Verh. Internat. Verein. Limnol.	28	1–5	Stuttgart, December 2002

Alternative environmental benefits of agricultural drainage ditches

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Introduction

Agricultural drainage ditches have received mixed reviews pertaining to their influence, role, and definition within the agricultural ecosystem. In the early part of the 20th Century, drainage ditches were viewed as a positive means to reduce mosquito-infested wetlands and convert them into valuable agricultural production acreage (GRUMBLES 1991). In recent decades, however, there has been a concerted effort to attain a 'no net loss' of wetland acreage. This has placed drainage ditches in a precarious situation. They are needed to maintain field drainage, yet frequently their own characteristics may identify them as being wetlands themselves. Many drainage ditches possess the three macrofeatures of any wetland: hydroperiod, hydrosoil, and hydrophytes. There is, however, a fundamental difference in how agricultural drainage ditches are defined. For the purpose of the present study, drainage ditches are limited to those structures created to drain production acreage – not marginal wetlands.

Within the agricultural community, drainage ditches have been viewed as conduits for removing water from production acreage. The public perception has generally been negative in recent years, because constructed ditches have replaced natural drainage systems. Drainage ditches have largely been ignored in scientific research. Research from the Netherlands has focused on drainage ditch maintenance issues (VAN STRIEN et al. 1989, 1991), while DRENT & KERSTING (1992) reported the use of experimental drainage ditches for ecotoxicological evaluations. Until now, little information has been available on the potential mitigation capabilities of drainage ditches.

By viewing drainage ditches as buffers between production acreage and downstream aquatic receiving systems, it is possible to increase the water quality of agricultural runoff following storm events. Therefore, ditches may serve as an alternative best management practice (BMP). Historical BMPs related to agricultural land include, but are not limited to, winter cover crops, stiff grass hedges, riparian zones, grass filter strips, constructed wetlands, and conservation tillage. Most BMP research has been performed in the capacity of reducing sediment and nutrient-laden agricultural runoff (BUTLER et al. 1974, HAYES & HAIRSTON 1983, HAYES et al. 1984, LEE et al. 1989, BARLING & MOORE 1994). Little to no research has attempted to document the capability of vegetated agricultural drainage ditches in the mitigation of pesticide-associated stormwater runoff. If drainage ditches, as proposed, serve as an effective means for the mitigation of pesticide-associated stormwater runoff, farmers and landowners will have a low-cost, environmentally beneficial BMP alternative.

Materials and methods

Simulated pesticide storm runoff was achieved through two different controlled-release experiments, beginning in the summer of 1998. Both experiments were conducted within the Mississippi Delta Management Systems Evaluation Area (MDMSEA) (SCHREIBER et al. 1996a, b) (Fig. 1). The first experiment was conducted on a 50-m reach of a vegetated agricultural drainage ditch within the Beasley Lake watershed. With a top ditch width of approximately 4 m, a depth of 1.3 m, and a bottom slope of 0.004, the drainage ditch discharge during the simulated event was 3680 L h^{-1}. Experimental sampling sites were established at the runoff point of entry, 10 m above the point of entry, and 10, 20, 40, and 50 m below the point of entry. A mixture of the herbicide atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and the insecticide lambda-cyhalothrin (λ-cyano-3-phenoxybenzyl-3-(2-chloro-3,3,3-trifluoro-1-enyl)-2,2-dimethyl cyclopropanecarboxylate), simulating pesticide runoff from a 10-ha field, was applied to the drainage ditch segment. Aqueous samples were collected at 0 min, 60 min, 90 min, 120 min, 150 min, 180 min, 24 h, 7 days, 14 days, and 28 days. Sediment and plant samples were also collected at all sampling intervals except 90 min, 120 min, and 150 min. Atrazine and lambda-cyhalothrin are most commonly used for pest con-

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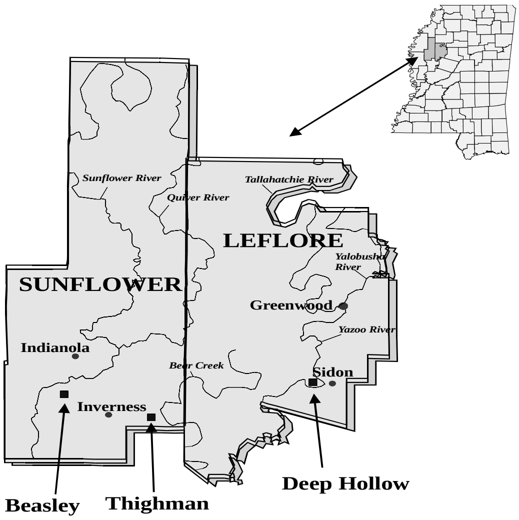

Fig. 1. Mississippi Delta Management Systems Evaluation Area (MDMSEA) watersheds in eastern Mississippi, USA.

trol in corn (*Zea mays*) and cotton (*Gossypium hirsutum*). The dominant aquatic plant species present in the ditch included *Polygonum* sp. and *Leersia* sp.

In 1999, the ditch study was conducted on a 650-m vegetated agricultural drainage ditch leading into Thighman Lake, still within the MDMSEA. The ditch had an approximate top width of 4.5 m, and a water width and depth of 2.8 m and 0.35 m, respectively. Sampling sites were established at 10 m above the point of entry, 0 m (point of entry), and 25, 50, 75, 100, 200, 400 and 650 m below the point of entry. Two pyrethroid insecticides, lambda-cyhalothrin and bifenthrin ([2 methyl(1,1'-biphenyl)-3-yl] methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethyl-cyclopropanecarboxylate) were mixed and amended into the ditch, simulating pesticide runoff from a 20-ha field. Aqueous samples were collected every 15 min for 1.5 h, then again at 2 h, 3 h, 6 h, 12 h, 24 h, 7 days, 14 days, 30 days, 44 days, and 99 days. Sediment and plant samples were collected at all sampling intervals from 3 h to completion of study, as well as at 0 min. In both studies, pesticide mixtures were amended with only water (e.g. no sediment particulates added), estimating a worst-case concentration scenario. Bifenthrin, like atrazine and lambda-cyhalothrin, is commonly used for pest control in corn and cotton. *Ludwigia* sp. and *Lemna* sp. were the dominant aquatic flora in the Thighman drainage ditch. For both ditch experiments, pesticide concentrations were based on label application rates and potential pesticide runoff percentages (WAUCHOPE 1978). Samples of water, sediment, and plants were collected spatially and temporally in both studies and analyzed according to BENNETT et al. (2000) for the presence of atrazine, lambda-cyhalothrin, and bifenthrin, according to the respective experiment.

Results

Atrazine

During the first 24 h following initiation of the simulated storm event on the Beasley Lake drainage ditch, 59–61% of the measured atrazine was associated with the ditch vegetation. Fourteen days after the simulation, atrazine aqueous concentrations in all five ditch monitoring sites were below the ecotoxicological threshold of 0.020 mg L^{-1} (HUBER 1993). Measured mean percentages of atrazine in water, sediment, and plant material were 15 ± 24%, 28 ± 23%, and 57 ± 21%, respectively, for the duration of the study (28 days).

Lambda-cyhalothrin (Beasley Ditch)

Within just 3 h of the simulation event, 97% of the measured lambda-cyhalothrin was associated with ditch vegetation, while the remaining 3% was associated with the water phase. By the end of the study (28 days), 3% of the measured lambda-cyhalothrin was associated with sediment, while 97% was associated with plant material. By end of the study, aqueous concentrations of lambda-cyhalothrin at each of the five monitored ditch sites were at, or below, the ecotoxicological threshold of 0.00002 mg L^{-1} (EXTOXNET 1996). Mean measured percentages of lambda-cyhalothrin in aqueous, sediment, and plant material at the end of the study were 1 ± 1%, 2 ± 1%, and 97 ± 0.4%, respectively.

Lambda-cyhalothrin (Thighman Ditch)
As with the 1998 lambda-cyhalothrin results, 96% of the measured lambda-cyhalothrin was associated with ditch vegetation only 3 h after initiation of simulation in the 1999 study. The remaining measured 4% was associated with the ditch sediment. Samples collected at 12 and 24 h indicated that between 94 and 99% of measured lambda-cyhalothrin was associated with the ditch vegetation. Lambda-cyhalothrin rapidly degraded in water concentrations throughout the length of the ditch within 24 h of the simulated storm event (Fig. 2). Aqueous concentrations in extreme downstream monitoring sites (200 m and beyond) were below the acceptable ecotoxicological threshold level 7 days after the simulation, with all monitoring sites recording concentrations below the threshold 30 days after the simulation. At the end of the study (99 days), mean lambda-cyhalothrin percentages in water, sediment, and plant material were 1 ± 1%, 12 ± 16%, and 87 ± 16%, respectively.

Bifenthrin
Three hours after the simulation, 99% of the measured bifenthrin was associated with ditch vegetation. Similarly, samples collected at 12 and 24 h indicated that 98–99% of the measured bifenthrin was associated with plant material. Bifenthrin concentrations in water quickly degraded along the length of the ditch, 24 h after the simulated storm event (Fig. 3). Extreme downstream monitoring sites (400 m and 650 m) were at, or below, the acceptable ecotoxicological threshold level (0.00018 mg L^{-1}) within 24 h of runoff simulation. Within 30 days, all ditch monitoring sites recorded aqueous concentrations at, or below, the acceptable threshold. Mean measured percentages of bifenthrin in water, sediment, and plant at the end of the study were 1 ± 0.5%, 18 ± 28%, and 81 ± 28%, respectively.

Discussion

As evidenced by current research, ditch vegetation plays a significant role in sequestering pesticides associated with storm runoff from agri-

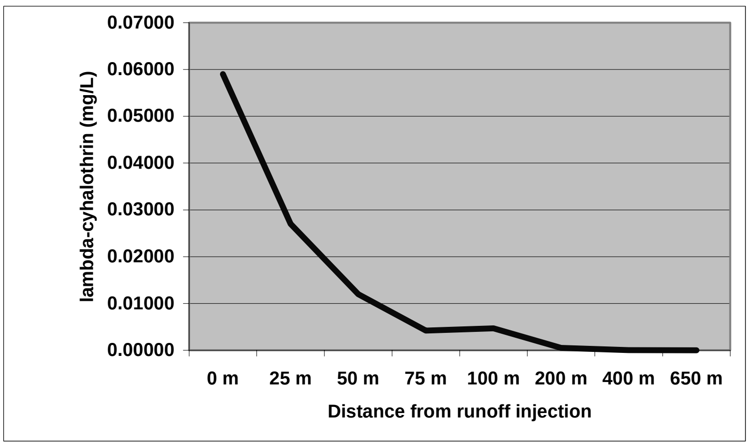

Fig. 2. Degradation of lambda-cyhalothrin in Thighman Ditch water during the first 24 h following runoff simulation, 1999.

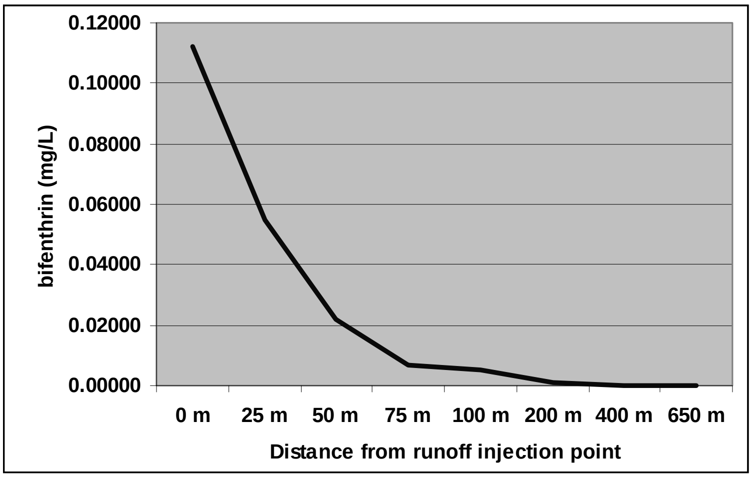

Fig. 3. Degradation of bifenthrin in Thighman Ditch water during the first 24 h following runoff simulation, 1999.

cultural fields. Particularly with pyrethroid insecticides, heavily used on cotton within the Mississippi Delta and other regions of the US, vegetation is a valuable component of the drainage ditch ecosystem. As mentioned previously, most drainage ditch research in the scientific literature deals with ditch vegetation management. In fact, it is a common practice in many European countries to selectively manage the height of ditch vegetation for drainage and aesthetic purposes. Many agricultural drainage ditches in the US are dredged or mowed to remove as much vegetation as possible. Generally this is to provide the least amount of water flow resistance during periods of drainage. However, research indicates that by allowing the vegetation to remain, to some degree, within the ditch, a significant amount of pesticides may be mitigated from stormwater runoff. Ditches must still perform their function of water drainage, but by allowing vegetation to remain in the ditch ecosystem, downstream aquatic receiving systems (rivers, lakes, streams, etc.) will ultimately benefit.

With the US national water quality interests focusing on the Clean Water Act and implementation of total maximum daily loads (TMDLs), the role of agriculture and its relation to water quality are at the forefront of public concern and policy. Agricultural scientists have been designing and continue to design new, innovative BMPs to increase the quality of agricultural stormwater runoff. Great strides have been made in this area in regards to stiff grass hedges, conservation tillage, and other BMPs. Now, with the proposed addition of agricultural drainage ditches, a holistic management water quality approach may be obtained. This research is unique because it emphasizes a new treatment concept – one encompassing processes in the field, at the edge-of-field, in the transitional flow zone, and the receiving waterbody. This concept goes beyond looking at a particular BMP by encouraging a suite of remediation tools for effective runoff mitigation. Farmers and landowners will be able to choose those practices that are both environmentally friendly and economically feasible. Some practices (e.g. constructed wetlands) may have associated costs that cannot be carried by all farmers. In those instances, perhaps a combination of management techniques, including agricultural drainage ditches, would prove most beneficial.

The scaling of drainage ditches is of utmost importance. Little to no information was previously available on the classification of drainage ditches. The research reported herein was conducted on relatively small drainage ditches, less than 5 m in top width. A novel ditch classification system is currently being proposed by FARRIS et al. (2000). The classification ranges from a primary ditch (less than 1 m in width) to a pentenary ditch (>10 m in width). Such pentenary ditches, also termed riverine ditches, may serve more for conducting water and less for mitigation of agriculturally related runoff. Early data suggest that smaller-scale ditches have a higher mitigation capacity for runoff than do larger ditches.

Drainage ditch research is relatively new, but vitally important. The present authors are currently examining several ditch ecosystem parameters, including refinement of the classification scheme, general water quality parameters, microbial activity, invertebrate and vertebrate assessments, nutrient load, and further pesticide mitigation capabilities. By incorporating a holistic approach to drainage ditch management, better decisions will result in improved water quality in downstream aquatic receiving systems.

Acknowledgments

Authors thank E. DEAVER, R. E. LIZOTTE, JR., and C. T. BRYANT for review of this manuscript. Special thanks to L. ARRINGTON and J. HARRIS for their cooperation and use of equipment and drainage ditches. Thanks also to F. GWIN, T. WELCH, S. DAVIS, and J. GREER for field collection and laboratory analyses.

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