CHAPTER 6

OTHER USES

OTHER USES, AND UTILIZATION OF VETIVER

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ABSTRACT:

In addition to being used to perform specific functions in soil and water conservation, environmental protection, disaster mitigation, etc., live plant of vetiver has also a few other uses, e.g. as forage for livestock, ornamentals, and miscellaneous other uses. Harvested vetiver leaves, culms and roots are utilized after some degree of processing in various ways, e.g. as input of agriculture-related activities (mulch, compost, nursery block / planting medium, animal feed stuff, mushroom cultivation, botanical pesticides, and allelopathy), handicraft and art works, medicinal applications, fragrance, input of construction-related activities (roof thatch, hut, mud brick, vetiver-clay composite storage bin, veneer / fiber board, artificial pozzalans, ash for concrete work, straw bale and bale building), containers (pottery, melamine utensils, water containers), bouquet, energy sources (ethanol, green fuel), industrial products (pulp and paper, panel), carbon sequestration and miscellaneous other utilization. This paper also discusses: (i) the main objective of growing vetiver, (ii) the growing of vetiver as a cash crop for utilization, (iii) the ecological benefit of growing vetiver, and (iv) botanical pesticides from vetiver.

Keywords: Use, utilization, ornamentals, mulch, botanical pesticides, handicraft, traditional medicines, perfumery, aromatherapy, industrial products.

1. INTRODUCTION

The present campaign on planting of vetiver in agricultural and non-agricultural areas for soil and water conservation has met with some problems in that the growers are not willing to plant vetiver as there is no direct income derived from such planting. In addition to the conventional uses, vetiver plant can also been used as forage for livestock grazing, as ornamental plant, and some other miscellaneous uses. In normal practice of growing vetiver for soil and water conservation, etc., there is a need to cut down the leaves every few months to encourage tiller growth and to reduce the danger of fire in the dry season. The cut leaves and culms can be utilized in various ways thereby providing extra income to the growers. In addition, the roots can also be utilized as a source of essential oil and botanical pesticides.

The present document attempts to distinguish between the terms 'use' of *live* vetiver plant and 'utilization' of *harvested parts* of vetiver plant. It then describes various other uses of *live* vetiver plant, and utilization of *harvested* vetiver leaves, culms, and roots.

1.1 Definition of Use and Utilization as Applied to Vetiver

1.1.1 Use: In this paper, 'use' is defined as "any direct exploitation of *live* vetiver plant".

1.1.2 Utilization: In this paper**, '**utilization' is defined as "the act of making profitable use of harvested (fresh, partly dried or dried) vetiver plant parts".

1.2 Use of *Live* Vetiver Plant

There are two main approaches of making use of *live* vetiver plant, namely:

1.2.1 Conventional Uses: These are the conventional uses of *live* vetiver plant to perform specific functions in agricultural and non-agricultural applications, such as for soil and water conservation, slope stabilization, erosion control, environmental protection, absorption of heavy metals, disaster mitigation, wastewater treatment, etc., without having to be harvested and processed into finished or semi-finished products. These, however, are not the subject of the present paper.

1.2.2 Other Uses: These are the non-conventional uses of *live* vetiver plant such as forages for livestock grazing, ornamentals, carbon sequestration and miscellaneous other uses. These will be discussed in Section 2.

1.3 Utilization of *Harvested* Vetiver Plant

As applied to vetiver, this involves the utilization of dried, partly dried, or even freshly harvested leaves and culms, and roots of the vetiver plant, either with no processing at all, or with some degrees of processing. These include the production of: (i) non-processed products, e.g. roof thatch, compost, mulch, mushroom medium, animal fodder, bouquet; (ii) semi-processed products, e.g. handicraft, some industrial products, botanical pesticides, pots, low-cost silo, furniture, bale building; and (iii) fully-processed products, e.g. essential oil and its derived products, herbal medicine, pulp and paper, fiber board, pozzalan cement, and industrial products. These will be discussed in Section 3.

2. OTHER USES OF VETIVER

2.1 Forage

Many investigators (e.g. Panichpol et al. 1996) have verified that the forage value of freshly cut vetiver leaves is comparable to other grasses. They also found that vetiver leaves contained insignificant amount of toxic substances, thus not harmful to the livestock. Vetiver is probably the only grass that provides any feed value at all during drought period. In Africa, for example, vast plains of *V. nigritana* are burnt each spring to produce an early bite for Fulani livestock (Juliard, pers. comm.).

2.2 Ornamentals

Being a grass with a beautiful form and aesthetic value, vetiver is sometimes used as an ornamental plant in landscaping, or as a decorative potted plant. These are discussed below:

2.2.1 Landscaping*:* Vetiver is a beautiful ornamental plant for gardens, patios, decks, etc. The bush of the vetiver plant is so large that it hides unsightly structures. Grown as a hedgerow, it forms a

dense, uniform, and attractive hedge under tropical and subtropical climates. It also forms an aesthetically beautiful barrier to unsightly view. Examples of the various uses of vetiver in landscaping are the followings:

2.2.1.1 As a Decorative Hedge: Vetiver is used as a decorative hedge on the round abouts. It looks good and seems to serve a good purpose. For example, it is grown primarily for aesthetic reasons by the C'mara Municipal de Portim'o, Portugal (Pease 2002a). These hedges also serve a useful function by hiding from view the traffic that is passing on the opposite side of the round **abouts.**

***2.2.1.2 For Dual Purpose in Beautifying the Landscape and Environmental Protection*:** Vetiver hedges have been used to stabilize soils and control erosion in amenity sites such as golf courses and water park recreational areas. In many countries such Australia, China, South Africa, the use of vetiver hedgerows as a combined landscaping and land stabilization tool also produce an aesthetically pleasing hedgerow system. In Thailand, vetiver hedgerows are used very effectively as borders to vegetable plots and flowerbeds, for filtering runoff water to farm ponds and for stabilizing their banks. Along the winding road up hill leading to the Doi Tung Development Project, Chiang Rai, vetiver was planted for decorative and ornamental purposes, in addition to its main objective of stabilizing roadside. On the US Virgin Islands, construction of the hotels and condominiums has added stress to the coral reef. These commercial properties are beautifully landscaped. Vetiver was planted in spring of 1999 along a huge side slope of a highway in Qinggliu County of Fujian Province, China, in conjunction with limited use of concrete walls at the most critical sections. A dense living hedge of vetiver formed after 3-4 months. The total cost for vetiver planting was only 50% of using other types of grasses, but the result is a green cover of the side slope instead of a huge concrete wall, which 'looks like a tomb' (Xu, pers. comm.)

***2.2.1.3. For Reservoir Landscaping*:** A common problem found around reservoirs is the barren strip on the shore caused by the fluctuation of the water level in the reservoir. The height of this level sometimes exceeds 10 m. Since reservoirs have become recreation sites and efforts to vegetate the banks have been unsuccessful in the past, vetiver, by virtue of its resistance to surviving in the water for a period of time, has been used to be grown on the bare banks of a reservoir in China which, after four months, were greened up completely (Xu, pers. comm.). In Thailand, vetiver was planted on reservoir bank of Kasetsart University Chalermprakiat Sakon Nakhon Campus (Anon. 2000). The result was beautiful scenery of the reservoir with no erosion of the lateritic soil.

2.2.2 Decorative Potted Plant: Grown in large pots, vetiver forms a nice bush with green foliages, some upright while the others drooping. They can be used to decorate platforms, stages, etc., as seen in the followings: Potted vetiver plants were used to decorate the stage at ICV-2 held at Dusit Resort in Cha-am, Phetchaburi, Thailand during 18-22 January 2000. In Senegal, small growers and nurseries grow vetiver in large clay pots and sell in nearby towns and cities for use as ornamental plants (Juliard 2002b). In Vietnam, vetiver is also grown in pots to be used as decorative potted plant outside an office. Thien Sinh Co., an ornamental plant firm, has promoted the use of vetiver for home decoration during the 'Tet' festival (Truong 2002).

2.2.1 Miscellaneous Other Uses

2.3.1 Wincing the Car out from the Ditch: This story was publicized in the Vetiver Network Discussion Board (Juliard 2002) whose details are as follows: "One day in August 2002, Scott Grenfelt of the World Wildlife Fund working in Andringitra, Madacasgar, and his teammate got caught in a rainstorm on the Namoly-Ambalavo road. The land cruiser they were in slipped down into a ditch of the road with steep bank where vetiver lines the sides. They could not get it out from

the ditch. An artist in the car suggested that the winch be hooked up to the vetiver plants along the side of the road and that it would most likely hold the force because the roots are so long. Nobody accepted the idea but the artist insisted on his idea by winding several strands of the vetiver plants, hooking on the winch to the tied-together plants, reveving up the engine and wincing. The car was pulled out with no sweat!"

2.3.2 As Field Boundaries: In many places, vetiver has been used as field boundaries, field subdivisions, separation between different sections of garden plots, etc. For example, in West Africa, as early as 1937, Dalziel (1937) reported that vetiver was used as a border for roads, gardens, and cultivated fields to prevent the extension of Dub grass *(Desmostachys bipinnata).* As it does not produce any seeds, and cannot 'move' to other places since it does not have stolons or runners, the demarcation is permanent and clear cut. Maintenance is minimal, by cutting down the leaves every 3-4 months. Many Thai farmers are now using vetiver to separate their fields and vegetable plots.

2.3.3 As a Barrier to Prevent Dust and Heat from Coming into the Property: A thick and permanent hedge of vetiver can act as an excellent barrier to prevent dust and heat from coming into the properties, especially those which are affected by dust or heat.

2.3.4 Water Purification: At ICV-3, Simon (2003) reported that many water sources in Cameroon were highly contaminated, causing a high rate of deaths of the people. Filtering water through stones, sand and charcoal, and then purifying with vetiver have been reported to improve the situation.

3. UTILIZATION OF VETIVER

3.1 Agriculture-related Activities

3.1.1 Mulch: In tropical countries with high and intensive rainfall, mulching is one of the most important conservation methods. Similar to other mulching materials, vetiver leaves provides shade to the plot, thereby decreasing the temperature and at the same time conserving moisture of the plot and keeping weeds under control. Vetiver leaves are excellent materials for mulching; they are durable and long lasting. Vetiver mulch can be applied to vegetable plots, at the base of fruit trees, and field-crop plots.

3.1.2 Compost: Vetiver leaves and culms are completely decomposed to become soft, disintegrated, and dark brown to black in color. Vetiver compost contains major nutrients from the decomposition process, i.e. N, P, K, Ca, and Mg with a pH of 7.0. In addition, vetiver compost also provides humic acid that enhances soil fertility.

3.1.3 Nursery Block and Planting Medium: The Doi Tung Development Project in Chiang Rai, Thailand is producing nursery block and planting medium from vetiver leaves and culms. The products are now on sale with increasing popularity.

3.1.4 Animal Feed: The young vetiver leaves can be ground to feed fish and livestock, but mature leaves cannot be used for such purposes because their nutritive value is lower than other grasses, and because of the high roughness and silica content. The analysis also indicated that vetiver has the content of crude protein lower than that of other grasses used for animal feed (Anon. 1990b; and Panichpol et al. 1996). In the State of Karnataka, India, vetiver is planted along the field boundaries and cut every two weeks or less for use as fodder. Vetiver was found to have relatively higher structural carbohydrates as compared to native grass and rice straw. On the other hand, it also had optimal levels of crude protein, considered to be enough to maximize intake and digestion of the vetiver forage. It was concluded that vetiver may be used as ruminant feed if it is mixed with other good quality feed and forages (Anon 1990b).

3.1.5 Mushroom Cultivation: Vetiver leaves contain chemical compounds such as cellulose, hemicellulose, lignin, and crude protein as well as various minerals in which certain mushrooms can feed on. Many investigators have been successful in cultivating mushrooms using vetiver as the medium for their growth. Oyster, shiitake, and straw mushrooms are among those that can be produced using small pieces of vetiver as a medium.

3.1.6 Botanical Pesticides: Traditional utilization of vetiver as botanical pesticides in various countries has been extensively reviewed by the author (Chomchalow 2001). These are:

3.1.6.1 Insecticides: With the evidence that vetiver has no serious insect pests, it is obvious that the insects have an absolute distaste for vetiver, as were reported in the following cases: Levy (1940) observed that the vetiver plant grown in close proximity to the sugar cane could inhibit to a very substantial degree the attack upon the sugar cane of certain insects such as the cane borer. Likewise, a farmer in Louisiana reported that in a plot of crop where vetiver was used as mulch, no insects of any kind ever came near. It has also been found that the tops of vetiver, in the same formation of mixture with the residue of the roots, will make an absolute repellent for the insects that may damage strawberries grown in southern U.S. (Grimshaw 2002b). Recently, Maistrello and Henderson (1999) found a group of compounds, such as nootkatone, in vetiver roots, which were able to disrupt termite behavior and physiology as a consequence of direct physical contact, ingestion, or exposure to the vapors. They also found that ingestion of wood treated with vetiver oil or nootkatone causes the progressive death of the protozoa living inside the termite gut, ultimately results in a progressive decline of its colony through starvation, as these termites rely on the protozoa for the digestion of their wooden food.

Criss Juliard (pers. comm.) informed the author that a man in Senegal invented a mosquito repellent by mixing vetiver root and groundnut shell into a small ball which he tested in a rainy season as a smoker against mosquitoes. It was evident that there was a significant drop in malaria in the village he tested.

3.1.6.2 Fungicides: In New Zealand, Greenfield (2002) noticed that fungal attacks on the vetiver-mulched plants have virtually disappeared and there seem to be little, if any other pest action around the host plants. Thus vetiver mulch seems to have natural fungicide to stop the growth of the fungi which attack the crop plants.

3.1.6.3. Agaricides: In Thailand, Korpraditkul (1996) found that 10% vetiver oils of different vetiver ecotypes were variably able to control cow ticks at both the larval and adult stages. Furthermore, extract of dry root was able to control adult stage of ticks better than larval stage.

3.1.7 Allelopathy: It has been observed that in the vicinity of the vetiver clumps, there are a few other plants growing. It was hypothesized that certain substances excreted by the vetiver plant may have allelopathic action in that they inhibit the growth of other plants. Techapinyawat (1994) reported that root and stem extracts of vetiver could inhibit the germination of soybean seeds. It was concluded that vetiver extract contains in vetiver oil has allelopathic effect in inhibiting the germination of seeds of any plant growing in its vicinity. It was further suggested that this could be applied to control the weeds of crop plants without the use of chemical herbicides.

3.2 Handicraft

3.2.1 From Leaves and Culms: Handicraft products made from vetiver leaves include: (i) handy accessories such as bags, hats, belts and brooches, (ii) containers such as baskets, pots, boxes, utility bowls, (iii) decorating materials such as clocks, picture frames, lamp shades, dolls, animal figures, flowers; and (iv) home appliances such as chairs, stools, room partitions, tables. The Thai Department of Industrial Promotion (1999) has developed a way to boil the leaves, and with a

needle, remove the sharp teethed edges before using the flexible leaf to weave a broad array of wonderful products.

3.2.2 From Roots: It has been well known since ancient times that vetiver possesses aromatic roots. A pleasant aroma is released from vetiver root dug from the soil and hanged in the shade. In India the dried roots are used to give fragrance to linen clothes while the root mass is used as a blind to cool down the heat of the summer, especially in northern India (Sastry 1998). The blind, known as 'Tatti', is woven from the wiry, fibrous root of vetiver. The vetiver blind is continually doused with water throughout the day, turning the hot wind into a scented cooling breeze, which passes through the soaked vetiver blind, releasing a bitter-sweet aroma. The scented vetiver roots are also used for making fans, cloth hangers, and are mixed with other kind of flower scents and leaves for making sachets.

3.3 Medicinal Applications

3.3.1 Traditional Medicines: Vetiver roots and leaves have been used in therapeutic treatments. An extensive review of the utilization of vetiver as medicinal plants has been made by the author (Chomchalow 2001). Thai people have long known how to use various vetiver parts for medicinal purpose. Rural people in Thailand have used vetiver roots in the treatment to dissolve gallstones, reduce fever, and in treating diseases related to bile and the gall bladder, and healing stomach discomfort. Lavania (2003a) described how vetiver oil was used in Ayurvedic system of medicine in India. He cited the cases of applying the oil locally to relief rheumatism, lumbago, headache, sprain (Anon. 1976), and of using infusion of roots as refreshing drink in fever, inflammation and irritability of stomach. At ICV-3, Simon (2003) described how vetiver is used as medicinal plants in Cameroon. The diseases which vetiver has been found to be most effective are prostrate cancer, diabetes, hernia, incontinence, stomach problem, and skin conditions.

3.3.2 Herbal Drink: In the hilly regions of Karnataka, India, people made use of vetiver roots to prepare refreshing drinking water (Sastry 1998). Chomchalow and Hicks (2001) described the method to make vetiver root drink or 'Nam Ya Faek', a Thai traditional beverage as follows: "A handful of vetiver roots and leaves in equal proportion are boiled with four glasses of water until the liquid is concentrated to a quarter of a glass". It is taken as herbal drink.

3.4 Fragrance

The use of vetiver root for essential oil extraction to produce perfume and other fragrant materials such as potpourri, aromatic soap, aromatic wax, and aromatic kaolin, etc. has been well known in tropical countries where vetiver thrives in natural condition. These countries include India, Indonesia, Reunion Island, Haiti Islands, Fiji, Sri Lanka, and Brazil. Certain countries in Central America, namely Hondurus, Guatemala, and Mexico, also make use of vetiver root in this manner.

In the olden days, Thai people made use of vetiver root as an ingredient of fragrant materials such as potpourri, hair pomade, and volatile oil for skin treatment. Such a process was passed on from generation to generation without written record. However with the extensive production of perfumes and other fragrant material from other aromatic plants or from synthetic substances at present, the use of vetiver root as a source of fragrant materials has lost its importance.

Commercial cultivation of vetiver for oil extraction as well as the extraction methods and properties of vetiver oil has been discussed in details by the author (Chomchalow 2001). The use of vetiver as fragrant materials will be discussed under the following headings:

3.4.1 Perfumery: Vetiver oil is viscous, light-brown oil with a rich green-woody earthy and nut-like fragrance (Downwaithe and Rajani 2002). In its diluted form, vetiver oil is used to provide

sweet note and soothing cool effect. It has been utilized as raw material for various fragrant products such as perfumes, deodorants, lotions, soaps, cosmetics, etc. (Chomchalow 2001). Having complex chemical composition and oil odor, high solubility in alcohol that improves it miscibility with other perfumery material, vetiver oil is a unique perfumery resource. Having low volatile rate, it is one of the finest fixatives known. For blending, it is used in oriental type of perfumes and floral compounds (Lavania 2003b).

3.4.2 Aromatherapy: Aromatherapy is the use of essential oils for therapeutic purposes. Vetiver oil has been used extensively in modern aromatherapy. It is used to balance the activity of the sebaceous oil glands as well as having deodorizing properties and helping normalize oily skin and clear acne. It also replenishes moisture in dry and dehydrated skin and has rejuvenating effect on mature skin. It prevents stretch marks of pregnant women if applied regularly. It also strengthens the central nervous system, and can overcome depression, insomnia, anxiety, stress, tension and nervousness (Lavania 2003a). It is also used as an aphrodisiac (Wilson 1995).

3.4.4 Flavor: In India, vetiver essence is used to flavor a soft drink *(Sharbat)*, syrup, and ice cream (Lavania 2003a).

3.4.5 Potpourri: Potpourri is a mixture of dried flower petals with spices, kept in a jar for its fragrance. Chopped, dried vetiver roots can be made into potpourri by mixing them with dried fragrant flower petals and spices.

3.5 As an Input of Construction-related Activities

3.5.1 Roof Thatch: Thai people as well as other rural people in Asia have long utilized vetiver culms and leaves for roof thatching in the same way as nipa palm and cogon grass leaves. Vetiver has a better quality for roof thatching than cogon grass because the culms and leaves of vetiver are coated with wax, and have a unique scent that repels insect and fungal attacks. The durability of a vetiver thatch depends on the neatness of thatch making. The thatches with more or denser vetiver grass will be more durable. The manner in which the thatches are laid on the roof also matters. For example, on a steep roof like that of a traditional Thai house, vetiver thatches can be more durable than on a flatter-roofed structure. Vetiver has also been used as roof thatch in several other countries in Africa where thatch is vital for roofing of many rural houses (Grimshaw 2002a). In Ethiopia, vetiver has replaced the traditional thatching grass in some areas as it lasts longer and makes a more rain-proof roof (Anon. 1990a).

3.5.2 Vetiver Hut: In Senegal, native vetiver *(Vetiveria nigritana)* leaves are used in the building of simple huts (Juliard, pers. comm.). In India, dried roots of vetiver have been used since ancient times for making makeshift huts and cabins as they provide cooling effects during the summer (Lavania 2003a).

3.5.3 Vetiver Mud Brick: Juliard (pers. comm.) reported that in Senegal vetiver is used in mud-brick making as it reduces cracking.

3.5.4 Prefabricated Vetiver-Clay Blocks: At ICV-3, Hengsadeekul and Nimityongskul (2003a) of the Asian Institute of Technology reported on the experimentation of making prefabricated vetiver-clay blocks for use as construction materials, starting with material preparation, laying vetiver-clay composite in mold, pressing process, remolding and turning face up on designed support plate, sun drying, dry heating, and block laying steps with clay slurry as wall panel. They concluded that vetiver could be used with clay composite for substituted bricks and columns for housing construction. The prefabricated wall has rather low thermal conductivity which makes it comfortable and energy saving. It is truly a labor-based appropriate technology.

3.5.5 Vetiver-Clay Composite Storage Bin: Vetiver can be used raw material for the construction of low-cost storage bin. At Chitralada Palace in Bangkok, a grain silo made of vetiver-clay composite was piloted (Nimityongskul and Hengsadeekul 2002; and Hengsadeekul and Nimityongskul 2003b). The silo has a diameter and height of 3m. It is about 1.2m above the ground and its capacity is $20m^3$. Its foundation was constructed with reinforced concrete while its ground wall and slab were built with cement-block filled with reinforced concrete. The silo walls were constructed with vetiver-clay bundle, coated with cow-dung mixed with clay and rice husk, while its roof was of bamboo structure thatched with vetiver bundle overlaps. A structural component for ventilation that reduces moisture and temperature forms part of the proposed structure.

3.5.6 Cement Replacement Material: Vetiver ashes have been experimentally used as low-cost, environmental-friendly, and energy-saving construction material. At ICV-3, Nimityongskul et al. (2003) reported on the experiment of using vetiver grass ash (VGA) as a new building material specifically for the rural areas of the developing countries. The properties of VGA were investigated in order to consider the possibility of using it as a pozzolanic material. The physical and mechanical properties of VGA and cement mortar containing VGA were also determined. They concluded that it is possible to use VGA as a cement mortar.

3.5.7 Fiber Board: The Royal Project Foundation (Thailand) has been successful in using vetiver to substitute wood in making furniture and interior decorative appliances.

3.5.8 Straw Bale: Straw bales are used in building construction. The concept of using straw bales with cement facing in building construction has been accepted by the fire authorities in a number of countries. The technology reduces costs greatly and provides excellent insulation. Pease (2002b) described the straw bales that were made from vetiver leaves; the bales were almost free from insect as the vetiver possessed repelling chemicals in it.

3.5.9 Bale Building: Cory Vitt (2007) of the Asian Institute of Technology experimented on the use of vetiver straw bale produced by square baling machine to make plastered walls. He then created a building which demonstrated the building techniques using the salvaged or recycled full-scale plastered walls that were used for testing purposes. He concluded that straw bale building techniques can be used to construct plastered vetiver-bale buildings.

3.5.1 Containers

Many kinds of containers can be made from vetiver. Among these are:

3.6.1 Pottery: In Senegal, artisans have made some pottery by mixing chipped vetiver mixed with clay, giving the finished non-fired product a nice earthy texture (Juliard, pers. comm.). In Thailand, a project on the production of vetiver pots has been initiated by the Doi Tung Development Project. The pots are low-priced and environmental friendly as they disintegrate after few months. Thiramongkol and Baebprasert (2002) have experimentally produced vetiver pot to be used as containers for plants prior to planting operation. The vetiver pot is made of clay, dry vetiver grass leaves and a binder (polyvinyl alcohol or 'Pival'), which is safe for soil and water. After hardening and planting in the pot, the potted plant is put directly into the ground without removing the pot. Production process includes mixing of clay with dry vetiver leaves, then mix with water and 'Poval' by extruder, jigger. Leave it in the plaster mold for 30 min, then take out the mold. Vetiver pots possess the unique property of allowing the user to plant any kind of plants, from vegetables to trees, without the trouble of removing the pot before planting.

At ICV-3, Thiramongkol et al. (2003) reported on the investigation on making glazed ceramic pots of various colors from vetiver and clay at the proportion of 1:10 and fired at $1,200^{o}C$. The pot is light-weight with good aeration on the surface, thus enhancing maximum benefit for growing orchids and other ornamental plants.

3.6.2 Melamine Utensils: The Thai Royal Project Foundation has attempted to produce melamine utensils from vetiver leaves. The products were of good quality.

3.6.3 Water Containers: These are based on the same principle as the vetiver-clay composite storage silo (as discussed in # 3.5.5), but built on ground level, and used as water containers or small fish ponds.

3.5.2 Energy Sources

Two forms of energy sources can be made from vetiver, namely:

3.7.1 Ethanol: Kuhirun and Punnapayak (2000) described the process of producing ethanol from vetiver leaves. Dry leaves were first pretreated with alkali. The simultaneous saccharification and fermentation (SSF) technique was used to convert plant residues into ethanol. The cellulase enzyme for SSF was prepared from *Trichoderma reesei*; this enzyme activates specific reaction for the release of glucose for fermentation into ethanol. The addition of alkali-pretreated leaves, cellulase enzyme, and fermentation yeast at 40^{o}C, pH 5.0, for seven days yielded ethanol. By using a one-cycle column distillation, the ethanol yield was 13%. The ethanol produced was clear in color with a slight pleasing odor.

3.7.2 Green Fuel: Broken vetiver culms and leaves that cannot be utilized for other purposes can be mixed with water hyacinth, as a mixer, in a proportion of 3:2 (Babpraserth et al. 1996). Then compress the mixture into shafts with a cylinder-shaped fuel squeezer, 1.7 cm in diameter. Fuel shafts can burn easily and produce little smoke, but yields high temperature. For example, it takes 5 min. to boil 1L of water, and the fuel still keeps on burning for up to 28 min.

3.5.3 Industrial Products

3.8.1 Pulp and Paper: Vetiver can be used as a raw material for making pulp and paper. In India, studies that were carried out at the Forest Research Institute, Dehra Dune, revealed that pulps suitable for making strawboards can be made from vetiver by digestion with lime (Anon. 1976). Vetiver has a high content of hemicellulose; its cellulose content is 45.8% (DW). Pilot-plant trials have indicated that vetiver yields a chemical pulp that can be used for making writing and printing papers. Containing short fiber, the pulp has to be used in admixture with 30-40% of a long-fibered pulp.

3.8.2 Panel: The Royal Project Foundation (Thailand) was successful in making a panel from vetiver root mass.

3.9 Miscellaneous Utilization

3.9.1 Bouquet: Bundle of cut vetiver leaves and culms can be used as materials of a bouquet, or decorative plant in containers such as vase, pot, etc. for display.

3.9.2 Mattress and Other Stuffing: In Ethiopia, vetiver has been utilized as a primary material for mattress stuffing (Anon. 1990a). In India, vetiver roots are used a stuffing material in ventilating panels used in electric desert coolers.

3.9.3 Cooling Effect: In India, the vetiver root have been used since ancient times for making woven screens, mats, blinds, hand fans, broom hangers, and baskets. When sprinkled with water and hung at the proper ventilating space, such materials provide cooling effect and pleasant aromatic air (Lavania 2003). They are also used on car rooftops to provide cooling effect. In outer Delhi, India, poultry farmers kept their large poultry houses cool using desert coolers and heat exchange by forcing air through ‘wet mats’ made from woven vetiver roots (Greenfield 2003).

4. DISCUSSION

4.1 Main Objective of Growing Vetiver

It must be stressed that the main purpose of growing vetiver is for soil and water conservation in agricultural and non-agricultural applications. Other related uses such as for environmental protection, heavy metal absorption, embankment stabilization, etc. have also been envisaged. His Majesty the King of Thailand has repeatedly summoned that uses other than the ones just mentioned, as well as the utilization of harvested material, should not be overemphasized to nullify the main uses of vetiver.

4.2 Growing Vetiver as a Cash Crop for Utilization

4.2.1 For Vetiver Oil Production:

4.2.1.1 Growing in the Field: World demand for vetiver oil has increased somewhat in recent years due to the shortage of supply from producing countries such as Indonesia, Haiti, India. This may be largely attributable to the increased use of vetiver oil for aromatherapy. This increase, however modest, in cash income from vetiver has both positive and negative aspects. Positively, the cash income could attract small-scale farmers to plant vetiver hedgerows where a market for oil exists. Negatively, there is the danger that farmers could remove plants from a soil conservation barrier for cash earning and, thereby, destroy the soil and water conservation attributes of the hedgerow barrier. In this connection, Pease (pers. comm.) proposed that planting of vetiver as a double hedgerow would help, especially the small holders. With a double-hedgerow system, one hedge would be harvested, say every two years for oil extraction from the roots, leaving the other to act as the soil and water conservation barrier. The harvested hedge would then be replanted and the system continued *ad infinitum*.

4.2.1.2 Growing in Bags or Other Containers: The author (Chomchalow 2001) described the experiment conducted in Thailand of growing vetiver in 30 cm diam., black polyethylene bags that yielded approximate half a kilogram of dry root within one year having 1% oil. The advantage of this system of growing vetiver in sand-based medium in large polybags is that harvesting is much more efficient than growing in the field, and can make efficient use of degraded land since the land is only used to lay polybags on.

4.3 Ecological vs. Economic Benefit of Growing Vetiver

There is no question that vetiver has a considerable ecological benefit in soil and water conservation as well as environmental protection. Its hidden economic value of an inexpensive means of stabilizing backslopes and sideslopes of the highways, railroads, as well as earthen dams is also increasingly being recognized. Increasing awareness of the ecological potential of vetiver in controlling pollution, and in protecting our environment such as in wastewater treatment, heavy metal contamination, etc. are likely to be envisaged in the near future.

To small-scale farmers, however, these somewhat intangible benefits may be difficult to be recognized. It is a challenge to the extension services to persuade farmers of the long-term ecological benefits of soil conservation and the much more immediate economic benefits of crop yields that are rapidly discernible in retaining soil moisture and plant nutrients between hedgerows. It is difficult for a small-scale farmer to allocate some of his scarce land resource to the planting of a vetiver hedge as this would remove the land from his subsistence agricultural production.

4.4 Botanical Pesticides from Vetiver

The author is intrigued by the proposal of Pease (pers. comm.) that, " If a packaged mulch product were to be made from the dried, chopped roots and tops that could be used to kill or repel

common garden pests and termites that could substitute for insecticides and fungicides, the mulch product could be used domestically by the farmers themselves for their needs, particularly for producers of certified 'organic' crops. Perhaps the mulch product could be exported in a compressed form to European and North American markets".

There was a report from Louisiana State University (Maistrello and Henderson 1999) that one of the components of vetiver oil kills the Formosan termite. It would be great if a mulch of vetiver roots and leaves could substitute some harmful insecticides. The farmers could grow their own supply and use it on their own plots.

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