SPECIAL ISSUE

VETIVER NEWSLETTER

NEWSLETTER OF THE VETIVER INFORMATION NETWORK, ASTAG *, WORLD BANK, NUMBER 6, JUNE 1991

Table Of Contents

This Newsletter issue presents the works selected to receive the Vetiver Incentive Awards. The Awards are in recognition both of the author's personal initiative and of the significant contribution they have made to the wider use and better management of contour vegetative barriers of vetiver grass.

THE NEWSLETTER

Vetiver Awards

This is the sixth Newsletter to be put out by the Vetiver Information Network. The focus of this Newsletter is on presenting some of the information that the Network has received as a result of the Vetiver Research Incentive Awards. In this issue we have tried to faithfully present the major work that was sent in by a number of individuals; unfortunately, given the length of some of the pieces some heavy editing was necessary. As a result many of the tables, figures and photographs that came in the reports have not been reproduced here. The Vetiver Information Network can, however, supply photocopies of the complete reports.

Reader Participation

Over the last 3 years the Network has received a constant stream of requests for information about vetiver grass; during the last year the Network has been receiving a slow but steady flow of information from people in the field. But we still are missing feedback from the hundreds of people who have indicated that they wish to locate vetiver and give it a try. We hope that some of you are now carrying out some work with vetiver, please keep us informed — your experience in testing and promoting vetiver can save others both time and false starts. And this is true not just for vetiver, but for the larger question of introduction and extension of resource conservation systems. We now know that, as much as anything else, “sustainable agriculture” is an information revolution and overcoming many of the critical constraints to the realization of a sustainable, productive agriculture will depend on those who are working in the field to disseminate their knowledge. We have all heard the years of complaints regarding insufficient networking and access to information in any field or endeavor in natural resource management/ conservation — well, here is a chance to do something about it, write ! And when you do, let us know what other types of information would be useful to you in the Newsletter.

Vetiver In Thailand and China/ Other Species With Potential - A Letter From Dick Grimshaw

On a recent visit to East Asia I had the opportunity to visit Thailand and China. There is a growing interest in Thailand in the use of Vetiver hedges. Vetiver

Photo 1. "There is much more soil erosion in the control estate plot." One of Dr. P.K. Yoon's vetiver trials in Malaysia.

* ASIA TECHNICAL DEPARTMENT AGRICULTURE DIVISION

Achnatherum splendens...like Vetiver ... it grows vigorously ...is not considered invasive...is strongly rooted...local people recognize its soil binding properties

(known in Thai as *Yaa Faeghom* or *Yaa Khom Faeg*) has been found in its "wild" state in water-logged areas in Eastern Thailand. Mr. Pitsanu Attaviroj of the Land Development Department is demonstrating its use. Also the Thai-German Land Development Project near Maehong Soen in North-East Thailand is test planting it. We also found it being used for medicinal purposes by Karen tribes people near Mae Sa-reaing (the Karen call Vetiver *Posiakhi*). Taking account of what we know about Vetiver and in particular Dr. P.K. Yoon's work on Vetiver in Malaysia I am in no doubt that Vetiver will do extremely well in all South-East Asian countries.

In China I visited two year old plantings in Chongren County of Jiangxi Province. The grass has grown very well and is making excellent hedges. It is also producing a large amount of biomass which is being used to mulch citrus and other fruit trees. I would guess that Vetiver, with its very deep rooting system, when used as a mulch on these heavily leached red soils, is doing an excellent job in recycling leached nutrients. Farmers are convinced of its utility, and expansion appears to be limited to the supply of seedlings. I was pleased to see on a yet to be developed 150 ha catchment area that Jiangxi officials have planted Vetiver on the contour in preparation for the following years' land clearing. Thus, this next year when the land is opened up for cropping the Vetiver hedges will be in place to protect the newly exposed soils.

I also spent some time in the Loess Plateau Region of China and visited one area where erosion losses were reputed to be the highest in the world - 60,000 tonnes/km^2 ! The winters are too cold for Vetiver in this region. However we found another grass that has great possibilities. Its name is *Achnatherum splendens* (Jiji grass). The grass has very similar features to *Vetiveria zizanioides* except that it is confined to areas of high ph (7.5+). It is a clump grass, looks very much like Vetiver, grows to two meters high, and is found naturally in saline swampy areas where it spreads through seeds. Like Vetiver, when taken out of this environment it grows more vigorously and will only grow from vegetative slips. It is not considered invasive. It is very strongly rooted and the local people recognize it for its soil binding properties. Livestock will only eat the young leaves, and like Vetiver is not destroyed by sheep and goats. The grass will not grow in acid conditions. We do not know how it behaves when planted closely to form a hedge, and it will be test planted as a hedge in this season. Assuming it grows into a good hedge (i.e., the clumps join together) we will have an excellent grass for these regions of Asia with very cold winters. Other biological barriers measures that have potential in these northern areas for nonarable land protection include Caragana (a small leguminous tree) and *Hippophae rhamnoides* (sea buckthorn, a shrub). The trick is to manage them as a hedge, i.e., dense line seeding.

-Dick Grimshaw

The Vetiver Awards

Last month a panel of two judges from the Board of Science and Technology For International Development at the (United States) National Academy of Science reviewed the reports and information received by the Vetiver Information Network over the last year on management or research associated with the utilization of vetiver grass as a contour vegetative barrier. The judges chose amongst the entries based on two equally weighted factors — (i) the contribution made toward providing significant information about some aspect of vetiver as a species and/or its utilization and/or its impacts and (ii) the degree of personal initiative displayed in carrying out the work or providing the information. This latter criteria was very important as the resources available to the participants varied greatly.

The Awardees, selected by the panel, are :

First Place (US$ 3000) - **Dr. P.K. Yoon** of the Rubber Research Institute in Malaysia for his comprehensive report on his (almost) two years of research work on the management and utilization of vetiver grass. In his report Dr. Yoon has made a rigorous study of each and every aspect associated with his work with vetiver and provided practical guidelines for utilization and management based on his findings.

Second Place (US$ 2000) -

Dr. G.M. Bharad from PKV University in Akola, Maharashtra, India for the consistently excellent research work he has carried out over the last four years on measuring the on-farm impacts of contour vegetative barriers of vetiver grass and leucaena, of graded earthen bunds and of farming with no conservation measures. Dr. Bharad was one of the people who early on grasped the importance of vetiver grass and the opportunities it opened up in conservation farming;

Third Place (US$ 1000) - **Drs. P.N. Truong, I.J. Gordon and M.G. McDowell** from the Land Management Research Branch of the Queensland Department of Primary Industries, Brisbane, Australia for their work on the effects of salinity on vetiver grass. Prior to this work indications from both the literature and other sources had led to the unchallenged belief that vetiver grass was highly sensitive to saline conditions; this work arrives at different conclusions and potentially opens up tens of thousands of hectares of degrading saline lands worldwide as sites where contour vegetative barriers of vetiver grass may be utilized to halt and reverse land degradation. Dr. Troung has also been active in introducing and spreading the word about the vetiver system in Australia.

The Panel also chose four recipients to receive US$ 500 awards for their work. The awardees are : **Dr. Zhang Xinbao** of the Institute of Mountain Disaster and Environment in Chengdu, China; this award is given for the All China Vetiver Information Network of which Dr. Zhang is the head. The role of the network in popularizing and providing practical information on vetiver within China is invaluable and represents the best of local initiative and innovation in extending technologies for sustaining agriculture. **Mr. Wang Zisong**, Deputy Director of the China Red Soils Project; this award is given to further the excellent work of those in Fujian Province who over the last two years have been working to define management systems, carry out trials and demonstrate the usage of vetiver grass while working with farmers to extend the vetiver technology. **Dr. S. Subramanian**, Professor and Head, Regional Research Station, Aruppukkotai, Tamil Nadu, India for his work on effects of contour vegetative barriers on soil moisture which compared vetiver, leucaena, desmanthus and cenchrus hedgerows. Dr. Subramanian's work has also included the management of vetiver. **Dr. Françoise Dinger** of the French Institute of Agricultural Engineering Research, Grenoble Regional Centre, Natural Hazards and Upland Erosion Control Division, St-Martin d'Hères, France for his work on multiplication (vegetative and tissue culture) and adaptability to sub-humid mediterranean climatic conditions in nutrient poor, eroded sites. Dr. Dinger's work could potentially introduce vetiver grass into a zone in which erosion rates (as a result of removal of native vegetation) are very high and, for climatic reasons, revegetation is extremely difficult.

The Network also had offered a US$ 2000 award for any other plant species that would be at least as suitable as vetiver for creating contour vegetative barriers. A number of individuals expressed interest in presenting alternative species, however, in the end only three people did. The review panel felt that while the information presented was interesting, none of the three submissions presented sufficient information for judging and/or they presented information on species which are known not to meet the criteria of, at a minimum, being as suited as vetiver as a contour vegetative barrier. The Network would like to thank these individuals : **Mr. N.B. Hiremath** of Karnataka, India (Subabul -*Leucaena leucocephala*), **Mr. Gao Weisin** of Chengdu, China (Napier grass -*Pennisetum pupureum*), and **Messrs. Wang Jing, Su Zhongren, and Liu Zhengjie** (Bhabar grass -*Eulaliopsis binata*). As the US$2000 was not awarded, the Network has utilized these funds to print copies of Dr. P.K. Yoon's excellent report; the copies are being disseminated to a number of individuals and institutions around the world who are active in farming systems and natural resource conservation concerns. One copy each will also be sent to those who submitted alternative species. The Network can have copies of Dr. Yoon's report printed for interested individuals, though the printing costs are US$ 35/copy as the report contains quite a number of color photographs. An unbound black and white copy may be had for free through the Network — as can any other report featured in this or other Newsletters .

The Network would like to thank all of those who took the initiative to participate in the Vetiver Awards and to congratulate those whose work was singled out by the panel for awards. For those whose work was not awarded, a special thanks is in order and please be assured that the Network values the information that you provided and intends to disseminate it widely.

Extracts From *A Look-See At Vetiver Grass In Malaysia - First Progress Report* By Dr. P.K. Yoon

My knowledge of Vetiver grass starts from 12/4/1989, when I first saw a clump of rather undistinguished-looking grass collected by my colleague, Encik Ahmad Azly, at my request. It looked so ordinary and so frighteningly similar to the horrible "Lalang" ! (ed. note :*Imperata cylindrica*). However, I have been stimulated by the Handbook: Vetiver Grass - The Hedge Against Erosion and, having spent more than 30 years visiting rubber plantings and having seen massive erosion problems especially on steep hills, I was prepared to have a look-see at any economic method.

1989 was the time to get to know the plant and to multiply it for distribution. 1990 was the main period for distribution, start some ad hoc trials and set the stage for 'proper' trials in co-operating estates. This report summarizes mainly efforts of 1989 and 1990 . 1991 should see better progress. Whereas, Vetiver is promoted by the World Bank as a low-cost hedgerow system for controlling soil-loss and improving soil moisture, this may be true only for the poorer developing countries. Malaysia is well developed agriculturally and money is readily available for any cost-effective technologies. My research targets assess the potential values of Vetiver from both ends of the economic spectrum and, therefore, the early results and discussions presented could be easily adapted to suit different input requirements.

On recognizing the potential value of Vetiver, after reading the handbook published by The World Bank, considerable time was spent before we managed to locate a clump of 57 tillers in Taiping, Perak, on 12 April 1989. After that, the first priority was to multiply the plant rapidly before we could do any observation and distribution to interested parties.

A. Multiplication Of Vetiver

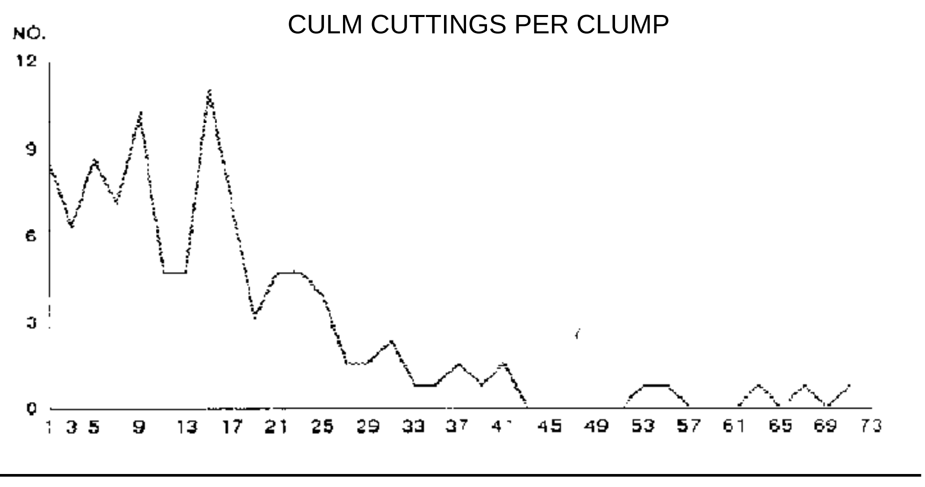
I. Multiplication using tillers

(1) Planting in polybags: Initially, all tillers were planted in polybags with sizes of 7" x 15" and 10" x 20". One six gram nugget of Kokei (N, P,K,Mg) slow release fertilizer was introduced into each bag and (a drip-type) irrigation system was used. Plants were divided as soon as they were observed to be bag-bound. At 4 months the smaller bags had 17.1± 1.1 tillers/plant and the larger bags 25.5 ± 1.6 tillers/plant.

(2) Planting in soil beds: (a) 2 rows of tillers were planted with in-between distances of 6" and irrigated system and one nugget of Kokei (6 gm) fertilizer per tiller were used Harvesting could be done at 5 months, yielding (on 2 occasions) 486 clumps with an average of 21.1 ± 0.6 tillers/clump and 185 clumps with an average of 20.6 ± 0.6 tillers/clump. (b) 6 rows of plants were established with in-between distances of 6" and irrigated. Fertilizer application was dried chicken dung. Growth up to 3 months was satisfactory but, thereafter, the plants in the central rows tend to grow and multiply slower because of shade-effect. This system should be used only if there were land constraint; otherwise, the 2-row system is much better.

(3) Planting in soil : A large block of approximately 20,000 sq. feet was ploughed and rotovated. Tillers were directly planted with a planting distance of 6" x 6". One round of dried chicken dung was applied at one week after planting. This approach ensures low establishment cost. There was little maintenance cost; with plant-

Figure 1. The number of culm cuttings obtained from vetiver



ing in the normal rainy season. watering was not needed. Also, there was no weeding nor any pest and disease control measures. Sampling of 100 clumps at 4 months showed average of 11 tillers per clumps (farmer's report). This rate of production was considered satisfactory because of the low input.

In Malaysia, labor cost is high. Therefore, the following system has been developed :

Fertilizer : use of one nugget of Kokei (6 gm) slow release fertilizer per plant. This is sufficient for 3 months. For longer periods of up to 6 months,a second nugget is required. Dried chicken dung is also very effective.

Watering : The Sumisansui (drip type)irrigation system is cheap to install and ensures good and uniform watering. Timing the planting to coincide with the rainy season minimizes the need to water.

Topping: The regular monthly topping to 40 cm to encourage tiller formation using a mechanized grass-cutter (bush wacker) which is readily available in all estates and most smallholdings.

With the above system, the cost of production is reduced to a minimum.

II. Multiplication by culm-branches

When Vetiver clumps are repeatedly topped at 40 cm and when they are more than 3 months old, the cut-culms produced many branches at the internode. These branches can be detached for planting. A trial was set up to study the multiplication and growth of these culm- branches which were separated into various types as follows: A - most vigorous with young shoots (with roots); B - less vigorous with young shoots (with roots); C - most vigorous (with roots) - single plant; D - less vigorous (with roots) - single plant; E - least vigorous (without roots) - single plant; F - Terminal shoots; G - Young shoots plants that were growing horizontally (with small roots/without roots). All types produced good root system under mist and transplanting success into polybags was nearly 100% for all types (lowest 99.6% for type E). The multiplication and growth of the various branch types will be discussed later.

"Vetiver is easy to multiply at low cost. Under normal conditions, multiplication by planting with tillers will give satisfactory results."

Dr. P.K.Yoon

III. Multiplication by culm-cuttings

It is recommended that clumps of Vetiver be cut-back to 30-50 cm to encourage tillering. Early observations suggest that too short cut-backs result in die-back of many culms under Malaysian conditions. An ad hoc trial testing 30, 40, 50 and 60 cm cut-back height suggested 40 cm to be the best with least set-back to growth, minimum die-back and good tillering.

The tops are normally discarded after cut-back at 40 cm height. However, if the Vetiver clumps are 3 months or older, the cut-tops include many culms. Each culm has varying numbers of internodal buds which can be induced to sprout and produce new plantlets under mist. Three methods of rooting under mist were tested :

(I) Layering of culms. The whole stem was buried in sand-bed with the following results after 5 weeks: (a) With leaf-sheath intact - 23.2% rooted; (b) With leaf-sheath removed - 28.4% rooted; (c) With leaf-sheath slit - 35.7% rooted.

(2) Rooting of individual node with leaf-sheath intact - at 5 weeks 5.1% rooted; at 9 weeks 14.6% rooted.

(3) Rooting of individual node with leaf-sheath slit - at 5 weeks 31.4% rooted; at 6 weeks 52,7% rooted and; at 8 weeks 76.3% rooted.

Treatment (3) of rooting each nodal culm cutting with the leaf-sheath slit was the most promising.

An assessment of 5-month old clumps in the ground yielded 16.4 ± 1.4 cuttings. The number of cuttings from each clump was highly variable as shown in Figure 1. Note that the above work was done under mist. However, based on experience with other crops, similar results would likely be obtained if materials are rooted in sand-bed under polythene sheet to keep the atmosphere moist; this has not been specifically tested because of time constraint.

Conclusion

Vetiver is easy to multiply at low cost. Under normal conditions, multiplication by planting with tillers will give satisfactory results. However, refined methods of vegetative propagation by culm branches and culm cuttings may be considered from two view points: (1) They will be of little value in mass vegetative propagation because they may not be commercially cost-effective (2) They will be of value in the following scenarios: (a) Initial stage of multiplication of a newly found cultivar. (b) Initial stage of multiplication of a newly imported cultivar. (c) Where base cultivars are imported at high cost from other countries. Certainly these methods are much cheaper than the tissue culture method. However, once the base source for multiplication is established, the normal method of splitting the tillers should suffice. In the early phase of my work, all methods using all plant parts are used. This accounts for the large amount of materials that I have produced and distributed.

B. Growth Of Vetiver

I. Effect of shade on growth of vetiver

To be able to use a plant as for any extended period under perennial crops, such as rubber or oil palm, dictates that the plant must be shade-tolerant under the canopy of the main crop. Three trials were started to test such effect.

(i) Trial 1

Plants raised in polybags for 6 weeks, were put under shade (80%) of rubber plants at nursery spacing of 6' x 6' and in the full sun. At 3 months after treatment, sample of leaves were taken from two levels of the leaves to determine specific leaf areas.

Results

Shading significantly increases the specific leaf area (Table 1) suggesting significant response of the plant.

At 3 and 4 months after treatments, 10 polybags each were sampled and the soil washed off. Results showed that shading significantly reduces: (i) tiller formation; (ii) plant weight; (iii) shoot weight; (iv) root weight but did not modify the % root/shoot ratio significantly. Therefore, we can conclude that Vetiver (at least the cultivar I have been working with) is not shade tolerant. It is, however, not expected to be since most grasses are likely to be climax plants. The good feature is that the % root/shoot stayed rather constant and we should be able to modify agricultural methods to make the best use of this point.

(ii). Trial 2

The plants from Trial 1 were used in this trial. Half the plants grown under shade were shifted to the open, while the reverse approach was applied to plants grown in the full sun. After 3 months, 15 polybag plants were harvested They showed the following: (i) Plants from the open performed poorly under shade; (ii) Plants in shade condition continued to grow poorly with poor tillering under continuous shade; (iii) Plants from shade condition performed well once they are exposed to the open. The conclusion is: "Vetiver is not shade-tolerant" but can survive under shade (intensity ?) for a period (?) and could be easily rejuvenated if the shading canopy is removed.

In effect, such information allows us to plan the following: (i) Plant the Vetiver before or at the same time as the planting of the main perennial crop of oil palm or rubber; (ii) Leave the Vetiver along the terracing to grow or sustain itself; (iii) When the main crops of oil palm or rubber have grown over, the rows of Vetiver can either perish as in oil palm area or periodically re-established as in rubber during wintering. In either case, the Vetiver would have done its job of reducing soil erosion.

(iii). Trial 3

This trial studied the growth of plants under very intense shade of (87%) of rubber nursery and also examined 3 possible methods of establishing plants in the field. The 3 planting methods are: (i) polybag completely removed exposing the core of soil and roots; (ii) base removed and with 4 slits cut with 10 cm clearance from top and bottom; (iii) base of polybag removed. All 3 methods of planting had no influence on the intense shade effect, viz. all plants under rubber performed badly at 2 months compared with those in

Table 1. Specific leaf area (leaf area/leaf weight; cm^2/gm) as effected by available sunlight

	20-40cm		40-60cm	
	Shade	Sun	Shade	Sun
Mean	157	140	151	142
s.e.(±)	4.0	2.1	4.0	2.6
n	10	10	10	10
t-test	***		P< 0. 1	

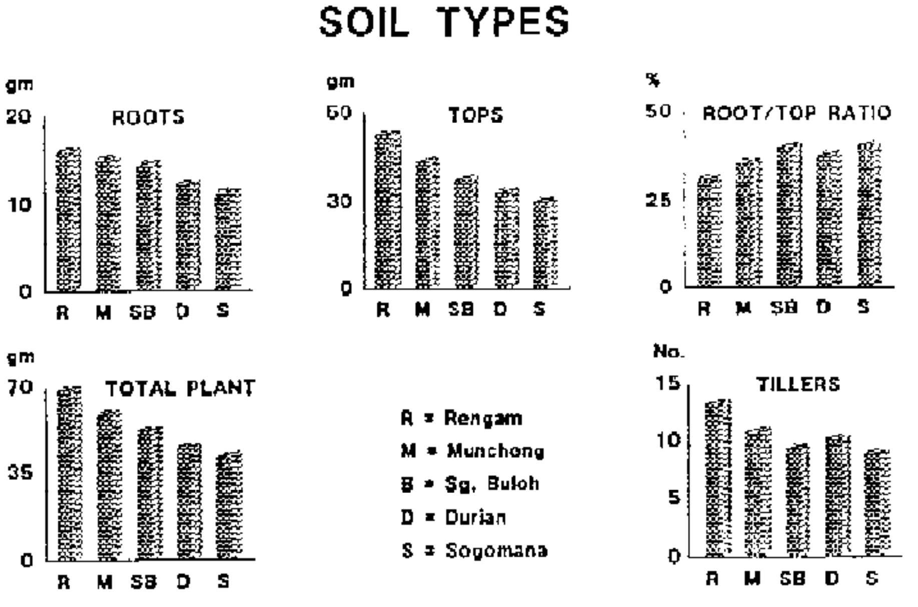


Figure 2. Effect of soil types on the growth of vetiver.

the open, then eventually, all the plants under the intense shade died off. The following points are of note: (i) Normally, the % shade under mature rubber is not so intense; (ii) The attempt to raise polybag plants to establish under established shade has to be re-examined. Direct planting *in situ* in the ground before shading by the main crop may modify the response.

Conclusion

The following points should be noted:

(i) Very intense shade was used. This is of value to study shade tolerance at the preliminary stage; but normal shade in rubber is not so intense.

(ii) Because of (i), it is important to study response to various intensity of shading. This is easy to do, using available plastic nets but we have delayed this to combine with studies of different cultivars for more meaningful results.

(iii) Polybag materials were established under existing shade. The root system at establishment was confined within the bag and therefore may not be best expressed. Would the planting "*in situ*" before canopy closure have performed the same?

(iv) Nevertheless, all evidences point to Vetiver being shade-sensitive. At what level of shade would tolerance be possible?

(v) However, because of (i), the possible value of Vetiver may be manipulated in the following manner : Because of the shade sensitivity and the possible competitive effectiveness of Vetiver against perennial crops as rubber. oil-palm. fruit trees, etc. vetiver should be used for: early function for soil and moisture conservation; allow the Vetiver plants to fade out because of shading so as to remove any possible competitive effect with the main crops;

(vi) Trial 2 showed that plants poorly grown under shade were rapidly revived upon exposure to light. This suggests shade survival may be dependent on the degree of shading, and with the periodic dose of more light as during winter period in rubber.

(vii) Vetiver will not be shaded out in crops which do not produce dense canopies or are relatively short. Examples are cocoa, tea, etc.

<u>II. Effect of soil types on growth of vetiver</u>

Plants were grown in polybags filled with 5 soil types (Keys to Soil Taxonomy, 4th Edition, 1990. SMSS Technical Monograph No. 6., Blacksburg, Virginia, USA) :

(1) Munchong (Typic Hapludox); (2) Rengam (Typic Kandiudults); (3) Durian (Typic Kanhapludults); (4) Sg. Buloh (Typic Quartzipsamments); (5) Sogomana (Typic Tropaquepts). A uniform fertilizer application of 1 Kokei (6 gm) nugget was used for all treatments. The results, shown in Figure 2 and summarized in Table 2 show that :

(i) Rengam soil produces the biggest number of tillers; the other 4 types of soil have similar production.

(ii) Rengam gave the best dry matter production followed by Munchong. Sogomana is clearly the worst soil type (ed. note : this is a very wet soil).

This trial shows that while there is soil type effect on tillering and dry matter production, Vetiver performs fairly well even in the worst soil type. It should be noted that the trial is on polybags with filled soil; future work on soil *in situ* may show different results. Effect of nil fertilizer and different levels of fertilizer would be of interest to show whether difficult physical characteristics may be ameliorated by additional input.

Soil	Tillers No.	Dry weight (gm) Shoot	Roots	Total Plant	Root / Shoot
'Sogomana	8.8 b	29.9 c	11.2 c	41.2 c	40.2a
Durian	10.1 b	32.9 c	12.1 bc	45.0 c	37.6ab
Sg. Buloh	9.3 b	37.4 bc	14.3ab	51.7 bc	39.6a
Munchong	10.7 b	43.3 b	15.0a	58.3ab	35.4 b
Rengam	13.2a	52.6a	16.0a	68.6a	31.0 c
se (±)	0.11	3.22	0.98	4.12	1.38
LSD (P<0.05)	0.3	9.0	2.8	11.6	3.9

Table 2. Effect of soil types on multiplication and growth of vetiver.

III. Effect of bag sizes on growth of vetiver hedgerows

While it would be cheapest to plant Vetiver slips directly, such approach invariably results in: requirements for replacement of dead plants, filling of gaps of less vigorous growing slips, slower establishment and less uniform establishment. Under certain conditions as highway embankments, steep slopes in housing estates, etc., it would be more advantageous and possibly more cost-effective to use polybag plants. This ensures virtually 100% survival, fast establishment and good uniformity; producing the best hedgerows in the shortest time. The cost of establishing hedgerows using polybag plants will be affected by cost of: bags, filling the bags, digging the trench and planting the polybag plants. A trial was therefore started to assess the maximum reduction in bag sizes possible without compromising the quality and speed of hedge formation.

Five bag sizes were used that ranged in size from 4" x 6" to 6" x 13" (5 bag sizes x 4 reps x 20 plants/treatment) and a fertilizer application of 1 Kokei/bag was carried out at the time of planting. The planting distance was kept at a constant 6" between clumps. The time for digging the trench and for planting were taken. Timing studies show that only the larger sized bags of 6" x 13" take significantly longer time to be planted and for the deeper trench to be dug. All other plants in the smaller sized bags have similar time requirements. To assess growth rates, two measurements were taken at monthly intervals by : (i) the tops above 40 cm were cut and weighed (dry wt.) — other than in the first month, the amount of dry matter production was similar for plants originating from all bag sizes and ; (ii) gap measurements show that the original larger polybag sizes produce smaller gaps, however, the gaps diminish with time and the differences between the different treatments also narrowed. Tentative conclusion at this stage suggests that the smaller sized bags of 4" x 6" could be the most economical size for fast and good establishment of Vetiver hedgerow. The experiment continues.

IV. Effect of fertilizer on growth of vetiver

Whereas it is generally claimed that Vetiver will grow under nutrient-stressed condition and whereas it is also generally expected not to fertilize Vetiver hedgerows under normal practice, it is critical to know the response of Vetiver to fertilizer. This is especially so under special condition where Vetiver hedgerows need to be established very rapidly. Examples are highways, dams, waterway constructions and housing areas in humid tropics with intense rainfalls. The different requirements of cut-earth and filled-earth are entirely different and have to be assessed. Maximizing production at economic cost is also important in relation to possible production of fodder.

(i) Trial 1

This trial compared (5 treatments x 4 reps) the use of differing amounts of slow release fertilizer; which is conditioned by 2 factors: easy to control at application and therefore would not confound results and economical to use in Malaysian context where labor is expensive. Treatments were : no fertilizer - NIL; 1 nugget (6 gram) of Nursery Ace - N; 1 nugget (6 gram) of Kokei - K1; 2 nuggets (12 gram) of Kokei - K2; 4 nuggets (24 gram) of Kokei - K3. Response to fertilizer application was measured by the dry weight of cut-off tops at 40 cm at 3 months and 4 months after application and the number of tillers produced at 4 months. The results, which are illustrated in Figure 3 and summarized in Table 3 show that : (i) Fertilizer aids in dry matter production and tiller production; (ii) even without fertilizer application, the plants grow and multiply; (iii) increasing fertilizer application rates did not increase growth and multiplication rates significantly, suggesting that the cheapest application rate of one Kokei nugget is sufficient.

<u>(ii) Trial 2</u>

This trial tests 3 treatments: one Kokei nugget at beginning of trial - K1 + 0; one Kokei nugget at beginning of trial followed by another nugget after 2 months - K1 + K1; and one Kokei nugget at beginning followed by 2 nuggets after 2 months - K1 + K2. The main results were : (i) Kl + K2 increases the rate of height growth; while there was no difference between Kl + 0 and K1 + K1; (ii) dry weight of tops at 3 and 4 months were improved by a second round of fertilizer, but the 2 rates of application do not produce different dry matter production; (iii) Tiller production was not affected by fertilizer treatment; (iv) dry weight of shoots and whole plant was increased by the second round of fertilizer application; (v) Root production and % root/shoot were not affected by fertilizer application; (vi) In general, increased fertilizer application resulted in higher nutrient value of the leaves and roots.

Conclusion

These 2 trials show that fertilizer improves the growth and tiller production. However, increasing the amount of fertilizer application does not result in corresponding increase in productivity. Therefore, a minimum amount of fertilizer application of 1 Kokei nugget is sufficient for polybag plants raised to 3 months. Only for longer periods is another nugget necessary.

<u>V. Effect of spacing cum fertilizer on growth of vetiver hedgerows</u>

On any terrain and soil condition, producing a good hedgerow is dependent on 3 factors: (1) The quality of plant materials used; (2) The distances of planting between clumps; (3) The amount of fertilizer used. A trial was set up to test this using 3 spacing distances and 3 rates of fertilizer applications; 3- month-old polybag plants, selected for uniformity, were used for all treatments.

The preliminary data suggests that dry matter production per clump is not significant where between clump competition has not arisen and that fertilizer plays a bigger part in field planting than previously experienced in polybag planting. The experiment continues.

<u>VI. Effect of different starting materials on variability of tiller formation and growth rates of vetiver.</u>

Vetiver plants can be grown from tillers, culm-branches and culm-cuttings; within each group there are differences mainly due to physiological age. This Chapter looks into the effects of different planting materials on subsequent multiplication and growth rates.

<u>(i) Different tiller types</u>

Preliminary observations have suggested that each clump of Vetiver produces different types of tillers; thus their growth and tiller formation would be quite different. This would lead to high variations in response of experimental treatments where assessment is by tiller formation and dry matter production. This could be one of the causes of non-significant effect of fertilizer, soil types, etc. previously reported. The experimental error may be higher than the treatment effect. To overcome this, the tiller types must be sorted out and the within-population studied before planning any experiment. The starting material must be the same tiller type and

Table 3. Effect of fertilizer on multiplication and growth of vetiver

	Dry weight (gm) of tops at 40 cm height		Tillers No.
	1st cutback (3 mths)	2nd cutback (> 4 mths)	
Nil	20.2 c	11.7 b	24.9 c
Nursery Ace	25.2 bc	18.3a	34.0 b
Kokei (1 nugget)	32.7ab	18.5a	32.4 b
Kokei (2 nuggets)	33.6ab	17.5a	35.8 b
Kokei (4 nuggets)	37.2a	19.1a	42.3a
se (±)	3.01	1.52	0.137
LSD (P<0.05)	9.3	4.7	0.4

fine-tuned to minimize experimental errors. The 4 major types are :

Type A - the most mature and multiplies fast. The culm produces a variable number of culm-branches; dry matter production is thus highly influenced. This type is not good for experimentation;

Types B & C - mature tillers but with no culm formation. Suitable for raising plants for experimental purposes.

Type D - youngest tillers. Tend to give variable growth.

(ii) Different culm-branches

Previous work (reported here) shows that different types of culm-branches can be rooted easily under mist and then transplanted easily into the soil. The rate of tiller production was studied and the results showed significant differences of tiller production by the various culm-branch types which also lead to differences in dry matter production. For experimental purpose the different types of culm-branches should be grouped separately.

D. Effect Of Vetiver On Soil Erosion

I. Demonstration of the effectiveness of vetiver against top-soil loss

A simple demonstration site was set up in a nursery land. The terrain was gently undulating (4°-5° slope) and planting was across an existing small gully. After 3 months the Vetiver hedgerows had trapped the (eroded) top soil and the gully had disappeared; in fact the slope has become platforms between the hedgerows. This demonstration site continues to exist for showing to interested parties. Invariably all visitors, to-date, were impressed enough to want to use Vetiver on their land.

II. Growth of vetiver and its effect on filled earth

It is a statutory requirement of the Department of Environment that all latex concentrate factories must discharge their effluents into a designed effluent pond system. The construction of a new factory in a co-operating estate necessitate the ponding to be done with bunds of filled earth. This gave us a good opportunity to test the value of Vetiver to control soil erosion. Three attempts were made to plant vetiver grass: (1) Demonstration plot set up on 24/7/1990; (2) Trial 1 set up on 31/7/1990; (3) Trial 2 set up on 3/9/1990. The plants established very well , but heavy rainfall over 4 consecutive days in October caused the bunds (on which the vetiver was planted) to collapse. Despite the collapse the row alignments of vetiver plantings were barely out.

(i) Trial 1

This trial was initiated to have more detailed measurements of surface water run-off, soil wash, etc. Experimental plots were demarcated by zinc-sheet boundaries to measure surface water run-off and soil-wash into the drums. At each level, there were 3 marked wooden pegs to measure top-soil loss. Measurements were conducted for a few days but with the heavy rains in October the drums were washed away and the zinc boundaries collapsed leading to extensive leakage. It was not possible to repair this and the trial had to be abandoned. However, visual evidence indicated the better effect of Vetiver to reduce top-soil erosion when compared with estate practice (See Photo 1).

(ii)Trial 2

This trial was on bunds where filled earth had been in

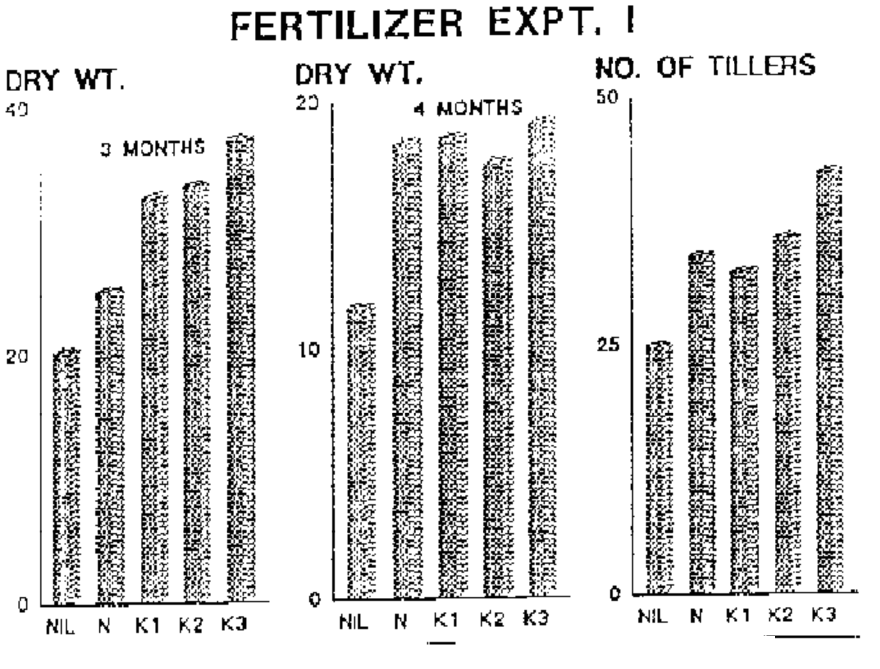


Figure 3. Effect of fertilizer on multiplication and growth of vetiver.

Photo 2. The subsoil has collapsed. The Vetiver plots had slipped 4 to 5 meters from the original level (L_O) to the new lower level (L_N).

place for about a month prior to the filled earth bunds being planted with vetiver immediately upon construction.

The details of the trial are : two treatments (Estate practice, Vetiver hedges @ 1m V.I.) with 10 reps. After the collapse in October the interesting phenomenon was that the alignment of Vetiver planting held very well though the whole top area of soil in the plots had slipped down (Photo 2). In the plot with the latest constructed bund, the plants have been dropped more than 4-5 meters. Examination of the various plots showed that the Vetiver planted on the oldest filled soil held well and continued to do so. Such observations confirm that the root system of Vetiver established most rapidly and penetrated and held approximately one foot of soil. This trial was abandoned but the earliest planted block continues to show the better value of Vetiver to reduce soil erosion, as compared to normal practice of using cow grass and New Guinea grass.

Conclusion

A large effort, in terms of labor and finance, was expanded on the demonstration plot and the 2 trials. The collapse of the filled-earth bunds was a big disappointment to us. However, rather than showing the failures of the Vetiver system, it tended to show its intrinsic strength. This is best illustrated in the overall picture --Photo 3 of the general view of the two trials and Photo 4 showing the collapse of the bund. Because of the great height and steep slope of the bunds, we were too optimistic not to have taken care of the sub-soil and the poor physical structure by piling. A combination of some structural work and planting of Vetiver may have overcome the collapse of the bund. The main conclusions were: (i) the top 1 foot of soil was held together by Vetiver though the whole area slid down (ed. note : at the time of the collapse the vetiver plantings were less than 3 months old); (ii) earlier plantings before the onset of heavy rain would have allowed longer time for the Vetiver to establish further and may have helped; (iii) Very deep soil fill will still need structural/ physical engineering work. Nevertheless, the results are so encouraging that the owner intends to repeat and expand the use of Vetiver and has offered additional and increased amount of funds for my future observations.

<u>III. Growth of vetiver and its effect on cut-earth.</u>

The value of Vetiver on cut-earth of highway embankments, etc. are of interest. An experiment is being carried out on a co-operating estate using an area of 150 meters width. The main study tests 2 densities of planting on: (i) the growth of Vetiver and formation of hedgerows; (ii) surface soil erosion as measured by wooden pegs. Early observations suggest that plants grown on the top terrace with some top soil are much more vigorous when compared to those with only sub-soil. In the later cases, while the plants established successfully, their growth is slow and stunted. This experiment is continuing.

E. Diseases

For any introduction and expanded planting of a new plant species or even a new cultivar, it is important that the introduction is not an alterative host for any disease of economic importance to major crops in the country. We, therefore, pay special attention to any pest and disease affecting Vetiver.

Results

In the period under observation, fungal attack was observed and identified as: *Nigrospora spp., Curvularia spp., Helminthosporium spp.* With the help of a mycologist, we isolated the inocula involved. We then tried to inoculate new emergent leaves. Our first two attempts failed to produce similar symptoms despite using all known information available to us for such actions. It was only recently (February 1991) at the third attempt using cut leaves in inoculation chamber that we were able to inoculate and develop symptoms using *Helminthosporium spp*. spores. *Nigrospora spp.* and *Curvularia spp*. were only pathogenic on detached leaves which had been subjected to wounding.

Photo 3. General view of the experimental sites

Conclusion

Of the many areas planted, only 2 sites experienced such fungal attacks and these are in the crowded nurseries of RRIM Experiment Station, Sungei Buloh; after the plants in the affected plots were topped at 40 cm growth continued as normal. Also, as there were difficulties in inoculating with the isolated inocula suggest the fungal attacks to be non-virulent. However, on examining the check-list of hosts and pests in Malaysia, we spot certain potential hosts of economic importance :

Elaeis guineensis (oil palm): *Curvularia lunata* (leaf spot); *Curvularia maculans* (leaf spot); *Helminthosporium halodes* (leaf spot); *Helminthosporium incurvatum* (leaf spot); *Helminthosporium rostratum* (leaf spot);

Cocos nucifera (coconut) - *Helminthosporium incurvatum* (leaf spot);

Zea mays (maize) - *Helminthosporium maydis*, *Helminthosporium turcicum* (leaf blight);

Saccharum officinarum (sugar cane) - *Helminthosporium* sacchari (sugar cane eye spot), *Helminthosporium stenospilum* (brown stripe).

It is important to identify the correct species (and cultivar) of the various fungi attacking Vetiver albeit on a small scale. Such knowledge is not available in Malaysia and we therefore plan to send our inocula to the British Mycology Institute for identification.

F. Adaptive Use Of Vetiver By End-Users

Vetiver plants have been given to many end-users. For illustration, this Chapter discusses the uses of the grass by one recipient. This is a privately-owned estate of about 700 acres planted with rubber and oil palm. As returns from these 2 crops are low, the owner wanted to convert to growing fruit trees. However, the estate is sited in an area with a distinct dry spell. A good water source is therefore essential. In addition, because the land are fairly steep, soil erosion and moisture control becomes critical.

The main targeted uses for Vetiver in this estate are: (i) Center for production and distribution of materials for interested smallholders around the area; (ii). Ponding; (iii) Erosion control in irrigation piping; (iv) Modify nursery land topography; (v) Erosion control and moisture conservation.

<u>I. Production of planting materials.</u>

Based on early experience gained, 2 methods were used: (1) Polybag nursery producing about 30,000 bags of 6" x 9" polybag plants under a Sumisansui irrigation (drip-type) system and fertilizer applied at 1 Kokei (6 gm) per bag. The polybag plants were ready for use in 2-3 months. (2) Ground nursery. Raised beds were prepared mechanically; each bed was $3\,^{1}/_{2}$ feet x 50 meters with 3 feet spacing in-between. Planting distance of the tillers were 6" x 6" with each bed producing 1800 clumps. At the initial phase, 6 beds were planted to produce 10,800 clumps. With

Photo 4. The collapse at the top of the bund. Note how the vetiver lines have remained intact.

the Sumisansui irrigation system and liberal use of dried chicken dung, the plants were ready for use in the field after 2 months. However, for multiplication, the plants were left to grow longer. It was estimated that these beds produced more than 150,000 tillers after the first 3 months. Currently (October 1990), the estate has 12 such beds.

<u>II. Ponding</u>

For conversion into any orchard, abundant water is essential. Because there is no river in or near the estate, ponds have to be dug. A series of ponds occupying a total of 50 feet width x 1750 feet length was excavated and the embankments of filled earth and cut-earth were planted with Vetiver. Slips with about 5 tillers of Vetiver from the ground nursery were used. The Vetiver established very well and the embankments stabilized very fast to hold 10-11 feet of water. An interesting observation was that the Vetiver survived more than a month of being partly or fully submerged under water during the rainy weather. Another side benefit is that Chinese carp loves the cut-leaves and now these ponds are also used to rear fish. The owner is so pleased with this set of ponds produced at such relatively low cost that he is producing more! Also, this attempt has stimulated the neighboring smallholders who are introducing fish-rearing into their farms.

<u>III. Erosion control in irrigation piping</u>

With the abundance of water available, a complete automatic irrigation system for the whole estate was being attempted. Three hills were already fitted with drip irrigation. To minimize cost, the main supply pipe for each hill must travel from the pond to the top of the hill in the shortest distance, i.e. at a steep gradient. Such arrangement normally creates severe erosion. Vetiver planting has effectively eliminated this problem. (ed. note. irrigation pipe was laid in a shallow ditch which ran straight up the slope)

<u>IV. To protect terracing</u>

A large nursery is essential for the estate to propagate fruit trees. A level nursery facilitated operation and will reduce costs in the long run. This estate has mainly undulating to rather steep land. To create the 1500 sq. feet nursery, the land was bull-dozed and made into 3 terraces, each with a drop of 1-1 1/2 meters. The embankments were well protected by Vetiver hedgerows.

<u>V. Erosion control and moisture conservation.</u>

Oil palm and rubber fields will be cleared for replanting with fruit trees. Vetiver plants are being prepared to be planted on the terraces to reduce soil erosion and to conserve moisture.

G. Ad Hoc Notes

<u>I. Labor</u>

Labor cost in the agricultural sector in Malaysia is relatively higher compared with other developing countries. Therefore, cost of multiplication and establishment must be looked into. Consequently, we use slow release fertilizer and irrigation systems. These are all established and proven practices introduced to the Industry by me and my co-workers. Use of polybags is an accepted practice and may be more cost-effective. Mechanized topping is obviously more cost effective. A worker can cut a 50m bed of 6 rows of plants at 6" square planting, in 5 minutes, i.e. topping of 1,800 clumps.

<u>II. Weather conditions</u>

The high intensity rainfall in Malaysia dictates that the hedgerows must be established fast in order to be effective. For highway construction, the contract of establishment of cover on embankment to control erosion runs into $100 millions and therefore cost of establishment is not prohibitive. What is expensive is the following "repair" work, if there were any failure. Therefore, the main target is to establish the good uniformed hedgerows fast. The same also applies to land fills in ponding, irrigation canals, housing estates, etc.

III. Fodder production

Vetiver hedgerows purposely grown in the normal path that sheep travel from their pen to young rubber grazing fields were not eaten by them. It seems that sheep do not prefer this grass if they have other food. The farmer-selected variety from India will be tried as soon as sufficient materials have been multiplied. Meanwhile it was noted that the tops of Vetiver, cut at monthly intervals at 40 cm height, were found to be readily consumed by sheep and Chinese grass carp. Therefore, the rate of dry matter production was studied under the following conditions in the ad hoc experiments: (1) Fertilizer effect, (2) Spacing, (3) Soil types. The fodder value of Vetiver reported in Vetiver Newsletter No. 4 is most welcome. Those smallholders who use Vetiver for protection of erosion in fish pond will be most encouraged to top the Vetiver and feed the fish. Likewise, those using Vetiver for soil erosion would be encouraged to cut the tops for fodder. Such repeated topping would make the hedgerows dense and neat.

IV. Vetiver as a mulch

The effect of mulches on establishment and growth of crops, soil erosion and soil water conservation is well documented. In Malaysia, use of lalang (*Imperata cylindrica*) as a mulch is an accepted practice, though in recent years it has been superceded by oil palm empty fruit branches where available. A preliminary observation comparing Vetiver cut tops with lalang has shown that it was longer-lasting and without the adverse effect of seeding. Analysis also show considerable available nutrient (N, P. K, Mg). Therefore, in addition to usage as erosion and soil moisture control, Vetiver planting in agricultural crops would also contribute in terms of a ready and repeated supply of quality mulch.

...the results clearly show the vast potentials of Vetiver which are too tempting for any one not to look further into it!

Dr. P.K. Yoon

V. Tolerance to contact weedicide spray drift

Weedicide spray drift is at times, unavoidable. An incident occurred in one Vetiver multiplication nursery next to a rubber seedling nursery. The weedicide used was Paracol; a contact weedicide. Only the tops of the plants were affected and there was good recovery after $2^1/_2$ months.

VI. Effect of vetiver on growth of Hevea

A colleague is looking into possible competitive effect of Vetiver on growth of Hevea. This compares with effect of other common weed species. Briefly, there are 4 trials: (1) In pots, (2) In large polybags buried in the ground, (3) Next to newly planted rubber buddings, and (4) Next to 9-month old rubber buddings. The effect on rubber as measured by height and girth will be studied.

VII. Competition with other weeds

In a commercial ground nursery, no weeding was carried out. The Vetiver plants in rows grows well in competition with the weed *Borreria spp*. and some sedges. However, it should be noted that *Borreria spp*. is normally regarded as a weak weed. The ability of Vetiver to compete with weeds is important because any need for weeding will increase the cost of multiplication, establishment and maintenance of Vetiver nurseries and hedgerows.

H. Trials Being Initiated

Vetiver plants are being multiplied in many commercial nurseries of end-users. They are to be used in cooperative trials where all funds will be supplied by the interested parties. The following summarizes those in advanced stage of being set up.

Trials 1 & 2: To study the effect of Vetiver on growth of rubber; two different estates.

Trial 3: To study the effect of Vetiver to prevent soil erosion on steep terrain.

Trial 4: To study the effect of Vetiver growth on the stability of highway embankments.

I. The future of vetiver in Malaysia

The report presented here covers work done over a short period of less than 2 years. Even so, the results clearly show the vast potentials of Vetiver which are too tempting for any one not to look further into it! The future is being written .

EXTRACTS FROM *ROLE OF VETIVER GRASS IN SOIL AND MOISTURE CONSERVATION* BY DRS. G.M.BHARAD AND B.C BATHKAL

Around 90 percent of the area in Vidarbha, a part of semi-arid tropics, are put to rainfed agriculture. Rainfall in these areas is seasonal, limited and uncertain creating dry spell situations which result in high between-year annual variances in yield. Improvement in agro-ecosystems (productivity, stability, sustainability and equitability) in these areas is a priority. Rain water management for improved in-situ conservation of natural resources (viz.water and soil) has been identified as a main concern for this rainfed agriculture.

Very recently the watershed has become accepted as basic unit for the management of organic and biophysical resources. However, in India, unlike some other countries, the land holdings owned by farmers are very small and are often divided along (up and down) the slope; the farmers have a very strong sense of possession for their land. Taking mechanical (structural) measures to control erosion and runoff from these fields is often not feasible in these areas. The cost of structures also act as an inhibitory factor.

Greenfield (1987) introduced the concept of vegetative hedges (Vetiver) on the contour for in-situ conservation of soil and water in rainfed areas under the World Bank-aided Manoli Watershed Development Project. Punjabrao Krishi Vidyapeeth University was given the task of carrying out the research and training component of this project. Comperhensive on-station and on-farm research was formulated and is being executed with continuous refinement since the 1987 kharif season.

Materials and Methods

The on-station research programme was located in a model watershed (25 ha) developed in 1987 with the central objective of dealing with planning for development, execution and monitoring of watershed management activities. Along with the development of various systems, a monitoring block with seven large runoff plots (128m x 28m) was established with the required equipment to look at crop productivity, surface runoff and soil loss. The average main and lateral slopes are 1.6% and 0.7%, respectively. Three plots have a shallow soil with a sandy loam texture and the other four are medium-deep soils with a clay loam texture. The treatments on the shallow soil plots consist of : i) across the slope cultivation; II) contour cultivation along a Leucaena keyline and; iii) contour cultivation along a Vetiver keyline. In the medium-deep soils a fourth treatment was added - cultivation along a graded bund (0.2% grade). On-farm trials were initiated in the 1988-89 season on farmer's fields in the Chambhai micro-watershed (very shallow soil) where the average slope is less than 2%. The treatments are : i) along the slope sowing; ii) contour sowing along a vetiver keyline; iii) untreated nonarable lands and; iv) nonarable land with continuous contour trenches.

Results and Discussion

1. Productivity

1.1 Shallow Soils (Model Watershed,University farm)

Mean productivity of crops viz.green gram + Pigeon Pea-Saffower (1987-88), Pearlmillet-Safflower (1988-89) and pearlmillet (1989-90) grown on shallow soils was seen to be favorably influenced by contour cultivation. The average productivity recorded by contour cultivation was highest for contour cultivation along vetiver, followed by leucaena and across the slope

Table 4. Effect of conservation measures on crop productivity (Q/ha) on Shallow Soils in Model Watershed

Treatment	1987-88	1988-89	1989-90	Total	Mean	% (+) increase (-) decrease
Across Slope Cultivation (T_1)	11.05	20.91	13.72	45.68	15.23	
Contour Cultivation Along Leucaena (T_2)	14.21	21.76	14.91	50.88	16.96	+ 11.35
Contour Cultivation Along Vetiver (T_3)	17.34	22.88	18.50	58.72	19.57	+ 28.50

(Table 4)

1.2 Medium Deep Soils (Model Watershed, University farm)

Productivity of sorghum hybrid CS11-9 (1988-89) with contour cultivation along vetiver key line was highest. Grain yield of hybrid Sorghum was seen to be reduced with the graded bund system when compared with across the slop sowing during a season with very high rainfall (1356 mm.). During the year 1989-90 the increase recorded in yield of sorghum R-73 by contour cultivation along vetiver was again the highest. (Table 5).

Treatment	1987-88	1988-89	Total	Mean	% (+) increase (-) decrease
Across Slope Cultivation (T_1)	29.26	38.24	67.50	33.75	
Contour Cultivation Along Leucaena (T_2)	31.80	41.88	73.68	36.84	+ 9.15
Contour Cultivation Along Vetiver (T_3)	33.28	43.80	77.08	38.54	+ 14.19
Cultivation Along Graded Bund (T_4)	27.00	42,82	69.82	34.91	+ 3.43

Table 5. Effect of conservation measures on crop productivity (Q/ha) on Medium Deep Soils in Model Watershed

1.3 Very Shallow Soils (Manoli Project Area)

On farmers field in the Chambhai micro-watershed, contour cultivation along a vetiver keyline increased yields 45% in 1988-89 (rainfall = 1109mm) and 25% in 1989-90 (rainfall = 669mm) compared to along the slope cultivation.

2. Surface Runoff

2.1 Shallow Soils (Model Watershed, University Farm)

Contour cultivation along vetiver keylines resulted in lower total runoff over the three seasons. Runoff from the contour cultivation along Leucaena keylines was lowest in year one; Contour cultivation along vetiver keylines was lowest in the second and third years (Table 6).

2.2 Medium Deep Soils (Model Watershed, University farm)

The surface runoff from Sorghum was consistently less from the contour cultivation along vetiver keylines plot for all three years. The runoff from the graded bund system recorded from July to August 1989 was recorded, however, the runoff from September onwards could not be recorded due to over-topping (Table 7).

2.3 Very Shallow Soils (Manoli Project Area)

The rainfall recorded at the Chambhai micro-watershed during 1988 and 1989 seasons was about 1778 mm (1109mm first season and 669 mm the second). Total runoff from along the slope sowing, contour sowing along a vetiver keyline, untreated nonarable lands and nonarable land with continuous contour trenches was 445mm,171mm, 378mm, and 87mm, respectively.

3. Soil Loss

3.1 Shallow Soil (Model Watershed, University Farm)

Maximum soil losses were recorded during the month of July followed by August. Soil losses were highest 1989 due to the high rainfall and increased runoff. Cumulative and average soil losses were less from the contour cultivation with vetiver keyline system than that from the other plots (Table 6).

3.2 Medium Deep Soil (Model Watershed,University Farm)

The same pattern for soil loss was observed in the Medium Deep Soils as was observed in the Shallow soils with contour cultivation with vetiver keyline system showing the least soil losses.

Conclusions

Higher productivity of crops under on-station and on-farm trials with adoption of contour cultivation was mainly due to uniform in-situ soil and moisture conservation over the entire toposequence reflected in terms of lesser surface runoff and soil loss. Similarly contour cultivation along the vetiver key line was found to be more effective in terms of arresting surface runoff and soil than with the leucaena key line. This is attributed to the formation of a dense, uniform and continuous barrier. This has also resulted in higher productivity. In case of Leucaena, during the first year the barrier was quite good. However, with age, some shoots began to dominated the adjoining seedlings resulting in open barriers adjacent to the ground surface.

The graded bund system was found to enhance runoff and soil loss and in high rainfall situations the productivity was lower

Season	Total Rainfall (mm)	Surface Runoff (mm)			Soil Loss (t/ha)		
		T_1	T_2	T_3	T_1	T_2	T_3
1987-88	639	51.1 (8.0)**	13.3 (2.1)	25.8 (4.0)	8.3	1.7	2.5
1988-89	1267	293.2 (23.2)	226.3 (17.4)	167.0 (13.2)	24.3	15.7	6.8
1989-90	577	69.1 (12.0)	53.6 (9.3)	30.4 (5.3)	1.9	1.3	0.6
Total	2482	413.5	293.2	223.2	34.5	18.7	9.9
Mean	827.3	133.9	97.7	74.4	11.4	6.2	3.3

T_1 = Across Slope Cultivation ; T_2 = Contour Cultivation Along Leucaena ; T_3 = Contour Cultivation Along Vetiver

** Figures in parenthesis indicate percent surface runoff

Table 6. Effect of conservation measures on surface runoff and soil loss on Shallow Soils in Model Watershed.

than even the across the slope sowing plots. The vetiver barriers functioned both in low and high rainfall situations and did not effect the crop in any way. In view of the above results, it could be inferred that the contour cultivation along vetiver key lines for raising crops is necessary to improve productivity and *in situ* conservation of soil and moisture in rainfed farming.

Excerpts From *Effects Of Soil Salinity On The Establishment And Growth Of Vetiveria Zizanioides* (L.) *Nash* By Drs. P. N. Truong, I.J. Gordon & M.G. McDowell

Introduction

Vetiver grass [*Vetiveria zizanioides* (L.) Nash] is believed to have been first introduced into Queensland, Australia in the 1930s as a potential crop for its essential oil - (P. Cameron pers. comm.). In Queensland, its role in soil and water conservation was not realized until 1986 when it was promoted by the World Bank as a natural, effective and low cost method of soil and water conservation. Vetiver grass is presently being evaluated as a means of gully stabilization in grazing lands.

One of the characteristics of the soils in the semi arid regions of sub tropical eastern Australia is the presence of soluble salts and exchangeable sodium in amounts likely to affect plant growth. Solodic soils frequently contain high levels of exchangeable sodium and magnesium and low levels of exchangeable calcium (Isbell 1957).

In Queensland, most grazing land degradation (sheet and gully erosion) in semi arid regions is often associated with saline - sodic soils and to be effective in stabilizing gullies on these soils, Vetiver needs to be moderately salt tolerant. There are practically no references in the literature on the salt tolerance level of Vetiver grass. Only one reference is listed in the comprehensive bibliography, *Plant Response to Salinity* (Francois and Mass, 1978) but this does not give any details on the soil salinity level where Vetiver was evaluated for its essential oil production (Chandra et al, 1968). As a result, a series of glasshouse and field experiments were conducted to determine the salt tolerance of Vetiver grass. The objectives of these trials were:

- To determine the salt tolerance of Vetiver grass in compari-

Table 7. Effect of conservation measures on surface runoff and soil loss on Medium Deep Soils in Model Watershed.

Season	Total Rainfall (mm)	Surface Runoff (mm)				Soil Loss (t/ha)			
		T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
1988-89	1267 (671)*	341.7	296.6 (27.0)**	227.5 (23.4)	173.3* (18.0)	34.9 (25.9)	18.1	8.3	27.3*
1989-90	577	54.0	37.5 (9.4)	24.4 (6.5)	41.5 (4.2)	1.8 (7.2)	0.64	0.33	1.06
Total	1843 (1248)	395.6	334.2	251.9	215.2***	36.7	18.8	8.03	28.4

T_1 = Across Slope Cultivation ; T_2 = Contour Cultivation Along Leucaena ; T_3 = Contour Cultivation Along Vetiver ; T_4 = Cultivation Along Graded Bund

* Data from July & August 1989 only

** Figures in parenthesis indicate percent surface runoff

*** Not comparable with other figures, as data set not complete son with some well known pasture grasses.

• To determine the effects of shallow saline groundwater on Vetiver growth.

• To determine the soil salinity level and plant chloride content of Vetiver grass at which toxic symptoms appear and to describe these symptoms.

Table 8. Mean EC values (1:5 and se), Chloride and Sodium levels in soils of different treatments under Vetiver, Rhodes and Paspalum grasses of Experiment 1.

Treatment Solution EC	$EC_{1:5}$*	EC_{se}**	Cl^-	Na^+
O (Control)	0.05	0.64	21	0.07
6	1.17	15.02	1814	4.42
12	2.08	26.71	3325	8.30
18	3.34	42.89	5597	12.68

All EC in $mScm^{-1}$

Cl^- in mg/L

Na^+ (exchangeable) in mequiv/100g

* $EC_{1:5}$ (Electrical conductivity soil/water ratio)

**EC_{se} Electrical conductivity (Saturation extract)

Experimental Design

An integrated series of pot, column and field experiments were carried out to achieve the objectives mentioned above. Three pot experiments were conducted. Experiment 1 compared the salt tolerance of Vetiver with *Chloris gayana* (c.v. Pioneer) (Pioneer Rhodes grass) and *Paspalum dilatatium* (Paspalum). Rhodes was the most salt tolerant and Paspalum the second most sensitive species among the ten tropical grasses evaluated by Russell (1976). Experiment 2 investigated the effects of osmotic stress, caused by high soil salinity level, on mature plants of the three grasses. Experiment 3 determined the soil salinity level at which yield was reduced by 50%. The column experiment was set up to determine the effect of shallow saline watertable on Vetiver and Paspalum. A field trial was also established to correlate the results of pot and column experiments to field conditions.

Methods

I. Soil salinity levels of the pot experiments

Different soil salinity levels were obtained by watering the pots with a saline solution of various salt concentrations (the treatment solution). Daily watering of the pots with the treatment solution was undertaken to maintain field capacity. Although the pots were free-draining, salt accumulation occurred in the top soil. To reduce this accumulation, the pots were flushed with 500ml of treatment solution every week. The final soil salinity levels varied with the volume and the salt concentration of the treatment solution used.

The salinity levels taken at harvest were considered as treatment levels. There were four salinity levels including the control treatment in the first pot experiment, three in the second and eight in the third.

II. Column Experiment

Four salt concentrations, similar to those used in experiment 1, were used in this experiment. For each treatment Vetiver and Paspalum plants growing in separate columns stood in a tray of 10cm depth. This tray was refilled with the treatment solution daily and the solution was replaced once a week. Again the soil salinity levels taken at harvest were considered as treatment levels.

III. Field experiment

Two rows of Vetiver plants, approximately 80m in length each, were established across a drainage line where saline seepage water flowed after rain. The composition of this seepage water is similar to that of the water used in the glasshouse experiments. The salt concentration ranged from 6 to 14 $mScm^{-1}$ depending on previous rainfall.

IV. Harvest

Six weeks after planting all glasshouse experiments were harvested by cutting all green materials at the crown level.

Treatment Solution EC	Rhodes		Vetiver		Paspalum	
	g/pot	Soil EC_{se}*	g/pot	Soil EC_{se}*	g/pot	Soil EC_{se}*
0 (Control)	21.50 (100)** *a*	0.37	13.24 (100) *a*	0.96	15.44 (100) *a*	0.64
6	13.02 (60) *b*	16.80	7.93 (60) *b*	15.79	5.98 (39) *b*	12.32
12	8.00 (37) *c*	30.56	1.55 (12) *c*	25.80	1.07 (7) *c*	23.75
18	1.52 (7) *d*	42.88	0 (0) *c*	37.36	0 (0) *c*	48.4
LSD 5%	4.17		2.97		2.61	

All EC values in $mScm^{-1}$

* Mean values for 0-12 cm depth

** Relative yield expressed as percentage of yield from control treatment.

a,b,c,d - Treatments with similar alphabet are not significant at 5% level.

Table 9. Dry matter yields of Rhodes, Vetiver and Paspalum at four soil salinity levels in Experiment 1.

Materials

I. Soils

A Udalf soil with 10% clay was used in the glasshouse experiments. This soil has very low levels of chloride and soluble salts. The field experiment was established on a Typic Agiustoll soil with 25% clay in the top 10cm and 50% at 30cm depth.

II. Saline water

Saline water used in the glasshouse experiments was collected from a seepage pond near the field trial site. This saline water was diluted with de-ionized water to the required salt concentrations for each treatment, immediately before watering every day.

III. Planting materials

Slips of Pioneer Rhodes and Paspalum grasses, comparable in size to Vetiver, were used as planting materials.

IV. Containers

Black polyethylene pots (17cm x 17cm) were used in the pot experiments and PVC pipes (11cm (dia) x 60cm (long)) were used for the column experiment. Each pot was filled with 2700g of air dry soil, and 5000g of soil was used in each column, giving the overall soil depth of 50cm (after settlement).

V. Fertilizers

To compensate for the low soil fertility level in the pot experiments, a relatively high rate of fertilizer application was needed. A complete mixture, including micro-nutrients (Zn, Cu, Mn, Mo, Fe and B) was used and the N,P,K rates were 184, 104 and 144 kg/ha, respectively.

Results And Discussion

I. Soil Salinity Levels

Electrical conductivity (EC) was determined using a 1:5, soil deionized water suspension at 25°C. To enable a more consistent comparison with published literature and to assess more fully the plant response, it was decided to convert all EC 1:5 measurements to EC_{se} (EC saturation extract). Plants respond to salinity at water contents equal to or drier than saturation. EC_{se} is the most dilute soil solution concentration that plants could be expected to encounter and has been used widely to relate plant response to soil salinity across a range of soil textures.

The relationship between EC 1:5 and EC_{se} can be calculated using a water content conversion factor. Although the chemistry of solutions is profoundly affected by water content, if the salts are essentially all Cl and there are limited levels of partially and slowly soluble salts, a reasonable conversion based on water content can be determined (Shaw et al 1987). The solutions used in this experiment were dominantly chloride salts, hence EC_{se} was calculated using the following equation:

$$EC_{se} = EC_{1:5} [500 + 6ADMC / SP]$$

where ADMC = air dry moisture content (g/100g) and SP = saturation percentage (g/100g).

The EC_{se} figures used throughout the text have been calculated as above, and to maintain consistency all further electrical conductivity figures will be discussed as EC_{se}.

In the pot experiments a wide range of soil EC_{se} was obtained by watering the pots with the treatment solution as described in Section 3.1. The EC_{se} recorded for experiment 1 ranged from 0.96 to 42.89 $mScm^{-1}$, for experiment 2 from 23.88 to 73.44 $mScm^{-1}$ and for experiment 3 from 3.39 to 20.92 $mScm^{-1}$. The values for the column experiment were from 2.63 to 52.26 $mScm^{-1}$. These values cover a wide range of soil salinity levels, ranging from non toxic to highly toxic concentrations.

Both soil chloride and sodium concentrations also increased proportionally with the salinity levels of the soil (Table 8). Despite the weekly flushing, considerable amount of salt concentrated in the top 3cm of soil.

<u>II. Salt tolerance of Vetiver grass</u>

Table 9 shows that Vetiver grass has a very high salt tolerance level, much higher than Paspalum and almost comparable with Rhodes. When yield was expressed as a percentage of control treatment yield, Vetiver grasses produced as much growth as that of Rhodes (60%) with soil EC_{se} up to 16 $mScm^{-1}$. At higher salt levels (EC_{se} > 16 $mScm^{-1}$) Vetiver yield reduced more sharply than Rhodes.

Using NaCl, Russell (1976) reported that among the ten most commonly used pasture grasses in sub-tropical Australia, Pioneer Rhodes could stand the highest soil salinity level (EC_{se} = 23.2 $mScm^{-1}$) before its yield was reduced by 50%. Results from experiment 1 indicate that soil EC_{se} at approximately 17.5 $mScm^{-1}$ reduces Vetiver yield by 50% (Figure 4). This represents a very high soil salinity level and it compares very favorably with that of Rhodes in this experiment (approximately 22.5 $mScm^{-1}$). Soils with EC_{se} of 16 $mScm^{-1}$ or higher are considered to be highly saline by the United States Salinity laboratory (1954).

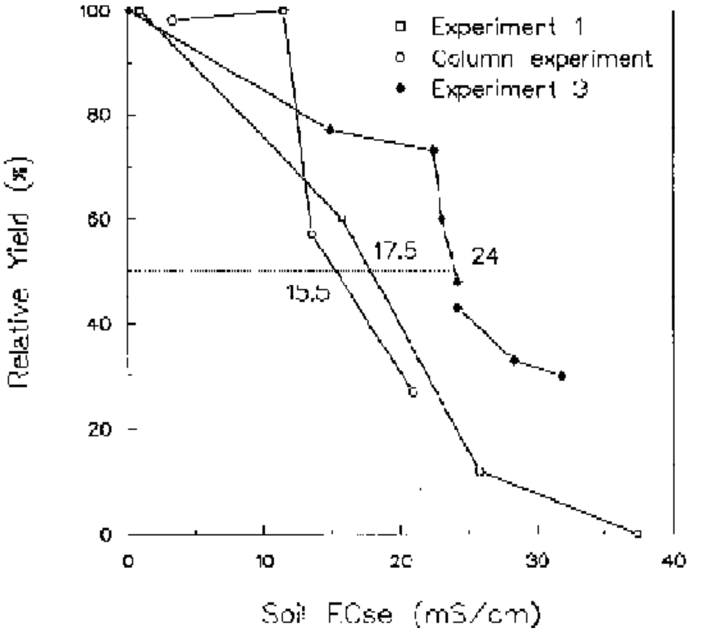


Figure 4. Soil ECse values for a 50% Vetiver yield reduction in pot and column experiments.

<u>III. Effects of shallow saline groundwater</u>

Saline shallow watertables are often associated with dryland salting in sub-tropical Australia. Dryland salting is one of the main causes of scald erosion in grazing lands in Queensland. Results from the column experiment indicate that Vetiver grass is much more tolerant of high saline watertables than Paspalum, particularly at higher salt levels (Table 10). This could be attributed partly to the different root distribution characteristics of the two grasses and partly to the salt profile in the soil column.

Table 11 shows a very high salt accumulation in the top 5cm of the soil column, a typical salt distribution profile under shallow saline groundwater conditions. Vetiver grass is known to be deep rooted and tends to develop roots vertically rather than laterally, thus having a better chance of escaping the high salt concentration in the top soil of this experiment. Conversely, Paspalum roots which are more evenly distributed were affected by the high salt level. Photos 5 and 6 illustrate the root distribution pattern of Vetiver and Paspalum from Experiment 2. Figure 5 indicates that 50% yield reduction occurred when soil EC_{se} reached approximately 15.6 mScm-l.

The deeper rooting characteristic of Vetiver and the typical salt distribution profile of the soil column may explain why under the same treatments, particularly at higher salt concentration, the relative yield of Vetiver growing in the columns was higher than those growing in the pots. (Tables 9 and 10). The total soil depth of the pots was only 12cm so Vetiver roots probably could not escape from the high salt levels in the top soil.

IV. Effects of saline water on mature Vetiver

In experiment 2, well established plants, which had been grown under non-saline conditions for five weeks, were watered with saline solutions to examine the adaption of mature plants to saline water.

Results from Table 12 show that mature Vetiver, Rhodes and Paspalum plants were not adversely affected by saline water. Growth of Vetiver was not greatly affected by relatively high salinity levels which had depressed yield considerably in experiments 1 and 2, suggesting that mature Vetiver roots can tolerate considerably high salt levels in the soil solution. Therefore, once established, Vetiver can tolerate fairly high concentrations of salt over a considerably long period.

V. Effects of soil salinity on Vetiver growth under field conditions

Two rows of Vetiver grass were planted across a saline seepage depression in an attempt to stabilize a gully head 5m further downstream. Vetiver slips were planted in late summer (February 1990) and good rain fell after planting. However a very cold winter (-6°C minimum grass temperature) and a very dry spring followed (only 26mm of rain fell between July and mid December 1990). Soil on the higher part of the slope was very dry, whereas soil on the lower part was moist due to seepage. Despite the unfavourable conditions, Vetiver grass grew well and the effect of soil salinity was clearly obvious.

The difference in plant growth can be attributed to both soil salinity and soil moisture. Poor growth (40cm height) of plants grown in the lowest part was most likely due to high soil salinity level. This is supported by the high salt level of the soil (mean value of 15.49 mScm^{-1} for top 50cm) and the appearance of salt toxicity symptoms. Growth of Vetiver plant grown on the higher part was also poor (40cm) and this was most likely due to moisture stress, rather than salt toxicity as soil salinity level was relatively low and there were no symptoms of salt toxicity. On the other hand, the intermediate area between the two above positions produced excellent plant growth (80cm). This can be attributed partly to better soil moisture and partly to lower soil salinity at lower depths. These results support the finding of the column experiment that the deep rooting characteristics of Vetiver could escape the high salt concentrations of the surface soil. These results also confirm that Vetiver has a high salt tolerance.

VI. Recovery after rain

Following the very dry period between July and mid December 1990. 229 mm of rain fell between mid December and early February 1991. Vetiver responded very quickly to the rain and warm weather (temperatures ranged from 20.5°C to 31.1°C in January 1991). Vetiver growth more than doubled over a five week period. Severe salt toxicity symptoms were no longer observed in new growth.

VII. Soil salinity level for 50% yield reduction

Dry matter yield of Vetiver grass from experiment 3 is much higher than that from experiment 1 over the six week period. This higher yield can be attributed largely to warmer growing condi-

Table 10. Soil ECse and dry matter yield of Vetiver and Paspalum grasses from the column experiment.

Treatment Solution EC	Vetiver		Paspalum	
	g/pt	Soil EC_{se} *	g/pot	Soil EC_{se}*
0 (control)	6.26 (98)** *a*	3.39	12.38 (100) *a*	5.91
6	6.40 (100) *a*	11.49	5.14 (42) *b*	9.53
12	3.63 (57) *b*	13.60	1.74 (14) *b*	12.70
18	1.72 (27) *c*	20.92	0.27 (2) *b*	18.87
LSD 5%	1.29		5.86	

All EC values in mScm^{-1}

* Mean values for 0-50 cm depth

** Relative yield expressed as percentage of highest yield

a,b,c, Treatments with similar alphabet are not significant at 5% level.

Soil Depth (cm)	Vetiver			Paspalum		
	Treatment Solution (EC)			Treatment Solution (EC)		
	6	12	18	6	12	18
	Soil EC_{se} ($mScm^{-1}$)					
0 - 5	28.37	26.96	52.26	20.03	25.16	27.60
5 - 10	8.97	11.31	16.18	6.44	11.93	14.12
10 - 20	9.24	12.62	16.05	5.34	12.20	14.12
20 - 30	10.12	12.11	14.12	5.16	10.12	14.12
30 - 40	7.70	9.51	12.08	5.78	9.91	18.36
40 - 50	4.57	9.05	12.30	2.63	7.45	12.54
Mean	**11.49**	**13.60**	**20.92**	**9.53**	**12.70**	**18.87**

All EC values in $mScm^{-1}$

Table 11. Salt distribution of soil columns of the column experiment

tions and better planting materials used in this experiment. While the temperature ranged between 12°C and 28°C (spring) for experiment 1, the range was between 22°C and 38°C (summer) for experiment 3. Faster growth and higher temperatures required more water, and led to higher soil salinity levels. As a consequence, for a 50% reduction in growth, soil EC_{se} needs to be at approximately 24 $mScm^{-1}$ (Figure 4).

Figure 4 shows that for a 50% yield reduction the soil EC_{se} ranged from 15.5 (column experiment), 17.5 (experiment 1) to 24 $mScm^{-1}$(experiment 3). For a similar yield reduction (estimate by plant height), the value of 15.6 $mScm^{-1}$ was obtained from the field trial. This value (15.6 $mScm^{-1}$) relates best with that from the column experiment and it may be explained by the fact that values from the column experiment and the field trial were mean EC_{se} of the top 50cm of soil whereas the soil of experiments 1 and 3 only reached 12cm depth.

VIII. Plant Chloride concentration

In general, the chloride concentration of Vetiver leaves increases as the soil salinity level increases. Figure 5 shows that a leaf chloride concentration of approximately 3.6%, is associated with a yield reduction of 50%. However this chloride concentration cannot be considered as the critical level, as results from the field trial showed that leaf chloride only reached 0.97% when plant growth was reduced by at least 50%.

IX. Symptoms of saline toxicity

Under glasshouse conditions, symptoms of mild salt toxicity first appeared on young shoots. The whole plants had a dull bluish green color in contrast to the bright green color of the healthy plant. Under moderate toxicity, chlorosis started from leaf tips so the lower part of the leaf remained green. As the severity of the symptoms increased, the whole leaf became chlorotic and all young emerging leaves were completely bleached. Even under the most severe toxicity, no necrotic spots were noticed, the whole leaf was chlorotic, bleached and dried up. These symptoms were more common when soil EC_{se} reached 23-24 $mScm^{-1}$.

Under field conditions, older leaves first turned light purple in color and dried up from the tip. In more severe cases the whole shoot became chlorotic and dried

Figure 5. Effects of soil salinity on Vetiver shoot chloride content

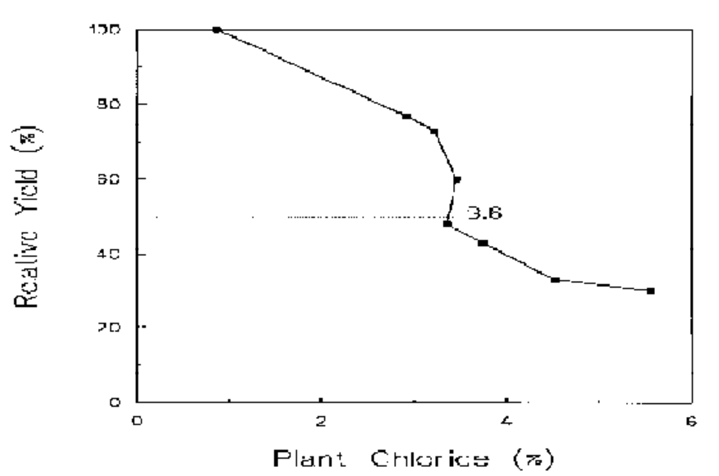


Photo 5. Root distribution pattern of Vetiver grass at varying salt concentrations

Photo 6. Root distribution pattern of Paspalum at varying salt concentrations

up. The chlorotic leaves in the field were not as bleached as those in the glasshouse.

Conclusion

This series of experiments indicate that Vetiver grass has a fairly high level of salt tolerance, especially in mature plants. Its salt tolerance is almost as high as Rhodes. Yield reduction of 50% can be expected when soil salinity (EC_{se}) of the top 50cm reaches between 15 and 24 $mScm^{-1}$ but more commonly near 16 $mScm^{-1}$. Plant chloride content is not a reliable indicator of salt toxicity in Vetiver grass.

Vetiver was found to be highly tolerant to shallow saline groundwater and could recover very quickly after rain. These attributes make Vetiver a suitable species for stabilization and reclamation of saline lands, especially in conjunction with gully stabilization.

Bibliography

1. Chandra, V., Singh, A. and Kapoor, L.D. (1968). Experimental cultivation of some essential oil bearing plants in saline soils. Perfumery Essential Oil Records 59: 869-73.
2. Francois, L.E. and Maas, E.V. (1978). Plant response to salinity - An Indexed Bibliography USDA, Science and Education Admin. ARM-W/6, October 1978.
3. Isbell, R.F. (1957). The soils of the Inglewood-Talwood-Tara-Glenmorgan region, Queensland. Queensland Bureau of Investigation. Technical Bulletin No. 5.
4. Russell, J.S. (1976). Comparative salt tolerance of some tropical and temperate legumes and tropical grasses. Australian Journal of Experimental Agriculture and Animal Husbandry 16: 103-109.
5. Shaw, R.J. (1988). Soil salinity and sodicity. In Understanding Soils and Soil Data. (Ed.I.F. Fergus) pp.109-134. Australian Society of Soil Science Inc. Queensland Branch, Brisbane, Australia.
6. Truong, P.N. and Scattini, W.J. (1990). Vetiver - the hedge against soil erosion? Australian Journal of Soil and Water Conservation 3: 16-18.
7. United States Salinity Laboratory (1954). Diagnosis and improvement of saline and alkaline soils. USDA, Agricultural Handbook No. 60 (U.S. Government Printer).

Table 12. Soil ECse and dry matter yields of mature Vetiver, Rhodes and Paspalum plants after six weeks exposure to saline water (Experiment 2)

	6	8	9	10	12	15	18	LSD
Rhodes Grass								
Yield*	n.i.	n.i.	n.i.	n.i.	22.99	16.34	16.43	n.s.
Soil EC_{se}**					50.72	72.16	73.44	
Vetiver								
Yield*	13.3	16.7	n.i.	13.7	n.i.	n.i.	n.i.	n.s.
Soil EC_{se}**	23.88	30.30		37.75				
Paspalum								
Yield	8.98	n.i.	11.18	n.i.	n.i.	n.i.	n.i.	n.s.
Soil EC_{se}	20.41		28.76					

n.i. not implemented

n.s. non significant at 5% level

* Dry matter yield g/pot

** Mean values ($mScm^{-1}$) for 0-12 cm depth

Excerpts From *The Experiments and Popularization of Vetiver Grass, Nanping Prefecture, Fujian Province, China*, By Mr. Wang Zisong

Three years have passed and we have achieved some success in research on propagation and utilization of vetiver grass.

Treatment	Depth of Roots (cm)	Width of Roots (cm)	Roots in 6.25m² profile	Number of roots at depths 0-20cm	20-40cm	40-60cm
Oil Seed Cake	55	42	165	120	30	15
Lime	35	35	41	32	9	0
CaMg Phosphate	40	40	55	28	27	0
Pig Manure	46	36	78	45	28	5
Control	50	35	50	20	20	10

Table 13. Root development under different manure treatments.

Utilizing Local Vetiver Grass

Our prefecture introduced and planted vetiver grass as an aromatic oil crop in the 1970s; later this cultivation was abandoned because of the low economic benefits. We were thus able to secure grass locally from Jianyang and Guangzhe Counties. We first did trial plantings for protecting the steep slopes of project tea farms and orchards. In 1989 we dug up 50,000 kg of the local vetiver and trial planted it on 29 farms. The planting area was 2,000 mu (133 ha) or 120 km of hedgerow. Since planting the hedges have grown well despite the cold winters, drought, flooding. Under normal conditions of water and fertilizer, survival rates are over 90%, tillering rates are 4-12 tillers/planted piece, grass height can reach 1.5m. The function of the grass for soil and water conservation is outstanding. To date, vetiver grass has now been planted on 50 project farms in our prefecture, planting over 3,500 mu (233 ha) with 195 km of hedgerow to protect 10,000 mu (666 ha) of land. Jianyang County has established about 6,100 meters of hedges.

To further experiment and popularize vetiver, a joint meeting was held between the Ministry of Agriculture and the Water Conservancy Ministry. This meeting moved the work on vetiver into a new stage in which a greater extension effort will be made.

I. Local vetiver grass growth

The climate in the prefecture is of the middle sub-tropical mountain-type. There are 1,668 to 1,972 hours of sunlight/yr; annual average temperature is 17.5°C to 19.3°C; in winter minimum temperature is -5.8°C to -9.5°C; maximum temperatures are from 39°C to 41.4°C. The no frost period ranges from 254 to 305 days. Annual rainfall is 1602mm to 1890mm. Local conditions provide that the growth of vetiver follows a general pattern of : i) late March to early April established vetiver begins to grow again; ii) from late April to middle July is the period of fast growth — many cuttings of fresh, young leaves can be had during this time; iii) growth slows from early to middle July through middle October as the grass moves into the reproductive stage ; iv) from early to middle October, flowering begins and seed bearing takes place in November; v) after middle November senescence begins. More frequent pruning in May to July will make for multi-peaks in growth; cutting from October to November will delay flowering and another growth peak will appear — this can be made use of to obtain more fresh cuttings.

Nursery Establishment

In 1989 we started with a 20mu (1.3 ha) nursery and today we have six nurseries totaling 48mu (3.2 ha); the six nurseries can supply 50,000kg/yr of vetiver slips. We have also developed 70mu (4.7 ha) of deserted vetiver plantation, through weeding and management, into a nursery. We have so far supplied 80,000kg of vetiver to the Provinces of Jiangxi, Guizhou, and Sichuan and to other prefectures in our province.

Research

I. Effects of different base fertilizers

A 5 x 3 fertilizer trial (12 plants/replicate) was carried out to compare applications of oil seed cake (10 g/plant), lime (42 g/plant), calcium magnesium phosphate (17 g/plant), pig manure (42 g/plant), and no fertilizer; though quantities differ, costs for each treatment is the same. The trial was carried out in a red soil (*ed. note* : red soils = Udults; acidic; high Al saturation). Table 13 shows the results on the plant root growth. Oil seed cake promoted the best root growth followed by pig manure. Table 14 shows that oil seed cake and pig manure's effects were about the same in aboveground biomass production. Oil seed cake manure than is the most effective for establishing vetiver grass in the marginal red soils, followed by pig manure. The effectiveness of lime and calcium magnesium phosphate was not very outstanding; though height and tillering under these treatments was better than in the control, the plants were slender and aboveground biomass reduced. This may have been a function of treatment-related change in pH and a decrease in available nitrogen.

Treatment	Average Number of Tillers	Height (cm)	Aboveground Biomass (kg)
Oil Seed Cake	23.7	136.3	5.0
Lime	12.0	96.7	1.7
CaMg Phosphate	17.7	104.0	2.4
Pig Manure	23.7	124.3	5.0
Control	10.0	94.0	2.6

Table 14. Treatment effects on aboveground biomass

II. Vetiver growth on barren lands

After six months, two area of vetiver planting were compared. Vetiver that was planted in good soils averaged 147 cm in height, 26.4 tillers/plant, and 136 fibrous roots whereas vetiver planted in barren, poor soils averaged 87cm in height and 5.9 tillers/plant. With fertilizer the vetiver on the barren soils would have done better but that it grew at all in the barren areas shows its resistance.

III. Cold tolerance of vetiver

In 1976 temperatures dropped to -9.5^{O}C, existing vetiver oil plantations were not killed out. These abandoned plantations still exist .

IV. Effect of varied planting densities

A 4 x 3 planting density trial was initiated in 1990; soils were red soils. Plant spacings of 15cm, 25cm, 35,cm and 45cm were tried. The 15cm and 25cm plant spacings were best, allowing a functional hedge to form within a year. Results are presented in Table 15.

V. Experiment of combining different hedge plants

A 5 x 3 experiment that looked at the effects of interplanting vetiver with other species (big mungbean, daylily, broadleaf barnyard grass, Japanese grass) versus vetiver by itself on hedge formation. Big mungbean was unable to survive the barren and droughty conditions but the other species did survive to form vegetative hedges in combination with vetiver grass. More work must be done in this area to see if such combinations may form more effective hedges.

VI. Experiment of different planting places

Vetiver was planted in 6 different locations (farms) in the project area. Grass height, and grass clump weight appeared to be correlated with the soil organic matter and available N. Table 16 summarizes the results.

VII. Experiment with vetiver as a contour vegetative barrier

Vetiver was planted within a chestnut plantation to see if it would form an effective vegetative barrier. Three kilometers (3 km) of vetiver hedgerow was planted in a 200 mu (13.3 ha) plantation. Planting was done at a 10m horizontal interval, with 3 slips of vetiver planted each 20cm. Within one year dense, functional hedgerows had formed; the average number of tillers/planting spot was 18.7.

VIII. Pilot experiment of vetiver contour hedges for controlling surface runoff

Two runoff plots of 100m^2 each were established side by side on a 20^{O} slope (36%). Both areas were made completely bare of vegetation. On Plot A, 3 hedgerows of vetiver grass were established; a runoff collection pond was dug at the base of each plot. Preliminary results from a few storm events showed that the vetiver plot had lost 60% less soil (115.8kg vs 284.9kg) than the untreated plot. This study will continue long term.

IX. Stemborers

Stemborers attacked a vetiver planting in a tea plantation in 1990. Across the effected area an average of 1.5% to 6% of individual plant's tillers were killed by the borers. Control may be achieved by insecticides or with cultural practices. The borers lay their eggs (which will overwinter) in early to middle September on young and tender growth, therefore pruning should stop in the autumn to allow growth to harden off before the egg-laying period.

Benefits Of Vetiver Planting

I. Preventing walls and ridges of terraces from collapsing

The cost of protecting terraces with stone walls is Yuan 22,500/ha whereas protecting with vetiver costs only Yuan 1,900. Also, according to multi-site experimental data the soil and water losses in some tea farms is serious and the terrace walls collapse easily without protection with vetiver. Terracing alone reduces soil losses on the average of 63%; terraces with vetiver plantings reduce soil losses 87%.

II. Preventing drought, decreasing temperature and storing water

Cutting vetiver hedgerows three times a year and spreading the clippings as a mulch in tea plantations and fruit orchards has reduced runoff an additional 7%; temperature in the top 15cm of the soil was also decreased 5°C compared to unmulched. Using vetiver from the in-plantation hedgerows can save Yuan 450/ha/yr by replacing rice straw.

Initial Spacing	Interclump distance (cm) (Replicate Number) I	II	III	Avg
15 cm	9	8	4	7
25 cm	10	6	11	9
35 cm	23	20	20	21
45 cm	26	23	20	23

Table 15. Effects of initial plant spacing on hedge closure at six months

EXCERPTS FROM *THE ALL-CHINA VETIVER NEWSLETTER; NO. 6 FEBRUARY 1991.*

Vetiver Grass News from Jiangxi Province

In Spring of 1989, a company in Jiangxi introduced some young Vetiver (V-grass) to many big provinces. The Jiangxi Province tried and planted 3,500 kg V-grass among 15 special fields. The V-grass being planted were about 5,000 m long, they spread over an area of 360 mu (15 mu = 1ha). The V-grass hedges are formed and sediment buildup is occurring. The effect of soil and water conservation is very obvious. As it is proved, V-grass is an ideal plant for soil and water conservation, it is worthy of promotion.

V-grass do not produce seeds, it can only be reproduced by vegetative propagation. In India, where V-grass is very popular it is propagated mainly by splitting young shoots from the plants. On the average, such method reproduces 12 young shoots per year. This rate of reproduction is very slow, and it requires digging into the original clumps. In order to promote reproduction, and not to dig into the V-grass clumps, we tried planting from culms. Basically, we have succeed. In August 10, 1990, we did an experiment. The experiment contained 4 sets, 3 applied different treatments, and 1 acted as a control without applying external treatments. 30 culms were planted in every set of the experiment. In about 7-10 days, new buds appeared on the branches, in 10-15 days, new roots begin to emerge. By September, the number of young shoots to appear in each set of the experiment are as follows: Set A: 23 tillers, 77% success; Set B: 20 tillers, 67% success; Set C: 2 tillers, 7% success; Set D (control) : 1 tiller, 3% success. It is seen that without any external treatment, the success rate is very low. Sets A & B have

Table 16. Site effects on vetiver grass

Location	Year Planted	Org. Matter (%)	Avail. N (ppm)	Avail. P (ppm)	Avail. K (ppm)	# of Tillers	Sum of Leaf Length (cm)	Root[1] Area (cm²)	Weight (kg)	Weight (kg)
1	90	0.60	23.8	1.8	0.30	3.5	122	110 x 10	0.17	0.09
2	90	1.19	32.2	2.5	0.36	6	360	20 x 20	0.17	0.09
3	90	1.37	32.7	3.0	0.65	8	880	50 x 30	0.58	0.33
4	90	1.48	42.9	2.3	0.30	12	1080	50 x 35	1.28	0.68
5	89	1.60	48.1	2.6	0.26	18	1620	50 x 40	1.43	0.83
6	89	1.99	57.4	2.7	0.36	41	6150	100 x 58	5.8	3.34

[1] Cross-sectional area occupied by the roots (vertical spread x horizontal spread)

a high percentage; planting culms has a practical value. On August 24, we tried the experiment for a second time, we repeated the experiment with Sets A & B and we obtained results which were close to the first one. Set A: planted 30 culms with 22 successfully establishing and Set B: planted 30, culms with 19 successfully establishing. Overall, planting of culms to reproduce V-grass is successful. This requires no digging, it makes use of the cut-offs of the V-grass shoots to grow the plant. This method of reproduction is very fast. This experiment was carried out during a dry and hot season which affects budding and growth of V-grass. If the experiment were carried out in a warm and humid spring weather, it is expected that V-grass would have a higher growth rate.

Vetiver Grass News from Hunan Province

The experiment site is located between the northern equator of 25" 44' to 26" 13' and eastern meridian of 113" 27' to 114" 14'. The weather here is hot and humid, the land is high above sea level and is surrounded by mountains. Over the years, it averages about 1689.6 sunny hours per year, temperature averages about 14.9 - 15.9°C. The highest temperature is 35.5° C, and the lowest is -9° C. No snow days average 240 days/yr, average annual rainfall is 1578 mm, average annual evaporation is 1323 mm.

In Winter of 1989, V-grass was planted in red and yellow soils. There was no rainfall for 57 days straight. V-grass survival rate was above 90%. After 5 months of rough management, its average yearly growth rate is 142 cm, the highest is 231 cm. Yearly tillering rate is about 15.8 young shoots, the most is 44. The root was as deep as 125 cm.

It has been observed that V-grass is very sensitive to temperature. V-grass planted in winter 89 began budding in February 90. By the middle of March, there are as yet few young shoots. During March and April, the temperature is low, avg 20.8 “C. Highest average soil temp: at 10cm deep is 14°C, at 20 cm deep is 12°C, at 30 cm deep is 10.2°C. From budding to April, some 40 days, its average growth is 17.5 cm, its average branching is 1.5. After May, average temerature is 24°C, highest average soil temp: at 10cm deep is 16.2°C, at 20 cm deep is 14.2 °C, at 30 cm deep is 12.4°C. Growth is rapid, it averages about 1.1cm/day, average branching is 2. When the weather is hot in the summer, V-grass grows even faster, it reaches 1.5cm/day and average branching is 3. Between the peak month of May and Aug, some insects affect the growth of V-grass.

	4/20	5/21	5/28	6/4	6/11	6/18	6/25
Average Height (cm)	0.12	13.5	20.5	26.5	31.5	36.8	51.4
Average Number of Tillers	1.3	2.7	3.7	4.5	5.4	7.2	10.9

Table 17. Observations on early growth of vetiver grass in Sichuan.

Vetiver Grass News from Sichuan Province

A nursery site is located in a rural area which is surrounded by rivers, it is located near N31°18'5" by E104° 23'. Planting began on March 27, 1990; 60 mu have been planted. The site is alongside a river and was used previously for growing vegetables. The land is sandy, it contains 2.5% organic matter, 0.125% nitrogen, 15 ppm active phosphorus, 125 ppm active potassium, 110 ppm potassium, pH is 7.0. Experience in the nursery has shown that when the V-grass clump has more than 20 tillers it is ready to be divided. This division can be done 4 times a year. From our experiments, if the avg temperature is above 12“C, V-grass can be transplanted. Retired roots and withered leaves would be trimmed, the branch is kept within 15-25 cm. Transplanting with soils can guarantee 100% survival rate. This procedure eliminates the period of budding, and it promotes fast tillering.

Observations on early growth (see Table 17) showed that when daily temperature averages 20°C, V-grass grows about 1cm/day and a tiller is produced every 7 days. When daily temperature averages 25°C, V-grass grows about 2 cm or above per day, and 3-4 tillers are produced every 7 days. From 12/27/90 to 3/27/91 average growth within a subsample (n=12) was 12.3 tillers/plant.

As a benefit from the management of the nursery fodder for cows is produced from the pruning of the plants.

In 1990, between August and September, there was some problem with worms. These worms penetrated into the stems of the V-grass and caused the stems and leaves to wither and die. After discovering this, on August 10, the tips of leaves and stems were cut and chemical sprays were used, but in early September, the situation got worse, chemical spray were applied again, after 3 days, all worms were dead. No diseases were during the whole growth period.

Excerpts From *A Preliminary Study On Vetiver (Vetiveria zizanioides) For Utilization In The Fight Against Erosion*, By Dr. Françoise Dinger

Propagation Of Vetiver

The objectives were to ascertain Vetiver's performance under our climatic conditions; its aptitude for vegetative multiplication (the current method for propagation); to develop *in vitro* (tissue culture) multiplication techniques and to introduce and put onto the market in the Mediterranean basin both the plant and planting techniques.

In July 1989 we received two ecotypes of vetiver from India — one from the regional research station in Paiyur and the other from a state horticultural farm in Thimmapuram; the latter type with a finer leaf so that the two types were referred to as large vetiver (LV) and small vetiver (SV). In August 1989 we received another type with a New Caledonian provenance; this type also had a finer leaf than the LV-type. We named it for its provenance as "NC". In total we had 53 plants with which to begin work.

Half of the vetiver was sent to the Centre de Formation et de Promotion Horticole (CFPH) in Ecully where they would also carry out experiments in vegetative and tissue culture propagation.

CEMAGREF Tests

I. Cold tolerance

The vetiver plants were placed in containers filled with a potting mixture ($^1/_2$ sand and $1/_2$ compost) on 20 July and grown until 10 October, providing material for testing. The first trials were to determine vetiver's cold tolerance, trials were carried out concurrently in Draix (Haute-Provence Alps)and in Grenoble (Isère).

"The objectives were to ascertain Vetiver's performance under our climatic conditions; its aptitude for vegetative multiplication; to develop tissue culture multiplication techniques and to introduce and put Vetiver onto the market in the Mediterranean basin ..."

Dr. Françoise Dinger

Draix is located in the mid-mountain country of the Mediterranean, soils are highly erodible black marls located between 850m to 1200m above sea level. Climate is Mediterranean with dry summers (some few, occasional storms) and most precipitation occurring in spring and fall. Winters are cold with little snow; between December and March there are an average of 90 icy days. Average annual rainfall is 900mm occurring over about 80 raindays; characteristically, rainfall events are intense and of short duration. Constraints to the development of the local vegetation in this zone are the high insolation (i.e. strong sunlight), unfavorable rainfall distribution, and low water holding capacity of the soils. For vetiver grass we considered that the lack of snow as an insulating blanket for the plants protection during freezing weather was potentially a constraint. In Grenoble, plants were placed in a greenhouse and received little sunlight, nor were they watered during the winter.

None of the plants in Draix survived the winter and in grenoble, only 3 (GV) vetiver plants survived out of the 34 planted. The survivors did not recover well, showing little vigor — by August 1990 they had only produced 3 or 4 tillers/each.

Research work was also carried out in the center at Ecully on both the Indian (LV and SV) and New Caledonian vetiver. The objective was to look at vegetative multiplication in consideration of light and temperature. Plants were placed in pots at four different dates and grown for ten weeks. Fertilization was every 15 days. Pots were placed outside to test cold tolerance and within a greenhouse where they were exposed to natural light conditions and extended (16 hours/day light using a mercury vapor lamp) light conditions. At the end of ten weeks note was taken of the growth. Results showed that the Indian plants were very sensitive to the cold though the winter of 89/90 was not severe (min. temp. - 6° C). Tillering rate was low in the winter period and no significant influence on tillering was observed as a result of differing photoperiod length; though the plants with the greater amount of light exhibited a greater degree of homogeneity in growth rates and had better root growth. The New Caledonian plants, which were observed under greenhouse conditions only, appeared to respond to the longer photoperiod with greater tillering. We concluded that the Indian vetiver is freeze-constrained under a temperate European climate and that photoperiod seems to influence growth and rhizogenesis but this conclusion requires further confirmation.

II. Tissue culture

Based on work that had been done previously with mediums for multiplication of Alpine Bluegrass (*Poa alpina*), vetiver grass was tested in the mediums which had produced the best results. The results with the vetiver were not as good; the vetiver did less well though rooting was not a problem. Continuance of this work has now provided nearly 5,000 plants to be outplanted in tests of hedgerow formation and efficiency. No particular problems have been noted to date with either diseases or pests.

III. Conclusions

Studies covered growth, development and propagation through two work phases : (1) laboratory, where a few samples were reproduced and (2) larger scale multiplication, where tissue culture was used to provide sufficient material for further testing of vetiver for erosion control and on conditions for reproduction. Resistance to cold was also tested in areas subject to freezing conditions and the ecotypes tested did not perform well. Further work should evolve based on testing of other ecotypes (e.g. Himalayan) which may display greater cold tolerance.

A third phase of work, coming up, will study flowering and germination; tests in somatic embryogenesis to develop resistance and to look at mycorrhization for optimization of plant multiplication and growth. Major-scale testing of vetiver for erosion control, perfecting of management techniques, and marketing feasibility studies will also be carried out during this third phase.

IV. Field Testing

Six sites were chosen for testing of vetiver grass as a hedgerow species based on microclimate (so results will be transferable to arid and semi-arid Mediterranean sites); on soil (to begin work on finding a vegetative solution to controlling erosion on blue marl soils) and strategic considerations. The sites are all located on a massif where the forests have been burned off and *Calamagrostis argentea* is common. Soils on 5 of the 6 sites are blue marls and the other is a friable clay. The altitudes of the sites range from 430m to 510 m above sea level and have aspects of north, south, southeast, east, northeast and west. Slopes range from a nearly level area on one site to 35% to 70% on the others. Four of the six sites are planted with tissue cultured plants and the other two with vegetatively propagated stock. On one site the native species *Calamagrostis argentea* is being compared to the vetiver. No results are yet available at this time.

Hedge	October	November	December	January	February
Vetiver	12.8	12.3	10.4	8.6	7.6
Cenchrus	11.1	11.5	10.9	9.4	8.4
Subabul	12.9	9.2	6.7	7.2	5.2
Desmanthus	11.4	11.1	10.2	9.0	7.9

Table 18. Effect of hedging (by species) on soil moisture (%) - 1988/89

Excerpts from *Vetiver Vegetative Hedge - Experience At Regional Research Station Aruppukottai* By Dr. S. Subramania

For sustained agriculture, conservation of agricultural assets are essential. This is more true in dryland agriculture. Land and water are the two major natural resources which need efficient management to ward against degradation of the environment and of agricultural productivity. Various soil conservation measures have been attempted and con-

Hedge	September	October	November	December	January	February
Vetiver	12.6	21.2	23.0	21.0	19.5	17.3
Cenchrus	12.1	20.1	22.8	20.4	19.2	16.9
Subabul	12.1	20.6	20.4	19.3	17.7	15.3
Desmanthus	11.9	19.0	23.0	20.1	18.1	15.7
Control	12.1	17.2	17.4	16.4	15.1	13.1

Table 19. Effect of vegetative hedging (by species) on soil moisture (%) - 1989/90

tour bunding had been accepted in India on slopes up to 6%. The system is effective, however, it is not without difficulties. (In) deep vertisols, where shrinking and swelling results in cracks up to one meter in depth, contour bunds get destabilized and become ineffective. Also saturation of soils and waterlogging behind the bund result in poor crop stand and growth. Another difficulty is that landholdings in India are small and this type of bunding requires co-operative efforts to achieve safe disposal of surplus water; in practice this cooperation is only achieved in stray instances. These factors necessitate new thinking on contour bunding, especially for deep vertisols; vegetative hedges seem to offer an advantage.

Tamil Nadu Agricultural University, Regional Research Station began in 1987 experimenting with Vetiver (Vetiveria zizanioides); Kolukkattai grass (Cenchrus glauca) which had been found to be the most drought tolerant grass in this part of the country. Hedge Lucerne (Desmanthus virgatus) and Subabul (Leucaena leucocephala) were added to the trials in 1988.

The establishment growth and coverage as a hedge was quite encouraging with vetiver as well as Cenchrus grass. The establishment was quick probably due to the fact that vegetative parts; plantlets for vetiver and grass slips for cenchrus, were used . However, the seed propagated Desmanthus and subabul experienced difficulty in establishing as hedge.

We monitored the moisture in the hedged portion as well as in the control with no hedge. The tabulated data shows greater moisture conservation through the vegetative hedge (Tables 18 and 19). Among the hedging systems tried, the vetiver hedging system has recorded higher percentage of soil moisture at all stages of the crop, followed by cenchrus hedging system .

Based on the experience of the first two years we are now planning and also planting with Vetiver, Cenchrus and Desmanthus in two mini-watershed areas of 8 ha each to study their relative performance in conserving soil and moisture. We are also planning interbund management practices to further improve the system. Among the various hedging materials, vetiver grass is the best known plant at this time, which can be used to help prevent sheet erosion and increase moisture conservation.

As the station does not have silt measuring devices we are not able to record soil erosion. From our visual observations we used to have rills and sometimes gullies in a field of 4.00 ha of about 1.2% during earlier years. After establishment of the Vetiver and Cenchrus vegetative hedges soil loss has been greatly reduced. We could also observe silt accumulation behind the contour vegetative hedges when we had a storm of 250 mm on a single day on 30.11.90 and 524 mm during the week 28th October to 3rd November.

The Vetiver Information Network

The purpose of the Network is to provide a central point where information on the use of contour vegetative barriers of Vetiver grass may be compiled and disseminated free of charge to all interested parties. If you wish to join the Network, request further information or supply information to other users, please write to :

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