Narrow stiff grass hedges for erosion control

JERRY C. RITCHIE
USDA-ARS Hydrology Laboratory, BARC-West, Bldg-007, Beltsville, Maryland 20705, USA

W. DORAL KEMPER
USDA-ARS National Program Staff, BARC-West, Bldg-005, Beltsville, Maryland 20705, USA

JOHN M. ENGLERT
USDA-NRCS National Plant Materials Center, BARC-East, Bldg-509, Beltsville, Maryland 20705, USA

Abstract Concentrated flow erosion is a major concern in agricultural areas around the world. Many methods have been used to reduce or slow soil loss from areas of concentrated flow erosion. Narrow, stiff grass hedges have been used to slow runoff and reduce soil loss caused by concentrated flow erosion in many countries. However, few quantitative data are available on the effectiveness of these hedges. This study was developed to study the effectiveness of narrow, stiff grass hedges for reducing soil loss from agricultural fields. Miscanthus (*Miscanthus sinensis* Andress) and eastern gamagrass (*Tripsacum dactyloides* L.) were used to establish stiff grass hedges on the contour across concentrated flow erosion areas in agricultural fields. Miscanthus hedges were established in 1991 and 1992 using transplants. Eastern gamagrass hedges, used to supplement the miscanthus hedges, were established in 1994 from seed. The miscanthus grew rapidly and formed dense hedges within two years that slowed runoff. Comparison of land survey measurements made in 1991 and 1995 found 8 to 15 cm of sediment deposition above miscanthus hedges. Deposition patterns were related to the original topography with low areas having the greatest deposition. Crop yields were reduced in the two rows closest to the hedge in two of three years. This study found that stiff grass hedges were an alternative conservation practice for reducing soil loss and dispersing runoff from areas of concentrated flow erosion in agricultural fields.

INTRODUCTION

Soil erosion and concentrated flow erosion are major concerns in many parts of the world (Brown & Wolf, 1984). Grass filters and buffer strips, planted in 5-15 m wide strips, have been widely used and have been effective barriers for trapping sediment and some chemicals (Magette *et al.*, 1989; Daniels & Gilliam, 1996). However, the effectiveness of these strips is reduced as flow increases and in areas of concentrated flow (Flanagan *et al.*, 1989). Narrow, stiff grass hedges planted on the contour across areas of concentrated flow are an alternative method for using vegetated barriers to slow runoff and to reduce soil loss. Grass hedges have been used in many countries to reduce soil loss (National Research Council, 1993).

In recent years a renewed interest has developed in the use of narrow, stiff grass hedges as a conservation practice for reducing sheet, rill, and ephemeral gully erosion from eroding fields (Kemper *et al.*, 1992; NRC, 1993; McGregor & Dabney, 1993). Research has shown that narrow, grass hedges disperse water, trap sediment, reduce ephemeral gully development (Dabney *et al.*, 1993, 1995), and reduce wind erosion (Aase & Reitz, 1989; Aase & Pikul, 1995; Siddoway, 1970). Grass hedges slow concentrated flow, thus dispersing runoff and promoting deposition in the ponded backwaters above the hedges (Dabney *et al.*, 1993, 1995; Meyer *et al.*, 1994) and enhancing terrace formation (Aase & Pikul, 1995). Grass hedges are an inexpensive biological conservation technology compatible with many tillage systems when planted along the contour (McGregor & Dabney, 1993).

Grass hedges differ from other types of grass barriers (i.e. buffer strips, filter strips) in that they are narrow, planted with stiff, erect grasses, and are designed to stimulate the formation of terraces by deposited materials. A dense stand of coarse, stiff, grass stems planted in hedges across concentrated flow paths, causes ponding of runoff water above the hedge that allows time for eroded particles in the concentrated flow to be deposited. The deposited material fills low places in the field so that future runoff is even more broadly dispersed and less erosive. Narrow, stiff grass hedges are planted in lines along the dominate contours and across concentrated flow areas of the field (Kemper *et al.*, 1992). The design, spacing, and lateral extent for these grass hedges in concentrated flow area depend on runoff rates, topography, and other factors (Dabney *et al.*, 1993; Kemper *et al.*, 1992).

Vetiver (*Vetiveria zizanioides* (L.) Nash) is the most famous grass used for hedges to reduce erosion. Vetiver has been used in many tropical countries, but most of the reports about its effectiveness are based on empirical observations and anecdotal reports rather than quantitative studies (National Research Council, 1993). The World Bank promotes the use of vetiver for erosion control (World Bank, 1990). In 1991 the United States Department of Agriculture (USDA), Agriculture Research Service (ARS) in cooperation with the USDA Natural Resource Conservation Service (NRCS) and several Universities began a programme to evaluate narrow, stiff grass hedges for controlling soil loss from concentrated flow erosion areas. Vetiver was a candidate species, but it quickly became evident that this species could not withstand the low temperatures in temperate regions. Other grasses included in these studies were miscanthus (*Miscanthus sinensis* Andress) and indigenous grasses such as eastern gamagrass (*Tripsacum dactyloides* L.), switchgrass (*Panicum virgatum* L.), tall fescue (*Festuca arundinacae* Schreb.), perennial tall wheatgrass (*Elytrigia elongata* (Host) Nevski) and others.

The purposes of this study were to establish narrow, stiff grass hedges across developing concentrated flow erosion areas in agricultural fields at Beltsville, Maryland, USA and to determine the effectiveness of these hedges to slow ephemeral gully development, capture eroded material, and reduce the loss of soil from the fields.

METHODS AND STUDY SITES

Two study sites were chosen. The first study site was on the South Farm of the USDA, ARS, Beltsville Agricultural Research Center (BARC), Beltsville, Maryland. This agricultural field has a history of strip cropping on the contour and row cropping with alternating years of corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merrill) on alternate strips. Slopes in the field are between 10-15% with a total slope length of 250 m. Cropping strips are approximately 50 m wide. Corn is no-till planted into the soybean stubble while soybeans are planted after minimum tillage (surface disking) to incorporate the corn residue. Two concentrated flow erosion areas were observed in the field, starting near the crest of the slope and crossing three cropping strips before joining near the base of the slope. On 17 April 1991, miscanthus was transplanted along the contour between strips of crops and across concentrated flow erosion areas below where the two concentrated flow areas joined near the base of the slope. Miscanthus was transplanted using 2-5 cm clumps at 10 to 15 cm intervals. Transplants were made on the contour between strips of crops to reduce interference with farm operations and to reduce disturbance to the hedge during the field and harvest operations. In May 1994, the hedges were repaired by transplanting miscanthus to fill gaps in the original hedges. Also in May 1994, eastern gamagrass was planted using seeds in gaps and used to extend the length of this miscanthus hedge.

Corn and soybeans yields were measured on either side of the miscanthus hedge in the South Farm field in 1993, 1994, and 1995. Sampling was done by harvesting crop rows 1, 2, 4, 8, 16, and 32 away from the miscanthus hedge. In each sample row four (4) 5 m sections of crop were harvested. Samples of the harvested crops were dried and yields were determined. In 1993 no treatment was made to the hedge. In 1994 and 1995 half the length of the hedge was kept trimmed to 75 cm or the maximum height of the soybeans during the growing season in an attempt to reduce shading of the crops by the hedge.

In April 1991, shortly after the original transplanting of the miscanthus hedge, a topographic survey was made at the hedge site. In August 1995, a second topographic survey was made for comparison with the original topographic surveys. Lines were surveyed 5 cm below and 5 cm and 1 m above the hedge.

The second study site is on the East Farm of Beltsville Agricultural Research Center. This agricultural field has a slope of 10 to 15% with a total slope length of about 200 m. The field had a history of being planted in either corn or soybeans. A concentrated flow erosion area was visible in the field. In April 1991, a tile drain was installed in the approximate location of the concentrated flow area. On 23 May 1991, after the installation of the tile drain, miscanthus was transplanted into a hedge at the lower edge in this field where overland flow exited the field and entered a wooded area. Miscanthus was transplanted in 2-5 cm clumps at 10 to 15 cm intervals. In 1991 and 1992, the field was surface ploughed and planted in corn. After the corn was harvested in September 1992, clover was no-till planted in the field to provide a winter cover.

During the winter and spring of 1992/1993, a conservation plan was developed for this field to reduce soil loss. This plan directly affected our activities at the East Farm field by changing the farming practices from a single field to a field with five strips of crops. This plan did not affect the original miscanthus hedge. On 24 March 1993, two new miscanthus hedges were transplanted on the contour between the newly developed strips of crops. The three miscanthus hedges grew actively during 1993 and are now well established. After the 1993 growing season, row crop agriculture was stopped in the field. The field has been planted with small grain/clover since 1993 that provides continuous cover. In 1994, gaps in the hedge were filled and the hedge was extended in length by planting eastern gamagrass seeds. In 1995, a topographic survey was made along the hedge at the edge of the field for comparison with surveys made in 1993. Lines were surveyed at 5 cm below and at 5 cm and 1 m above the hedge.

RESULTS

Miscanthus rapidly formed a dense hedge. Beginning with 2-5 cm clumps planted 10 to 15 cm apart in 1991, hedges in both fields have grown to a width of 20-30 cm and a height of 2.5 to 3.5 m by 1994. At the South Farm, miscanthus was 2 m tall at the end of the first (1991) growing season. Trimming this hedge to 75 cm along half its length during the 1994 and 1995 growing seasons did not affect its growth or expansion. Miscanthus quickly developed new growth and continued to expand after each trimming. Each spring, the hedges were trimmed to a height of approximately 30 cm. Trimmed material was left in the field where it fell.

In 1994, eastern gamagrass was planted from seed to fill gaps and expand the length of the hedges at both field sites. These plantings were successful with high rates of seed germination, although eastern gamagrass is considered difficult to germinate. Dewald *et al.* (1996) discuss the proper techniques for establishing eastern gamagrass. Eastern gamagrass grew rapidly to form a hedge 30-60 cm tall and 10-15 cm wide by the end of the 1994 growing season. In 1995 and 1996, these eastern gamagrass hedges continued to grow and are developing into dense hedges of 0.2-0.3 m width and 3 m height.

Topographic surveys (Fig. 1) of the miscanthus hedge at the East Farm in 1995 showed 10 to 15 cm of deposition above the hedge after four years. The deposition area extends at least 1 m above the hedge. More detailed surveys are needed to determine the full extent of the deposition pattern near this hedge. This hedge at the lower edge of the field is capturing eroding particles that have moved from the field. However, this field is now in continuous grass/clover cover so that the soil loss and

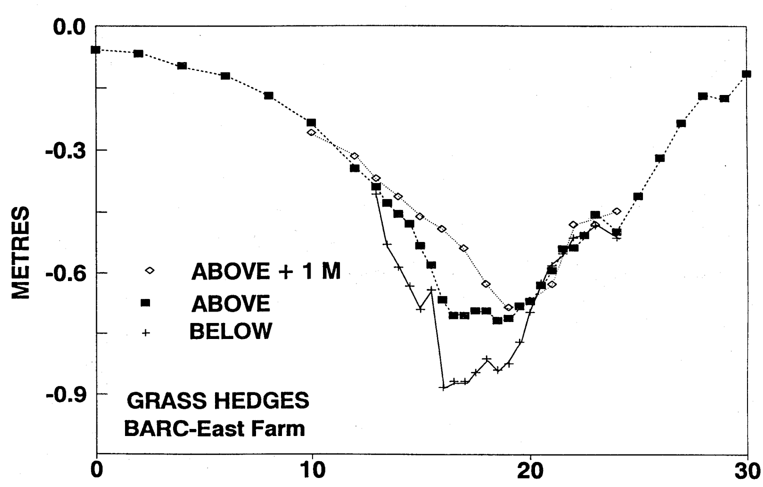

Fig. 1 Topographic survey made in 1995 of the grass hedge at the BARC East Farm at Beltsville, Maryland, USA. Survey lines were 5 cm below the hedge, 5 cm above the hedge, and 1 m above the hedge.

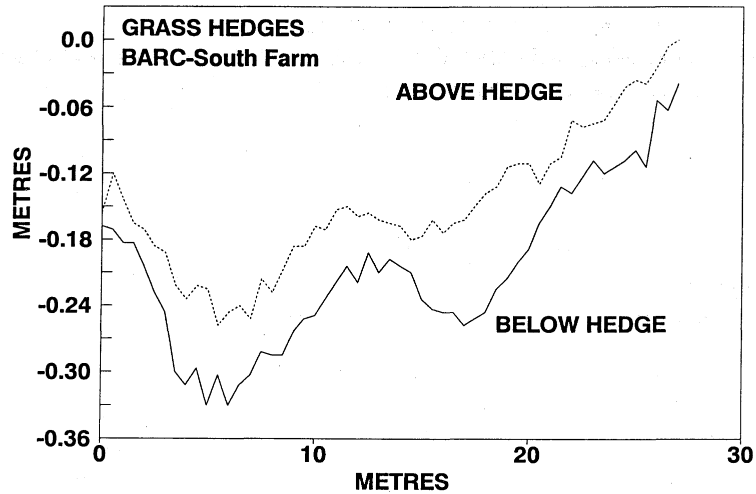

Fig. 2 Topographic survey made in 1995 of the grass hedge at the BARC South Farm at Beltsville, Maryland, USA. Survey lines were 5 cm below the hedge and 5 cm above the hedge.

concentrated flow area development have been reduced over the past two years. Observations in 1995 and 1996 noted the lack of well defined concentrated flow channels in the area near this hedge that were evident in early spring of 1991 and 1992. Only during large rainfall events does surface erosion occur in this field. The lack of development of the concentrated flow area could be due to a) reduced runoff from the field due to the continuous crop cover or b) the development of the terrace area above the hedge that further disperses the water as it approaches the hedge.

Surveys above and below the miscanthus hedge on the South Farm site in 1995 also showed 8 to 15 cm of deposition above the hedge (Fig. 2). Greater deposition occurred along the hedge in the areas where concentrated flow areas (depressions in the topographic survey) cross the border between the strips of crops. A general smoothing of the topography above the hedge is occurring. This smoothing is attributed to the hedge slowing and spreading the water across a wider area as it crossed the hedge barrier. This ponding of water would allow the sediment load carried in the runoff to be deposited over a wider area.

A comparison of topographic surveys made in April 1991 and August 1995 along the same survey line (5 cm upslope of the hedge) at the South Farm also showed an 8-15 cm depth of deposition (Fig. 3). Again the deposition is greatest in areas where concentrated flow had eroded the deepest channels before the establishment of the hedge. The measured deposition along this survey line is greater in the low areas. That is also evident in Fig. 2 where a comparison was made between above and below survey lines. The August 1995 survey line in Fig. 3 is the same as the "above" survey line in Fig. 2 showing that the comparison of above and below the hedge survey line probably give a conservative estimate of total deposition.

At the South Farm site an extensive area of deposition of material is present approximately 50 m above and west of the centre of the hedge. Whether this deposition area is due to the hedge is not clear, since survey data are not available for comparison, but this area of deposition has developed since the hedge was

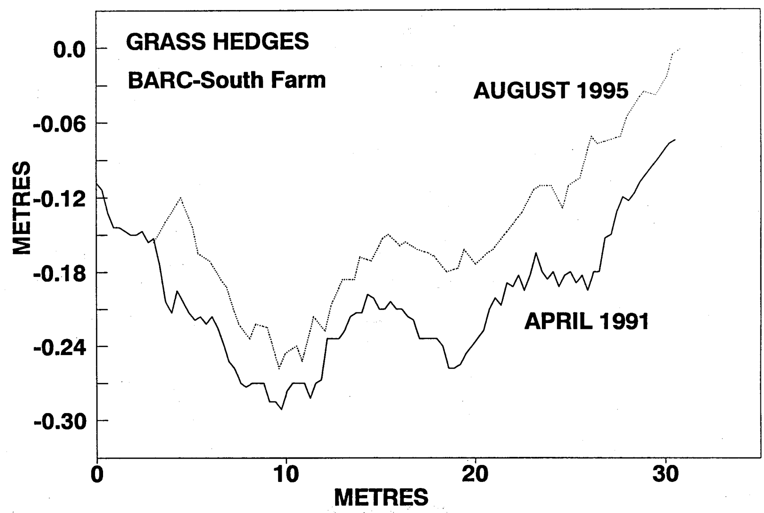

Fig. 3 Comparison of topographic surveys at the BARC South Farm of the same line (5 cm above the hedge) shortly after the hedge had been transplanted in April 1991 and again in August 1995.

established. There is also evidence of the development of new concentrated flow areas below the hedge that is of concern. More extensive surveys of the area above and below the hedge need to be made to evaluate the full extent of the deposition patterns and rates.

Studies of crop yield near the miscanthus hedge at the South Farm site were begun in 1993 after the hedge was well established. These studies were to determine the effect of the hedge on crop yields near the hedge and to determine the distance the hedge effects could be measured. In 1993, substantial decreases in yields of corn and soybeans occurred near the hedge. For soybeans, yields reached maximum level at approximately 2 m from the hedge. For corn, yields reached maximum level at approximately 6 m from the hedge. Rainfall was below average during the 1993 growing season. The hedge grew to heights of 2-3 m shading the adjacent rows of soybeans. In the early part of the growing season the hedge shaded adjacent rows of corn although the corn eventually grew to heights greater than the hedge. Plant populations were reduced in the first two rows near the hedge.

In 1994, half the length of the hedge was kept trimmed to a maximum height of 75 cm. Only the first row of soybeans showed yields that could be related to the proximity and height of the hedge. Shading was the probable cause of decrease in yields of soybeans next to the hedge that was not kept trimmed. Few soybean plants developed and matured in the row closest to the hedge. The differences in yield patterns with distance from the hedge between 1993 and 1994 were probably due to rainfall. In 1994, rainfall was slightly above average and was adequate to meet the needs of both the hedge and the crops growing near it during the growing season. The well-established roots of the perennial miscanthus hedge could deprive the crop of moisture in dry years.

Yields in 1995 were similar to 1993 yields, with yields lower in the rows near the miscanthus hedge. However, in 1995 yields were only affected in the first two rows for the soybeans and corn. Keeping the hedge trimmed to 75 cm did not affect yields of the corn or soybeans.

DISCUSSION

Miscanthus hedges were established easily and expansion by shoot production has been rapid and vigorous. During the five-year study no evidence has been found that miscanthus produced viable seeds. While these miscanthus hedges are very robust and are capturing eroded materials, the cost of purchasing miscanthus shoots and the labour needed to transplant the shoots may reduce farmer acceptance and application of miscanthus hedges as a conservation practice. The use of an indigenous grass that could be seeded and used for other purposes should have greater farmer acceptance. Switchgrass and eastern gamagrass are good candidates for use in the eastern United States. Eastern gamagrass was planted successfully thus making the establishment of hedges easier and cheaper. Farmers can use conventional farm equipment to plant eastern gamagrass hedges using seeds (Dewald & Louthan, 1979; Dewald *et al.*, 1996). The use of indigenous grasses also reduces the chances of the introduction of an unwanted competitor to agricultural fields. While our emphasis has been on narrow (< 1 m) grass strips, developing grass strips 1-5 m wide with indigenous grasses could provide both erosion protection and the potential for harvesting as a feed crop.

Miscanthus hedges are trapping eroded materials under field conditions. Two to four centimetres of eroded material have been deposited annually immediately above the hedges. Grass hedges have been found to trap two-thirds of the sediment from small plots (McGregor & Dabney, 1993; Dabney *et al.*, 1993). The hedge row is working as a porous filter that slows the water but lets it pass. Water is ponded above the hedge row slowing its velocity and allowing time for part of the material in suspension to be deposited. The deposition is occurring in the area above the hedges rather than in the hedge row itself. Flume studies have shown that hedges of switchgrass, vetiver, and miscanthus caused backwater depths of up to 40 cm and trapped more than 90% of sediment greater than 125 μm. Trapping efficiency was more related to particle size than to flow rates. Sediment trapping was upslope of the hedge rather than being filtered by the hedge. Once the material reaches the hedge, it passes through (Meyer *et al.*, 1995). Over time, the hedge can cause the development of terraces (Aase & Pikul, 1995) that flatten the slope and broadens the flow area resulting in larger ponding areas and greater storage capacities, increased settling times, and lower flow rates through the hedge (Dabney *et al.*, 1996).

Soil deposited above established hedges will flatten the slope. Concentrated flow areas above the hedge fill rapidly. However, incised areas below the hedge may be increased due to the increased erosive power of the water passing through the hedge that has increased carrying capacity due to the sediment deposited above the hedge. This erosion below the hedge should be controlled. In time, terraces may be complete so that the areas between hedges are flattened and erosion reduced. Stiff grass hedges should not be seen as a panacea to reduce erosion but as another tool in the arsenal of weapons to manage the landscape. Conservation practices should be in place on the field to prevent the movement of soil so that the need for hedges is reduced.

Three years of yield studies suggest that stiff grass hedges will probably affect yields of crops in the first few rows from the hedges. Lyles *et al.* (1984) found that vegetative barriers could affect yields at distances up to 2 times the height of the barrier. The reduction of yields probably is dependent on shading and water use although many other factors (i.e. nutrient supply, deposition) may contribute to changes in yields (Lyles *et al.*, 1984). At the South Farm site, field observations noted fewer plants grew near the hedge and in areas where deposition was the greatest.

CONCLUSIONS

In a series of recent studies, quantitative data have been collected that show that narrow, stiff grass hedges do act as a filter to slow and broaden the flow area, resulting in ponding that increases settling times for suspended material. This causes the development of terraces that further reduce the steepness of slopes giving even larger areas for the water to spread.

Narrow, stiff grass hedges should not be seen as a panacea but as another tool to control soil loss from agricultural fields. Continued efforts to control soil loss at the point of detachment are critical. Proper management of stiff grass hedges is required. With the development of terraces, there is an increased potential for the development of sediment patterns that may concentrate flow passing through the hedge creating conditions for the development of erosion problems immediately below hedges.

While grasses such as vetiver and miscanthus are good candidates for narrow, stiff grass hedges, indigenous grasses should be used when possible to reduce the potential for the introduction of exotic material into new environments. Planting hedges of indigenous grasses in wider strips (2 to 5 m) also raises the potential for harvesting or grazing these strips. Thus soil loss could be reduced and the farmer could have a crop that could provide added income.

Acknowledgements The authors express our appreciation to personnel from the NRCS National Plant Material Center at Beltsville, Maryland who helped transplant the miscanthus. We also thank Tim Badger, Farm Manager at the Beltsville Agricultural Research Center, who helped find study sites and allowed us to plant strange grasses in the fields where he attempts to eliminate competitors for the field crops. Carole and Karen Ritchie provided field assistance during the topographic surveys.

REFERENCES

Aase, J. K. & Pikul, Jr, J. L. (1995) Terrace formation in cropping strips protected by tall wheat grass barriers. *J. Soil Wat. Conserv.* **50**(1), 110-112.

Aase, J. K. & Reitz, L. L. (1989) Conservation production systems with and without grass barriers in the northern Great Plains. *J. Soil Wat. Conserv.* **44**(4), 320-323.

Brown, L. R. & Wolf, E. C. (1984) *Soil Erosion: the Quiet Crisis in the World Economy*. Worldwatch Paper #60, Washington, DC.

Dabney, S. M., McGregor, K. C., Meyer, L. D., Grissinger, E. H. & Foster, G. R. (1993) Vegetative barriers for runoff and sediment control. In: *Integrated Resource Management and Landscape Modification for Environmental Protection* (ed. by J. K. Mitchell), 60-70. Am. Soc. Agric. Engrs, St Joseph, Michigan, USA.

Dabney, S. M., Meyer, L. D. Dunn, G. H., Foster, G. R. & Alonso, C. V. (1996) Stiff-grass hedges a vegetative alternative for sediment control. In: *Proc. 1996 Interagency Sedimentation Conference.*

Dabney, S. M., Meyer, L. D., Harmon, W. C., Alonso, C. V. & Foster, G. R. (1995) Depositional patterns of sediment trapped by grass hedge. *Trans. Am. Soc. Agric. Engrs* **38**(6), 1719-1729.

Daniels, R. B. & Gilliam, J. W. (1996) Sediment and chemical reduction by grass and riparian filters. *Soil Sci. Soc. Am. J.* **60**(2), 246-251.

Dewald, C., Henry, J., Bruckerhoff, S., Ritchie, J., Dabney, S., Shepard, D., Douglas, J. & Wolf, D. (1996) Guidelines for the establishment of warm season grass hedge for erosion control. *J. Soil Wat. Conserv.* **51**(1), 16-20.

Dewald, C. L. & Lougthan, V. H. (1979) Sequential development of shoot systems components in eastern gamagrass. *J. Range Management* **32**(1), 147-151.

Flanagan, D. C., Foster, G. R., Neibling, W. H. & Burt, J. P. (1989) Simplified equations for filter strip design. *Trans. Am. Soc. Agric. Engrs* **32**(6), 2001-2007.

Kemper, D., Dabney, S., Kramer, L., Dominick, D. & Keep, T. (1992) Hedging against erosion. *J. Soil Wat. Conserv.* **47**(4), 284-288.

Lyles, L., Tatarko, J. & Dickerson, J. D. (1984) Windbreak effects on soil water and wheat yield. *Trans. Am. Soc. Agric. Engrs* **27**(1), 69-72.

Magette, W. L., Brinsfield, R. B., Palmer, R. E. & Wood, J. D. (1989) Nutrient and sediment removal by vegetated filter strips. *Trans. Am. Soc. Agric. Engrs* **32**(2), 663-667.

McGregor, K. C. & Dabney, S. M. (1993) Grass hedges reduce soil loss on no-till and conventional-till cotton plots. In: *Proc. Southern Conserv. Tillage Conf. For Sustainable Agriculture,* 16-20.

Meyer, L. D., Dabney, S. M. & Harmon, W. C. (1994) Sediment-trapping effectiveness of stiff-grass hedge. *Trans. Am. Soc. Agric. Engrs* **38**(3), 809-815.

National Research Council (NRC) (1993) *Vetiver Grass: A Thin Green Line Against Erosion.* Board on Science and Technology for International Development, National Academy Press, Washington, DC.

Siddoway, F. H. (1970) Barriers for wind erosion control and water conservation. *J. Soil Wat. Conserv.* **25**(2), 181-184.

World Bank (1990) *Vetiver Grass - The Hedge Against Erosion.* Washington, DC.