AU JOURNAL OF TECHNOLOGY

VOL. 2 NO. 4 **APRIL 1999**

AU Journal of Technology (AU J.T.), an international quarterly publication of Assumption University, deals with topics of current research interest, mainly in the fields of science, engineering and technology. The Journal is owned by Assumption University and published on non-profit basis. All articles appearing herein are the property of Assumption University; all rights are reserved. Inquiries or comments on materials published may be addressed to the Editor, AU Journal of Technology, Assumption University, Ram Khamhaeng 24 Rd., Hua Mak, Bangkok 10240, Thailand. Tel. (662) 300-4543 to 4553, Fax. (662) 300-4563, 300-4552, 300-4511. E-mail: *journal@au.ac.th*

DNA Fingerprints of the Pantropical Grass Vetiver, *Vetiveria zizanioides*

Robert P. Adams and Mark R. Dafforn *

Plant Biotechnology Center, Baylor University
Gruver, Texas, USA

VETIVERIA

Abstract

*Random Amplified Polymorphic DNAs (RAPDs) were used to examine accessions (n=121) of vetiver (*Vetiveria zizanioides *(L.) Nash) and related taxa from its region of origin and around the world. It appears only one V. zizanioides genotype, 'Sunshine', accounts for almost all germplasm utilized outside South Asia. Curiously, no 'Sunshine' types were detected from within this region of vetiver's early distribution. Additional RAPD analyses revealed that at least seven other non-fertile accessions are distinct genotypes. This germplasm diversity holds promise for reducing the vulnerable genetic uniformity in what is now essentially a pantropical monoculture of an economically and environmentally important plant resource. Evaluation trials of these accessions are planned. DNA from air-dried leaves was often found to be degraded beyond use (n=22). Material submitted for DNA analysis should be small (actively growing) leaves, harvested fresh and immediately placed into activated silica gel or other suitable drying agent.*

Introduction

Elite germlines of vetiver *(Vetiveria zizanioides* (L.) Nash*)* have long been cultivated throughout the tropics for their fragrant roots, which contain the essential oil of vetiver. This oil is clearly distinguished chemically and in commerce from *Khus* oil, which comes from natural (fertile) populations of *V. zizanioides* in the Ganges Plain of north India (CSIR 1976). Populations of the oil of vetiver types have increased enormously in the past decade through vegatative reproduction for widespread plantings (over 100 countries) of hedges to stabilize soil and control water flow.

One of the desirable features of most hedgerow (essential oil) vetiver is that it is non-fertile (produces no seed or seeds do not produce viable seedlings), and so it must be propagated from cuttings (clumps of rootstock). Because it does not reproduce by seed, for centuries it has been a very well-behaved grass throughout the tropics and subtropics. It has not escaped cultivation or become a weed. However, the mere fact that it is always distributed by cuttings could lead to the widespread cultivation of a single clone. This could be extremely dangerous. An insect or disease adapted to a particular genotype could spread and decimate millions of erosion control terraces of vetiver. In order to investigate this concern, we assembled leaf materials from around the world and compared these accessions to known wild and related materials using RAPDs (DNA fingerprints).

Genetic variability was initially investigated by Kresovich *et al.* (1994), who reported on vetiver variation in the US. They found RAPD patterns were very stable within clones, that the non-fertile 'Huffman' and 'Boucard' cultivars were identical (>0.99), and that these were clearly distinct from the USDA PI 196257 seed introductions from north India (Simla, Punjab). Interestingly, they found that three samples of this USDA accession (# 1,2,3), though similar, were genetically distinct

* *Office of International Affairs, National Academy of Sciences, Washington, DC 20418, USA; vetivernet@aol.com*

AU J. of Technology
2(4): 173-180

from one another. They concluded that RAPDs would be useful for identifying truly distinct sources of genetic diversity. Srifah *et al.* (1998) confirmed this in Thailand (where vetiver is ancient if not indigenous) by showing that RAPDs could easily distinguish among landrace "ecotypes".

Materials and Methods

The reader is referred to Adams *et al.* (1998) for DNA extraction and analyses. However, it should be noted that a number of the accessions that were merely air dried or shipped fresh did not yield any DNA or the DNA was so degraded that it could not be analyzed. In the future, vetiver material submitted for DNA analysis should be small (actively growing) leaves, picked fresh and immediately placed into activated silica gel or other suitable drying agent.

Results and Discussion

An initial screening of accessions (n=53) using 222 banding patterns found almost no variation among cultivated materials. The uniform pattern obtained by primer 268 is typical of that obtained using primers 184, 239, 249, 327, and 346. Essentially no variation was detected in an initial 27 accessions for outside South Asia, except for a quite-similar accession from Malawi.

A second series of accessions (n=68) were analyzed running only one highly discriminating primer (268). This analysis, while revealing additional variation in non-fertile types, reinforced patterns that form several distinct genetic clusters. These groupings are validated by correspondence to botanical taxa and field observations (reports of fertility) (Table 1).

Of 60 total samples submitted from 29 countries outside South Asia, 53 (88%) were a single clone of *Vetiveria zizanioides*. At least two-thirds of these samples were first accessioned from traditional, in-country sources, i.e, oil producers, herbalists, botanical gardens, and other planted sites, and therefore may be considered representative of *ex situ* vetiver populations. Because vetiver is vegetatively propagated, it thus appears that one single essential-oil clone (which we are denoting as 'Sunshine' because of accession priority) is distributed throughout the tropics. Its introduction was done certainly before WWII and most likely before this century. For instance, vetiver has been in the US since at least the early 19th century, although the earliest authenticated germline identifications of the 'Sunshine' type are currently 'Vallonia', South Africa, via Mauritius, *ca.* 1900, M. Robert; 'Monto', Australia, 1930s, P. Truong; 'Sunshine', USA, 1960s, E. LeBlanc; and MY044693 & MY081268, Venezuela, 1982, O. Rodriguez; (information from Vetiver Network members). Such a consistent identity in a spatially and temporally scattered distribution implies that virtually all of the *Vetiveria zizanioides* outside South Asia could be the single 'Sunshine' genotype, which today certainly dominates soil stabilization and water flow control usage.

Conclusions

Based on DNA fingerprinting data, it appears that almost all the vetiver used for erosion control outside South Asia has been derived from a single genotype, which we call 'Sunshine'. Nevertheless, discontinuities of geographic and genetic patterns in our analysis imply much vetiver diversity awaits discovery. There is a critical need to screen other, reportedly non-fertile vetiver to uncover additional germlines to diversify current and future plantings of this very important "hedge against erosion" (NRC 1993). Especially needed are samples from areas on the periphery of South Asia, where vetiver has been cultivated for centuries. Common garden studies are planned using the divergent vetiver accessions in Table 2. Further promising germplasm needs to be accessioned and observed. The challenge is to assure the genetic diversity of cultivated vetiver, which is proving of immense importance to agricultural stabilization and civil engineering.

Table 1. Preliminary classification of vetiver accessions by DNA fingerprinting.

A = pattern based on 6 primers: 184, 239, 249, 268, 327, and 346. B = pattern based only on primer 268.
Fertile codes: N = no, Y = yes, F = fully, L = low, + = confirmed, - = assumed, ? = unknown.
* = botanically verified at the species level.

Type	Accession #	Lab #	Species; Source (other locations)	Fertile?
			Vetiveria zizanioides	
			Vetiveria zizanioides (L.) Nash cv. 'Sunshine' clone (S) (= Haiti, 'Monto', 'Boucard', 'Huffman', 'Vallonia')	
S[A]	VET-RPA-7655	7655	*V. zizanioides*; Haiti, Massif de la Selle	N+
S[A]	VET-RPA-7659	7659	*V. zizanioides*; Haiti, Marigot	N+
S[A]	VET-RPA-7660	7660	*V. zizanioides*; Haiti, Jacmel	N+
S[A]	VET-RPA-7661	7661	*V. zizanioides*; Haiti, Jacmel	N+
S[A]	VET-RPA-7663	7663	*V. zizanioides*; Haiti, Massif de la Selle	N+
S[A]*	VET-PT-1A	7711	*V. zizanioides* cv. 'Monto'; Australia, Queensland	N+
S[A]*	VET-PT-1B	7712	*V. zizanioides* cv. 'Fiji'; Australia, Queensland (Fiji)	N+
S[A]*	VET-PT-1D	7714	*V. zizanioides*; Australia, Queensland (W Australia)	N+
S[A]*	VET-PT-1E	7715	*V. zizanioides*; New Guinea	N+
S[A]	VET-RGG-PA-A	7719	*V. zizanioides*; Panama, site A	N+
S[A]	VET-RGG-CR-A	7721	*V. zizanioides*; Costa Rica, San Jose	N+
S[A]*	VET-MR-VAL1	7722	*V. zizanioides* cv. 'Vallonia'; South Africa, Natal	N+
S[A]	VET-OSR-1.0	7729	*V. zizanioides*; Venezuela, Maracay	N+
S[A]	VET-DEKN-1001	7730	*V. zizanioides*; Aneityum Island, Pacific	N+
S[A]	VET-DEKN-1003	7731	*V. zizanioides*; Efate Island, Pacific	N+
S[A]	VET-DEKN-1002	7732	*V. zizanioides*; Atiu Island, Pacific	N+
S[A]	VET-DEKN-1004	7733	*V. zizanioides*; Mangaia Island, Pacific	N+
S[A]	VET-GVB-001	7742	*V. zizanioides* cv. 'Boucard'; USA, Texas (Haiti or Guatemala)	N+
S[A]	VET-MJ-F1	7747	*V. zizanioides*; USA, North Carolina	N+
S[A]	VET-MJ-F2	7748	*V. zizanioides*; USA, North Carolina	N+
S[A]*	VET-MRL-0001	7749	*V. zizanioides* cv. 'Sunshine'; USA, Louisiana	N+
S[A]	VET-MRD-0001	7750	*V. zizanioides* cv. 'Sunshine'; USA, Louisiana	N+
S[A]	VET-MRD-0002	7751	*V. zizanioides* cv. 'Huffman'; USA, Florida (Louisiana)	N+
S[A]	VET-RDH-0001	7767	*V. zizanioides*; Hong Kong (Thailand?)	N-
S[A]	VET-RDH-0002	7768	*V. zizanioides*; Hong Kong (South China)	N-
S[B]	VET-JG-23	7773	*V. zizanioides*; New Zealand, Northland	N
S[B]	VET-EB-5997	7776	*V. zizanioides*; Netherlands Antilles, Bonaire (USA)	N
S[B]	VET-JGN-0001	7777	*V. zizanioides*; USA, California	N+
S[B]	VET-EAB-5262	7950	*V. zizanioides*; Philippines, Leyte	N
S[B]	VET-CXH-0001	7952	*V. zizanioides*; China, Guiyang	N+
S[B]	VET-JA-1-1	7954	*V. zizanioides*; Kenya, Nairobi, ICRAF	N
S[B]	VET-JA-1-3	7956	*V. zizanioides*; Peru, Iquitos, ICRAF	N
S[B]	VET-JA-1-4	7957	*V. zizanioides*; Peru, Iquitos, ICRAF	N
S[B]	VET-JA-2-3	7960	*V. zizanioides*; Peru, Iquitos, ICRAF	N
S[B]	VET-OSR-1-B	7961	*V. zizanioides*; Venezuela, Maracay (Carabobo)	N+
S[B]*	VET-OSR-2	7962	*V. zizanioides*; Venezuela, Maracay (Bajo Seco)	N+
S[B]	VET-HGR-01	7965	*V. zizanioides*; Colombia, Bogota	N+
S[B]	VET-TS-F1	7967	*V. zizanioides*; Ethiopia, Filakit	N+
S[B]	VET-TS-F2	7968	*V. zizanioides*; Ethiopia, Filakit	N+
S[B]	VET-TS-F3	7969	*V. zizanioides*; Ethiopia, Filakit	N+
S[B]	VET-TS-D1	7970	*V. zizanioides*; Ethiopia, Digitosh	N+
S[B]	VET-TS-D2	7971	*V. zizanioides*; Ethiopia, Digitosh	N+
S[B]	VET-TS-M1	7973	*V. zizanioides*; Ethiopia, Minikaba	N+

S^B	VET-TS-M2	7974	*V. zizanioides*; Ethiopia, Minikaba	N+
S^B	VET-TS-M3	7975	*V. zizanioides*; Ethiopia, Minikaba	N+
S^B	VET-HP-01	7986	*V. zizanioides*; Honduras, Zamorano	N
S^B	VET-HP-03	7988	*V. zizanioides*; USA, Florida (Louisiana)	N
S^B	VET-JMJS-VC1	8000	*V. zizanioides*; Mexico, Oaxaca (Vera Cruz)	N
S^B	VET-CED-0001	8002	*V. zizanioides*; Bolivia, Sucre (MASDAR germplasm?)	N
S^B	VET-DD-A1	8005	*V. zizanioides*; Ethiopia, Dilla, Gedio	N
S^B	VET-DD-B1	8006	*V. zizanioides*; Ethiopia, Dilla, Gedio	N
S^B	VET-DD-C1	8007	*V. zizanioides*; Ethiopia, Dilla, Gedio	N
S^B	VET-MB-01	8029	*V. zizanioides* cv. 'Huffman'; USA, Florida (Louisiana)	N+

Sunshine affinities: S- = Sunshine pattern with one missing band, S+ = Sunshine pattern with one additional band

$S+^B$	VET-IPA-MUIR-001	7989	*V. zizanioides*; Mozambique, Maputo	?
$S+^B$	VET-LW-0001	8048	*V. zizanioides* cv. 'Capitol'; USA, Louisiana	N
$S-^{B*}$	VET-TGAVC-002	8051	*V. zizanioides* cv. 'AVC'; Spain, Murcia (USA)	N+

Sri Lanka (Chiapas) clone (SL)

SL^B	VET-IMZ-AGA	7765	*V. zizanioides*; Malawi, Lilongwe	N-
SL^{B*}	VET-RN-001	7951	*V. zizanioides*; Sri Lanka, Colombo	N-
SL^B	VET-SBR-VNN-96/2	7993	*V. zizanioides*; Sri Lanka, Kandy	N-
SL^B	VET-SBR-VNN-96/3	7994	*V. zizanioides*; Sri Lanka, Kandy	N-
SL^B	VET-SBR-VNN-96/4	7995	*V. zizanioides*; Sri Lanka, Kandy	N-
SL^B	VET-SBR-AN-96/2	7997	*V. zizanioides*; Sri Lanka, Kandy	N-
SL^B	VET-SBR-AN-96/4	7999	*V. zizanioides*; Sri Lanka, Kandy	N-
SL^B	VET-JMJS-CH1	8001	*V. zizanioides*; Mexico, Oaxaca (Chiapas)	N-

'Farmers Fodder' or 'Karnataka' (KM)

KM^B *	VET-TGKN-003	8052	*V. zizanioides* cv. 'Karnataka'; Spain, Murcia (Malaysia, India)	N+

'Breeder' complex (G)

G^{B*}	VET-UCL-027	7981	*V. zizanioides*; India, Lucknow, CIMAP	L?
G^{B*}	VET-HP-02	7987	*V. zizanioides*; India, Uttar Pradesh (USDA PI 554617, 'Carter')	YL

'Breeder' affinities: G+, G++ = with one (+) or two (++) extra band(s); G- = with a missing band

$G+^B$	VET-JGN-0002	7778	*V. zizanioides*; USA, California (Philippines?)	YL?
$G++^{B*}$	VET-UCL-024	7980	*V. zizanioides*; India, Lucknow, CIMAP	?
$G+^{B*}$	VET-UCL-040	7982	*V. zizanioides*; India, Lucknow, CIMAP	?
$G-^{B*}$	VET-UCL-042	7983	*V. zizanioides*; India, Lucknow, CIMAP	?
$G+^{B*}$	VET-UCL-045	7984	*V. zizanioides*; India, Lucknow, CIMAP	?
$G+-^{B*}$	VET-UCL-M1	7985	*V. zizanioides*; India, Lucknow, CIMAP	?

Khus type of Northern India (Kh): similar to Indian type I, cf. 7761

Kh^{B*}	VET-SCRC-001	8035	*V. zizanioides*; USA, USDA (India)	YF+

'Ganges' complex (North India): loose group with considerable banding differences

I^{B*}	VET-BANG-B001	7723	*V. zizanioides*; Bangladesh	YF+
I^{B*}	VET-BANG-B002	7724	*V. zizanioides*; Bangladesh	YF+
I^{B*}	VET-BANG-B003	7725	*V. zizanioides*; Bangladesh	YF+
I^{B*}	VET-BANG-B004	7726	*V. zizanioides*; Bangladesh	YF+
I^{B*}	VET-USDA-U1	7735	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF+
I^{B*}	VET-USDA-U2	7736	*V. zizanioides*; India, A-3225 (USDA PI 213903)	YF+
I^{B*}	VET-USDA-U3	7737	*V. zizanioides*; India (USDA PI 271633)	YF+
I^{B*}	VET-USDA-U4	7738	*V. zizanioides*; India, A-7026 (unverified) (USDA PI 302300)	YF+
I^{B*}	VET-USDA-U5	7739	*V. zizanioides*; India, NBPGR Hybrid 7 (USDA PI 538753)	YF+
I^{B*}	VET-USDA-U6	7740	*V. zizanioides*; India, BE-2668, NBPGR Hybrid 8 (USDA PI 538754)	YF+

I^{B}*	VET-USDA-U7	7741	*V. zizanioides*; India, BE-2668, NBPGR Hybrid 26 (USDA PI 538756)	YF+
I^{B}	VET-K-Dtp-1	7752	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-K-Pub-2	7753	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-K-Dnk-3	7754	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-K-Brk-8	7759	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-U-Blp-9	7760	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-U-Nlg-10	7761	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-U-Gsg-11	7762	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-U-Bdm-12	7763	*V. zizanioides*; India, Orissa	YF+
I^{B}	VET-CWDS-01	7764	*V. zizanioides*; Nepal, Kathmandu (lowlands) (low flowering)	?
I^{B}*	VET-UCL-005	7976	*V. zizanioides*; India, Lucknow, CIMAP	?
I^{B}*	VET-UCL-007	7978	*V. zizanioides*; India, Lucknow, CIMAP	?
I^{B}*	VET-BANG-B006-B	8037	*V. zizanioides*; Bangladesh	YF+

Ganges affinities: I- = Ganges type with one missing band

I^{-B}*	VET-BANG-B005-B	8036	*V. zizanioides*; Bangladesh	YF+
I^{-B}*	VET-TGSB-004	8053	*V. zizanioides* cv. 'Sabah'; Spain, Murcia (Malaysia, India?)	N+
I^{-B}*	VET-TGSBB-005	8054	*V. zizanioides* cv. 'Sabik Bernam', Spain, Murcia (Malaysia, India?)	N+

Grafton type (Gr)

Gr^{A}*	VET-PT-1C	7713	*V. zizanioides* cv. 'Grafton'; Australia, Queensland	YL+
Gr^{B}	VET-SBR-AN-96/1	7996	*V. zizanioides*; Sri Lanka, Kandy	?

Other *V. zizanioides* banding patterns (O): various banding, each of which is different

O^{B}	VET-SJC-2	7775	*V. zizanioides*; Malawi, Zomba	N+
O^{B}*	VET-TGML-001	8050	*V. zizanioides* cv. 'Malaysia'; Spain, Murcia (Malaysia, India?)	N+
O^{B}*	VET-TGPB-006	8055	*V. zizanioides* cv 'Parit Buntar'; Spain, Murcia (Malaysia, India?)	N+
O^{B}	VET-JM-PV1	8076	*V. zizanioides*?; Costa Rica, Puerto Viejo	N?

Other *Vetiveria* species

V. elongata (R. Br.) Stapf, (Eg): very similar to one another

Eg^{A}*	VET-PT-2A	7716	*V. elongata* (narrow leaf); Australia, Northern Territory	YF-
Eg^{A}*	VET-PT-2B	7717	*V. elongata* (broad leaf); Australia, Northern Territory	YF-

V. filipes (Benth.) C.E.Hubb., (Fp): quite distinct, 7772 may be a different species or genus

Fp^{B}*	VET-PT-2C	7718	*V. filipes*; Australia	YF-
Fp^{B}*	VET-FA-257810	7772	*V. filipes*; Australia, USDA PI 257810	YF+

V. nigritana (Benth.) Stapf, (Ng): very similar to one another

Ng^{A}	VET-ISV-AGA	7766	*V. nigritana*; Malawi, Lilongwe (few seed)	YL?!
Ng^{B}	VET-SJC-1	7774	*V. nigritana*; Malawi, Zomba	YF+

Unknown taxa[1]

P^{A}	VET-RGG-PA-B	7720	*Vetiveria* sp.?; Panama, Western, site B (Costa Rica)	?
Vb^{B}	VET-BANG-B005	7727	*Vetiveria* sp.?; Bangladesh	YF+?
Vb^{B}	VET-BANG-B006	7728	*Vetiveria* sp.?; Bangladesh	YF+?

[1] All three samples are anomolous; results are presented to maintain completeness of data presentation. VET-RGG-PA-B ('Panama B'), currently under curation in Costa Rica, falls well outside the variability shown in the *Sorghum/Vetiveria/Chrysopogon* complex; nonetheless, to experienced eyes it has the morphology of *V. zizanioides* (information from The Vetiver Network, vetiver@vetiver.org). The RAPDs of two specimens from Bangladesh also fell outside the *Sorghum/Vetiveria/Chrysopogon* complex, most likely due to handling error or contamination (for which the authors apologize). Upon resampling, VET-BANG-B006-B (from the same mother plant as VET-BANG-B006) fell comfortably among fertile 'Ganges' vetivers.

Other genera

Chrysopogon Trin.

Cf^{A}*	VET-CFP-219579	7769	*C. fulvus* (Spreng.) Chiov.; Pakistan (USDA PI 219579)	YF
Cg^{A}*	VET-CGP-383762	7771	*C. gryllus* (L.) Trin.; Turkey (USDA PI 383762)	YF
Ca^{B}*	VET-BANG-B007	8038	*C. aciculatus* (Retz.) Trin.; Bangladesh	YF+
Cn^{B}*	VET-JVTH-ZN001	8040	*Chrysopogon nemoralis* (Balansa) Holttum (received as *Zizania nemoralis* (Balansa) Camas); Thailand	Y?F?

Sorghum Moench.

Sh^{A}*	VET-AW-01	8030	*S. halepense* (L.) Pers.; USA, Texas	YF+
Sb^{A}*	VET-RPA-8031	8031	*S. bicolor* (L.) Moench.; USA, Texas	YF+

Not tested

NT = not tested; D = degraded DNA; see text

NT	VET-MJ-B1	7701	*V. zizanioides*; USA, North Carolina, fungus on seeds	?
NT	VET-MJ-B2	7702	*V. zizanioides*; USA, North Carolina, fungus on seeds	?
NT	VET-MJ-B3	7703	*V. zizanioides*; USA, North Carolina, fungus on seeds	?
NT	VET-MJ-B4	7704	*V. zizanioides*; USA, North Carolina, fungus on seeds	?
NT	VET-MJ-B5	7705	*V. zizanioides*; USA, North Carolina, fungus on seeds	?
NT*	VET-USDA-F1	7734	*V. filipes*; Australia, USDA (PI 257810) (duplicate accession under 7772)	YF+
NT	VET-K-Bdln-4	7755	*Vetiveria* sp.; India, Orissa	YF+
NT	VET-K-Bdln-5	7756	*Vetiveria* sp.; India, Orissa	YF+
NT	VET-K-Bdln-6	7757	*Vetiveria* sp.; India, Orissa	YF+
NT	VET-K-Bdln-7	7758	*Vetiveria* sp.; India, Orissa	YF+
NT	VET-JSC-0001	7953	*V. zizanioides*?; Cambodia (Australia)	?
NT	VET-JBH-1267	8039	*C. schmidianus*; Laos	?
D*	VET-USDA-B6	7706	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF
D*	VET-USDA-B7	7707	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF
D*	VET-USDA-B8	7708	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF
D*	VET-USDA-B9	7709	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF
D*	VET-USDA-B10	7710	*V. zizanioides*; India, Punjab, Simla (USDA PI 196257)	YF
D*	VET-CFI-554618	7770	*C. fulvus* (Sprengel) Chiov.; India (USDA PI 554618)	YF
D	VET-EAB-5261	7949	*V. zizanioides*; Philippines, Leyte	?
D	VET-JA-1-2	7955	*V. zizanioides*; Kenya, Nairobi, ICRAF	?
D	VET-JA-2-1	7958	*V. zizanioides*; Kenya, Nairobi, ICRAF	?
D	VET-JA-2-2	7959	*V. zizanioides*; Kenya, Nairobi, ICRAF	?
D	VET-NSC-01	7963	*V. zizanioides*; Cameroon, Mbingo Bamenda (Nigeria)	?
D	VET-NSC-02	7964	*V. zizanioides*; Cameroon, Maroua	?
D*	VET-HGR-02	7966	*V. zizanioides*; Colombia, Cundinamarca (flowering)	?
D	VET-TS-D3	7972	*V. zizanioides*; Ethiopia, Digitosh	N+
D*	VET-UCL-006	7977	*V. zizanioides*; India, CIMAP	?
D*	VET-UCL-008	7979	*V. zizanioides*; India, CIMAP	?
D	VET-SBR-VA-96/1	7990	*V. zizanioides*; Sri Lanka, Kandy	N?
D	VET-SBR-VH-96/1	7991	*V. zizanioides*; Sri Lanka, Kandy	N?
D	VET-SBR-VNN-96/1	7992	*V. zizanioides*; Sri Lanka, Kandy	N?
D	VET-SBR-AN-96/3	7998	*V. zizanioides*; Sri Lanka, Kandy	?
D	VET-BBG-001	8003	*V. zizanioides*; Ghana, Central	N+
D	VET-BBG-02	8004	*V. fulvibarbus* (Trin.) Stapf; Ghana, Central	N+

Table 2. *Vetiveria zizanioides* germplasm of high priority for maintenance and evaluation.

Type	Accession #	Lab #	Species; Source (other locations)	Fertile?
S^A	VET-PT-1A	7711	*V. zizanioides* cv. 'Monto'; Australia, Queensland	N+
S^A	VET-MR-VAL1	7722	*V. zizanioides* cv. 'Vallonia'; South Africa	N
S^A	VET-GVB-001	7742	*V. zizanioides* cv. 'Boucard'; USA, Texas	N+
S^B	VET-MRL-001	7749	*V. zizanioides* cv. 'Sunshine'; USA, Louisiana	N
S^B	VET-MB-01	8029	*V. zizanioides* cv. 'Huffman'; USA, Florida	N+
S^B	VET-OSR-1-B	7961	*V. zizanioides*; Venezuela, Maracay (Carabobo)	N+
$S+^B$	VET-IPA-MUIR-001	7989	*V. zizanioides*; Mozambique, Maputo	?
$S+^B$	VET-LW-0001	8048	*V. zizanioides* cv. 'Capitol'; USA, Louisiana	N
$S-^B$	VET-TGAVC-002	8051	*V. zizanioides* cv. 'AVC'; Spain, Murcia (USA)	N+
SL^B	VET-IMZ-AGA	7765	*V. zizanioides*; Malawi, Lilongwe	?!
SL^B	VET-RN-001	7951	*V. zizanioides*; Sri Lanka, Colombo	N+?
SL^B	VET-JMJS-CH1	8001	*V. zizanioides*; Mexico, Oaxaca (Chiapas)	N+?
CR^B	VET-JM-PV1	8076	*V. zizanioides?*; Costa Rica, Puerto Viejo	N?
Gr^A	VET-PT-1C	7713	*V. zizanioides* cv. 'Grafton'; Australia, Queensland	YL+
Gr^B	VET-SBR-AN-96/1	7996	*V. zizanioides*; Sri Lanka, Kandy	?
$G+^B$	VET-JGN-0002	7778	*V. zizanioides*; USA, California (Philippines?)	YL?
KM^B	VET-TGKN-003	8052	*V. zizanioides* cv. 'Karnataka'; Spain, Murcia (Malaysia, India)	N+
G^B	VET-HP-02	7987	*V. zizanioides*; India, Uttar Pradesh (USDA PI 554617, 'Carter')	YL+
P^A	VET-RGG-PA-B	7720	*Vetiveria* sp.?; Panama, Western, site B (Costa Rica)	?
O^B	VET-SJC-2	7775	*V. zizanioides*; Malawi, Zomba (few seed heads)	?
O^B	VET-TGML-001	8050	*V. zizanioides* cv. 'Malaysia'; Spain, Murcia (Malaysia, India?)	N+
$I-^B$*	VET-TGSB-004	8054	*V. zizanioides* cv. 'Sabik Bernam'; Spain, Murcia (Malaysia, India?)	?
O^B	VET-TGPB-006	8055	*V. zizanioides* cv. 'Parit Buntar'; Spain, Murcia (Malaysia, India?)	N+

Acknowledgments

This research was supported in part by funds from Baylor University, project RDJJ-032-4524. Thanks to Ming Zhong and Yerlan Turuspekov for assistance in running the RAPDs. We also want to thank the many collaborators from The Vetiver Network who contributed samples of vetiver tissue.

References

Adams, R.P., Zhong, M.; Turuspekov, Y.; Dafforn, M.R.; and Veldkamp, J.F. 1998. DNA fingerprinting reveals clonal nature of *Vetiveria zizanioides* (L.) Nash, Gramineae and sources of potential new germplasm. *Mol. Ecol.* 7: 813-818.

CSIR 1976. Vetiveria. *In:* The Wealth of India, Vol. X, pp. 451-457. Publ. & Info. Directorate, Council on Scientific and Industrial Research, New Delhi.

Kresovich, S.; Lamboy, W.F.; Li, R.; Ren, J.; Szewc-McFadden, A.K.; and Bliek, S.M.. 1994. Application of molecular methods and statistical analyses for discrimination of accessions and clones of vetiver grass. *Crop Sci.* 34: 805-809.

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

Srifah, P.; Sangduen, N.; and Ruanjaichon, V. 1998. The use of random amplified polymorphic DNA for classification of *Vetiveria* spp. in Thailand. *In:* N. Chomchalow and H.V. Henle (eds.) Proc. 1st Int. Conf. Vetiver: A Miracle Grass, Chiang Rai, Thailand, 4-8 Feb.96, pp. 141-146. Office of the Royal Development Projects Board, Bangkok.

Postscript - February 1999

The above results and subsequent analyses (Adams *et al.* 1998) have identified several reportedly non-fertile genotypes of vetiver. Some of these clones can be traced to Sri Lanka, Malaysia, and perhaps South India, where "non-flowering" vetivers have long been reported[1]. The use of vetiver root is a cultural heritage throughout this area, where traditional clonal materials are widely distributed. Molecular verification of potentially distinct genotypes, however, has scarcely begun. The authors strongly encourage further investigations in the region, which may shed light on ancient human pathways as well as reveal "new" vetiver variation.

NB: A summary of current understanding can be found in Adams, R.P, and Dafforn, M.R. 1998. Lessons in diversity: DNA sampling of the pantropical vetiver grass (*Vetiveria zizanioides*) uncovers genetic uniformity in erosion-control germplasm. Diversity 13(4): 27-28. An on-line version is also available at *http://user.aol.com/vetivernet/vip/dnadiv.htm.*

[1] Occasional caryopses (seeds) are formed in non-fertile vetivers but these are technically "non-germinative" and in intensive testing none have produced viable seedlings. It seems likely that the non-fertile vetivers are domesticates; as with potatoes and other root crops, which have been selected for improved root quantities and oil content, thereby allowing fertility to fall by the wayside. (Reference: Dafforn, M.R. 1998. Know Your Hedge Vetiver: Environmental Concerns about *Vetiveria zizanioides*. *In:* N. Chomchalow and H.V. Henle (eds.) Proc. 1st Int. Conf. Vetiver: A Miracle Grass, Chiang Rai, Thailand, 4-8 Feb. 96, pp. 293-303. Office of the Royal Development Projects Board, Bangkok).

Erratum

A few mistakes have appeared inadvertently in the inside covers of AU J.T. 2(3) – Jan. 1999. These, with the corrections, are:

Inside Front Cover: 33. 'Nong Bua Lam Phu' should be 'Nong Bua Lamphu'.

Inside Back Cover: Note 1 (iii) 'Korat' (a word of common usage by foreigners) should be spelled as 'Khorat'.