## ABSTRACT

JELINEK, SUSAN THERESA. The Association of Weed Species Richness and Abundance with Field Margin Type in Crop Fields. (Under the direction of Dr. J. Paul Mueller and Dr. Nancy G. Creamer).

Natural vegetation on farms such as field margins, successional fallow fields, ditch systems, and neighboring forests provide increased biodiversity, structural diversity, habitat for wildlife and beneficial insects, and can act as protective buffers against agrochemical drift. Nevertheless, farmers frequently view these areas as potential sources of weeds, insect pests, and diseases. Objectives of this study were to examine weed species richness and abundance in cropland bordered by managed versus unmanaged field margins to determine if differences in weed infestation exist. Weed abundance and richness were measured in crop fields along permanent transects that extended from the field edge to the center of the crop fields. Presence/absence data for all plant species in the field margin were also recorded.

Transect data from fields with margins of natural vegetation were compared to transect data from fields with managed margins using analysis of variance. There were no differences between log total abundance of weeds in crop edges adjacent to managed and unmanaged field margins ($P$=0.44). For both margin types, more weeds were found near the field edge than in the center of the field (1.37±0.08 to 0.52±0.07 and 1.39±0.07 to 0.41±0.06, for managed and unmanaged field margins respectively). Species richness was slightly higher along crop edges of managed field margins (7.35±0.32) than crop edges along unmanaged field margins (6.55±0.31).

Across all sampling dates, a total of 105 plant species were identified in the field margins. Of these species, 42 (40% of all species) were found somewhere in a field when all sampling dates were pooled. Managed field margins had lower species richness than unmanaged field margins - less than half the mean number of species (5.8±0.28 versus 14.7±0.62 species, respectively).

No association was found between plant species occurring in the field margin and in the crop field by generating 2 x 2 contingency tables via PROC FREQ and testing the association with Fisher's exact two-sided test. Using logistic regression via PROC GENMOD, margin type and weed presence in the field margin were not effective predictors of weed occurrence in the crop field.

KEYWORDS: field margin, weed populations, crop edges, farm natural areas

**The Association of Weed Species Richness and Abundance with Field Margin Type in Crop Fields**

by

**Susan T. Jelinek**

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Approved by:

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| Co-chair, Advisory Committee | Co-chair, Advisory Committee |

To Melissa Bell

a great friend, confidant, and mischief-maker.

This wouldn’t have been any fun without you.

and

To Brian Mellage

You are the Johnny to my June.

## Biography

Susan Theresa Jelinek was born in Huntsville, Alabama on January 25, 1979 to Frederick and Anne Jelinek. As an Army brat, she grew up in Hampton, Virginia and Fayetteville, North Carolina. Her family moved to the Triangle in 1993, and she graduated from Chapel Hill High School in 1997.

Susan was awarded the Roy H. Park scholarship to attend North Carolina State University where she earned a B.S. in Horticultural Science with a minor in Entomology. Susan was part of the first class of summer interns at the Center for Environmental Farming Systems in 2000 where she was introduced to the principles of sustainable agriculture. She entered a Master's program in the Crop Science department in the fall of 2001 under the direction of Dr. J. Paul Mueller.

Susan is a member of Gamma Sigma Delta, the honor society of agriculture, Pi Alpha Xi, the honor society of Horticulture, and served as the Vice President of the Crop Science Graduate Student Association in 2002.

She married Brian Mellage on October 23, 2004 in Raleigh.

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## General Introduction

## The Association of Weed Species Richness and Abundance with Field Margin Type in Crop Fields

### Agricultural Systems as Ecosystems

Agriculture has long been considered apart from classical ecological and conservation biology research. In managed systems where plant succession is arrested by an array of human activities, agricultural lands have not been viewed as augmenting the biodiversity and ecosystem services provided by the natural world. Thus, in past decades, agricultural lands have largely been ignored by ecologists as depauperate in species richness despite the enormous land area that is used in agriculture or is considered a managed system (over 52% of total United States land area) (Vesterby and Krupa 1997). Much ecological research has focused on the restoration of ecosystems degraded by human use and the conservation of biodiversity through nature preserves (Jackson and Jackson 2002). Nevertheless, conservation effects focused on nature preserves are cited as making limited conservation contributions for two reasons: 1) ecological processes do not recognize the borders of reserve areas and 2) many species (i.e. fugitive, early succession, or agrestal species) depend on disturbance and are hence not able to survive in undisturbed areas (Le Couer et al. 2002). With crop and economic productivity as the main goals of agriculture and maintaining species richness a primary goal of conservation ecology, these two disciplines seemed incompatible.

Nonetheless, in recent decades a new paradigm, Agroecology, has emerged that recognizes the value of applying ecological principles to agricultural production systems in the context of the surrounding landscape. With increasing landscape fragmentation through human activity (housing and road construction, etc.), it is imperative that agricultural lands be included in a holistic strategy to reduce negative effects on the natural world. Sustainable farming practices that use ecologically-based problem-solving techniques strive to minimize negative impacts on the environment, preserve soil and water quality, rely on on-farm resources, and conserve biodiversity (Gliessman 1998). With such principles in place, farmland can become more hospitable for a diversity of plant and animal species. By encouraging conservation in both "preserved" and managed areas, conservation goals have the potential of resulting in more and larger positive environmental effects.

This focus on agricultural ecology has turned attention to the potential importance of uncropped areas of the farm (field margins, successional fallow fields, ditch systems, and neighboring forests) in an effort to understand the role these areas play in the agroecosystem. Ecotones, the area between two different ecosystems (in this case managed and unmanaged land), are unique in that they generally possess physical characteristics and species from both bordering ecosystems. The field margin ecotone may be one of the most important aspects of a farm landscape, potentially contributing more biodiversity than either of the two ecosystems it borders (Powers and McSorley 2000).

That agricultural lands border natural ecosystems is obvious; attention is now focused on the managed/natural ecotone in order to understand how these habitats interact and how they perform important ecosystem functions in the farm landscape.

**The Structure and Role of Field Margins: Implications for Conservation**

Field margins are the most common semi-natural habitat on farms. They are composed of the crop edge, a margin strip and farm track (if present), and the boundary (Figure 1) (redrawn from Marshall and Moonen 2002). The crop edge refers to the outer few meters of the crop field and may be a conservation headland. The margin strip is an established strip for access to the crop field and may be sown to grass, wildflowers, bird habitat, or be strips where natural vegetation is allowed to regenerate. The field margin strip may also include a farm track. The field edge separates the crop edge from the margin strip. The boundary is any natural or semi-natural habitat bordering the margin strip. These areas can include successional fallow fields, ditch systems, forest, fencerows, streams, or formal hedgerows.

The classic example of a field margin is the formal hedgerow, most commonly associated with farms in Europe. For centuries these strips of trees, shrubs, and herbs have been used to divide property, pen livestock, provide wood for construction, heat and cooling, and to shelter animals and crops (Kleijn 1997; Marshall 2002; Marshall and Moonen 1998). Agricultural modernization and mechanization led to the removal of thousands of hectares of hedgerows throughout Western Europe in the 1960s and 1970s. As total area devoted to field margins declined, ecologists began to take interest in uncropped areas and collect baseline data of field margin plant species composition. Le Coeur et al. (2002) suggests that initial research was little more than a census of what vegetation occurred in hedgerows. It has only been in more recent studies that ecologists have come to question how unmanaged ecosystems vary spatially, how managed and unmanaged areas affect each other, and what ecosystem functions these areas contribute to their landscape.

Natural and semi-natural areas provide an array of added diversity to an agroecosystem. Natural areas provide an increase in plant biodiversity to agricultural landscapes (Kleijn 1997). Freemark et al. (2002) reported that of ten different farm habitats, the semi-natural and natural areas of the farmscape (woodlots, fallow fields, and fencerows) had higher overall plant species richness than managed areas (crop fields) and that this difference had an impact on the conservation potential of the habitat because unmanaged natural areas can provide habitat for plants that would otherwise be crowded out (Marshall and Moonen 1998). Field margins can also support a wide variety of species throughout a region. Kaule and Krebs (1989) reported that almost half of the species in the flora of southern Germany occurred in edge habitats which was only 8-10% of the total area of the landscape.

Besides increasing plant species richness, natural areas have also been found to positively impact animal diversity, particularly game birds and other wildlife. Vickery et al. (2002) attributes a decline in farmland birds in the United Kingdom over the past 20 years to agricultural intensification. Natural and semi-natural habitat on farms provide more foraging habitat for these bird species than heavily cultivated areas alone. Natural areas have also been shown to act as important breeding and nesting grounds for farmland birds (O'Connor 1987; Marshall and Moonen 1998). As habitats become more fragmented, it is important to provide travel corridors for wildlife (Tewksbury et al. 2002). Natural field margins can provide these corridors for mammals, birds, and insects reluctant to travel or move through open areas (Kleijn 1997, Le Coeur et al. 2002).

Natural vegetation can also provide important over-wintering habitat for insects (Marshall 2002; Kleijn 1997). Though studies have shown that these areas allow crop pests to over-winter, it should be emphasized that they provide much-needed over-wintering space for beneficial insects as well (Kleijn 1997). Species richness of arthropods was higher in both sown margin strips and large fallow fields than along sprayed field margins (Denys and Tscharntke 2002). Outward (2002) found higher populations of some beneficial arthropods in cotton fields that border vegetated field margins than in cotton fields without such margins. Uncultivated habitats on farms also have been found to be beneficial to many types of bumblebees by providing alternative food sources and over-wintering and reproductive habitat (Backman and Tiainen 2002).

Natural areas also provide structural diversity to farmland. By acting as windbreaks, uncultivated land with trees helps to protect crops from damaging winds and reduce soil erosion (Maclean 1992; Kleijn 1997). These barriers can also reduce drift of farm chemicals from reaching waterways or neighboring crops.

Interest in natural vegetation and unfarmed spaces on agricultural land has also come about due to their financial value. Cost-share programs sponsored through the Natural Resources Conservation Service provide farmers monetary incentives to take certain land out of production and develop these areas for soil conservation, wildlife habitat, and as natural buffers for streams and rivers. The Conservation Security Program encourages farmers to develop whole-farm land use plans that can include wildlife habitat restoration and native prairie and grassland initiatives.

Field margins also have cultural and aesthetic value. Europeans have long identified the rural countryside with small fields separated by hedgerows. Some hedgerows date back several hundred years and are regarded as important historical examples of rural life and deserving of conservation. Hedgerows have been viewed as an interesting part of the rural landscape and as giving people a “sense of place” (Marshall and Moonen 1998).

**Natural Areas as Reservoirs of Pests**

Though there are many benefits to diversifying farms with natural areas, farmers are still reluctant to maintain natural spaces. Consequently, these areas have been in decline over the last several decades, largely due to agricultural intensification. Farmers are cultivating larger fields and thus reducing total area of field margins. Also, the use of chemical fertilizers and pesticides has been found to significantly affect which and how many plant species appear in uncropped areas (Kleijn 1997; Marshall 2002). Schumacher (1987) attributed the loss of diversity in rare native plant species to the increased purity of cereal seed, the widespread use of mineral fertilizers, intensive soil management, and, most importantly, the use of herbicides.

Natural areas and field margins have been viewed as contributing water, light, and nutrient competition to crops. Farmers have also viewed these areas as reservoirs for pests (Marshall 1989, 2002; Kleijn 1997). Empirical studies have shown that weeds occur at highest densities in the crop edge, and it was assumed that this high abundance was due to field margin weeds invading adjacent land. Some research has shown that weeds in the field margin may be contributing to weed presence in the crop field. Wilson and Aebischer (1995) and Marshall (1989) found that most weed species were in highest abundance near the field edge and that weed abundance declined (or was totally absent) as distance from the field margin increased. Theaker et al. (1995) observed a strong association between allele frequencies of populations of *Bromus sterilis* in field margins and in adjacent crop fields, indicating that the populations were genetically similar and suggesting that field margins did contribute weeds to the crop field.

In the last century, the practice of "clean farming" was thought to be a remedy for the perceived dangers of leaving natural vegetation in the farmscape. Along with intensively managing crop fields, farmers were encouraged to manage the uncropped areas of the farm as well. Clean farming techniques can include everything from selective herbicide application in order to remove annual weeds to repeatedly disking field margins to remove all vegetation. Weed management in the field edge can be expensive and time-consuming for farmers who may not have the proper equipment to manage them (Kleijn 1997). Also, it has been suggested that more intensive management can actually lead to exacerbating the weed problem. Most agronomic weeds are successful colonizers, so regular disturbance of the field margin can result in higher weed abundance (Wilcox et al 2000).

Research has been conducted to determine if and how weeds are being distributed into crop fields from the field margin. In a study evaluating the composition of field margins with formal hedgerows, Marshall (1989) found that plant populations can be characterized by four types: (1) plants limited to the field margin (2) plants limited to the crop but occasionally found in boundary (3) plants occurring at the boundary and at decreasing density in the crop and (4) plants distributed through the immediate crop edge with highest densities between 1 and 5 m from the field edge. Overall, a majority of plant species in the field margin was limited to the field margin and only a few species (mostly grasses) seemed to originate in the field boundary.

**Field Margin Research: Implications for Southern Agriculture**

Most field margin research has been conducted in Western Europe, so little data is available for farmscapes in North America, and none is available for the Southeastern United States. While European research has focused on field margins with formal hedgerows as the boundary, our research examined boundary areas of natural vegetation most common to the Southeast (successional fallow fields, ditch systems, and neighboring forest). These field margins were compared to those in which the margin strip was regularly managed and the boundary was another intensively managed area (another crop field).

Our objectives were to better understand how weeds are distributed throughout a crop field and field margin with respect to distance from the field edge and to determine if plant species composition in the field margin is associated with weedy species in the crop field. By determining if a relationship exists between plants in the field margin and weeds in the crop field, the managed/natural ecotone can be better understood and management recommendations can be developed for the control of potential pest problems.

The Association of Weed Species Richness and Abundance

with Field Margin Type in Crop Fields

# The Association of Weed Species Richness and Abundance with Field Margin Type in Crop Fields

Susan T. Jelinek[1]

J. Paul Mueller[1], Nancy G. Creamer[2], Michael G. Burton[1] and Cavell Brownie[3]

Departments of Crop Science[1], Horticultural Science[2], and Statistics[3]

North Carolina State University

## INTRODUCTION

Agroecosystems are made up of two dynamic systems, managed agricultural land and unmanaged natural vegetation, which interact in positive and negative ways. Ecotones, the transitional areas between two different ecosystems (in this case managed and unmanaged land), are unique because they generally possess physical characteristics and species from both bordering ecosystems. The field margin ecotone may be one of the most important aspects of a farm landscape for wildlife, insect, and plant conservation, potentially contributing more to support biodiversity than either of the two ecosystems it borders (Powers and McSorley 2000).

Field margins are the most common semi-natural habitat on farms (Marshall and Moonen 2002). They are composed of the crop edge, a margin strip and farm track (if present), and the boundary (Figure 1) (redrawn from Marshall and Moonen 2002). The crop edge refers to the outer few meters of the crop field and may be a conservation headland. The margin strip is an established strip for access to the crop field (i.e. a farm track). Margin strips may also be sown to grass, wildflowers, or bird habitat, or be strips where natural vegetation is allowed to regenerate. The field edge separates the crop edge from the margin strip. The boundary is any natural or semi-natural habitat bordering the margin strip. These areas can include successional fallow fields, ditch systems, forests, fencerows, streams, or formal hedgerows.

On farms, areas of natural vegetation like field margins provide increased biodiversity, structural diversity, habitat for wildlife and beneficial insects, and can act as protective buffers against agrochemical drift (Kleijn 1997; Freemark et al. 2002; Marshall 2002; O'Connor 1987; Marshall and Moonen 1998; Maclean 1992). Nevertheless, farmers are still reluctant to leave natural vegetation, and these areas have been in decline over the last several decades, largely due to agricultural intensification. Contemporary farmers are cultivating larger fields and thus reducing total area of field margins. Also, the use of chemical fertilizers and pesticides has been found to significantly affect which and how many plant species appear in uncropped areas (Kleijn 1997; Marshall 2002).

Natural areas and field margins have been viewed as contributing water, light, and nutrient competition to crops. Farmers have also viewed these areas as reservoirs for weeds, insect pests, and diseases (Marshall 1989; Marshall 2002; Kleijn 1997). Some empirical studies have shown that weeds occur at highest densities in the crop edge, and it was assumed that this high abundance was due to field margin weeds invading adjacent land. Wilson and Aebischer (1995) and Marshall (1989) reported that most weed species are found in highest abundance near the field edge and that weed abundance declined (or was totally absent) as distance from the field margin increased. In a study evaluating the composition of field margins with formal hedgerows, Marshall (1989) characterized plant populations by four types: (1) plants limited to the field margin (2) plants limited to the crop but occasionally found in boundary (3) plants occurring at the boundary and at decreasing density in the crop and (4) plants distributed through the immediate crop edge with highest densities between 1 and 5 m from the field edge. Overall, a majority of plant species in the field margin was limited to the field margin and only a few species (mostly grasses) seemed to originate in the field boundary. Research has been conducted to determine if and how weeds invade crop fields from the field margin. Theaker et al. (1995) found a strong association between allele frequencies of *Bromus sterilis* species in field margins and in adjacent crop fields, indicating that the populations were genetically similar and suggesting that field margins contributed weeds to the crop field.

In the last century, the practice of "clean farming" was thought to be a remedy for the perceived dangers of leaving natural vegetation in the farmscape. Along with intensively managing crop fields, farmers were encouraged to manage the uncropped areas of the farm as well. Clean farming techniques can include everything from selective herbicide application for removal of annual weeds to repeatedly disking field margins for removal of all vegetation. Weed management in the field edge can be expensive and time-consuming for farmers who may not have the proper equipment to manage them (Kleijn 1997). Also, it has been suggested that more intensive management can actually lead to exacerbating the weed problem. Most agronomic weeds are successful colonizers, so regular disturbance of the field margin can increase weed abundance (Wilcox et al 2000).

**Field Margin Research: Implications for Southern Agriculture**

Most field margin research has been conducted in Western Europe, so little data is available for farmscapes in North America, and none is available for the Southeastern United States. The goal of our research was to assess how unmanaged strips (such as farm tracks) and areas of natural vegetation affect weed populations in neighboring crop fields. While European research has focused on field margins with formal hedgerows as the boundary, our research examined boundary areas of natural vegetation most common in the Southeastern United States (successional fallow fields, ditch systems, and neighboring forest). These field margins were compared to those where the margin strip was regularly managed and the boundary was another intensively managed area (another crop field).

Our objectives were: i) to determine if crop edges adjacent to unmanaged field margins are associated with higher weed species richness and abundance than crop edges bordering managed areas, ii) to determine how weedy species are distributed in the field with respect to distance from the field edge, iii) to assess the presence of weedy species in the field margins and boundary areas and to determine if there is an association between weeds occurring in the field margin and the presence of the same species in the crop field.

An improved understanding of the relationship between plants in the field margin and weeds in the crop field will help in the development of management recommendations for control of potential pest problems in the managed/natural ecotone.

## MATERIALS AND METHODS

### Research Site

Research was conducted in the Farming Systems Research Unit (FSRU) at the Center for Environmental Farming Systems (CEFS) in Goldsboro, NC. The design at the FSRU is a randomized complete block with three replications of five farming systems. The agricultural production systems include a conventional system with best management practices (BMP) currently used by farmers, an integrated crop and animal system, and an organic system. The two remaining systems are a successional ecosystem (old field succession) and a plantation forestry /woodlot system of commercially valued forest species (Mueller et al. 2002). The successional plots had been fallowed since the winter of 1998 when they were planted to a rye cover crop. The experimental site was approximately 80 ha with individual plots ranging in size from 0.8 to 4 ha. Some of the fields on the FSRU are bounded by forest area and the Unit is also drained by a large ditch system. Over the last several years, many have wondered how the areas of natural vegetation on the farm were affecting the adjacent crop fields.

Soil type on the entire 80 ha study area was previously mapped. The Neuse River and a forest border the FSRU on three sides and spatial variability in soil type is high, which is characteristic of river systems. The dominant soil type within each replication was considered the diagnostic soil. The diagnostic soil types are either Wickham (fine-loamy, mixed, semiactive, thermic Typic Hapludult) or Tarboro (mixed, thermic, Typic Udipsamment) (Mueller et al. 2002).

**Field Selection and Sampling Procedure**

Four fields were selected at the FSRU that bordered a large area of natural vegetation on one side (successional fallow field, ditch system, or forest) and adjoined a crop field on the other side – thus representing two types of field boundaries ("unmanaged boundary" and "managed boundary", respectively) (Figure 2). Each field was greater than or equal to 1.5 ha and rectangular in shape. Two more fields were selected that contained only one of the above field margins. One field had an unmanaged boundary and an unmanaged margin strip, the other field ran parallel to a managed boundary and had a managed margin strip (unmanaged and managed strips, respectively). In all, ten field margins were selected for study: 5 along unmanaged strips and 5 along managed strips.

Perpendicular to each of the ten field margins, five permanent transects spaced 10 m apart were established and sampling points were set at 1, 3, 7, 15, 30, and 50 m from the field edge (Figure 3). At each sampling point, a 30 x 75 cm quadrat was laid perpendicular to the row and weed species richness and abundance were determined. Three quadrat observations were taken from the transect row and each neighboring row at each point (i.e. three quadrat observations at each point). These observations were later combined, so area measured was equal to 0.675 $m^2$. Where possible, data were separated for weeds occurring in and between the rows.

**Field Margin Vegetation**

Farm tracks between crop fields were mowed or sprayed with nicosulfuron (applied at 1.68 kg(ai) $ha^{-1}$) mid-summer as scheduled by the farm crew. Margin strips between unmanaged boundaries and crop fields were allowed to grow unrestricted for the duration of the cropping season. After crop harvest, these areas were mowed to the edge of the boundary.

In addition to the aforementioned sampling points in the crop fields, field margin transects were extended away from the crop field and into the margin strips and boundaries. Additional sampling points were set at -2.5, -5, and -8 meters from the field edge into the margin strip and boundary (Figure 3). These distances allowed observations to be made in the center of the farm track, just inside the unmanaged boundary area, and at a distance well inside the unmanaged boundary. For managed margins, observations were only taken at the center of the farm track. At each of these points, a 75 x 75 cm quadrat was used in collecting species richness as presence/absence data.

**Field Management and Sampling Dates**

Within each year all fields were planted with the same crop under conventional tillage practices. Corn (*Zea mays)* was planted in 2002 and peanut (*Arachis hypogaea)* in 2003. Herbicides were neither used prior to spring sampling dates nor for at least six weeks before fall sampling dates (Table 1).

On April 17, 2002, Dekalb 687 Round-Up Ready corn was planted in conventional-till, BMP fields on 0.76 m rows. Two weeks after planting, fields were scouted for weed abundance and species richness. No herbicides were applied to the fields after May 23. Corn was harvested September 7 through September 9, 2002 and fields were sampled again two weeks after harvest.

In 2003, fields were disked in the first week of April 2003 and, after three weeks, fields were sampled for weed abundance and species richness with no crop present in the field. This was due to the fact that some peanut fields were to be planted with the pre-emergence herbicide metolachlor. Once all counts had been made, peanuts were planted the first week of June in raised beds on 0.97 m rows. No fields received herbicide application after July 8, 2003. Fields were sampled again during the last week of August 2003, just before the peanut canopy had completely closed over the rows.

**Statistical Analysis**

Weed species abundance was compiled by field, margin type (managed or unmanaged), transect, distance from the field edge, sampling date, and, for May 2002, row position. The total counts for all species were analyzed using a stripped split plot analysis of variance with PROC GLM in SAS (SAS 1988) on log transformed data. Field and margin type were whole plot factors, distance from the field edge was the subplot factor and date was treated as stripped across other factors. The random effects were transects within field and margin type, distance by transect in field and margin type, and date by transect in field and margin type.

Data sets were summarized by margin type and date to select ten dominant species for further individual analysis. Dominant species were chosen based on abundance, consistent presence for both margin types and consistent presence over sampling dates (Table 6). Similar ANOVAs were carried out on squareroot transformed counts for each dominant species.

Fields with only a single margin type were excluded from analysis of total abundance because ANOVA on log total counts demonstrated that margin types in these fields were more different than margin types on the same field.

Species richness was determined for weed species in the crop field and for plants found in the field margin and results were analyzed with PROC GLM. ANOVA on species richness was carried out separately for the crop field and field margin. Data for species richness and abundance for weeds in the crop field were then combined into two distances: near the field edge (including distances of 1, 3, and 7 m sampling points) and near field center (15, 30, and 50 m sampling points). Shannon's species diversity index was calculated from weed data in each of the two crop field regions (field edge and field center) and analyzed according to the stripped split plot ANOVA.

To determine whether an association existed between weeds appearing in the field margin and presence in the crop field, for each species, weed abundance in the crop field was converted to presence/absence data and combined with presence-absence data from the field margins. A 2 x 2 contingency table was were generated using PROC FREQ in SAS (SAS

1988) by year and margin type for each species, and Fisher's exact two-sided test was used to test for an association between the two areas.

Data for each dominant weed species combined across sampling dates were used to test if margin type or presence in the field margin were predictors of presence of the weed in the crop field. Logistic regression using PROC GENMOD in SAS (SAS 1988) tested the importance of the predictors: field, margin type, presence in the field margin, and year. Reduced models were chosen for each species when appropriate.

## RESULTS AND DISCUSSION

### Weeds in Crop Fields

For total weed abundance within crop field, field effect was significant ($P < 0.001$), but margin type was not ($P = 0.44$). This indicates that there were no differences, on average, between total abundance of weeds in crop edges adjacent to managed and unmanaged field margins. Distance effect was also significant ($P < 0.001$) indicating that total abundance of weeds differed according to distance along the transects into the crop field (Table 2).

For May 2002, the effect of row position (weeds found in or between the crop row) on weed abundance ($P < 0.001$) and the interaction of row position and field ($P = 0.001$) were significant, indicating that numbers of weeds in the crop row and between the crop rows was dependent on field. No differences in weed abundance as influenced by row position were observed between margin types ($P = 0.49$). No further analysis on the effects of row position could be performed because row position data was only collected on one sampling date.

The mean of log total weed abundance for both managed and unmanaged margin types was observed to be greatest near the field edge and declined toward the center of the crop field (Figure 4). This pattern of weed abundance is consistent with previous research

(Wilson and Aebischer 1995; Marshall 1989). In previous results of mostly European research, most species were found in highest abundance near the field edge and weed abundance declined (or disappeared) as distance from the field margin increased. Abundance remained similar between the two margin types except in one of the fields with an unmanaged margin. In this field there was one large isolated population of *Brachiaria platyphylla* that caused high weed abundance. Crop rows were perpendicular to the sampling transects and therefore the sampling points at 15 m along this margin were found in the same crop row or in neighboring rows at each transect. It is believed that these rows may have been missed during herbicide applications in previous years and the population was allowed to produce seed, causing higher abundance in the years of our study.

Species richness for weeds in the crop field along the two field margin types differed (*P*= 0.03) (Table 3; Figure 5). Crop edges along managed field margins tended to have greater mean number of weed species (7.35) than unmanaged margins (6.55). It is not certain how biologically important this difference may be for agroecosystems.

Shannon's species diversity index returned similar results. Diversity index results for weeds in the crop field differed along the two field margin types (P= 0.05) (Table 4). A significant distance by margin interaction (p=0.002) resulted because diversity index means were highest at the field edge and lowest in the field center for the unmanaged field margin, and similar at the two distances for the managed field margin (Table 5).

**Dominant Species in Crop Field**

It is important not only to look at the distribution of total numbers of weeds, but also the species composition of the assemblage. The dominant species included: broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash), prickly sida (*Sida spinosa* L.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), yellow nutsedge (*Cyperus esculentus* L.), morningglory species (*Ipomea* spp.), henbit (*Lamium amplexicaule* L.), goosegrass (*Eleusine indica* (L.) Gaertn.), sickle pod (*Senna obtusifolia* L. Irwin & Barneby), carpetweed (*Mollugo verticillata* L.), and redroot pigweed (*Amaranthus retroflexus* L.). These weeds are also known to be the most common and troublesome weeds at CEFS.

Although total weed abundance did not differ by margin type, most species differed by margin type individually (Table 7). *Amaranthus retroflexus*, *Digitaria sanguinalis*, and *Mollugo verticillata* differed by all factors: field, margin type, distance from the field edge, and sampling date. *Brachiaria platyphylla* differed by field, margin type, and distance from the field edge. *Senna obtusifolia* differed by field, margin type, and sampling date. *Cyperus esculentus*, *Sida spinosa*, and *Lamium amplexicaule* differed by field, distance, and sampling date. *Ipomea* spp. differed by distance alone. ANOVA results for *Eleusine indica* were not reliable due to a large number of zeros in the data set and this species was therefore not included in further analyses.

The square root mean number of weeds by distance from the field edge and margin type for nine of the ten dominant species (*Eleusine indica* not included) are presented in Figures 6-14. Differences between margin types in total abundance of each weed species are clear for all species except *Senna obtusifolia*, which did not show a significant effect of distance ($P$= 0.08).

For both margin types, *Brachiaria platyphylla*, *Amaranthus retroflexus*, *Digitaria sanguinalis*, and *Mollugo verticillata* (Figures 6-9) all had the highest number of weeds at the crop edge within the first 7 m and the lowest numbers of weeds toward the center of the field. The unmanaged margin of *Sida spinosa* (Figure 10) had highest abundance at the field edge, while the managed margin had lowest abundance at the field edge and in the center of the field. *Cyperus esculentus* (Figure 11) had highest abundance at the field edge for both margin types followed by a sharp decline at 7 m and an increase at 15 and 30 m. Abundance for the unmanaged margin continued to increase at points in the field center, while abundance along the managed margin declined towards the field center.

*Ipomea* spp. (Figure 12) were low in abundance in the crop edge but abundance increased at distances of 7 and 15 meters and then declined toward the center of the field. *Lamium amplexicaule* (Figure 13) was the only weed species that had lowest abundance of weeds at the field edge and a consistent increase in abundance toward the field center. *Senna obtusifolia* (Figure 14) was observed to have highest abundance at different points in the crop field depending on border type. Managed margins had lowest abundance at the field edge and at 50 m into the crop field, with the highest abundance at 30 m. The unmanaged margin had lowest weed abundance at the field edge and the center of the crop field and the highest abundance between 3 and 15 m.

Abundance of weeds at each point in the field remained similar across the two margin types for *Cyperus esculentus*, *Lamium amplexicaule*, *Sida spinosa*, and *Ipomea* spp., reflecting no effect of margin type. Species with a significant difference by margin type (*Brachiaria platyphylla*, *Amaranthus retroflexus*, *Digitaria sanguinalis*, *Mollugo verticillata*, and *Senna obtusifolia*) also differed in abundance at different distances from the crop edge. Nonetheless, *Amaranthus retroflexus* was the only species for which the managed margin was consistently higher in mean numbers than the unmanaged margin.

**Field Margin Species Richness**

In 2002, 80 plant species were found in field margins. For the spring sampling date, only 21 of those species appeared in a crop field as a weed, representing only 26.3% of total species. Results were similar for 2003: of the 73 plant species found in the field margin, only 18, or 24.6%, were found as weedy species in a crop field at the spring sampling date. At least 74% of species in the field margin were not present in crop fields surveyed.

Across all sampling dates, a total of 105 plant species were identified in the field margins. Of these 105 species, 42 were found in the crop field representing 40% of total species sampled (Table 8). These proportions are consistent with earlier observations of Marshall (1989) in which 20-40% of field margin species were weedy species that commonly occurred in cultivated fields and at least 60% of plant species were found in the field margin only (i.e. not found in the cultivated field).

Species richness between the two field margin types was found to be significantly different ($P < 0.001$) (Table 9; Figure 5). Managed field margins had less than half the mean number of species of unmanaged field margins (5.8 species versus 14.7, respectively). Thus, unmanaged field margins may have higher conservation and habitat potential than managed field margins. Joenje and Kleijn (1994) expected that, for a newly established field margin, species richness would be high initially, followed by a period of moderate diversity and then only increase in species richness over time. Kleijn (1997) maintains that because high plant species diversity is directly related to high insect diversity and low herbivore/predator ratios, these areas can act as ecosystem regulators of insect pest problems and perhaps reduce the need for agrochemicals in the crop field. Therefore, as field margins continue to increase in plant species richness, conservation and habitat potential are expected to increase.

**Field Margins as Reservoirs: Association between Weeds in the Field Margin and Presence in the Crop Field**

Because most of the species in the field margin were not found in the crop fields and because not all weedy species were found in the field margin, only a fraction of total species generated 2 x 2 frequency tables with a majority of non-zero cells. Most of these were dominant species. They included: *Brachiaria platyphylla, Amaranthus retroflexus, Sida spinosa, Cyperus esculentus, Digitaria sanguinalis,* and *Oxalis stricta* (Appendix A).

As presented in Appendix A and Table 10, the columns represent the 2 x 2 possible outcomes for presence and absence in the crop field and margin, and rows represent sampling date and margin type. Numbers are the percent of transects in which the weed was present or absent in the field and field margin. The first column, "presence in the crop field and present in the field margin", is of particular interest, as this number may suggest a relationship between weed presence in the field margin and field. A significant *P*-value for the tests means that an association exists. If Fisher's exact two-sided test is not significant, then one is neither more nor less likely to find the weed present in the crop field if it is present in the field margin.

No associations were found for any of the tested species, except for *Digitaria sanguinalis* for both managed and unmanaged margin types in 2003 (*P*= 0.072 and *P*= 0.017, respectively) (Table 10). The association does not seem reliable, however, because it was not found to be consistent over margin types nor over sampling year. Results from the unmanaged margin of 2003 imply a negative association (that one is less likely to find *D. sanguinalis* in the crop field if it is found in the field margin) and the managed margin of

2003 shows a positive association (that one is more likely to find *D. sanguinalis* in the crop field if it is found in the field margin.)

Theaker et al. (1995) found a strong association between allele frequencies of *Bromus sterilis* species in field margins and in adjacent crop fields, indicating that the populations were genetically similar and suggesting that field margins did contribute weeds to the crop field. Though it is possible that some individual plants of weed species in our study may have been contributed to the field from the field margin, total populations of the most abundant weeds do not support this association.

**Field Margins as Reservoirs: Presence in the Field Margin As Predictor**

PROC GENMOD did not produce estimates of *P*-values for *Mollugo verticillata*, *Eleusine indica* and *Lamium amplexicaule* due to large numbers of zeros in their data sets. For *Brachiaria platyphylla*, *Senna obtusifolia*, *Sida spinosa*, and *Amaranthus retroflexus*, field was the only significant predictor of the weed appearing in the crop field. Field and year were effective predictors of *Digitaria sanguinalis* and *Cyperus esculentus* appearing in the crop as a weed (Table 11).

Our analysis indicated field as an appropriate predictor of the weed occurring in the crop field for most weed species. This is understandable considering that field history and knowledge of past weed populations that may have impacted the soil seedbank are very important when predicting what weeds will occur the following year and determining which management tactics to use. For most species, the factors of greatest interest to this research, presence in the field margin and margin type, were not associated with presence of the weed in the crop field.

## CONCLUSIONS

Previous research has indicated that some weed species invade crop edges from adjacent field margins, however, these species are few compared to total numbers of plant species in the field margin and their impact has not been seen to be economically important. Blumenthal and Jordan (2001) suggested that because number of weeds is so limited, it may be possible to reduce management of natural habitat without negative consequences to the adjacent crop. Weed management in the field edge can be expensive and time-consuming for farmers who may not even have the proper equipment (Kleijn 1997). Eliminating this task from the list of farm chores could allow time and resources for weed management tactics or other necessary improvements to the farm.

Our results support the hypothesis that more weeds appear near the crop edge, not because they appear in the field margin, but because crop edges tend to be managed differently than the rest of the crop field. As fields are prepared for planting, different levels of cultivation, herbicide and fertilizer application are found at the outer edges of the field versus within the field. Wilcox et al. (2000) found a non-linear relationship between crop yield and weed biomass with respect to distance from the field edge, and suggested that weed competition alone could not be responsible for reduced yield in the crop edge because when yield was adjusted for weed biomass, there was still evidence of a distance effect. This suggests that other factors such as soil compaction, nonuniform application of herbicide and fertilizer could help explain reduced crop performance. They also suggest that high weed biomass may be a result of poor crop performance, not the opposite.

Above all, this research supports the hypothesis that natural and semi-natural habitats in the farm landscape are not necessarily associated with weed contamination of fields.

Agroecosystems contain two dynamic systems, managed and natural, that interact in positive and negative ways. To more fully recognize the benefits of such interactions, farms should be managed on landscape as well as field levels.

# LITERATURE CITED

Backman, J-P. C. and J. Tiainen. 2002. Habitat quality of field margins in a Finnish farmland area for bumblebees (Hymenoptera: Bombus and Psithyrus). Agriculture Ecosystems and Environment. 89, 53-68

Blumenthal, D. and N. Jordan. 2001. Weeds in field margins: a spatially explicit simulation analysis of Canada thistle population dynamics. Weed Science. 49, 509-519.

Denys, C. and T. Tscharntke. 2002. Plant-insect communities and predator-prey ratios in field margin strips, adjacent crop fields, and fallows. Oecologia 130: 315-324.

Freemark, K.E. C. Boutin, and C.J. Keddy. 2002. Importance of farmland habitats for conservation of plant species. Conservation Biology. 16, 399-412.

Gliessman, S. R. Agroecology: Ecological Processes in Sustainable Agriculture. Chelsea, MI: Ann Arbor Press.

Jackson, Dana L. and Laura L. Jackson. The Farm as Natural Habitat. Washington: Island Press, 2002.

Joenje, W. and D. Kleijn. 1994. Plant distribution across arable field ecotones in the Netherlands. Field Margins: Integrating Agriculture and Conservation. Proceedings of a symposium organised by the British Crop Protection Council. Monograph No. 58. 323-328.

Kaule, G. and S. Krebs. 1989. Creating new habitats in intensively used farmland. In: Buckley, G.P. Biological Habitat Reconstruction. London: Belhaven Press.

Kleijn, D. 1997. Species richness and weed abundance in the vegetation of arable boundaries. PhD thesis, Wageningen Agricultural University. Wageningen, 177 p.

Le Coeur, D., J. Baudry, F. Burel, and C. Thenail. 2002. "Why and how we should study field boundary biodiversity in an agrarian landscape context." Agriculture, Ecosystems & Environment 89, 23-40.

Maclean, M. 1992. New Hedges for the Countryside. Farming Press. Ipswich, UK.

Marshall, EJP. 1989. Distribution Patterns of plants associated with arable field edges. Journal of Applied Ecology. 26: 247-257.

Marshall, E.J.P. 2002. Introduction to field margin ecology in Europe. Agriculture, Ecosystems & Environment. 89, 1-4.

Marshall, E.J.P and A.C. Moonen. 1998. A review of field margin conservation strips in Europe. UK Ministry of Agriculture, Fisheries and Food. Long Ashton Research Station.

Marshall, E.J.P and A.C. Moonen. 2002. Field margins in northern Europe: their functions and interactions with agriculture. Agriculture, Ecosystems & Environment 89, 5-21.

Mueller, J.P., M.E. Barbercheck, M. Bell, C. Brownie, N.G. Creamer, A. Hitt, S. Hu, L. King, H.M. Linker, F.J. Louws, S. Marlow, M. Marra, C.W. Raczkowski, D.J. Susko, M.G. Wagger. 2002. Development and implementation of a long-term agricultural systems study: challenges and opportunities. HortTechnology. 12, 362-368.

O'Connor R.J. 1987. Environmental interests of field margins for birds. In: Field Margins: BCPC Monograph Number 35 - Proceedings of a Workshop organized by the British Crop Protection Council and held in London on 11th march 1986. J.M

Way and P.W. Greig-Smith. p. 35-48.

Outward, R.J., C.E. Sorenson, and P.T. Bromley. 2000. Effects of fallow vegetation field borders on arthropods in cotton and soybean fields in eastern North Carolina. Proceedings of the Beltwide Cotton Conference 2000, 1270-1272.

Powers, L. E. and Robert McSorley. Ecological Principles of Agriculture. Albany: Delmar Thomson Learning, 2000.

Shumacher, W. 1987. Measures taken to preserve arable weeds and their associated communities. In: Field Margins: BCPC Monograph Number 35 - Proceedings of a Workshop organized by the British Crop Protection Council and held in London on 11th march 1986. J.M Way and P.W. Greig-Smith. p. 35-48.

Tewksbury, J.J. D.J. Levey, N.M Haddad, S. Sargent, J. L. Orrock, A. Weldon, B.J. Danielson, J. Brinkerhoff, E.I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. PNAS 99 (20) 12923-12926.

Theaker, A.J., N.D. Boatman, and R.J. Froud-Williams. 1995. Variation in Bromus sterilis on farmland: evidence for the origin of field infestations. Journal of Applied Ecology. 32, 47-55.

SAS Inst., Inc. 1988-2001. SAS/STAT User's Guide: Release 8.02 Edition. SAS Inst., Inc., Cary, NC.

Vesterby, M. and K. S. Krupa. 1997. Major Uses of Land in the United States, 1997. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Statistical Bulletin No. 973.

Vickery, J., Nick Carter and Robert J. Fuller. 2002. The potential value of managed cereal field margins as foraging habitat for farmland birds in the UK. Agriculture Ecosystems and Environment. Agriculture, Ecosystems & Environment. 89, 41-52.

Wilcox, A. N.H. Perry, N.D. Boatman, and K. Chaney. 2000. Factors affecting the yield of winter cereals in crop margins. Journal of Agricultural Science. 135: 335-346.

Wilson, P.J. and N.J. Aebischer. 1995. The distribution of dicotyledonous arable weeds in relation to distance from the field edge. Journal of Applied Ecology. 32: 295-310.

*Table 1*. Herbicides and cultivation[1] for crop fields sampled in 2002 and 2003.

| | 2002 corn (*Zea mays*) | | | | |
|---|---|---|---|---|---|
| | 8 May | 16 May | 10 May | 18 May | 23 May |
| Field 5 | -------------- | glyphosate | -------------- | ------------- | ---------- |
| Field 13 | glyphosate[2] | -------------- | -------------- | ------------- | ametryn[4] |
| Field 23 | -------------- | -------------- | nicosulfuron[3] | cultivation | ametryn |
| Field 43 | -------------- | -------------- | nicosulfuron | cultivation | ametryn |

| | 2003 peanut (*Arachis hypogaea*) | | | |
|---|---|---|---|---|
| | 3 June | 16 June | 25 June | 8 July |
| Field 5 | -------------- | -------------- | cultivation | bentazon<br>acifluorfen<br>2,4-DB[9] |
| Field 13 | metolachlor[5] | paraquat[6]<br>bentazon[7]<br>acifluorfen[8] | cultivation | bentazon<br>acifluorfen |
| Field 23 | -------------- | -------------- | cultivation | bentazon<br>acifluorfen<br>2,4-DB |
| Field 43 | -------------- | -------------- | cultivation | bentazon<br>acifluorfen<br>2,4-DB |

[1] other operations included: 17-18 April 2002 corn planted, 5-9 Sept corn harvested, 3-5 June peanuts planted, 17-24 October peanuts harvested
[2] applied at 1.68 kg(ai) $ha^{-1}$
[3] applied at 0.0469 kg(ai) $ha^{-1}$
[4] applied at 0.367 kg(ai) $ha^{-1}$ and non-ionic surfactant at 0.5% V:V
[5] applied at 2.80 kg(ai) $ha^{-1}$
[6] applied at 392 g(ai) $ha^{-1}$ and non-ionic surfactant at 0.5% V:V
[7] applied at 1.40 kg(ai) $ha^{-1}$ and non-ionic surfactant at 0.5% V:V
[8] applied at 2.10 kg(ai) $ha^{-1}$ and non-ionic surfactant at 0.5% V:V
[9] applied at 1.12 kg(ai) $ha^{-1}$ and non-ionic surfactant at 0.25% V:V

*Table 2*. Sources of variance for log total abundance of weeds in the crop field.

| | DF | Mean Square | F Value | P- value |
|---|---|---|---|---|
| Field | 3 | 6.62 | 51.42 | < 0.001*** |
| Margin type | 1 | 0.078 | 0.60 | 0.44 |
| Field*Margin | 3 | 3.53 | 27.42 | < 0.001*** |
| Distance | 5 | 15.91 | 123.56 | < 0.001*** |
| Field*Distance | 15 | 0.99 | 7.71 | < 0.001*** |
| Margin*Distance | 5 | 0.55 | 4.27 | 0.001*** |
| Date | 3 | 35.40 | 274.77 | < 0.001*** |
| Field*Date | 9 | 5.27 | 40.88 | < 0.001*** |
| Margin*Date | 3 | 0.50 | 3.88 | 0.01** |
| Distance*Date | 15 | 1.14 | 8.84 | < 0.001*** |

*Table 3*. Sources of variance for species richness in crop fields on squareroot transformed data.

| | DF | Mean Square | F Value | *P*- value |
|---|---|---|---|---|
| Field | 3 | 1.53 | 18.79 | < 0.001 |
| Margin | 1 | 0.50 | 6.10 | 0.019 |
| Field*Margin | 3 | 0.23 | 2.79 | 0.05 |
| Year | 1 | 0.003 | 0.04 | 0.85 |
| Field*Year | 3 | 0.48 | 5.93 | 0.003 |
| Margin*Year | 1 | <0.001 | 0 | 0.99 |

*Table 4*. Sources of variance for Shannon’s diversity index for weeds in the crop field.

| | DF | Mean Square | F Value | P- value |
|---|---|---|---|---|
| Field | 3 | 2.40 | 23.24 | < 0.001 |
| Margin | 1 | 0.40 | 3.88 | 0.05 |
| Field*Margin | 3 | 0.42 | 4.08 | 0.01 |
| Distance | 1 | 1.08 | 10.39 | 0.002 |
| Field*Distance | 3 | 2.29 | 22.18 | < 0.001 |
| Margin*Distance | 1 | 1.04 | 10.10 | 0.002 |
| Date | 3 | 2.98 | 28.81 | < 0.001 |
| Field*Date | 9 | 0.78 | 7.58 | < 0.001 |
| Margin*Date | 3 | 0.87 | 8.41 | < 0.001 |
| Distance*Date | 3 | 0.24 | 2.34 | 0.08 |

*Table 5*. Mean Shannon's diversity indices for weeds in the crop field.

| Margin type | Distance level | N[1] | H | Standard Dev. |
|---|---|---|---|---|
| Unmanaged | Near field edge | 80 | 1.01 | 0.54 |
| Unmanaged | Near field center | 76 | 0.78 | 0.44 |
| Managed | Near field edge | 77 | 0.96 | 0.49 |
| Managed | Near field center | 76 | 0.96 | 0.44 |

[1]Sample sizes were < 80 because the index could not be computed at sites where no weeds were found.

*Table 6.* Summary of species found in crop field. Dominant species (in bold) were selected based on abundance, consistent presence for both borders and consistent presence over sampling dates. Dominant species include: broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash), prickly sida (*Sida spinosa* L.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), yellow nutsedge (*Cyperus esculentus* L.), morningglory species (*Ipomea* spp.), henbit (*Lamium amplexicaule* L.), goose grass (*Eleusine indica* (L.) Gaertn.), sickle pod (*Senna obtusifolia* L.), carpetweed (*Mollugo verticillata* L.), and redroot pigweed (*Amaranthus retroflexus* L.).

| | 2002 | | | | 2003 | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Spring | | Fall | | Spring | | Fall | | |
| Species[1] | Unmanaged | Managed | Unmanaged | Managed | Unmanaged | Managed | Unmanaged | Managed | |
| ACRRB | 17 | 5 | 0 | 1 | 5 | 1 | 0 | 2 | 31 |
| ALLVI | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| AMACH | 39 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 85 |
| **AMARE** | **264** | **1443** | **28** | **50** | **985** | **1843** | **18** | **142** | **4773** |
| AMBEL | 4 | 27 | 15 | 3 | 5 | 2 | 39 | 9 | 104 |
| **BRAPP** | **2727** | **1011** | **78** | **32** | **1952** | **1566** | **32** | **21** | **7419** |
| BRASP | 51 | 129 | 0 | 0 | 0 | 0 | 0 | 0 | 180 |
| CARHI | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 3 | 29 |
| **CASOB** | **139** | **46** | **128** | **88** | **68** | **20** | **13** | **5** | **507** |
| CHEAL | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 6 |
| CMIRA | 2 | 0 | 12 | 3 | 3 | 1 | 1 | 0 | 22 |
| COMBE | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| COMDI | 1 | 0 | 8 | 6 | 0 | 0 | 0 | 0 | 15 |
| COPDI | 0 | 0 | 0 | 15 | 0 | 0 | 1 | 19 | 35 |
| CYNDA | 0 | 0 | 1 | 0 | 30 | 22 | 0 | 0 | 53 |
| **CYPES** | **124** | **211** | **3** | **38** | **78** | **93** | **4** | **2** | **553** |
| **DIGSA** | **71** | **11** | **0** | **0** | **696** | **666** | **4** | **1** | **1449** |
| DIORE | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 |

*Table 6* (continued).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ECLAL | 0 | 27 | 3 | 8 | 0 | 0 | 3 | 1801 | 1842 |
| **ELEIN** | **16** | **118** | **17** | **33** | **0** | **0** | **0** | **0** | **184** |
| EPHHT | 8 | 2 | 12 | 6 | 0 | 0 | 0 | 0 | 28 |
| ERICA | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| EUPCP | 0 | 0 | 1 | 4 | 0 | 0 | 3 | 1 | 9 |
| GALAP | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| GNAPU | 0 | 0 | 257 | 379 | 0 | 0 | 150 | 27 | 813 |
| **IPOSP** | **75** | **73** | **23** | **44** | **59** | **70** | **7** | **3** | **354** |
| LACSE | 0 | 0 | 18 | 8 | 0 | 0 | 0 | 0 | 26 |
| **LAMAM** | **340** | **164** | **886** | **1140** | **64** | **98** | **1** | **0** | **2693** |
| LOLMU | 0 | 37 | 0 | 0 | 1 | 0 | 0 | 0 | 38 |
| **MOLVE** | **127** | **937** | **191** | **159** | **1109** | **2592** | **287** | **308** | **5710** |
| OEOLA | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| OXAST | 1 | 5 | 22 | 57 | 1 | 5 | 25 | 25 | 141 |
| PHTAM | 10 | 16 | 14 | 8 | 7 | 11 | 1 | 0 | 67 |
| PLALA | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| POAAN | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 4 |
| POROL | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 1 | 8 |
| RANBU | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 18 |
| RAPRA | 23 | 0 | 67 | 41 | 0 | 0 | 0 | 1 | 132 |
| RUMAA | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| RUMCR | 0 | 0 | 101 | 4 | 0 | 1 | 0 | 0 | 106 |
| SETFA | 0 | 0 | 1 | 95 | 0 | 0 | 0 | 0 | 96 |
| **SIDSP** | **68** | **68** | **54** | **99** | **223** | **179** | **29** | **24** | **744** |
| SINAR | 0 | 0 | 0 | 0 | 12 | 6 | 0 | 0 | 18 |

*Table 6* (continued)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SOLCA | 0 | 1 | 9 | 5 | 2 | 0 | 0 | 0 | 17 |
| SONAR | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| SONAS | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| SONOL | 0 | 0 | 6 | 14 | 0 | 0 | 0 | 0 | 20 |
| SORHA | 11 | 72 | 0 | 0 | 0 | 0 | 0 | 1 | 84 |
| SPRAR | 0 | 86 | 0 | 31 | 0 | 124 | 0 | 24 | 265 |
| STEME | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 10 |
| TAROF | 0 | 0 | 59 | 14 | 0 | 0 | 0 | 0 | 73 |
| THLAR | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| TRFRE | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 5 |
| VEROF | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | | | Unknown species[2] | | | | | |
| FTUT | 0 | 0 | 0 | 0 | 2 | 7 | 0 | 0 | 9 |
| TTUO | 0 | 0 | 0 | 0 | 2 | 7 | 0 | 0 | 9 |
| TTUT | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 7 |
| FUT | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 7 |

[1] See Table 6 for scientific and common names

[2] Not able to identify due to early development stage and limited abundance

*Table 7*. Sources of variance for *Amaranthus retroflexus*, *Senna obtusifolia*, *Sida spinosa*, *Lamium amplexicaule*, *Ipomea* spp., *Mollugo verticillata*, *Digitaria sanguinalis*, *Cyperus esculentus*, and *Brachiaria platyphylla* on squareroot transformed data.

| | | | | |
|---|---|---|---|---|
| | | *Amaranthus retroflexus* | | |
| | DF | Mean Square | F value | *P*- value |
| Field | 3 | 271.74 | 131.45 | < 0.001 |
| Margin type | 1 | 81.16 | 39.26 | < 0.001 |
| Field*Margin | 3 | 9.90 | 4.79 | 0.003 |
| Distance | 5 | 63.39 | 30.66 | < 0.001 |
| Field*Distance | 15 | 15.85 | 7.67 | < 0.001 |
| Margin*Distance | 5 | 20.53 | 9.93 | < 0.001 |
| Date | 3 | 42.83 | 20.72 | < 0.001 |
| Field*Date | 9 | 39.07 | 18.90 | < 0.001 |
| Margin*Date | 3 | 0.09 | 0.05 | 0.83 |
| Distance*Date | 15 | 5.21 | 2.52 | 0.03 |
| | | *Senna obtusifolia* | | |
| | DF | Mean Square | F value | *P*- value |
| Field | 3 | 21.25 | 100.93 | < 0.001 |
| Margin type | 1 | 4.66 | 22.15 | < 0.001 |
| Field*Margin | 3 | 5.16 | 24.51 | < 0.001 |
| Distance | 5 | 0.42 | 1.99 | 0.08 |
| Field*Distance | 15 | 0.54 | 2.56 | 0.001 |
| Margin*Distance | 5 | 1.13 | 5.36 | < 0.001 |
| Date | 3 | 1.72 | 8.15 | 0.005 |
| Field*Date | 9 | 1.18 | 5.60 | 0.001 |
| Margin*Date | 3 | 0.13 | 0.61 | 0.43 |
| Distance*Date | 15 | 0.15 | 0.71 | 0.62 |
| | | *Sida spinosa* | | |
| | DF | Mean Square | F value | *P*- value |
| Field | 3 | 43.73 | 143.06 | < 0.001 |
| Margin type | 1 | 0.88 | 2.87 | 0.09 |
| Field*Margin | 3 | 0.34 | 1.12 | 0.34 |
| Distance | 5 | 1.21 | 3.97 | 0.002 |
| Field*Distance | 15 | 1.37 | 4.47 | < 0.001 |
| Margin*Distance | 5 | 0.62 | 2.02 | 0.08 |
| Date | 3 | 13.75 | 44.98 | < 0.001 |
| Field*Date | 9 | 7.87 | 25.74 | < 0.001 |
| Margin*Date | 3 | 0.28 | 0.92 | 0.34 |
| Distance*Date | 15 | 0.23 | 0.76 | 0.58 |

*Table 7* continued.

| | DF | Mean Square | F value | *P*- value |
|---|---|---|---|---|
| | | *Lamium amplexicaule* | | |
| | DF | Mean Square | F value | *P*- value |
| Field | 3 | 63.78 | 210.76 | < 0.001 |
| Margin type | 1 | 0.89 | 2.95 | 0.087 |
| Field*Margin | 3 | 3.72 | 12.28 | < 0.001 |
| Distance | 5 | 2.41 | 7.97 | < 0.001 |
| Field*Distance | 15 | 3.57 | 11.80 | < 0.001 |
| Margin*Distance | 5 | 0.77 | 2.54 | 0.03 |
| Date | 3 | 1.95 | 6.44 | 0.011 |
| Field*Date | 9 | 10.72 | 35.41 | < 0.001 |
| Margin*Date | 3 | 3.87 | 12.79 | 0.0004 |
| Distance*Date | 15 | 2.74 | 9.05 | < 0.001 |
| | | *Ipomea species* | | |
| | DF | Mean Square | F Value | *P*- value |
| Field | 3 | 0.59 | 1.88 | 0.13 |
| Margin type | 1 | 0.11 | 0.34 | 0.56 |
| Field*Margin | 3 | 1.17 | 3.70 | 0.012 |
| Distance | 5 | 1.23 | 3.57 | 0.003 |
| Field*Distance | 15 | 1.07 | 3.39 | < 0.001 |
| Margin*Distance | 5 | 0.52 | 1.64 | 0.15 |
| Date | 3 | 0.58 | 1.84 | 0.18 |
| Field*Date | 9 | 2.56 | 8.11 | < 0.001 |
| Margin*Date | 3 | 0.05 | 0.15 | 0.70 |
| Distance*Date | 15 | 0.36 | 1.14 | 0.34 |
| | | *Mollugo verticillata* | | |
| | DF | Mean Square | F value | *P*- value |
| Field | 3 | 95.86 | 60.73 | < 0.001 |
| Margin type | 1 | 9.25 | 5.86 | 0.016 |
| Field*Margin | 3 | 18.64 | 11.81 | < 0.001 |
| Distance | 5 | 28.98 | 18.36 | < 0.001 |
| Field*Distance | 15 | 7.22 | 4.58 | < 0.001 |
| Margin*Distance | 5 | 3.50 | 2.22 | 0.05 |
| Date | 3 | 238.25 | 150.95 | < 0.001 |
| Field*Date | 9 | 73.74 | 8.11 | < 0.001 |
| Margin*Date | 3 | 1.49 | 46.72 | < 0.001 |
| Distance*Date | 15 | 4.11 | 2.60 | 0.03 |

*Table 8*: Common and scientific names, five-letter Bayer code, and location of plant species found in crop fields and field margins in 2002 and 2003.

| Code | Scientific Name | Common Name | Location[1] |
|---|---|---|---|
| ACRRB | *Acer rubrum* L. | maple, red | MF |
| ALLVI | *Allium vineale* L. | garlic, wild | MF |
| AMACH | *Amaranthus hybridus* L. | pigweed, smooth | F |
| AMARE | *Amaranthus retroflexus* L. | pigweed, redroot | MF |
| AMBEL | *Ambrosia artemisiifolia L.* | ragweed, common | MF |
| ANOVI | *Andropogon virginicus L.* | broomsedge | M |
| APCCA | *Apocynum cannabinum L.* | dogbane, hemp | M |
| ASTPI | *Aster pilosus Willd.* | aster, white heath | M |
| BACHA | *Baccharis halimifolia* L. | baccharis, eastern | M |
| BRAPP | *Brachiaria platyphylla* (Griseb.) Nash | signalgrass, broadleaf | MF |
| BRASP | *Brassica* sp. | brassica sp. | F |
| BROCA | *Bromus catharticus* Vahl | rescuegrass | M |
| CARAL | *Carex alata* Torrey | sedge | M |
| CARAN | *Carex annectens* | sedge | M |
| CARFL | *Carex flaccosperma* Dewey. | sedge | M |
| CARHI | *Cardamine hirsuta* L. | bittercress, hairy | F |
| CARLA | *Carex laxiflora* Lam. | sedge | M |
| CARSP | *Carya* sp. | hickory | M |
| CASOB | *Senna obtusifolia* L. Irwin & Barneby | sicklepod | MF |
| CERVU | *Cerastium vulgatum* L. | chickweed, mouseear | M |
| CHEAL | *Chenopodium album* L. | lambsquarters, common | F |
| CHPTA | *Chaerophyllum tainturieri* Hook. | chervil, hairyfruit | M |
| CMIRA | *Campsis radicans* (L.) Seem. ex Bureau | trumpetcreeper | MF |
| COMBE | *Commelina benghalensis* L. | spiderwort, tropical | MF |
| COMDI | *Commelina diffusa Burm.* F. | dayflower, spreading | F |
| COPDI | *Coronopus didymus (*L.*)* Sm. | swinecress | F |
| CRASP | *Crataegus* sp. | hawthorne | M |
| CRXLU | *Carex lupulina* Muhl. ex Willd. | sedge, hop | M |
| CYNDA | *Cynodon dactylon* (L.) Pers. | bermudagrass | MF |
| CYPES | *Cyperus esculentus* L. | nutsedge, yellow | MF |
| DIGSA | *Digitaria sanguinalis* (L.) Scop. | crabgrass, large | MF |
| DIORE | *Dichondra repens* J.R. & G. Forst. | dichondra | MF |
| DIQVI | *Diodia virginiana* L. | buttonweed, Virginia | M |
| DUCTN | *Duchesnea indica* (Andr.) Focke | mock-strawberry, Indian | M |
| ECLAL | *Eclipta prostrate* L. | eclipta | MF |
| ELEIN | *Eleusine indica* (L.) Gaertn. | goosegrass | MF |
| EPHHT | *Euphorbia humistrata* Engelm. ex Gray | spurge, prostrate | MF |
| ERASP | *Eragrostis* sp. | lovegrass | M |
| ERIAN | *Erigeron annuus* (L.) Pers. | fleabane, annual | M |
| ERICA | *Conyza canadensis* (L.) Cronq. | horseweed | MF |
| EUPCP | *Eupatorium capillifolium* (Lam.) Small | dogfennel | MF |

*Table 8* continued.

| | | | |
|---|---|---|---|
| EUPOB | *Euphorbia obtusata* Pursh. | esula | M |
| FIMAU | *Fimbristylis autumnalis* (L.) R. & S. | fringerush, slender | M |
| GALAP | *Galiumaparine* L. | bedstraw, catchweed | MF |
| GELSE | *Gelsemium semperviens* (L.) Aiton F. | yellow jessamine | M |
| GERCA | *Geranium carolinianum* L. | geranium, Carolina | M |
| GNAPU | *Gnaphalium purpureum* L. | cudweed, purple | MF |
| HENAM | *Helenium amarum (Raf.)* H.Rock | sneezeweed, bitter | M |
| HORPU | *Hordeum pusillum* Nutt. | barley, little | M |
| HRYRA | *Hypochoeris radicata* L. | catsear, common | M |
| IPOSP | *Ipomea* species | morningglory | MF |
| IUNTE | *Juncus tenuis* Willd. | rush, slender | M |
| JUNCO | *Juncus coriaceous* Mackensie | juncus | M |
| JUNDI | *Juncus dichotomus* | firework | M |
| KRIOP | *Krigia oppositifolia* Raf. | dwarfdandelion | M |
| KRIVI | *Krigia virginica* (L.) Willd. | dwarfdandelion, Virginia | M |
| LACSE | *Lactuca serriola* L. | lettuce, prickly | F |
| LAMAM | *Lamium amplexicaule* L. | henbit | F |
| LEPVI | *Lepidium virginicum* L. | pepperweed, Virginia | M |
| LESST | *Lespedeza striata* (Thunb.) H. & A. | lespedeza, common | M |
| LIQST | *Liquidambar styraciflua* L. | sweetqum | M |
| LOLMU | *Lolium multiflorum* Lam. | ryegrass, Italian | MF |
| LONJA | *Lonicera japonica* Thunb. | honeysuckle, Japanese | M |
| MEDLU | *Medicago lupulina* L. | medic, black | M |
| MICSP | *Microstegium sp.* | microstegium | M |
| MOLVE | *Molluqo verticillata* L. | carpetweed | MF |
| OEOLA | *Oenothera laciniata* Hill | eveningprimrose, cutleaf | MF |
| OXAST | *Oxalis stricta* L. | woodsorrel, yellow | MF |
| PANDI | *Panicum dichotomiflorum* Michx. | panicum, fall | M |
| PASDI | *Paspalum dilatatum* Poir. | dallisqrass | M |
| PHTAM | *Phytolacca americans* L. | pokeweed, common | MF |
| PLALA | *Plantago lanceolata* L. | plantain, buckhorn | MF |
| POAAN | *Poa annua* L. | bluegrass, annual | MF |
| POAAU | *Poa autumnalis* Muhl. ex Ell. | bluegrass | M |
| POLPY | *Polygonum pensylvanicum* L. | smartweed, Pennsylvania | M |
| POROL | *Portulaca oleracea* L. | purslane, common | MF |
| PRTQU | *Parthenocissus quinquefolia* (L.) Planch. | Virginia-creeper | M |
| RANBU | *Ranunculus bulbosus* L. | buttercup, bulbous | MF |
| RAPRA | *Raphanus raphanistrum* L. | radish, wild | MF |
| ROSMU | *Rosa multiflora Thunb.* ex Murr. | rose, multiflora | M |
| RUBAG | *Rubus argutus* Link | blackberry, highbush | M |
| RUBSP | *Rubus* sp. | blackberry species | M |
| RUMAA | *Rumex acetosella* L. | sorrel, red | MF |
| RUMCR | *Rumex crispus* L. | dock, curly | MF |
| SCPVA | *Scirpus validus* Vahl | bulrush, softstem | M |

*Table 8* continued.

| | | | |
|---|---|---|---|
| SCRAN | *Scleranthus annuus* L. | knawel | M |
| SECCE | *Secale cereale* | cereal rye | M |
| SETFA | *Setaria faberi* Herrm. | foxtail, giant | MF |
| SIDSP | *Sida spinosa* L. | sida, prickly | MF |
| SINAR | *Brassica kaber* (DC.) L.C.Wheeler | mustard, wild | F |
| SISAN | *Sisyrinchium angustifolium* Miller | blue-eyed grass | M |
| SMIRO | *Smilax rotundifolia* L. | greenbriar, roundleaf | M |
| SOLCA | *Solanum carolinense* L. | horsenettle | MF |
| SOLSP | *Soildago* sp. | Goldenrod species | M |
| SONAR | *Sonchus arvensis* L. | sowthistle, perennial | MF |
| SONAS | *Sonchus asper* (L.) Hill | sowthistle, spiny | MF |
| SONOL | *Sonchus cleraceus* L. | sowthistle, annual | MF |
| SOOCA | *Solidago canadensis* L. | goldenrod, Canada | M |
| SORHA | *Sorghum halepense* (L.) Pers. | johnsongrass | MF |
| SPHOB | *Sphenopholos obtusata* | wedge grass | M |
| SPRAR | *Spergula arvensis* L. | spurry, corn | F |
| STEME | *Stellaria media* (L.) Vill. | chickweed, common | MF |
| TAROF | *Taraxacum officinale* Weber in Wiggers | dandelion | MF |
| THLAR | *Thlaspi arvense* L. | pennycress, field | F |
| TJDPE | *Triodanis perfoliata* (L.) Nieuwl. | venuslookingglass | M |
| TOXRA | *Toxicodendron radicans* (L.) Ktze. | poison-ivy | M |
| TRADI | *Trachelospermum difforme* (Walter) G. | Lemaire | M |
| TRFAU | *Trifolium aureum* Pollich | clover, hop | M |
| TRFRE | *Trifolium repens* L. | clover, white | MF |
| TRIAR | *Trifolium arvense* L. | clover, rabbit | M |
| VERAR | *Veronica arvensis* L. | speedwell, corn | M |
| VERBR | *Verbena brasilensis* Vellozo | verbena | M |
| VEROF | *Veronica officinalis* L. | speedwell, common | F |
| VICVI | *Vicia villosa* Roth | vetch, hairy | M |
| VIOAR | *Viola arvensis* Murr. | violet, field | M |
| | Unknown Species[2] | | |
| FMU | Broadleaf species | | M |
| FTUT | Broadleaf species | | F |
| FUT | Broadleaf species | | F |
| TTUO | Broadleaf species | | F |
| TTUT | Broadleaf species | | F |
| FMUT | Broadleaf species | | M |

[1] Presence in margin (M), field (F), or both (MF)
[2] Not able to identify due to early development stage and limited abundance

*Table 9*. Sources of variance for species richness of field margins on squareroot transformed data.

| | DF | Mean Square | F Value | P- value |
|---|---|---|---|---|
| Field | 3 | 0.093 | 0.93 | 0.44 |
| Margin | 1 | 39.81 | 399.71 | < 0.001 |
| Field*Margin | 3 | 0.62 | 6.19 | 0.002 |
| Year | 1 | 4.92 | 49.42 | < 0.001 |
| Field*Year | 3 | 0.06 | 0.67 | 0.58 |
| Margin*Year | 1 | 0.21 | 2.17 | 0.15 |

*Table 10.* Relative frequency (percent occurrence in 25 transects) of *Digitaria sanguinalis* in the field margin and crop field. Significant *P*-values for Fisher's exact two-sided test indicates an association between weed populations in the field margin and the crop field.

| *Digitaria sanguinalis* | | | | | | |
|---|---|---|---|---|---|---|
| Year | Margin | PM-PF[1] | PM-AF[2] | AM-PF[3] | AM-AF[4] | *P*-value[5] |
| | | ---------------- % | ---------------- | ---------------- | ---------------- | |
| 2002 | U[6] | 12 | 36 | 24 | 28 | 0.41 |
| | M[7] | 20 | 32 | 8 | 40 | 0.38 |
| 2003 | U | 12 | 0 | 32 | 56 | 0.07 [+] |
| | M | 60 | 12 | 8 | 20 | 0.017 [*] |

[1] Weed present in the field margin and the crop field
[2] Weed present in the field margin and absent in the crop field
[3] Weed absent in the field margin and present in the crop field
[4] Weed absent in the field margin and the crop field
[5] P-value based on Fisher's exact two-sided test
[6] Unmanaged field margin
[7] Managed field margin
[+] Significant at the 0.1 level
[*] Significant at the 0.5 level

*Table 11*. Predictors of weed presence in the crop field. A significant *Chi*-Square value indicates that factor is a predictor of weed appearing in the crop field.

| | DF | *Chi*-Square | P-value |
|---|---|---|---|
| *Senna obtusifolia* | | | |
| Field | 3 | 48.61 | < 0.001 |
| Margin type | 1 | 0 | 0.99 |
| PM[1] | 1 | 0 | 0.96 |
| Year | 1 | 0.57 | 0.45 |
| *Cyperus esculentus* | | | |
| | DF | *Chi*-Square | P-value |
| Field | 3 | 7.56 | 0.05 |
| Margin type | 1 | 1.36 | 0.24 |
| PM | 1 | 1.21 | 0.27 |
| Year | 1 | 4.60 | 0.03 |
| *Digitaria sanguinalis* | | | |
| | DF | *Chi*-Square | P-value |
| Field | 3 | 37.07 | < 0.001 |
| PM | 1 | 1.29 | 0.26 |
| Year | 1 | 6.53 | 0.01 |
| *Brachiaria platyphylla* | | | |
| | DF | *Chi*-Square | P-value |
| Field | 3 | 11.08 | 0.01 |
| PM | 1 | 1.56 | 0.21 |
| Year | 1 | 2.81 | 0.10 |
| *Sida spinosa* | | | |
| | DF | *Chi*-Square | P-value |
| Field | 3 | 43.46 | < 0.001 |
| Margin type | 1 | 0.24 | 0.63 |
| PM | 1 | 0.73 | 0.40 |
| Year | 1 | 0.85 | 0.36 |
| *Amaranthus retroflexus* | | | |
| | DF | *Chi*-Square | P-value |
| Field | 3 | 69.87 | < 0.001 |
| Margin type | 1 | 1.53 | 0.22 |
| PM | 1 | 0 | 1.00 |
| Year | 1 | 0.30 | 0.58 |

[1] Presence in field margin

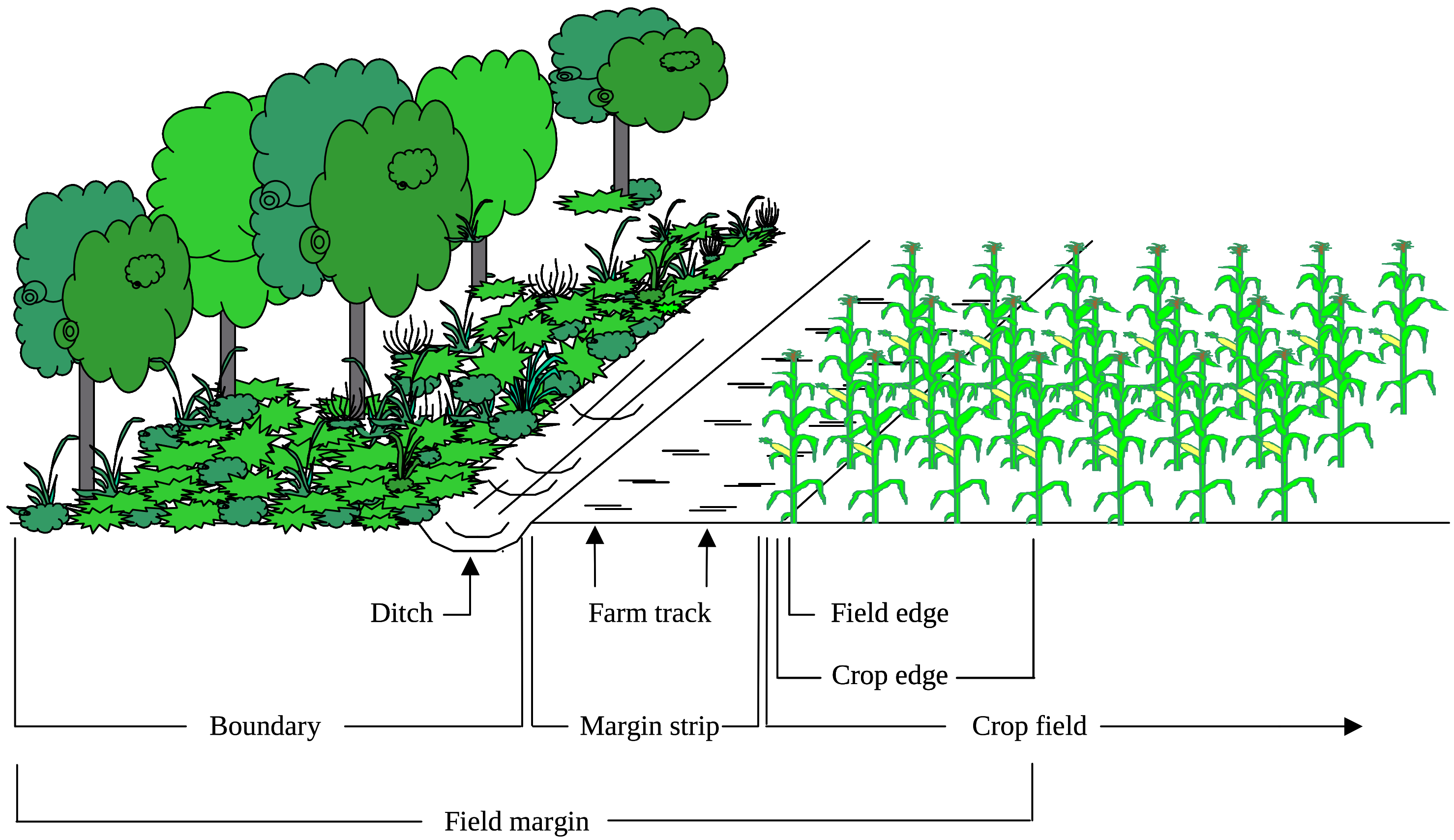
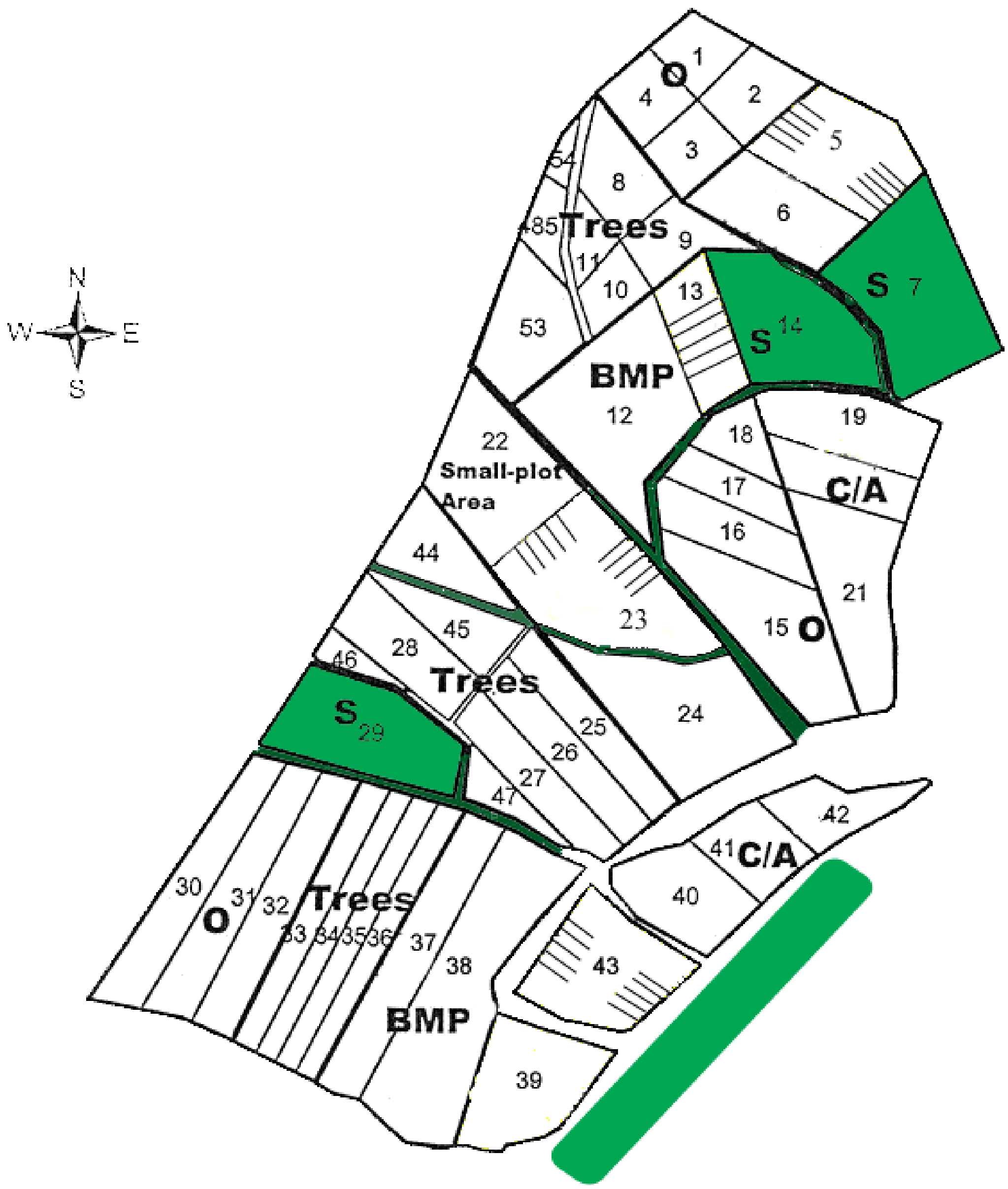



*Figure 1*. Principle components of a field margin

*Figure 2.* Farming Systems Research Unit at the Center for Environmental Farming Systems. Shaded areas reflect areas of natural vegetation (successional fallow fields, ditch systems, and bordering forest). Fields 5, 13, 23, and 43 with permanent transects.



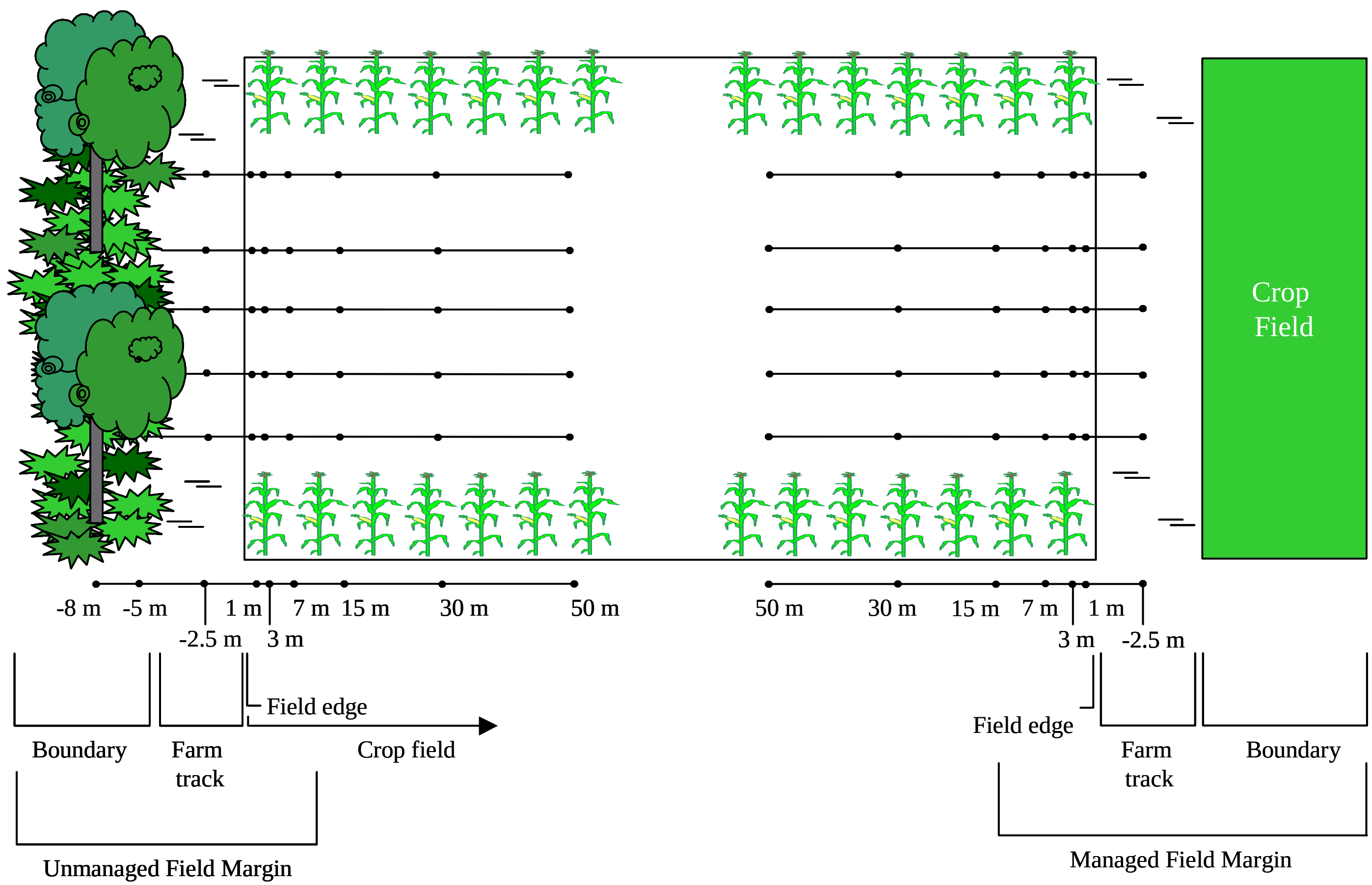



*Figure 3*. Diagram of field sampling points in crop field and field margins.

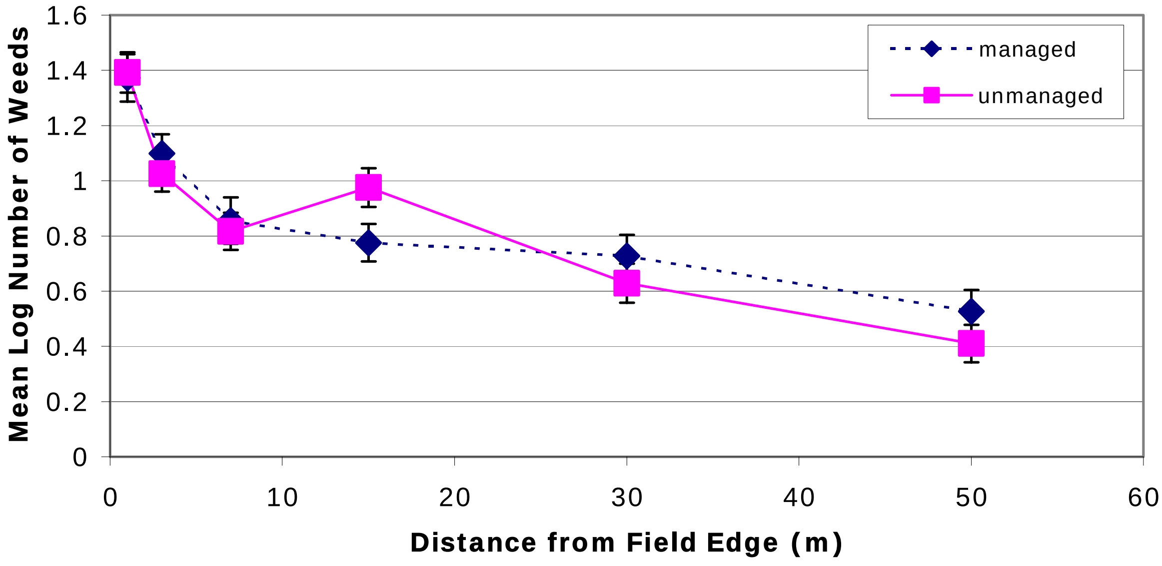



*Figure 4*. Mean log number of weeds by distance from the field edge for managed and unmanaged field margins across sampling dates. The slightly higher abundance of weeds for the unmanaged field border at 15 m was due to high abundance of *Brachiaria platyphylla* at all 15 m sampling points along one field margin.

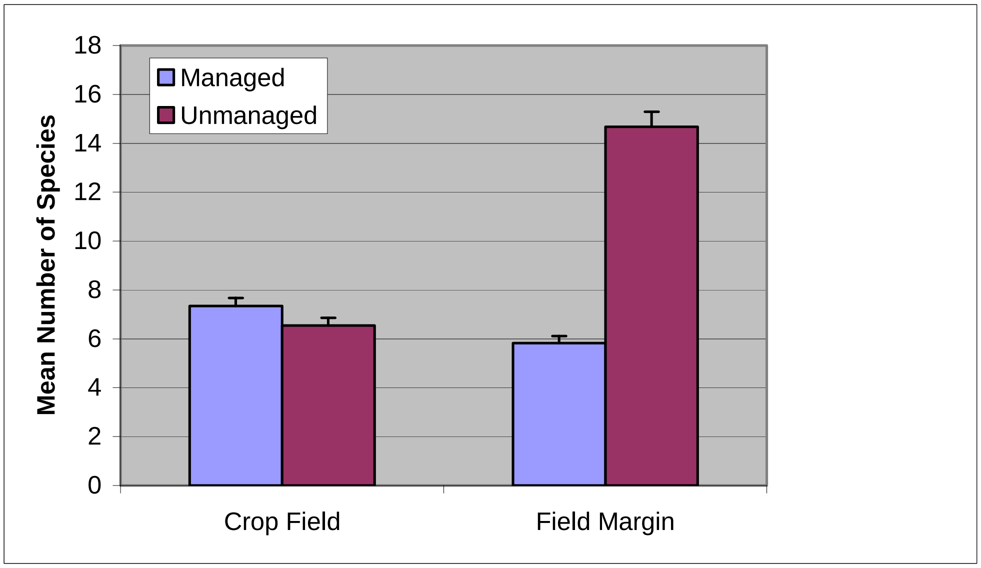



*Figure 5*. Species richness in crop field and field margin. Crop edges adjacent to unmanaged field margins had a lower mean number of weed species (6.55) than crop edges bordering managed field margins (7.35). Unmanaged field margins had a mean number of species of 14.67 and managed field borders had an average of 5.83 species.

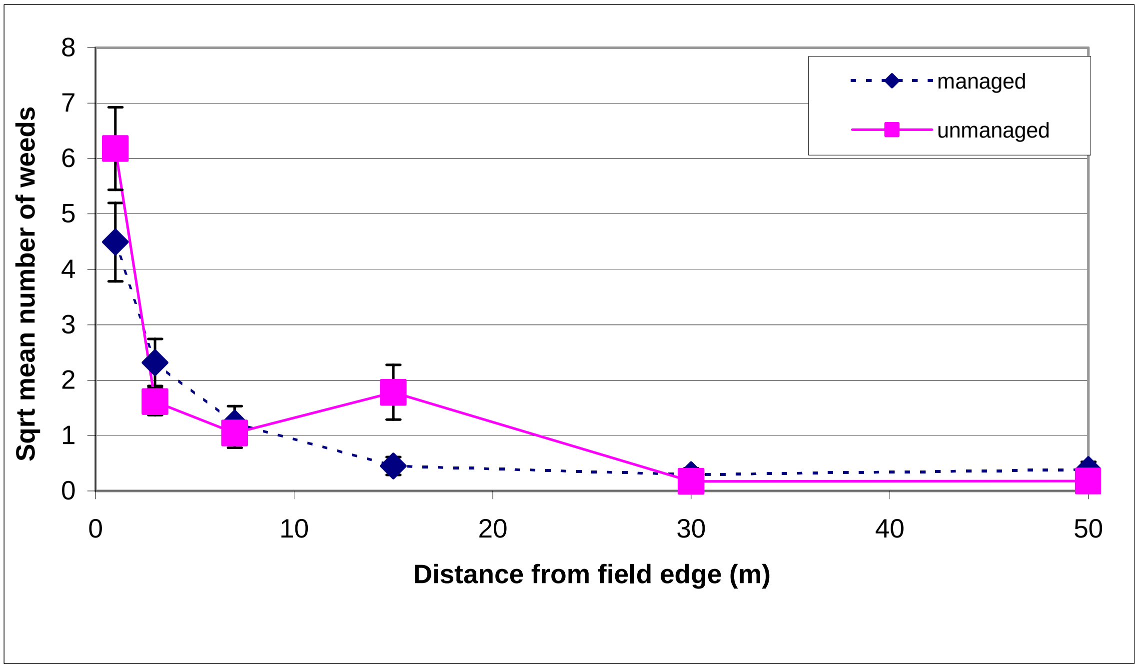



*Figure 6*. Square root mean number of *Brachiaria platyphylla* (Griseb.) Nash seedlings by distance from field edge for unmanaged and managed field borders across sampling dates. The slightly higher abundance of weeds for the unmanaged field border at 15 m was due to a high abundance of *B. platyphylla* in one field.

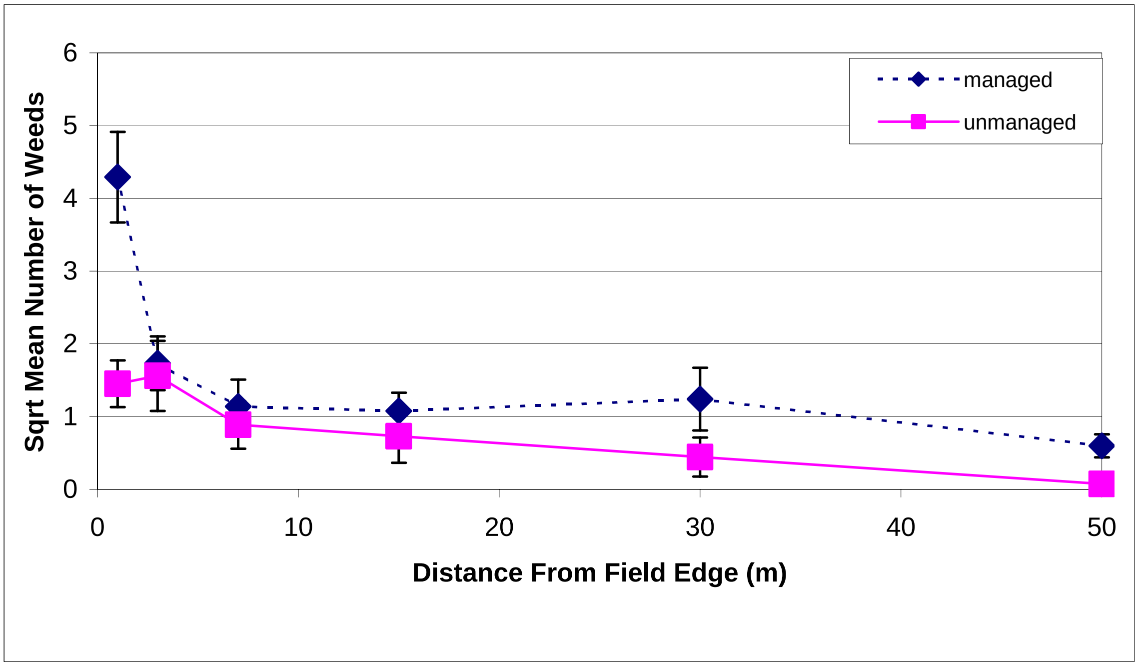



*Figure 7*. Square root mean number of *Amaranthus retroflexus* L. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

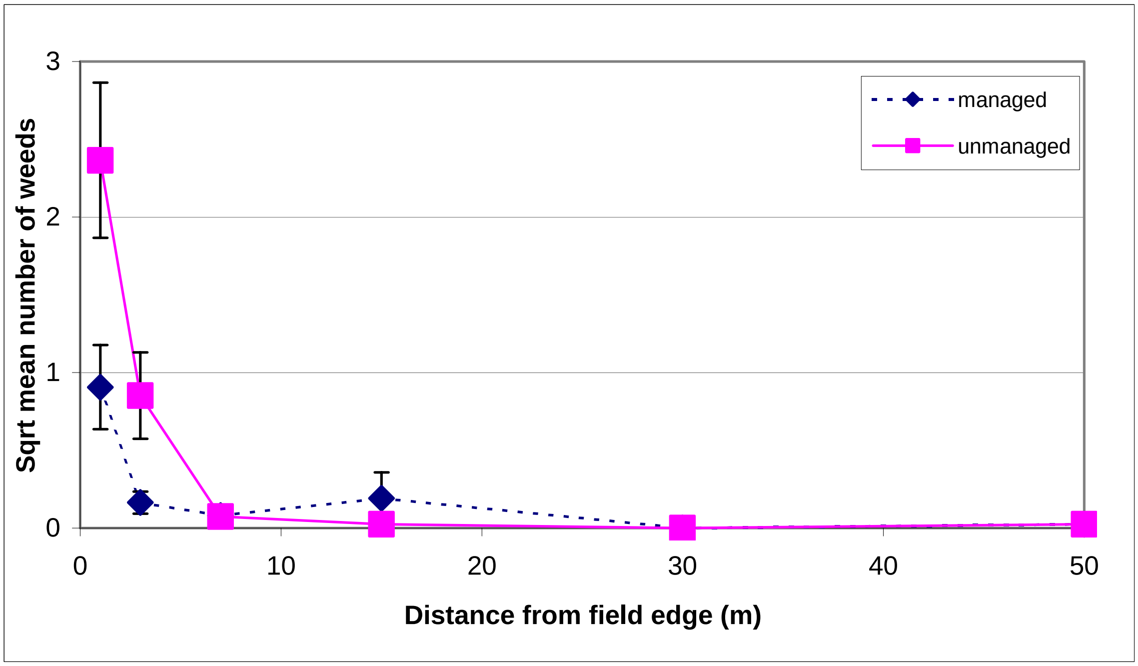



*Figure 8.* Square root mean number of *Digitaria sanguinalis* (L.) Scop. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

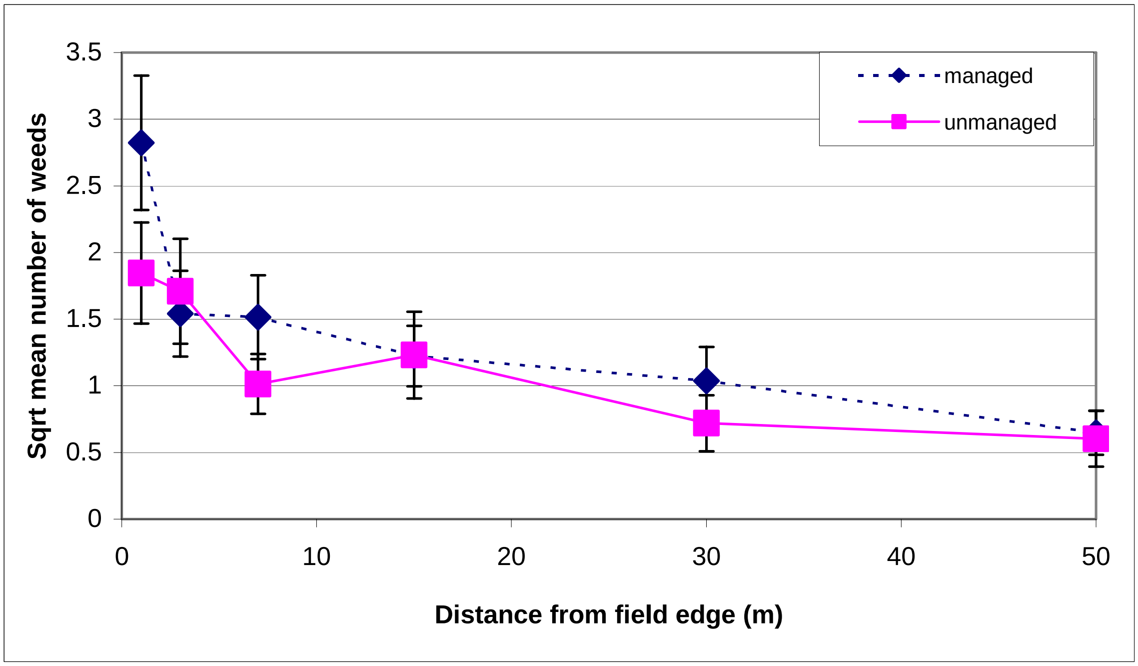



*Figure 9*. Square root mean number of *Mollugo verticillata* L. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

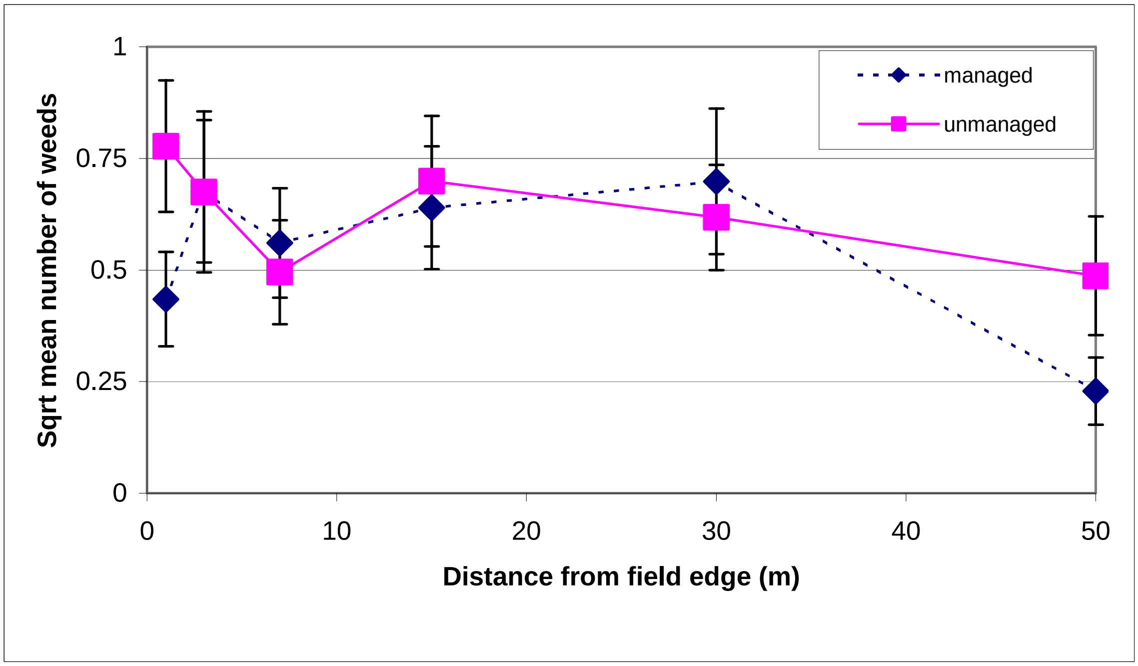



*Figure 10*. Square root mean number of *Sida spinosa* L. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

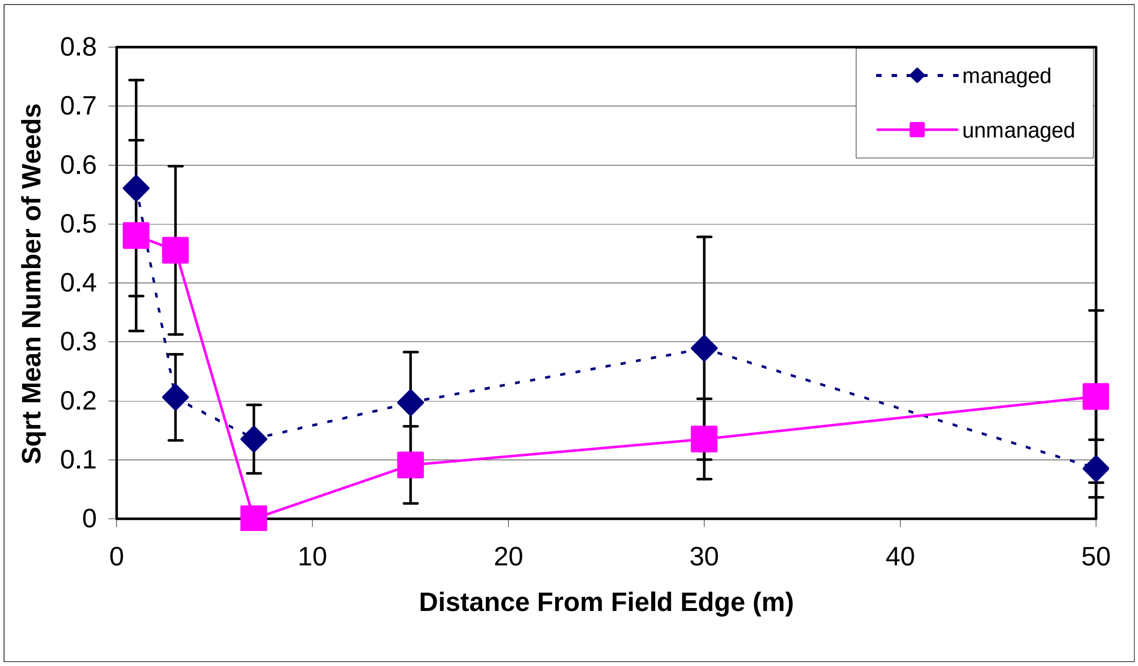



*Figure 11*. Squareroot mean number of *Cyperus esculentus* L. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

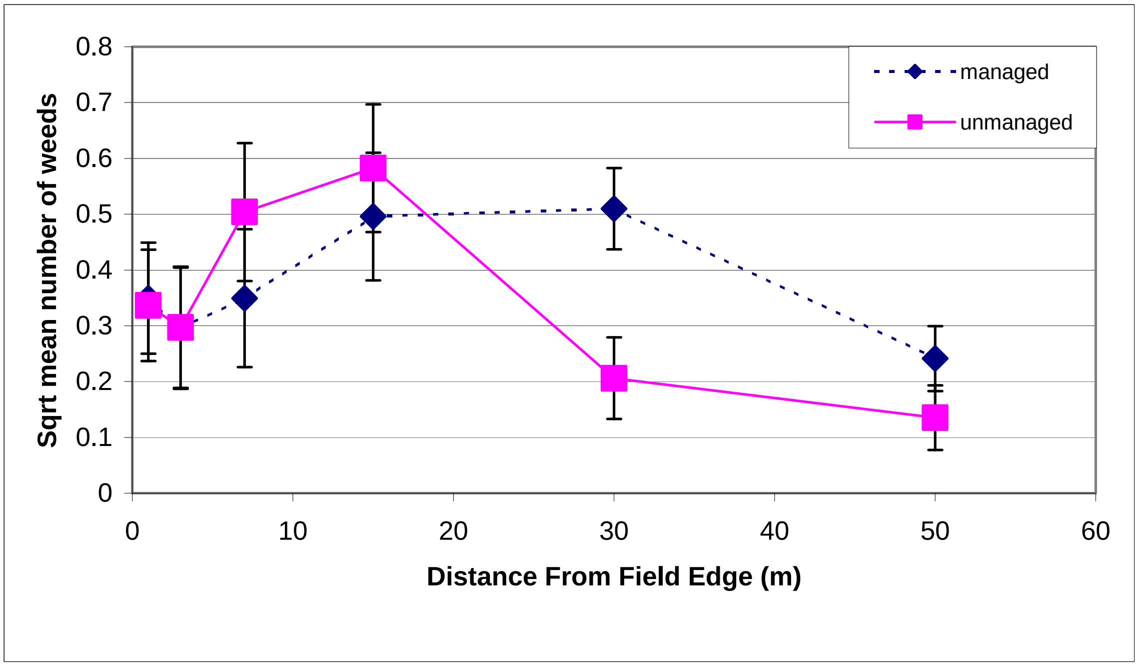



*Figure 12*. Square root mean number of *Ipomea* spp. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

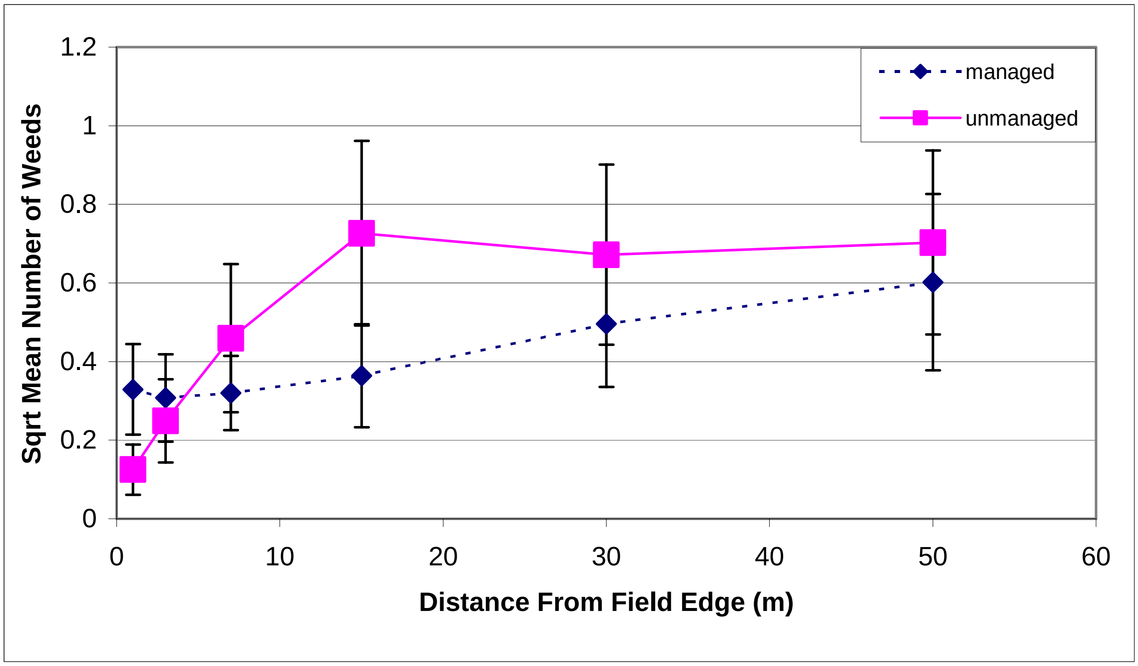



*Figure 13*. Square root mean number of *Lamium amplexicaule* L. seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

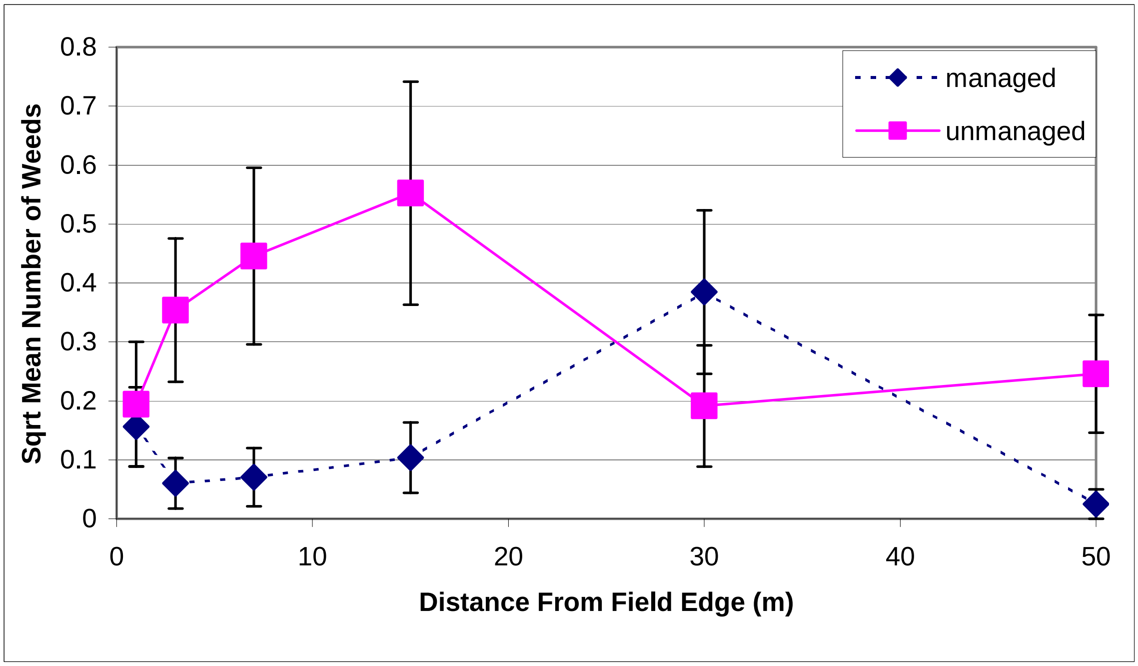



*Figure 14*. Squareroot mean number of *Senna obtusifolia* L. Irwin & Barneby seedlings by distance from field edge for unmanaged and managed field borders across sampling dates.

*Appendix A*. Relative frequency (percent occurrence in 25 transects) of *Brachiaria platyphylla, Amaranthus retroflexus, Sida spinosa, Cyperus esculentus* and *Oxalis stricta* in the field margin and crop field. Significant *P*-values for Fisher's exact two-sided test indicates an association between occurrence of a species in the field margin and in the crop field.

| *Brachiaria platyphylla* | | | | | | |
|---|---|---|---|---|---|---|
| Year | Margin | PM-PF[1] | PM-AF[2] | AM-PF[3] | AM-AF[4] | *P*-value[5] |
| | | ------------------- % ----------------------- | | | | |
| 2002 | U[6] | 44 | 0 | 44 | 12 | 0.23 |
| | M[7] | 16 | 0 | 60 | 24 | 0.54 |
| 2003 | U | 4 | 0 | 96 | 0 | N/a |
| | M | 24 | 0 | 68 | 8 | 1.00 |
| *Amaranthus retroflexus* | | | | | | |
| Year | Margin | PM-PF | PM-AF | AM-PF | AM-AF | *P*-value |
| | | ------------------- % ----------------------- | | | | |
| 2002 | U | 0 | 4 | 52 | 44 | 0.48 |
| | M | 44 | 0 | 36 | 20 | 0.05 |
| 2003 | U | 0 | 0 | 52 | 48 | N/a |
| | M | 28 | 0 | 52 | 20 | 0.27 |
| *Sida spinosa* | | | | | | |
| Year | Margin | PM-PF | PM-AF | AM-PF | AM-AF | *P*-value |
| | | ------------------- % ----------------------- | | | | |
| 2002 | U | 0 | 4 | 56 | 40 | 0.44 |
| | M | 4 | 0 | 56 | 40 | 1.00 |
| 2003 | U | 0 | 0 | 76 | 24 | N/a |
| | M | 12 | 0 | 60 | 28 | 0.53 |
| *Cyperus esculentus* | | | | | | |
| Year | Margin | PM-PF | PM-AF | AM-PF | AM-AF | *P*-value |
| | | ------------------- % ----------------------- | | | | |
| 2002 | U | 16 | 0 | 24 | 60 | 0.02 |
| | M | 28 | 4 | 40 | 28 | 0.21 |
| 2003 | U | 4 | 4 | 28 | 64 | 1.00 |
| | M | 16 | 12 | 32 | 40 | 0.67 |
| *Oxalis stricta* | | | | | | |
| Year | Margin | PM-PF | PM-AF | AM-PF | AM-AF | *P*-value |
| | | ------------------- % ----------------------- | | | | |
| 2002 | U | 4 | 28 | 0 | 68 | 0.32 |
| | M | 0 | 28 | 8 | 64 | 1.00 |
| 2003 | U | 4 | 12 | 0 | 84 | 0.16 |
| | M | 0 | 4 | 12 | 84 | 1.00 |

[1] Weed present in the field margin and the crop field
[2] Weed present in the field margin and absent in the crop field
[3] Weed absent in the field margin and present in the crop field
[4] Weed absent in the field margin and the crop field
[5] *P*-value based on Fisher's exact two-sided test
[6] Unmanaged field margin
[7] Managed field margin