2.29)	(0.91)	(1.19)	(1.04)
6	Kandy	3	5.3a	9.5a	24.3a	42.5a	55.0a	66.8a	82.5a
			(0.85)	(1.71)	(5.76)	(7.90)	(8.30)	(7.41)	(8.03)
7	Karnataka	3	5.5a	9.0ab	19.8abc	36.0ab	52.5ab	55.8ab	68.0ab
			(0.65)	(1.41)	(3.75)	(3.46)	(4.29)	(4.72)	(3.94)
8	Malaysia	3	3.5bc	4.8c	9.8d	17.0e	29.5de	37.3cde	44.0efg
			(0.29)	(1.03)	(1.89)	(1.22)	(4.13)	(7.20)	(7.56)
9	Parit Buntar	3	4.3ab	6.8abcd	17.0abcd	23.0cde	39.0bcd	47.5bcd	66.0bcd
			(0.63)	(1.11)	(5.34)	(4.24)	(7.55)	(8.29)	(6.92)
10	Sabak Burnam	3	4.5ab	7.8abcd	16.5abcd	28.8bcd	41.5abcd	49.0bcd	62.3bcd
			(0.65)	(1.11)	(2.50)	(3.20)	(4.29)	(4.93)	(5.55)
11	Domesticated	3	5.5a	10.3a	23.8ab	31.3abc	45.5abc	52.3abc	67.5ab
			(0.29)	(1.55)	(5.11)	(7.00)	(8.31)	(8.14)	(8.30)
12	Wild	3	4.3ab	8.0abc	17.0abcd	25.0bcde	35.8cd	40.0bcde	49.0defg
			(0.25)	(1.08)	(1.29)	(2.65)	(4.84)	(4.67)	(4.42)
	Max_Min	3	3.2	6	14.3	27.2	35.0	42.3	51.0

* Means (with (SE), n=4) followed by same letters in the same row indicate there is no significant difference at 5% level according to LSD test

3.2 Tiller Forming Capacity of Different Ecotypes

After vetiver was planted for only two months (December 2000), the number of tillers of different ecotypes were significantly different. Furthermore, the difference became larger and larger as time passed. At the last measurement (December 2001), the ecotype yielding the largest number of tillers was ‘Kandy’, which yielded 82.5 tillers average per clump, while the ecotype yielding the smallest number of tillers was ‘Zomba’, with only 31.5 tillers per clump. Thus, a large difference of 51 tillers between them exists as shown in Table 2. So, ‘Kandy’ is undoubtedly far better than all other ecotypes, while ‘Karnataka’ and ‘Domesticated’ ranked second and ‘Zomba’ the poorest with regard to tiller formation.

3.3 Blooming Situation of Different Ecotypes

Vetiver can hardly produce seeds in natural conditions, but blooms in every autumn if not cut. Not only does blooming greatly enhance vetiver’s height, but also the bloomed tillers gradually become old and brown, thus influencing the whole vetiver’s appearance. Although a spray of plant growth retardants can postpone vetiver’s blooming and dwarf somewhat vetiver’ height, the effects are all temporary (Xia *et al.*, 2000). Therefore, the problem of vetiver’s relatively unattractive appearance cannot be reduced if non- or less- bloom varieties cannot be found from different ecotypes.

In this experiment, the ecotype that came into bloom first was ‘Zomba’, followed in turn 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, 25 September, respectively; the maximum difference was 46 days. Since the main inflorescence stalk of vetiver is about 50–70 cm long, so this is the radical reason that all ecotypes suddenly become much higher in autumn, whereas ‘Karnataka’ remained the shortest ecotype (Fig.1) as it did not produce any bloom at all. In the subsequent two months after blooming, the growth rate of inflorescence of each ecotype was also different. ‘Zomba’, the earliest blooming ecotype, did not produce the highest number of inflorescence in the end, while ‘Capitol’, the latest blooming ecotype, eventually became one of the ecotypes with the highest number of inflorescence due to its exuberant reproductive growth (Table 3). It is worth noticing that the ‘Karnataka’ ecotype did not bloom, but kept on growing vegetatively during this period, 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. Because of the formation of culm-branches, ‘Karnataka’ ecotype kept green in winter while other ecotypes turned brown of varying shades. Due to the heavy stress of the formation of culm-branches, this ecotype became deflecting and even lodged. .

Blooming rate is referred to as the percentage of tillers with inflorescences to total tillers. Obviously, it is more precise to compare the blooming rates of different ecotypes than number of inflorescences. For example, the final inflorescence number of ‘Kandy’ ecotype was about 1/6–1/3 of other ecotypes, but its blooming rate was only 1/10–1/5 of other ecotypes (Table 3), which was due to far more tillers than those of other ecotypes.

Table 3 Number of inflorescences per clump and blooming rate (%) of 12 different ecotypes of vetiver

No	Ecotype	Total number of inflorescences					Blooming rate				
		Aug.	Sep.	Oct.	Nov.	Dec.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Capitol	0	0	13	34	44	0	0	7.30	17.78	21.57
2	Huffman	0	0	16	22	23	0	0	9.57	11.22	10.18
3	Sunshine	0	1	24	30	30	0	0.62	13.79	14.85	12.71
4	Lilongwe	0	4	19	25	28	0	2.94	13.97	16.80	17.72
5	Zomba	1	5	21	26	30	1.25	5.68	21.43	23.81	23.81
6	Kandy	0	2	7	7	7	0	0.84	2.62	2.309	2.126
7	Karnataka	0	0	0	0	0	0	0	0	0	0
8	Malaysia	0	1	16	33	36	0	0.74	10.72	20.63	20.45
9	Parit Buntar	0	1	22	27	27	0	0.58	11.58	12.32	10.23
11	Domesticated	0	4	26	36	37	0	2	12.43	14.68	13.70
12	Wild	0	5	35	45	45	0	3.38	21.88	25.57	22.96

3.4 Roots Biomass of Different Ecotypes

If vetiver did not have massive roots, its ecological effectiveness would be weakened dramatically. Therefore, it is necessary to consider the growth of roots when screening for excellent ecotypes. It can be seen from Table 4 that there was a large difference of the biomass of roots of different ecotypes. The ecotype 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 ability of producing tillers.

Table 4 Root performance of 12 different vetiver ecotypes*

Item	Ecotype #											
	1	2	3	4	5	6	7	8	9	10	11	12
A*	0.87	0.82	0.88	1.25	1.44	0.77	0.42	0.51	0.97	0.58	0.57	0.39
B*	50	60	60	20	30	40	80	70	60	70	40	30

* Item A is the root weight (g DW/tiller) per tiller, and Item B is percentage of the root amount with diameter < 1 mm to the total root amount (%)

3.5 Comprehensive Evaluation of the Growing Performance

It can be seen from the foregoing discussion that various ecotypes of vetiver present distinct differences regarding their growing performance.

Table 5 A comprehensive evaluation for the 12 ecotypes of vetiver*

No.	Ecotype	Plant height	Total tiller number	Tillering rate	Blooming rate	A*	B*	Total points	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 the root amount with diameter <1 mm to the total root amount (see Table 4)

Each ecotype has its own advantages and disadvantages. No one ecotype performs the best in all aspects. In order to screen out the best ecotype on the whole, 12 ecotypes have been divided into 12 grades; each grade endowed with 1 point. This means that the best ecotype in a certain aspect is given 12 points and the poorest one, 1 point. The ones with same performance are given a mean value. Then, accumulative point for each ecotype could be figured out. The ecotype obtaining the highest scores is obviously the best one. Table 5 shows the scores of the 12 ecotypes in different aspects and their total scores. Karnataka ranks first, which is beneficial mainly from its non-blooming and low stature resulting from non-blooming. In addition, the culm-branches growing from the culm nodes were found to be good propagating materials. If these culm-branches were cut off from mother plants after they attain the length of 30–40 cm, they not only increase new propagating materials, but also keep the mother plants' normal appearance from lodging. 'Kandy' lies in the second; it has the rapidest tillering speed, its blooming rate is very low and its appearance is quite good and therefore is also worth disseminating widely.

‘Domesticated’ and ‘Sunshine’ belong to the same genotype and their points are quite close, indicating that the former has produced quite a few changes even after 50 years of being introduced into China. Regarding the ‘Wild’ ecotype, the main reason that it scores the lowest points is, no doubt, associated with its prior long-term waterlogged habitat. The waterlogged environment is disadvantageous to root growth and tiller formation. 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 features as the ‘Domesticated’ or other ecotypes.

In summary, the ‘Karnataka’ is evaluated as the best ecotype in terms of its growth and development. This experiment, however, did not measure the length of roots; so we do not yet know how long its roots grow. But another special experiment on ‘Karnataka’ roots’ growth rate and length is now ongoing. In addition to this, the ‘Karnataka’ ecotype has just begun to be applied for the purpose of erosion control and pollution mitigation, thus its ecological efficiency remains to be investigated.

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A Brief Introduction to the First Author

Dr. Hanping Xia, a restoration ecologist, is working at the South China Institute of Botany, 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 soil erosion control and polluted environment mitigation, including highway slope stabilization, land reclamation and re-greening, quarry rehabilitation, mine and landfill phytoremediation, wastewater purification, etc. He creatively initiated “the Vetiver Eco-engineering” from his working experience of many years. So far he has one monograph and over 30 academic papers in this aspect published.