RESEARCH ON SELECTION, PROPAGATION AND CULTIVATION TECHNIQUES OF VETIVER GRASS AND THEIR APPLICATION IN THAILAND

Land Development Department *
Bangkok, Thailand

Abstract

Soil erosion is a major cause of the land degradation that affects agricultural areas in Thailand. Resolving the soil erosion problem can be achieved only by appropriate technological solutions that are accepted by the local land users, the farmers. His Majesty's initiative on vetiver grass as an agronomic measure against soil erosion has been recognized increasingly. Being one of the implementing agencies, the Land Development Department has been assigned to conduct research to identify appropriate methods for the cultivation of vetiver grass in Thailand.

Research stretching over eight years has concerned vetiver cultivation, large-scale field plantation, quantification of environmental impact and non-agricultural uses of vetiver. Interesting research results by statistical means are highlighted. Clearly, vetiver provides a simple, cheap and comprehensive means to control or minimize soil erosion. Hence, vetiver is increasing in popularity, is being widely adopted by Thai farmers and can be used for many purposes.

Introduction

Thailand's impressive agricultural growth rate in the past decade has been achieved largely through expansion of cultivated land. However, agricultural development has exacerbated land degradation. Today, the principal cause of land degradation is misuse of the land and vegetation cover, which often results in soil erosion or removal of the topsoil by water. After rainfall, water rushes down slopes, carrying away precious topsoil and plant food. Down slope, ploughing worsens the situation, and often serious gullying develops. It is estimated that the rate of erosion in the region where most field crops (such as cassava) have been cultivated is about 12.5-62.5 tons/hectare/year. It is most regrettable, however, that only a small area of these croplands is protected by erosion control measures.

In recognition of the serious problem of soil erosion, particularly on cultivated land, His Majesty King Bhumibhol Adulyadej came up in 1991 with the idea of using vetiver grass as a practical tool to reduce soil erosion and improve water conservation. The Land Development Department (LDD) was assigned to conduct studies to identify appropriate methods for wide-scale cultivation of vetiver grass, as well as research appropriate applications for different purposes. His Majesty the King has given most valuable suggestions, at different times, to enhance the effectiveness of the studies and for implementing activities. This paper attempts to highlight the results of the research studies which are of interest to researchers, developers and farmers on the use of vetiver on a wide scale as a technology for soil and water conservation, for solving environmental problems and for realizing its many uses of benefit to non-agricultural production.

Establishment of Vetiver Grass Cultivation

Selection of the Planting Cultivars

In Thailand, vetiver grows naturally throughout the country, on both upland and lowland soils at maximum elevations of approximately 800 m. Recent studies have indicated that only two species of

* *Research conducted by S. Morakul, P. Vijarnsorn, C. Anecksamphant, S. Rajani, W. Chinapan, A. Sukhkasem, U. Taejajai, A. Pothinam and P. Tepnaraprapai*

vetiver, namely *Vetiveria zizanioides* (Linn.) Nash and *Vetiveria nemoralis* (Balansa) A. Camus, have been recognized in Thailand. The main characteristics of these two species are differences in shape of clump, leaves, roots, inflorescence and seed. Detailed studies have been made on ecotypes and varieties suitable for various soil types and physiographic regions have been selected. Seventy-eight ecotypes were collected from different sites all over Thailand and detailed study of their botanical characteristics was conducted. The final study indicated that, in Thailand only 17 ecotypes of *Vetiveria nemoralis* and 11 ecotypes of *Vetiveria zizanioides* could be differentiated. Each ecotype was named after the site where it was found. By using these 28 ecotypes, their adaptability to different soil types, and 12 sites in different physiographic regions (LDD 1998), inquiries were made on how to obtain suitable cultivars for use around Thailand. The parameters indicating their adaptability to the sites included the number of tillers per clump, diameter of the clump, and height. To date, six ecotypes of *Vetiveria nemoralis* and four ecotypes of *Vetiveria zizanioides* have been recommended to grow in various parts of the country. Tables 1 and 2 summarize the results of the study on growth of different vetiver ecotypes cultivated on sandy soils, medium-textured soils and skeletal soils (lateritic soils) at the 12 study sites. The data show that cultivation of vetiver in Thailand is feasible in most areas of the country. Furthermore, it can grow well on some problem soils, as illustrated in Table 3.

Table 1. Growth of vetiver on various soil types from 12 experimental plots in areas of the country

Ecotype	Sandy soil			Medium-textured soil			Skeletal soil		
	A	B	C	A	B	C	A	B	C
1. *Vetiveria nemoralis*									
Loei (V6)	-	-	-	34	14	115	18	12	101
Nakhon Sawan (V7)	31	8	79	39	15	-	-	-	-
Kamphaeng Phet 1 (V8)	30	9	92	38	14	120	-	-	-
Roi Et (V13)	26	7	70	-	-	-	-	-	-
Ratchaburi (V20)	25	8	102	38	16	117	-	-	-
Prachuap Khiri Khan (V22)	-	-	-	37	17	124	16	12	100
2. *Vetiveria zizanioides*									
Sri Lanka (V4)	-	-	-	-	-	-	12	10	106
Kamphaeng Phet 2 (V9)	26	8	102	-	-	-	14	10	104
Surat Thani (V28)	-	-	-	38	17	137	15	12	94
Songkhla 3 (V28)	29	10	106	36	16	141	16	14	110

NB: A = no. of plant/tiller, B = stem diameter (cm), C = height (cm)
Source: Department of Land Development (1998b)

Table 2. Suitable ecotypes of vetiver for different soil types and physiographic regions in Thailand

Ecotype	Suitable for						
	Sandy soil	Medium-textured soil	Skeletal soil	Physiographic region			
				C & SE	N	NE	S
1.*Vetiveria nemoralis*							
Kamphaeng Phet 1	✓	✓		✓	✓		
Loei		✓	✓				
Nakhon Sawan	✓	✓			✓		
Prachuap Khiri Khan		✓	✓	✓			
Ratchaburi	✓	✓		✓			
Roi Et	✓					✓	
2.*Vetiveria zizanioides*							
Kamphaeng Phet 2	✓		✓	✓			
Songkhla 3	✓	✓	✓	✓		✓	✓
Sri Lanka			✓		✓		
Surat Thani		✓	✓	✓			✓

NB: 1. ✓ = *suitable*
2. *C + SE* = *Central Plain and South-eastern Coast*
N = *North*
NE = *Northeast*
S = *South*
3. *Suitable ecotypes on high land (elevation about 1 000-1 200 m) are Japanese, DLD, EXT 09 and Mae La Noi*

Source: Department of Land Development (1998b)

Table 3. Suitable ecotypes of vetiver for some problem soils

Ecotype	Feasible to grow on						
	ASS	SLS	PS	SS	HL	HW	GP
Phra Ratchathan	✓				✓	✓	✓
Mae La Noi					✓		
Monto					✓	✓	
Nakhon Sawan						✓	
Songkhla 3		✓	✓	✓			✓
Sri Lanka	✓	✓		✓			
Surat Thani	✓		✓	✓			✓

NB: 1. *ASS* = *Acid sulphate soil (with liming)*
SLS = *Saline soil*
PS = *Peat soil*
SS = *Shallow soil*
HL = *High land*
HW = *Side slope of highway*
GP = *Industrial garbage pit*
2. *Data obtained from plot experiment in 1998*
3. *Fertilizer application is needed*

Source: *Department of Land Development (1998a)*

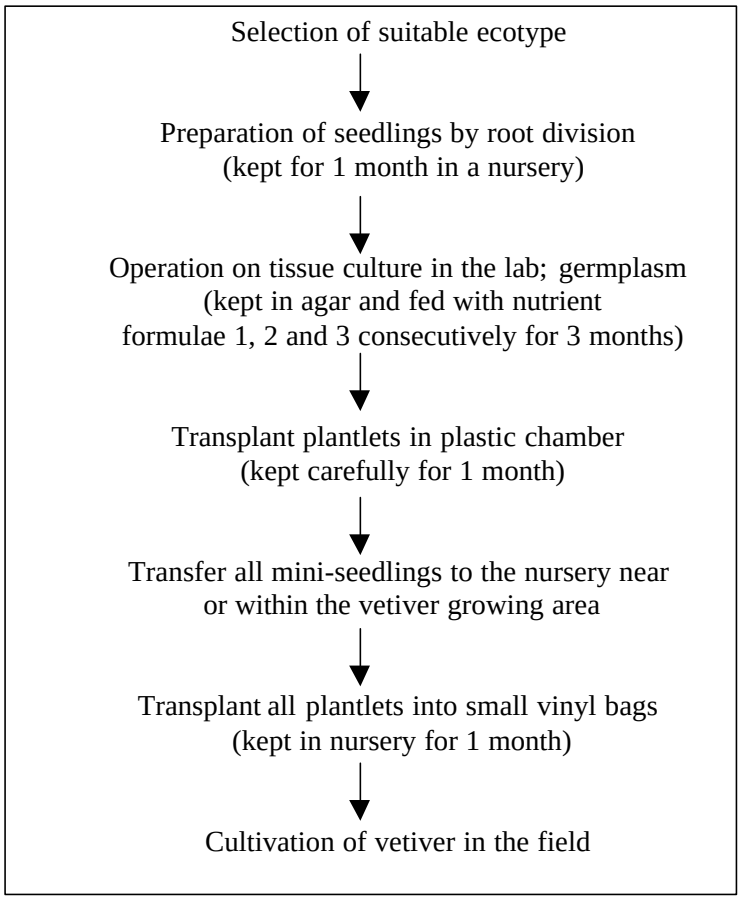
(Space for Fig. 1)

Although the tissue culture method has several advantages over the conventional method, it is highly technical and a laboratory is required. In most cases the multiplication of vetiver by root division or slips is easy and many propagating materials can be produced. Vetiver slips, kept in well-prepared light soils in vinyl bags, at the early stage, need to be cared for in a nursery. To enhance growth of the seedlings or for profuse tillers, fertilizer application and irrigation are necessary.

Propagation

The production of propagating materials is the first requirement for the establishment of vetiver cultivation. After selection of the suitable ecotype, a propagation program needs to develop quickly to obtain the hundreds of thousands of seedlings to plant. In general, the simplest way is to propagate vetiver by root division or slip. However, micropropagation (tissue culture) has been practiced in Thailand since 1994, particularly at the sloping land conservation project at Doi Tung in Chiang Rai province of the North (LDD 1998). The propagating materials from tissue culture are known as plantlets, which are very easy to handle and relatively convenient to transport for transplanting in the field.

The flow chart below illustrates production of the propagating material of vetiver by tissue culture.



Cultivation of Vetiver in the Field

Many studies, not only in Thailand but also in other tropical countries, have assured of the usefulness of vetiver grass in the field to prevent soil erosion and to promote water conservation. After His Majesty the King's initiatives on uses of vetiver in Thailand, 10 ecotypes were nominated and extensive propagation programs were launched. In 1993, 6 500 000 plants were available and in 1999 the number increased to 99 500 000 plants. The trials have been incorporated into several specific projects dealing with topics discussed next.

Research on Cultivation of Vetiver on Farming Areas Prone to Erosion

In Thailand, it is common for vetiver to be planted in narrow strips aligned on the contour. The vertical distance between the vetiver strips depends on the slope gradient of the soil surface. For more effective prevention of soil loss and reduction in the velocity of runoff, ploughing, planting and cultivation on the contour are practised additionally.

The planting method for vetiver is simple but needs much labour because the interval for each tiller to be transplanted is about 10 cm. If the soils are very low in fertility, fertilizer application both in chemical and organic forms is needed in the planting holes or planting furrows. However, when planting material is scarce and the field is hard to reach, slips can be spaced at about 20 cm (National Research Council 1993) or the planting material can be removed directly from the main clump and planted into the ground (like rice seedlings). It is important that the planting be done at the beginning of the wet season for enough moisture to enhance the quick establishment of the vetiver line or hedge. In Thailand, it is generally recommended for vetiver to be planted from 30 May to 30 July and from 15 August to 30 September. After planting, if the survival rate exceeds 90 %, it takes about 90 days to form a complete hedge or a complete green line. Once the vetiver grass barriers are complete, they should provide full protection against erosion and last for years.

On experimental plots conducted by LDD, vetiver hedges reduced the rate of soil loss and crops could be grown between the vetiver lines.

Table 4 indicates the effectiveness of the vetiver lines against soil erosion on experimental plots on 20-% slopes under field crops (maize and black beans). The data show that in the first year, vetiver hedges reduced annual erosion to less than 0.75 t/ha compared with 12.6 t/ha for conventional practices or without vetiver hedges.

Since degree of slope is one of the factors that can contribute to loss of the topsoil by water erosion, determining the vertical interval for the layout of each line of vetiver is necessary.

Table 4. Measurement of the annual soil loss from different treatments of the vetiver trial

Treatment	Annual soil loss (t/ha)
Single line of vetiver	
Tr. 1: Spacing between tiller 10 cm	0.21 b
Tr. 1: Spacing between tiller 15 cm	0.32 b
Tr. 1: Spacing between tiller 20 cm	0.70 b
Double lines of vetiver, interval distance between lines 30 cm	
Tr. 2: Spacing between tiller 10 cm	0.75 b
Tr. 2: Spacing between tiller 15 cm	0.67 b
Tr. 2: Spacing between tiller 20 cm	0.64 b
No vetiver (control)	12.57 a
LSD. (0.05)	

Source: Inthaphun, P. et al (Chiang Mai, 1999)

Table 5 presents the results of these studies. It indicates that the vertical interval at 1.0, 2.0 and 3.0 m makes no difference in soil loss. Therefore, the vertical interval can vary from 1.0 to 3.0 m depending upon the crop to be grown. However, the higher the value of the vertical interval (VI), the wider the horizontal interval (HI) of the vetiver line will be when using this formula:

$$HI = \frac{VI}{\%Slope} \times 100$$

(Space for Fig. 2-3)

(Space for Fig. 4-5)

(Space for Fig. 6-7)

(Space for Fig. 8-9)

Soil loss was significantly decreased from the first year to the third year, which can be attributed to the quick establishment of the vetiver hedge after a year of planting. Research on maximizing and increasing the efficiency of vetiver grass continues.

Table 5. Measurement of annual soil loss from different vertical interval of the vetiver lines

Treatment	Annual soil loss (t/ha)		
	1st yr	2nd yr	3rd yr
Tr. 1. Control (fallow)	20.39 a	28.72 a	29.05 a
Tr. 2. Single line of vetiver (V.I.=1.0 m)	8.57 b	0.74 b	0.66 b
Tr. 3. Single line of vetiver (V.I.=2.0 m)	9.06 b	1.17 b	0.77 b
Tr. 4. Single line of vetiver (V.I.=3.0 m)	8.37 b	1.10 b	0.76 b
DMRT at 5%			

Source: Inthaphun et al. (1999)

Research on the Cultivation of Vetiver on Waterways

The purpose of waterways in a conservation system is to convey runoff at a non-erosive velocity to a suitable disposal point. Within a complete system, there are three types of waterway that can be incorporated, i.e. diversion channels, terrace channels and grass waterways. Diversions are commonly placed upslope to intercept runoff water and divert the water across the slope to a grass waterway. Terrace channels collect runoff from the inter-terrace areas and also divert it across the slope to a grass waterway. Grass waterways are designed to drain (down slope) the runoff from these sources to natural streams or natural waterways, farm ponds and reservoirs.

To prevent grass waterways from deterioration by gulley or rill erosion, a straddling green line of vetiver can help a great deal. Rows of grass are planted like an inverted V across the channel or grass waterway, with the apex pointing upstream. Determination of the number of vetiver lines depends on the gradient of the waterway. In general, a vertical interval of about 50 cm is recommended. Three months after planting, cutting the top of the plant to about 40 cm above the ground surface is practised for denser tillering or hedges. Cultivation of vetiver on the waterway on a wide scale is relatively practical because construction is easy; only a minimal amount of equipment is needed and simple techniques are used (Fig. 10).

Research on the Cultivation of Vetiver Along the Edges of Farm Ponds, Reservoirs, Canals, Dikes or Small Check Dams

It has been reported that rows of vetiver grass planted on the edges of excavated ponds, irrigation canals, and dikes on dams prevent scouring to form rills and gullies. For this purpose, two lines of vetiver are planted on the edges of the farm ponds, three lines on the edges of a reservoir and only one line along irrigation canals and natural waterways.

On the edges of a reservoir, the first line is located at the top of the spillway or the outlet where the maximum water level is reached. The other two lines will be above and below the first line, with a vertical interval of 20 cm. For a farm pond, the first line is at the top of the inlet and the second line is below the top of the edge (50 cm). For an irrigation canal or a natural waterway, a line of vetiver is planted on the dike or levee away from the edge (50 cm).

Because the soil at the edge of the excavated pond is generally not fertile, chemical fertilizer (15-15-15) mixed with compost is usually applied in the planting furrow. Three months after planting, it is recommended to cut the tops of the plants to produce more tillers. Sometimes, two fertilizer applications may be needed.

(Space for Fig. 10-11)

(Space for Fig. 12-13)

Research on the Cultivation of Vetiver on the Side Slopes of Highways or Roads

The conventional method to control soil erosion along the side slopes of highways or roads is to build concrete structures along them. However, the construction cost is relatively high. Therefore, to a certain extent, the vetiver hedge can protect roads from washouts or landslides. If the slope length does not exceed 10 m, rows of vetiver with a vertical interval of 20 to 50 cm can prevent erosion satisfactorily. If the slope length is longer and the gradient is very steep, planting of vetiver hedges with an engineering system (such as terraces, berms, bunds or contour drains) can protect soil erosion. For example, vetiver grass can be planted at the edge of each terrace in one line or two lines. To enhance the effectiveness of the vetiver hedges, the exposed soil surface should be cultivated with cover crops like Bermuda grass or legumes. However, it is worth mentioning here that the use of vetiver for side-slope protection of highways or roads in Thailand still needs further study to obtain an appropriate and less expensive technology.

Research on Integrated Vegetation Management

In general, once the vetiver hedge is completely established, little management is needed except for cutting the tops of the plants to produce denser tillers. Furthermore, vetiver is a great survivor as it is difficult to destroy by fire, grazing, drought or flooding. However, it has been reported that vetiver can be damaged by diseases and pests in Thailand. For example, the Chiang Mai ecotype can be attacked easily by leaf blight caused by *Curvularia trifolli*. Root rotting, perhaps caused by *Fusarium* spp., attacks *Vetiveria zizanioides* ecotypes, particularly the Sri Lanka ecotype during the rainy season.

Pests such as termites, rats and insects attack vetiver. Perhaps the most serious pests are aphids and mealy bugs. Stem borers also damage young seedlings in nurseries.

Cutting and thinning, of course, are necessary for vegetation management. Cutting the tops of the plants and taking out the old tillers after flowering (from the clump) can increase the number of young shoots and tillers, to make a denser hedge. However, time of cutting and thinning should be suitable otherwise it will retard the growth of vetiver. Studies recommend that cutting and thinning of vetiver should be done only once or twice a year. If the farmers want the vetiver leaves as raw material for making roofs or handicrafts, cutting the leaves at 180 days can obtain more leaf biomass. If leaves are needed for mulching, the time of cutting should be about 90-120 days. If used for feeding livestock, cutting at 30-60 days is appropriate because leaf analysis shows a narrow C/N ratio. However, the young shoots or tillers can be removed to feed the livestock at any time.

(Space for Fig. 14/shifted from p 85)

Table 6. Biomass obtained from different times of leaf cutting of one-year-old vetiver (Sri Lanka ecotype)

Treatment*	No. of cuttings	Fresh leaves (kg)	Dry leaves (kg)	C/N ratio
T1	12	69.34	22.99	39
T2	6	98.05	32.99	53
T3	4	111.58	42.94	63
T4	3	107.97	37.32	67
T5	3	106.45	32.85	67
T6	2	98.25	39.38	67
T7	1	92.27	30.61	71

*NB: * Cutting the top of the plant at 30 cm: T1 = every 30 days; T2 = every 60 days; T3 = every 90 days; T4 = every 120 days; T5 = every 150 days; T6 = every 180 days; T7 = every 360 days*
Source: Suwannakert, V. et al. (1998)

By-products and Benefits of Vetiver Cultivation

As previously mentioned, cultivation of vetiver helps to prevent soil erosion and conserve soil moisture. Moreover, vetiver has a deep-root system that can make soil more porous and the numerous fibrous roots can increase soil organic matter after decomposition. Therefore, it is worth knowing whether such a deep-root system can benefit soils in terms of increasing micro-organisms and nutrients. Tables 7, 8, 9 and 10 illustrate the results of recent studies. The data indicate clearly that the cultivation of vetiver increases the population of micro-organisms and soil nutrients. These are by-products of vetiver that can benefit the soil and the environment at no additional cost.

Non-agricultural Uses of Vetiver

Strong evidence confirms that vetiver can be used for environmental conservation of both natural resources and farmland with good care and management. People pay more attention to the technology if they perceive direct benefits. Vetiver then becomes a high priority for consideration. LDD and the Royal Project Foundation assist technical collaboration for preliminary testing among institutes of technology and private agencies.

The following projects have been conducted prior to actual experimental designs for further research and more detailed investigation.

Table 7. Total population of microorganisms at a soil depth of 0-30 cm and 30-60 cm in plots of various vetiver ecotypes

Treatment (vetiver ecotype)	Soil depth 0-30 cm			Soil depth 30- 60 cm		
	No. of cell/g soil			No. of cell/g soil		
	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi
Check (no vetiver)	3.8×10^6	6.4×10^5	9.9×10^2	1.1×10^6	3.6×10^5	6.7×10^2
Phra Ratchathan	2.6×10^7	4.8×10^7	7.1×10^3	1.3×10^8	2.7×10^8	8.9×10^3
Prachuap Khiri Khan	9.0×10^7	3.6×10^6	4.3×10^3	6.1×10^8	3.3×10^7	7.0×10^3
Ratchaburi	5.8×10^6	7.4×10^6	9.1×10^3	7.2×10^7	2.6×10^7	4.3×10^3
Songkhla 3	1.7×10^7	3.5×10^6	8.3×10^3	1.5×10^8	6.7×10^7	3.1×10^3
Surat Thani	1.7×10^7	2.2×10^6	5.6×10^3	6.7×10^8	2.6×10^7	4.0×10^3
Sri Lanka	1.3×10^7	4.8×10^6	5.8×10^3	8.0×10^7	7.2×10^6	8.8×10^3

Source: Sunanthapongsak et al. (1999)

Table 8. Population of cellulose digestible micro-organisms at a soil depth of 0-30 cm and 30-60 cm in plots of various vetiver ecotypes

Treatment (vetiver ecotype)	Soil depth 0-30 cm			Soil depth 30-60 cm		
	No. of cell/g soil			No. of cell/g soil		
	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi
Check (no vetiver)	5.1×10^6	1.07×10^6	1.7×10^2	2.0×10^5	5.06×10^5	4.5×10^2
Phra Ratchathan	2.8×10^8	1.4×10^8	6.4×10^4	2.4×10^8	3.1×10^8	8.3×10^4
Prachuap Khiri Khan	8.6×10^7	2.2×10^7	2.3×10^4	1.0×10^7	2.8×10^6	5.3×10^3
Ratchaburi	3.2×10^8	1.8×10^8	3.9×10^3	2.0×10^8	4.4×10^6	5.8×10^3
Songkhla 3	7.7×10^7	1.4×10^7	1.1×10^4	1.0×10^6	4.4×10^7	7.9×10^3
Surat Thani	1.2×10^7	1.0×10^7	4.2×10^3	1.0×10^8	4.4×10^8	7.0×10^3
Sri Lanka	3.5×10^7	1.5×10^7	6.4×10^3	3.1×10^8	2.1×10^7	8.8×10^4

Table 9. Nutrient status at a soil depth of 0-30 cm in plots of various vetiver ecotypes

Treatment	Nutrient (ppm)					pH	Organic matter (%)
	P_2O_5	K_2O	Ca	Mg	S		
Check (no vetiver)	2.07	103	271	345	0.83	5.04	0.58
Phra Ratchathan	4.98	161	534	507	2	6.03	1.03
Prachuap Khiri Khan	4.89	159	530	494	1.59	5.98	1.03
Ratchaburi	4.29	148	516	618	1.775	5.93	0.91
Songkhla 3	5.02	147	575	682	1.727	5.78	1.01
Surat Thani	4.80	145	378	433	1.952	5.45	1.03
Sri Lanka	4.49	161	563	656	1.67	6.23	0.94

Table 10. Nutrient status at a depth of 30-60 cm in plots of various vetiver ecotypes

Treatment	Nutrient (ppm)					pH	Organic matter (%)
	P_2O_5	K_2O	Ca	Mg	S		
Check (no vetiver)	2.39	93	280	362	0.82	5.06	0.42
Phra Ratchathan	5.43	156	508	506	1.62	5.88	0.92
Prachuap Khiri Khan	4.22	141	472	596	1.45	5.63	0.82
Ratchaburi	6.11	136	434	496	1.5	5.53	0.81
Songkhla 3	3.18	132	496	506	1.45	6.15	0.74
Surat Thani	4.79	142	430	423	1.41	5.95	0.85
Sri Lanka	4.66	157	515	538	1.45	6.11	0.93

Source: Sunanthapongsak, W. et al. (1999)

.

Vetiver Root Harvest Technique

(Space for Figs. 15-16)

Vetiver Soil-cement Brick

(Space for Fig. 16-17)

.
.
.
.
.
.
.
.
.
.

Light-weight Panel

(Space for Fig. 18-19)

.
.
.
.
.
.
.

Vetiver Chip Board

(Space for Fig. 20-21)

.

Thermal Insulator Panel

(Space for Fig. 22-23)

.
.
.
.
.
.
.
.

Natural Organic Fibers as Fiber Reinforcement

(Space for Fig. 24)

Essential Oil

(Space for Fig. 25)

.
.
.
.
.

Vetiver Crusher

(Space for Fig. 26)

Cloth Sheets and Clothes

(Space for Fig. 27)

.
.
.
.
.
.
.

Furniture and Decoration

(Space for Fig. 28-29)

Conclusions

So far, the vetiver research programs of LDD have achieved the following:

- Classification of 78 ecotypes from various locations throughout the country; 28 ecotypes have been accepted as promising ecotypes for further application in sandy, loamy clay and skeletal soils.
- Various propagation techniques have been tested, for example tissue culture, tiller propagation in polythene bags and tiller propagation on strips. At present, there are approximately 99 500 000 seedlings belonging to LDD which are available to the public for planting in Thailand.
- Effective planting techniques such as planting time, spacing and other relevant methods have been developed and are undergoing further investigation.
- Research programs are focusing on applications of vetiver for soil and water conservation on arable land, waste land and sloping land; various problem soils such as acid, saline, shallow and peat soils; on the banks of farm ponds, rivers, roads, waterways and man-made dikes. Downstream industry, based on vetiver, is also a component of the programs.
- Currently, LDD has an extensive knowledge base on vetiver ecotypes, effective propagation techniques and how to use vetiver to investigate efficiently deterioration and rehabilitation of soil and land resources. Vetiver grass is also easy to obtain.
- In the near future, vetiver application should not be limited to arable land. Owing to the aforementioned knowledge base, it can be used for environmental rehabilitation and development programs. The other promising area of use is the downstream industry. After preliminary testing, cottage industries are likely to expand.

References

Inthaphun, P. et al. 1999. Study on the Effects of Vetiver for Control of Soil Erosion on Sloping Land. Department of Land Development, Bangkok (in Thai).

LDD. 1998a. Progressive Report on the Study of Growing Vetiver on Problem Soils in Thailand. Land Development Department, Bangkok (in Thai).

LDD. 1998b. Vetiver Grass Overview. Land Development Department, Bangkok (in Thai).

National Research Council. 1993. Vetiver Grass: A Thin Green Line against Erosion. National Academy Press. Washington, DC.

ORDPB. 1995. Vetiver Grass for Environment Protection and Other Uses: Thailand's Experiences. ORDPB, Bangkok.

ORDPB. 1998. Report on the evaluation of the development and promotion on the use of vetiver grass. ORDPB, Bangkok. (in Thai).

Sunanthapongsak, W. et al. 1999. Study of the Effects of Vetiver on the Biodiversity of the Soil Microorganism in Some Problem Soils of Thailand. Land Development Department, Bangkok (in Thai).

Suwannakert. V. et al. 1994. Study on Vegetative Management of Vetiver. Land Development Department, Bangkok (in Thai).