IMPROVING THE EFFICIENCY OF THE VETIVER SYSTEM IN THE HIGHWAY SLOPE STABILIZATION FOR SUSTAINABILITY AND SAVING OF MAINTENANCE COST.

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Abstract

Department of Highways planted vetiver along Highway Route No.3272 in Kanchanaburi province, at 7 sites, with 21 experimental plots. The objectives of this experiment were : i) to study the methods and cost of maintenance after planting vetiver, ii) to study the efficiency of *Arachis pintoi* ('Pintoi') -fodder legume- in combination with vetiver to control weeds and provide nitrogenous fertilizer to vetiver, and iii) to study the spacing of *Arachis* 'Pinto' for maximum benefit to vetiver.

The result of the experimental have shown that : a) the success of application VS depends largely on suitable period for planting, at least 2 months in the period of rainy season is needed for growing, b) there is a need to fertilize the soil with basal application of chicken manure with some chemical fertilizers, c) Poly-bagged vetiver slips at the age of 45-60 days should be employed with proper maintenance after planting during the first year, d) Vetiver slips can develops a completely dense hedgerow within 3-4 months.

In the case of interplanting with *Arachis* 'Pinto' ; this could cover 30-40 % land area within 3-4 months, and 80-90 % within one year. Suitable for planting with vetiver, could significantly reduce the cost of weeding and increase soil fertility for the vetiver plants, will lead to sustainability of the vetiver system. The optimum spacing of 'Pintoi' was 25x25 cm.

The results of this study will be modified the Standard Drawing "Vetiver grass planting for highways slope protection" and will be beneficial for bioengineering applications in Thailand.

Keywords : Vetiver system , *Arachis* 'Pinto', Bioengineering

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1 INTRODUCTION

Vetiver grass technology for erosion control and stabilization of highway slopes is a specific technique and has a degree of difficulty in establishing on highway slopes, because of low nutrient of planting soil and steeper slopes compare with farmlands. Moreover, in some area the local weeds growth have been vigorous and replace the vetiver after 1 – 2 years of planting, which would then lead to the unsustainability of vetiver system. In order to achieve maximum benefit and sustainability of the vetiver system, this study for improving the efficiency of vetiver system is considered to be essential.

The study area is located on Highway Route No. 3272 : Ban Rai – Ban I Thong, Thong Pha Phum district, Kanchanaburi province, where approximately 686,000 vetiver slips were planted on 48 highway slopes along STA.5 + 350 – STA.27 + 025 in the year 2004 – 2005 (Fig. 1).

The study has conducted from 2004 to 2006 in order to reaffirm and verify of Vetiver Grass Technology for erosion control and stabilization of highways slopes. The objectives of this study are as follows :

1) To study the methods and cost of maintenance after planting.

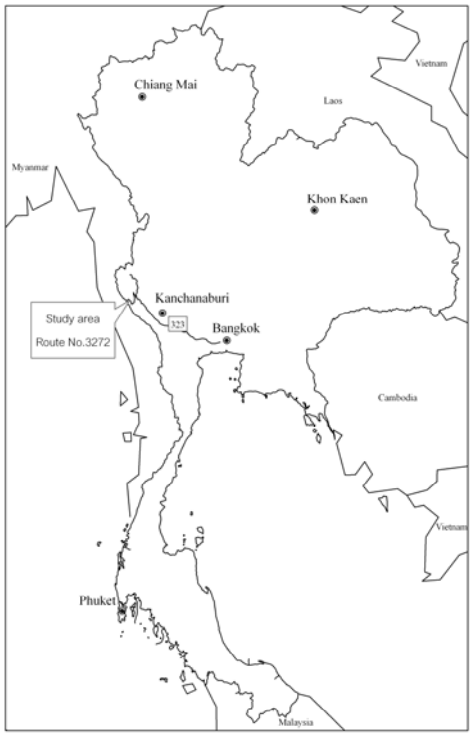


Fig.1 Location of study area.

2) To study the efficiency of *Arachis* Pintoi ('Pintoi') – folder-legume in combination with vetiver to control weeds and provide nitrogenous fertilization to vetiver.

3) To study the spacing of Arachis 'Pinto' for maximum benefit of vetiver.

The results of the study will be used as a tool for setting up and enhanced unit rates, maintenance technique, planting patterns and standard drawing of vetiver grass planting. These will be beneficial for the applications of vetiver system for erosion control and stabilization of highway slopes in Thailand.

2 BACKGROUND OF THE VETIVER GRASSING PROMOTION AND DEVELOPMENT PROJECT OF THE HIGHWAYS DEPARTMENT.

After his Majesty the King of Thailand's initiative, since 1993, each year over 4.5 millions slips has been planted for erosion control and stabilization in highway construction and maintenance projects. In 1999, training to highway officials involved in vetiver implementation were provided to ensure satisfactory performance. Vetiver system has been proven and accepted to be an effective measure for erosion control and prevent shallow failure of highway slopes (Sanguankaeo et al., 2000, 2003). The Department of Highways has prepared Standard Drawing, unit rates and code items of vetiver grass planting, for directions, helping the maintenance and construction units to utilize the vetiver grassing correctly and perfectly through out the country. Sanguankaeo et al. (2003) classified the benefits of application from five formations and the pattern of the vetiver grassing on highway slope into two categories according to the seriousness and tendency of erosion.

3 SITUATION AND PROBLEMS IN THE VETIVER GRASS PROJECT

3.1 Unsustainability of Vetiver System.

Replacement of the vetiver by vigorous local weeds and planting vetiver in late of rainy season will lead to the unsustainability of vetiver system (Fig. 2). Survival rate of

vetiver grassing for erosion control and stabilization of highway slopes in the years 2001 to 2005 are illustrated in Fig. 3. Almost 30 - 40 % of the vetiver grassing on erosional control sites did not survive after planting for 2 years. The success of planting (rate of survivals > 70 %) in grassing sites were planted during optimum period (April – July). To overcome this problems, maintenance of weeds and fertilization are needed for 1 – 2 years after planting. As a result, these maintenance costs would be decreased.

Fig.2 Ungrowth vetiver grass covered by local weeds and will replace vetiver grass in the end.

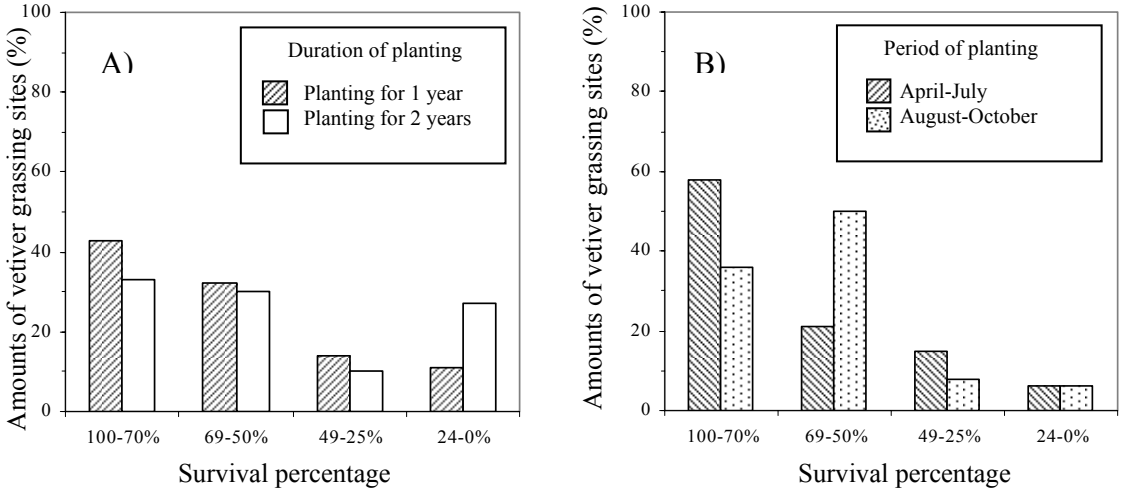


Fig.3 Survival rate of vertiver grassing on highway slopes
A) Base on duration of planting
B) Base on period of planting

3.2 Obsolete Standard Drawing.

The Department of Highways has prepared a Standard Drawing [SP – 206, 1999] "Vetiver grass planting for highways slope protection" and unit rates. Standard Drawings describes the quality of slips, planting procedures and maintenance techniques, planting patterns for various types of situation. These Standard Drawing and unit rates are not conform with modern VGT, that need to be enhanced and verified.

4 MATERIALS AND METHODS.

4.1 Study Site Description The Highways Route No. 3272 destination to Thailand – Myanmar, Ban I Tong, Thong Pha Phum district, 220 km. Northeast of Kanchanaburi province, in the Eastern region of Thailand.

4.1.1 Climate and topography. The climate of the area is tropical humid and average annual rainfall is 1,200 mm. The area is located at the TANAOSRI mountain range with 250 to 950 meters elevation above MSL.

4.1.2 Geology and soil classification. The area is underlain chiefly by phyllitic shale, sandstone and siltstone of Carboniferous - Devonian Period (DMR, 1985). According to Unified Soil Classification (VDT, 2003), the soil are classified as ML group, clayey silt with low plastic soils (Table1).

Table 1 Physical properties of soils

Location	Grading characteristics			Atterberg Limits			Group Symbol (USCS)
	Gravel (%)	Sand (%)	Silt and clay (%)	LL (%)	PL (%)	PI (%)	
Km.15+325	35	15	50	29.9	21.2	8.7	CL
Km.20+200	27	11	62	38.8	29.2	9.6	ML
Km.20+800	17	7	76	44.8	32.4	12.4	ML
Km.24+800	22	12	66	39.7	32.8	6.9	ML

Note : ML = Clayey silt with low plastic soils

4.1.3 Existing eroded and collapsed highway slopes. In rainy season of 2004, fourty-eight highway slopes (Route No. 3272) were damaged cause by erosion and shallow mass movement of soils in cut slopes (21 sites), fill slopes (20 sites) and highway curve sections (7 sites) Fig.4 – 5. All of these damaged slopes were planted and stabilized with vetiver. Seven experimental sites were conducted on these damaged slopes in late July – August 2004. The rest were planted in June-July 2005.

Fig.4 Erosion and shallow seated failure on highway cut slope

Fig.5 Shallow seated failure on highway embankment slope

4.2 Experimental Plots

There were seven experimental sites of total area 40,000 square metres, four sites of them were vetiver planting in combination with *Arachis* 'Pinto'. Each site was further divided into 3 rectangular experimental plots for planting with different treatments. There were three treatments with three replicates each (Table 2).

Arachis 'Pinto' was planted between the vetiver rows for coverage land area, in order to block or control weeds. The spacing of ' Pinto' were 25 cm. x 25 cm. (P1) and 15 cm x 15 cm. (P2).

Table 2 Experimental design.

	Treatments
S1	Soil fertility improvement + Maintenance for 2 years (Leaf trimming, Weeding, Fertilizing)
S2	Soil fertility improvement
S3	Control

Note: Soil fertility improvement = chicken manure 600 g. + NPK fertilizer (15 – 15- 15) 60 g. (per linear metre) at the bottom of planting holes

4.3 Planting Techniques.

- The pattern of planting : spacing between rows 1 metre and 10 cm. between the clumps
- Active tiller: Polybagged raised 45 -60 days vetiver nursery (vetiveria zizanioides)
- Period for planting : June – July
- Soil fertility improvement (S1 and S2)

4.4 Observation and Analysis

The observation and data collection during 2004 – 2006 are based on fourty-eight experimental sites. The data were analyzed using a SPSS statistical package by one way analysis of variance (ANOVA) to compare the means of different treatments, where significant F values were obtained.

4.4.1 Situation of plant growth. The items under observation included : plant height, number of tillers, biomass of shoots, effect of slope inclinations. The data were analyzed and compared.

4.4.2 Change the cover of *Arachis* 'Pinto'. Estimated percentage of coverage land area of 'Pinto' were investigated monthly. A 4 $m.^2$ quadrate (2 m. x 2 m.) was randomly placed on each plots for estimating.

4.4.3 Effect of slope inclination to the growth situation. Investigation and measurement of slope inclinations in which vetiver were planted. Observation of growth situation and survival of vetiver were conducted on various slope inclinations.

5 RESULTS AND DISCUSSION.

5.1 Plant Height and Percentage of Death After Planting.

The comparison of plant height and percentage of death with different treatments are illustrated in Fig.6-7. The height measurement and percentage of death were significantly different from each treatments. S1 exhibited the highest average height for every period, S2 and S3 were almost the same height at 60 days after planting. Percentage of dead slip after 45 days which the least value were recording in treatment S1 which S3 shown the highest rate of dead slip (25-33 %). This indicated that the soil fertility improvement at the bottom of planting holes and maintenance of weeds are strongly effect to plant growth and the number of dead slips. The vetiver in treatment S3 are being

takeover by native species. Therefore soil improvement is needed to be done and weeds must be wiped out.

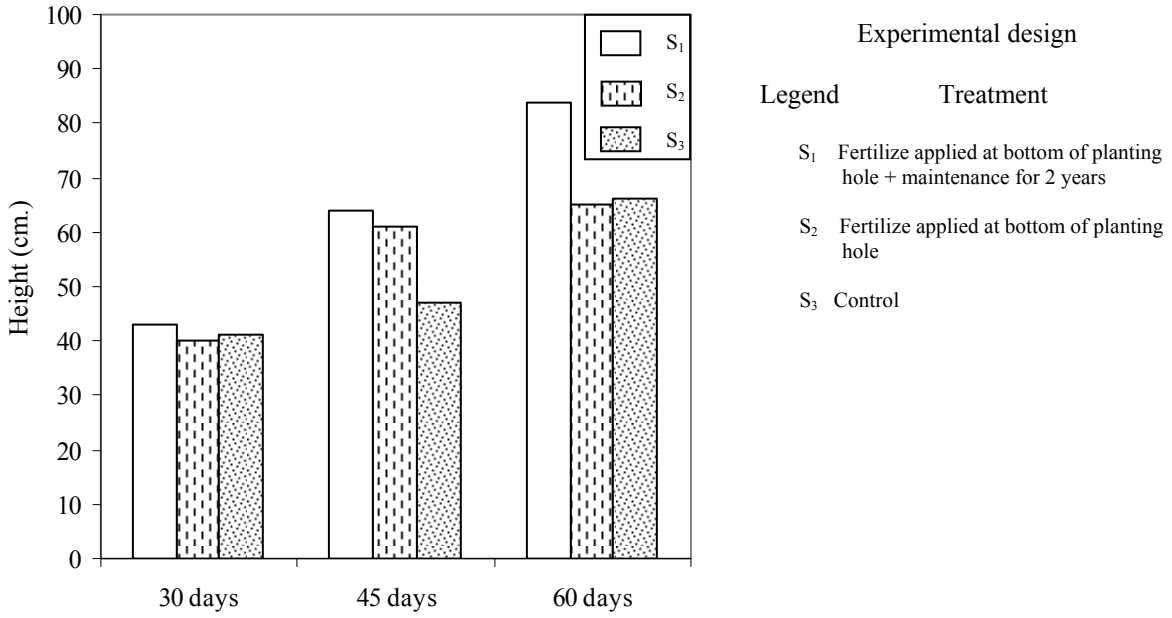
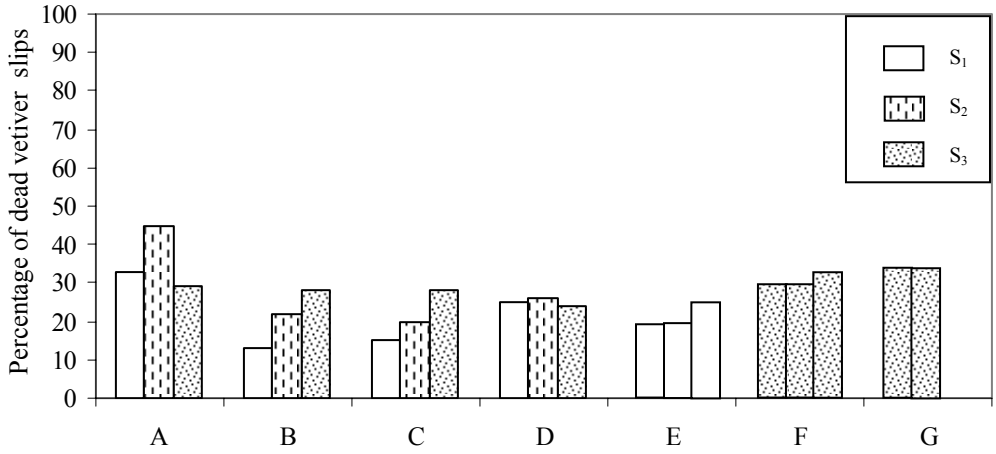


Fig.6 The comparison of height of vetiver growing on different treatments

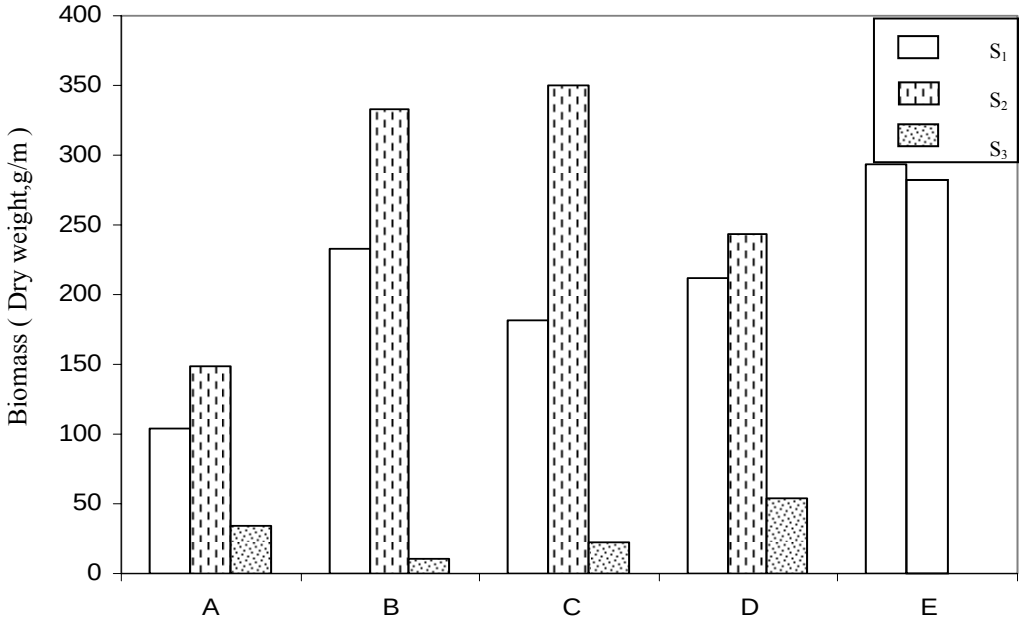


Remark : A = Experimental plots STA.8+250R, B = STA.9+800R, C = STA.10+095R,
D = STA.12+700R, E = STA.15+325L, F = STA.15+725L, G = STA.25+765L,

Fig.7 Percentage of dead vetiver slips after planting for 45-days from experimental plots with
various treatments

5.2 Biomass of Vetiver Grass

The dry weight of vetiver growing in each treatments after 17 and 6 months of planting has shown in Fig.8 and Table 3 respectively. The total biomass of treatment S3 always has the least values and presented quite big differences when compared with the two other treatments. This indicates that the soil fertility improvement and maintenance are strongly effect to growth situation and survival of vetiver in the longterm condition.



Remark : A = Experimental plots STA.8+250R, B = STA.9+800R, C = STA.10+095 R
D = STA.12+700R, E = STA.15+325L.

Fig.8 Biomass of vetiver grass growing on experimental plots with different treatments.

Table 3 Biomass of vetiver grass growing on erosional control sites (Treatment S1)

STA.	Biomass (Dry weight)	
	g./m.	%
STA.21+425 L	272	95.65
STA.22+025 R	251	92.28
STA.22+500 R	250	89.43
STA.26+550 L	273	94.81
STA.26+900 L	251	92.12
STA.27+025 L	275	93.83

5.3 Covering of *Arachis* 'Pinto'

Change of covered *Arachis* 'Pinto' on experimental plots and erosional- control sites are illustrated in Fig.9 –13. The results presented here showed that for 25 cm. x 25 cm. spacing of 'Pinto' the covering were 30 – 40 %, 40-60%, 50-70%, and 80-90% in land area with in 3,5,7, and 12 months, respectively. The covering 30-40% land area is considered to be effective for blocking or controlling weeds, that clearly proved by this experiment. In order to reach the goal, in case of controlling weeds by interplanting with 'Pinto', these vetiver system must be operated in the beginning of rainy season no later than July.

5.4 Covered Rate of Weeds

The observation of coverage land area of weeds growing on treatment S3 experimental plots are illustrated in Fig.14, The coverage of weeds 40-80% in land area with in 5 months and eventually reached 100% in 1 year. Almost of the vetiver on experimental plots did not survived and were replaced by native species. This evidences

are conform with least values of biomass in treatment S3 indicated that the maintenance of weeds is necessary.

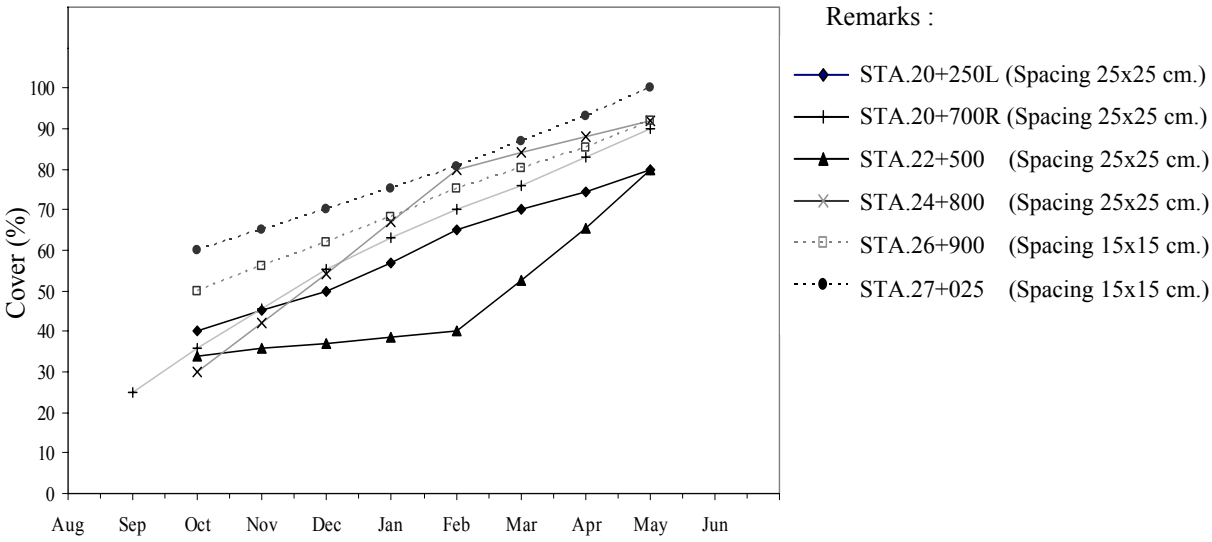


Fig.9 The increments of covered *Arachis* ‘ Pinto’ growing on erosional control sites.

Fig. 10 The approximate coverage of ‘Pinto’ 30-40% land area within 3 months

Fig.11 The approximate coverage of ‘Pinto’ 40-60% land area within 5 months

Fig. 12 The approximate coverage of ‘Pinto’ 50-70% land area within 7 months

Fig. 13 The approximate coverage of ‘Pinto’ 80-90% land area within 12 months

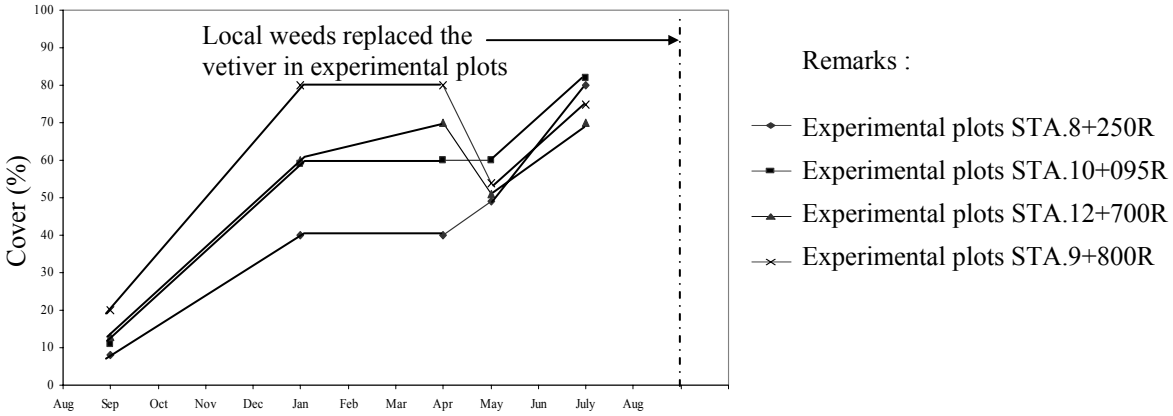


Fig.14 The increments of covered weeds growing on experimental plots with treatment S3

5.5 Effect of Slope Inclination to the Growth Situation.

Growth situation of the vetiver on various inclination of slopes were investigated. A lot of observation have indicated that the vetiver grow well on slopes which inclination less than 1: 1.75 (H:V) or 60 degree and did not survived on inclination steeper than 1:2.75 (H:V) or 70 degree (Fig.15).

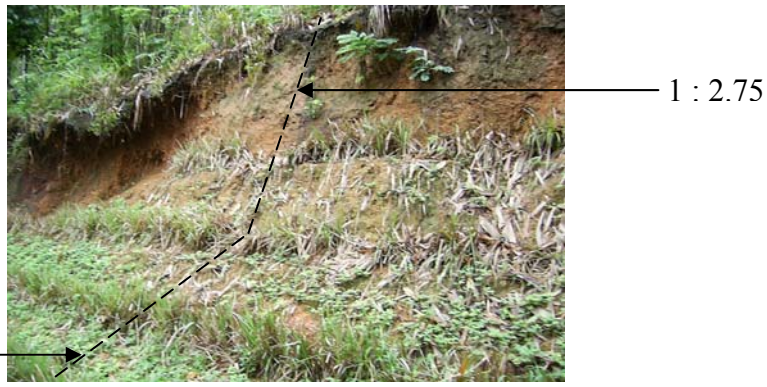


Fig.15 Difference growth situation of the vetiver planted in steeply (>70^0 , 1:2.75) and gently (<45^0, 1:1) inclined slope portions.

5.6 Efficiency of Erosion Control and Stabilization of Highway Slopes

The application of vetiver system in eroding and collapsed highway slopes has been proven to be an effective measures for erosion control and stabilization against shallow seated failure. Since 2006, after these damaged highway slopes has stabilized with the vetiver. There were not any progressive soil mass movement take places on these slopes (Fig.16-17).

Fig.16 Shallow seated failure of embankment slope at STA.15+325-STA.15+510L before stabilized by vetiver.

Fig.17 Repair of the collapse embankment slope in Fig.16 and stabilized with vetiver.

6 UNIT RATES OF VETIVER GRASS PLANTING FOR HIGHWAY SLOPE PROTECTION

- The unit rates given in this paper are expressed in Baht.(Thai) and for Highways projects in mountainous area has shown in Plate 1.

Project name…….

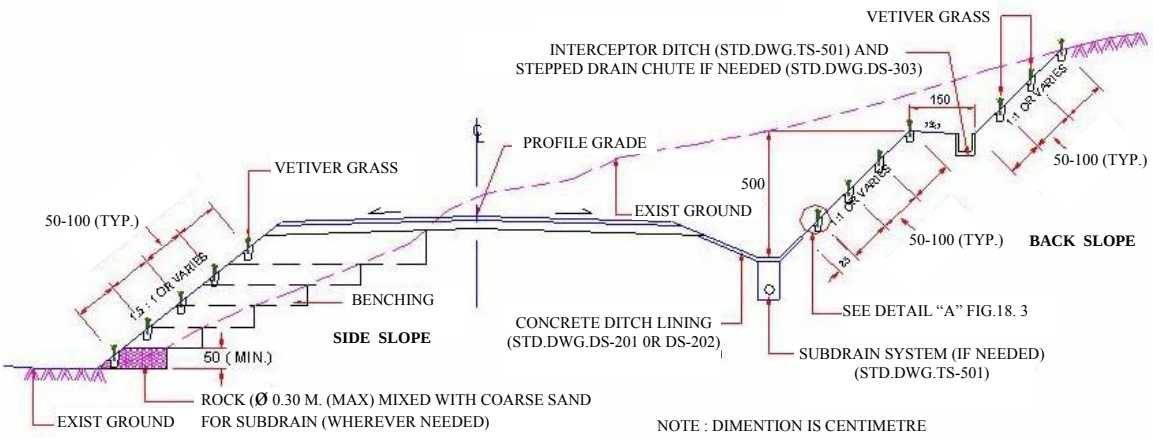
Amount of tillers…… Tillers
Labour cost 212.00 Baht/day
Diesel oil 26.00 Baht/lite
All rates are on the basis of 12 Tillers/m^2

A) Ground Preparation		
Cleared and Benching (Minibench)	0.18	Baht/tiller
B) Materials Cost		
1] Materials for multiplication in plastic bags (2x6 in.)		
1.1 Cost of vetiver tiller (In case of bare root slip)	0.25	Baht/tiller
1.2 Soil and planting materials	0.23	Baht/tiller
1.3 Accelerating hormones	0.15	Baht/tiller
1.4 Plastic bag 2x6 in.	0.10	Baht/tiller
2] Cost of vetiver tiller (In case of tiller in plastic bag 2x6 in.)	1.50	Baht/tiller
3] Materials for basal application in bottom of planting hole		
3.1 Chicken manure (0.6 Kg./linear metre) or Farmyard manure (2.0 Kg./linear metre)	0.20	Baht/tiller
3.2 15-15-15 Fertilizer (60 g./linear metre)	0.05	Baht/tiller
4] Materials for maintenance ≈ 30-40 days after planting		
4.1 Urea fertilizer (30 g./linear metre)	0.12	Baht/tiller
C) Labour Cost		
1] Labour cost of nursery for 60 days		
1.1 Planting in plastic bag (325 bags/1 worker/day)	0.65	Baht/tiller
1.2 Watering (50,000 tillers/1worker/day)	0.25	Baht/tiller
2] Labour cost for planting at the target area		
2.1 Hole digging and basal application of manure (350 tillers/1 worker/day)	0.60	Baht/tiller
D] Transportation cost in mountainous area.		
1] In case of bare root slips		
1.1 Light truck or pick-up : 250-300 km.(20,000 slips/trip)	0.30	Baht/slip
1.2 Medium truck: 250-300 km.(400,000 slips/trip)	0.025	Baht/slip
2] In case of tiller in plastic bag 2x6 in.		
2.1 Medium truck: 250-300 km.(25,000 tillers/trip)	0.40	Baht/tiller
3] Transportation cost of tiller (in plastic bag) from vetiver nursery to target area		
3.1 Light truck (4,000 tillers/trip)		
- Distance 30 km.	0.125	Baht/tiller
- Distance 60 km.	0.25	Baht/tiller
3.2 Medium truck (25,000 tillers/trip)		
- Distance 30 km.	0.025	Baht/tiller
- Distance 60 km.	0.05	Baht/tiller
E) Maintenance cost for 1 year after planting		
1] Weeding (2 times)	0.10	Baht/tiller
2] Leaf trimming (2 times)	0.20	Baht/tiller
3] Fertilization (2 times)	0.20	Baht/tiller
F) Miscellaneous		
1] Fuel (For ≤ 100,000 tillers)	0.10	Baht/tiller
2] Other expenses (For ≤ 100,000 tillers)	0.15	Baht/tiller
G) In the case of interplanting with *Arachis* 'Pinto'		
1] Cost of 'Pinto' sprout(in plastic bag 2X6 in.)	0.75-1.00	Baht/sprout
2] Labour cost for planting (650 sprout/1 worker/day)	0.35	Baht/sprout

Plate 1 Unit rates of vetiver grass planting

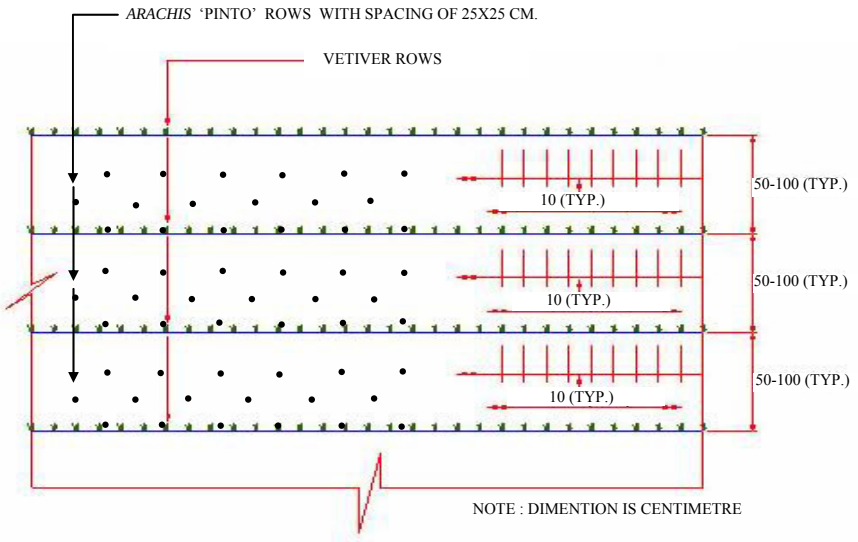
7 MODIFICATION OF STANDARD DRAWING.

Fig.18 Standard Drawing "Vetiver grass planting for highways slope protection" (2006)



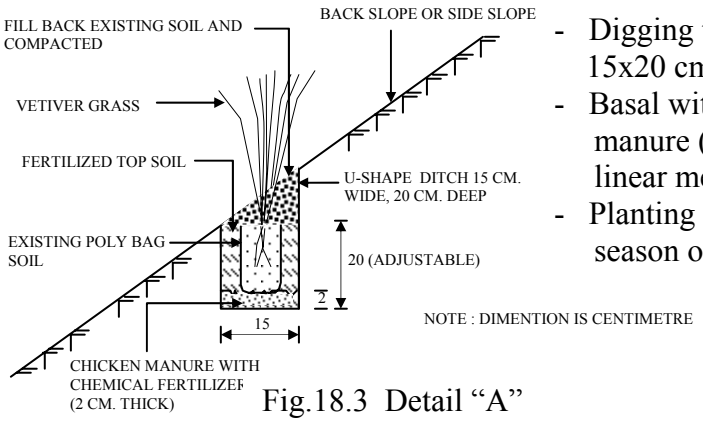
- Spacing of vetiver grass rows varies from 50-100 cm. and in clump 10 cm. which depend on severe erosion problems on soils.
- Drainage system i.e. interceptor ditch, drain chute, subdrains are also necessary.

Fig.18.1 Cross-section : Vetiver grassing on back slope and side slope



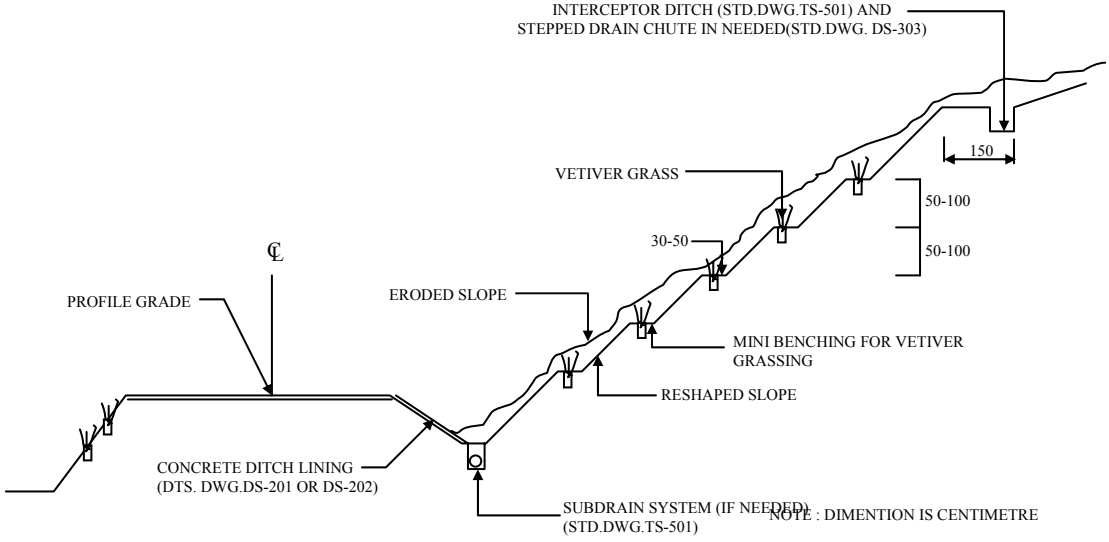
- For not serious cases, planting in rows is 1.00 m. apart and in clump 10 cm spacing.
- For serious cases, planting in rows is 50 cm. apart and in clump 10 cm spacing.
- For minimal maintenance of weeds and fertilization, *Arachis* 'Pinto' is planted between the rows of vetiver.

Fig. 18.2 Plan : Vetiver grassing on back slope and side slope



- Digging the existing soil U-shape ditch 15x20 cm.
- Basal with chicken manure (600 g.) /farmyard manure (2 kg.) + fertilizer 15-15-15(60 g.) per linear meter.
- Planting time should be the beginning of rainy season or in rainy season.

Fig.18.3 Detail "A"



- Reshape the eroded back slope
- Make mini benching 30-50 cm. wide, 50-100 cm. height
- Plant the vetiver grass on the bench
- Together with drainage systems

Fig. 18.4 Cross-section : Vetiver grassing on existing eroded back slope

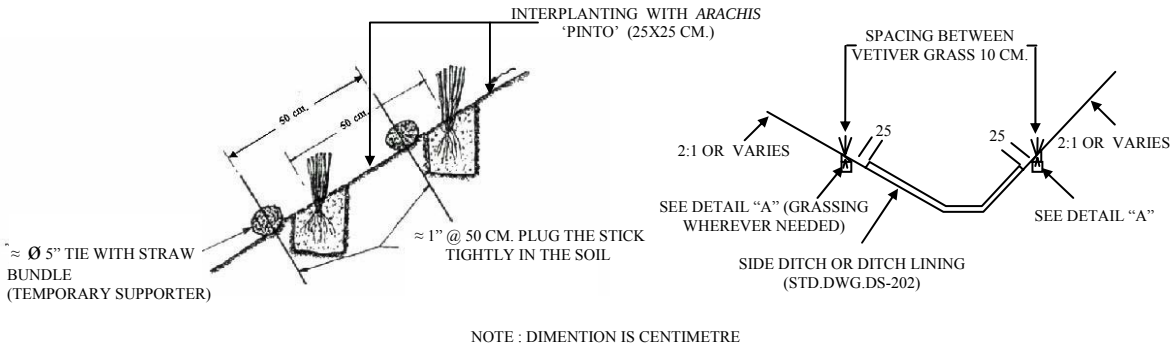


Fig. 18.5 Vetiver grassing on high erosible area and side ditch.

CONSTRUCTION DETAILS

1. THE PLANTING MATERIALS : VETIVER (VETIVERIA ZIZAIOIDES NASH) SHOULD BE LOCAL KINDS OR OTHER APPROPRIATE ONES AS APPROVED BY THE DIVISION WHO INCHARGES THE CONSTRUCTION PROJECT, DEPARTMENT OF HIGHWAYS. THE SHOOTS SHOULD BE NURSERY VETIVER IN A POLY BAG WHICH HAS DIAMETER OF 2 INCHES AND THE LENGTH OF 5-6 INCHES (SIDE – FOLDED). EACH BAG WHICH CONTAINS SOIL AND FERTILIZER IS TO SEVER 1-2 VETIVER SHOOTS. RESTED THE SHOOTS WIIL BE IN BAGS FOR 45-60 DAYS BEING TAKEN TO THE PREPARED SOIL.
2. HOLE DIGGING AND GROUND PREPARATION : AFTER THE WORKS FOR BACK SLOPE, SIDE SLOPE, ARE FINISHED ACCORDING TO THE CONSTRUCTION PLAN, GROUND PREPARATION FOR VETIVER PLANTING SHOULD BE STARTED BY DIGGING A U-SHAPE DITCH WHICH IS 15 CM. WIDE AND 15 – 20 CM. DEEP.
3. SOIL FERTILITY IMPROVEMENT CHICKEN MANURE (600 G.) OR FARMYARD MANURE (2 KG.) MIX WITH FERTILIZER 15-15-15 (60 G.) PER LINEAR METRE OF PLANTING APPLIED AT THE BOTTOM OF PLANTING HOLES.
4. PLANTING : THE SPACING BETWEEN ROWS IS AS SHOWN IN THE PLAN. THE DISTANCE BETWEEN SHOOTS IS 10 CM. TRIM AND LEAVE THE LEAVES OF THE SHOOTS FOR 20 CM. BEFORE PLANTING, CUT OFF THE BOTTOM PART OF THE BAG AND LET 10 CM. OF THE ROOT BE SHOWN. TAKE OFF THE BAG AND PUT THE VETIVER SHOOT ON THE TOP OF IMPROVED SOIL IN ITEM 3. FILL THE HOLE WITH THE PREPARED SOIL AS SHOWN ON FIGURE 18.3 AND COMPACT TO MEET EXISTING SLOPE.
5. PERIOD FOR PLANTING : THE SUITABLE PERIOD SHALL BE ON MID APRIL – JULY, EXCLUDING IN EASTERN COAST REGION SHALL BE ON OCTOBER-FEBRUARY.
6. PLANT CARING : THE RATE OF SURVIVAL OF VETIVER GRASS SHOULD BE NOT LESS THAN 95 % AFTER 2 MONTHS OF PLANTING IF LESS, THE CONTRACTOR HAS TO REDO THE PLANTING WITHIN 15 DAYS. THE NEW PLANTING WILL BE RECHECKED ANOTHER 2 MONTHS.
7. THE SHOOTS : OTHER THAN THE LOCAL SHOOTS, THE CONTRACTOR MAY USE ANY SHOOTS REPRODUCED THROUGH VARIOUS WAYS, SUCH AS BY TISSUE CULTURE BUT THE QUALITY OF THE SHOOTS NEED TO BE APPROVED BY THE DIVISION WHO INCHARGES THE CONSTRUCTION PROJECT, DEPARTMENR OF HIGHWAYS
8. LEAF TRIMMING, WEEDING AND FERTILIZING : AFTER 30 DAYS OF PLANTING , POUR HALF A TEA-SPOON OF AMMONIAM SULPHATE FERTILIZER (21 : 0 : 0) OR ONE-FOURTH OF TEA-SPOON OF UREA FERTILIZER (40 : 0 : 0) OVER EACH HOLE AND OVER EACH SPACE BETWEEN HOLES. THE VETIVER GRASS WILL BE TRIMMING, WEEDING AND FERTILIZING ON MAY AND SEPTEMBER BUT ON NOVEMBER AND MARCH IN THE EASTERN COAST REGION. THE TRIMMING SHOULD LEAVE THE HIGH OF THE PLANT FOR 20 – 30 CM.FOR FERTILIZING NPK FERTILIZER (15-15-15) SHOULD BE PUT ON THE GROUND IN THE PROPORTION 20 GRAMS PER METER OF VETIVER GRASS ROW.
9. MINIMAL MAINTENANCE IN THE CASE OF PLANTING THE VETIVER IN COMBINATION WITH *ARACHIS* 'PINTO' IN THE SUITABLE PERIOD OF PLANTING AS MENTION IN ITEM 5, LEAF TRIMMING IN ITEM 8 CAN ONLY BE DONE, THE WEEDING AND FERTILIZING ARE NOT NECESSARY.
10. VETIVER GRASSING ON DEEP CUT AND HIGH FILL SLOPE : IN CASE OF PLANTING THE VETIVER GRASS ON DEEP CUT SLOPE OR HIGH FILL SLOPE OF THE HIGHWAYS SHOULD BE NEEDED MORE CARE , CLOSED SPACING BETWEEN CLUMPS AND ROWS SHOULD BE APPLIED, AND THE COMBINATION WITH SURFACE DRAINAGE STRUCTURAL WORKS FOR EXAMPLE INTERCEPTOR DITCH , DRAIN CHUTE ARE ALSO NECESSARY AS DIRECTED BY THE ENGINEER OR AS PARTICULAR DESIGNED FOR THE INDIVIDUAL SITE.
11. DIMENSION ARE IN CENTIMETERS UNLESS OTHERWISE INDICATED.

DESIGN BY **Surapol Sanguankaeo**
Ekawit Veerapunth
Lalit Sawasdimongkol
JUNE, 2006
DEPARTMENT OF HIGHWAYS, THAILAND

Fig. 18.6 Construction details.

8 CONCLUSIONS

8.1 Efficiency of *Arachis* 'Pinto' to Control Weeds.

Arachis 'Pinto' has efficiency to control weeds. The covering were 30-40 %, 40-60 %, 50-70 % and 80-90 % in land area within 3,5,7 and 12 months respectively. *Arachis* 'Pinto' planting with vetiver could significantly reduce the cost of weeding and increase soil fertility for vetiver plants. This planting technique will lead to sustainability of Vetiver System. Vetiver System is multitechnology, a mixed planting technique combining vetiver with others suitable plants should be studied and applied for improving efficiency of Vetiver System in the long run.

8.2 Optimum Spacing of 'Pinto' was 25 cm. x 25 cm.

8.3 Optimum Planting Techniques.

- Poly-bagged active vetiver slips at the age of 45-60days should be applied.
- The suitable period for planting vetiver should be at the beginning of rainy season (mid April – July) at least 2 months for growing in rainy season.
- It is obligatory to fertilize the soil at the bottom of planting holes with chicken manure or farmyard manure mix with chemical fertilizers.
- Maintenance of weeds and fertilization are necessary at least 1 year after planting.
- In the case of planting the vetiver in combination with *Arachis* 'Pinto' in mid April – July, maintenance of weeds and fertilization are not necessary or could be reduced to 1 time of weeding.
- Vetiver slips can develops a completely dense hedgerow within 3-4 months.
- Vetiver grow well on slopes which inclination is less than 1 : 1.75 (H : V) and did not survived on inclination steeper than 1 : 2.75 (H : V)

8.4 Transfer of Technology. In 2006, This Vetiver System technologies have been transferred to highway officials involved in vetiver implementation in the Northern part of Thailand.

8.5 Vetiver System has been proven to be an effective measures for erosion control and stabilization against shallow seated failure.

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A Brief Introduction to the First Author.

Mr.Surapol Sanguankaeo, an engineering geologist, is Director of Engineering Geology Branch of the Department of Highways, Thailand. His past experiences included a variety phase of problems in erosion control and stability analysis of highway slopes in mountainous area. He has published 21 technical papers in the fields of slope stability analysis and construction materials. He creatively initiated the application of VS in erosion control and stabilization for highway slopes in Thailand.

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