LINKING FARMS: RECONNECTING DAIRY AND CASH-GRAIN FARMS THROUGH SHARED MANURE MANAGEMENT

II. Assessing weed pressure from manure applications on corn grain fields

Amy Cook[1], Joshua Posner[2], Janet Hedtcke[3], Herika Kummel[4]

INTRODUCTION

Due to higher stocking rates, suburban land development, and stricter nutrient management regulations, Wisconsin dairy farmers are looking beyond their own land for areas to spread manure. One possible alternative is to transport and apply manure to nearby, willing cash-grain farmers' land. However, grain farmers have concerns that adding manure to their fields may increase weed pressure, and cause higher expenses in their weed management programs. Other studies that have examined weed pressure from manure have focused on indirect measurements, such as counting viable seeds extracted from various types of manure storage facilities (Takabayashi et al., 1979; Cudney et al., 1992; Sarapatka et al., 1993), or measuring the viability of weed seeds following animal digestion (Oswald, 1908; Harmon and Keim, 1934; Blackshaw and Rode, 1991). In this study, we took a direct approach of measuring weed pressure (in-field weed counts, species richness and diversity, and biomass) from paired manured and non-manured plots in corn fields. In the first year of the study, 2004, the following questions were studied:

1. Does manure spreading influence early weed germination?
2. Does manure influence overall weed density (number of weeds) or competitiveness (weed biomass), particularly under normal weed control practices?
3. Does manure spreading influence weed communities (species richness and diversity)?
4. Does manure introduce new weed species not already present in the field?

MATERIALS AND METHODS

Five on-farm trials in corn fields were conducted. Main plots were laid out as described in the previous report "Production results and nutrient budgets 2003 and 2004," with manured and non-manured treatments in a randomized complete block design. In **Table 1** the manure application and weed control practices for each site are summarized.

For weed monitoring, six 1-m^2 quadrats were established in each manured and non-manured strip. Three of these six quadrats had no pre- or post-emergent weed control, while the other three quadrats received the same herbicide or mechanical weed control as the rest of the plot. The two manure treatments, Manure (M) and No Manure (NM), and the two weed control treatments, Weed Control (WC) and No Weed Control (NWC), resulted in four total treatments.

[1] Graduate student, UW-Madison, Agronomy Dept. amycook@wisc.edu
[2] Professor, UW-Madison, Agronomy Dept. jlposner@wisc.edu
[3] Research specialist, UW-Madison, Agronomy Dept. jlrieste@wisc.edu
[4] Undergraduate student, UW-Madison, Agronomy Dept. hkummel@wisc.edu

Figure 1 represents one replication from a typical site. Two replications were made at MP and MS, while three replications were made at JB I, NH I, and RJ I.

At the times of pre-emergent and post-emergent herbicide spraying, the NWC quadrats were covered with 1.15 m^2 tarps. In the case of the one organic site, NWC areas were created by having the farmer lift her cultivator bar as she tilled those areas.

A first pass to collect data on early emergence was made at approximately 18 days after planting (DAP), when the corn was between VE and V2. Weeds in all quadrats were counted and designated as broadleaf or narrow leaf (mainly grass) weeds. Due to logistical issues, this count was not made at the MP site.

A second pass to collect data on weed density and species richness was made at approximately 46 DAP (V6 stage in corn). Weeds were counted and identified to species level, primarily, but in the case of highly related species, such as smooth and redroot pigweed, only to the genus level.

A third pass was made at approximately 68 DAP to harvest all aboveground weed biomass that stood over four inches tall. Broadleaf weeds and perennial grasses were separated into individual species, excepting very small or infrequent weeds, which were combined as "miscellaneous." Annual grasses were combined. Weeds were oven-dried for 5 to 7 days and weighed for dry biomass.

A fourth pass was made after corn harvest at most sites to scout the field for exotic weed species not already encountered at the monitoring stations. The areas scouted were approximately 200 feet long and 6 rows wide, or 3000 ft^2. All weeds seen in this swath were identified but not individually counted.

Hill's 2nd Species Diversity Index was used to classify weed communities (Ludwig and Reynolds, 1988). This index was chosen over other diversity indices because it incorporates both species richness (number of species present in the sample) and evenness (the distribution of individuals in each species). Additionally, it is simple to calculate and is used frequently in community ecology research.

The index, based on Shannon's index, H', uses the following equations:

Equation 1 $$H' = -\sum\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right]$$

Equation 2 $$N1 = e^{H'}$$

In **Equation 1**, n_i represents the number of individuals of the ith species, and n represents the total number of individuals in the sample. H' is defined as a measure of "uncertainty" in predicting to what species an individual randomly chosen from a collection of species will belong. H' increases as the number of species increases, and as the distribution of individuals in each species becomes more even. The benefit of Hill's function, N1 (**Equation 2**), is that the units are actually in terms of species, such that N1 represents the number of species that would,

if all species were equally distributed, produce the same H' as the sample. A higher N1 represents a sample that is both more rich and even in species.

The treatment design was a 2-factor factorial of manure (with and without) and weed control (with and without). Due to logistical constraints, the experiment was set up as a split-plot design with 2 or 3 replications, as described above, in which the two manure treatments defined the whole-plots, and the two weed control treatments made up the subplots. Within each replication, three repetitions of each treatment were made (see **Figure 1**). In order to maintain enough degrees of freedom to best approximate error for the analysis of variance (ANOVA) within each location, the whole-plot error, subplot error, and residual error were all pooled. The resulting reduced model was identical to the standard Randomized Complete Block ANOVA, ignoring the split-plot layout. A mixed effects model was used in order to comply with the postulates that the two treatments (manure and weed control) were fixed effects, and site and blocking were random effects. Proc univariate, proc plot normal, and proc mixed of SAS 8.2 software were used in the analysis. Because the data did not adhere to the statistical assumptions of homogenous variance and normality, it was largely log-transformed for the analyses, such that [$y = log(x + 1)$]. Thus, the means reported are the least squares means of the untransformed data, while p-values are from the transformed analyses.

Due to the time-intensive nature of this study, some key changes are being made for the 2005 season. No early emergence pass will be made. All data collection will be made in one combined pass, dated between 6 and 8 weeks after corn planting. Weeds will be identified to species (or genus, in the case of highly related weeds), counted, and harvested for biomass measures. In addition to identifying weeds in the quadrats, scouting passes will be made in each plot to search for introduced weeds that were not present in the quadrats.

RESULTS AND DISCUSSION

A. Baseline Weed Pressure:

In order to interpret the data collected on weed pressure from manure applications, it is useful to understand the potential "weediness" of each field, without manure additions or weed control effects. Results from each site's check quadrats (Pass 2) are recorded in **Table 2**. Also shown in **Table 2** are the average weed density measurements made by Clark Wagner (Wagner, 1992). These averages, taken in 1990 and 1991 at 37 non-treated field corn and 12 non-treated sweet corn sites in southern and central Wisconsin, serve here as "standards" of total weed pressure in non-treated fields, and are used to help categorize the relative weediness of each site. They appear in the last row of the table.

As can be seen from the table, the cooperating farmers previously had good control of grass weeds in their fields, with the exception of MS. Potential broadleaf pressure was more variable. By and large, however, it appears that at most of the sites, historic weed control had been good, and the weed pressure potential prior to applying manure was comparative to or lower than the sites used in the Wagner study.

B. Early Emergence

Results of the analyses of Pass 1 (DAP ~ 18) are displayed in **Table 3**. As can be seen, adding manure did not seem to cause earlier emergence of weeds. It was found that in all 4 sites, with no weed control, weed density was not higher in the manured plots. In the case where the farmers' weed control programs were employed, there was a larger early flush of weeds in the manured treatment at only one site (NH 1) but the numbers were fairly low. When the total weed density was separated into grasses and broadleaves and analyzed again, the results proved similar to the total weed analysis. Thus, in response to the first question of whether manure influenced weeds early on in the season, the results did not point to any predictable effect of manure applications on weed emergence timing.

C. Weed Density and Biomass (Resource Competitiveness)/Weed Control Efficacy

The results of the analyses on total weed density in Pass 2 (approximately 46 DAP) are displayed in **Table 4**. These results show that manure did not cause a significant increase in weed density at any site under the No Weed Control conditions, as well as when weed control was used. At one site in fact, the weeds in the non-manured plots significantly outnumbered the weeds in the manured plots. The individual analyses of grasses and broadleaves (not shown) followed the same pattern as the analysis of total weeds. As might be expected, total aboveground weed biomass also did not increase as a result of manure additions (see **Table 5**). Similar results were found from the individual analyses of grasses and broadleaves (not shown): no significant increase in biomass in the manured plots.

These results indicate that in both the absence and presence of weed control, manure did not cause an increase weed numbers or growth rates. Thus, corn yields should not have been affected by greater weed pressure in the manured plots.

D. Impact on Weed Communities

A number of weed species were identified across the five sites—over 25 broadleaf species, and at least 9 grass species. The most widely seen weeds included common lambsquarters (*Chenopodium album*), various pigweeds (*Amaranthus* spp.), velvetleaf (*Abutilon theophrasti*), dandelion (*Taraxacum officinale*), eastern black nightshade (*Solanum ptycanthm*), giant foxtail (*Setaria faberi*), and yellow foxtail (*Setaria glauca*). In the Wagner study in Wisconsin, common lambsquarters, redroot pigweed, velvetleaf, and giant, yellow, and green foxtail (*Setaria viridis*) were also the most common species counted (Wagner, 1992). Analyses on the prevalence of individual weed species in each treatment were not made for this report for sake of brevity.

Data collected on species richness was analyzed to see whether manure had any effect on the number of species present in the plots. The results, reported in **Table 6a**, show that species richness did not increase with the addition of manure. The only significant difference in species richness was found at RJ I (NWC and WC), where a greater number of species was actually found in the non-manured plots than in the manured plots. Whether weed control was used or not did not greatly affect these results.

Hill's Species Diversity Index #2 (N1) was used with the Pass 2 data in order to determine manure's effect on species diversity (richness and evenness); these results are shown in **Table 6b**. Similar to the species richness results, manure did not increase species diversity by a significant amount in either weed control treatment.

E. Introduced species

Species identifications from Passes 2, 3 and 4 were combined to see if there were any weed species that were unique to only the manured or non-manured plots at each site. These results may be found in **Table 7**. While there are some species at each site that only were found in the manured plots, there are also species identified only in the non-manured plots. Thus, this method of identifying seedlings in both small quadrats and large scouting passes did not seem to be an adequate technique for answering the question of whether new species were introduced or not. More information is needed, such as a detailed historical weed species inventory of all the sites, and more complete scouting that covered a greater percentage of each plot, in order to better address the question of introduction of exotic species.

CONCLUSIONS

With a few exceptions, manure additions did not cause more rapid weed emergence, nor significantly increased weed density, biomass or species diversity. Manure applications also did not seem to influence weed communities, in terms of species richness and evenness in these five on-farm trials. The 2004 results suggest that incorporating manure into a cash-grain rotation is unlikely to cause any difference in weed density, competitiveness, or species richness, and that the weed control strategies already employed by the farmers are as effective on the manured plots as on the non-manured plots. It appears that even without weed control, the addition of manure did not result in much higher weed density or biomass. Thus, adding manure to a cropping system should not cause alterations to a farmer's weed management program, nor subsequent declines in yield as a cause of weed pressure.

TABLES AND FIGURES

Table 1: On-farm Site Information: Manure application and weed control practices

Site	County	Manure Source: Type /Amount	Manure Application Date	Tillage/Mechanical Weed Control	Chemical Weed Control, Application Timing
JB I	Dane	Dairy A: Slurry / ~ 12,000 gal/a	Aug. 15, 2003	Fall chiseled, disked, dragged. Spring field cultivated.	Outlook (1 pt/a), Pre-E Prowl (3 pts/a), Post-E Distinct (6pts/a), Post -E
RJ I	Columbia	Dairy B: Solid / ~ 31 tons/a	Aug. 26, 2003	Fall deep chiseled.	Accent (2/3 oz/a) + Hornet (3 oz/a), Post-E
NH I	Columbia	Dairy B: Slurry / ~ 11,500 gal/a	Oct. 31, 2003	None (Fall strip-tilled with 8" bands)	Dual II Magnum (1.6 pts/a), Pre-E Clarity (0.5 pts/a), Post -E
MP	Outagamie	Dairy C: Solid / ~ 10 tons/a	Early June, 2004	None (Fall zone tilled with 1.5" bands)	Clear Out burndown, Pre-P Callisto (2-5 oz/a) + Atrazine (0.75 lbs/a), Post-E
MS	Brown	Dairy D: Solid / ~ 15 tons/a	Early June, 2004	Spring rotary hoed (1x); Lilliston cultivator (2x)	None (organic farm)

Notes: All chemical weed control products listed above are commercial products. Generic active ingredients are as follows: Accent = nicosulfuron; Buctril = bromoxynil; Callisto = mesotrione; Clear Out = glyphosate; Distinct = dicamba + diflufenzopyr; Dual II Magnum = s-metolachlor + safener; Hornet = flumetsulam + clopyralid; Outlook = dimethenamid-P; Prowl = pendimethalin. Application timing: Pre-E = pre-emergent; Post-E = post-emergent; Pre-P = pre-plant.

Table 2: Weed density of baseline quadrats (No Manure, No Weed Control); Pass 2 (~ 46 DAP, weeds m^{-2})

Site	Grasses	Broadleaves	Total	Relative density
JB I	5	55	60	Low
NH I	0.1	30	30	Very Low
RJ I	20	29	49	Very Low
MP	0.3	121	121	Medium
MS	3542	94	3636	Very High
Wagner's Average	*394*	*115*	*509*	

Notes: Wagner's counts made at 40 DAP (Wagner, 1992).

Table 3: Early Emergence, at approximately 18 DAP (Total weeds m^{-2})

	No Weed Control			With Weed Control		
	Manure	**No Manure**	**Manure Effect**	**Manure**	**No Manure**	**Manure Effect**
JB I	29	57	NS	26	44	NS
NH I	27	9	NS	18	3	*
RJ I †	7	13	**	N/A	N/A	N/A
MS I	2199	1939	NS	211	616	***

Notes: With α = 0.10: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.
†No pre-emergent herbicide sprayed at RJ I, so only No Weed Control data was available.

Table 4: Weed Density at approximately 46 DAP (Total weeds m^{-2})

	No Weed Control			With Weed Control		
	Manure	**No Manure**	**Manure Effect**	**Manure**	**No Manure**	**Manure Effect**
JB I	37	60	NS	6	12	NS
NH I	24	30	NS	4	8	NS
RJ I	44	49	NS	14	10	NS
MP I	36	121	***	0.8	4	**
MS I	2806	3636	NS	291	498	NS

Notes: With α = 0.10: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

Table 5: Weed Biomass at approximately 68 DAP (aboveground DM grams m^{-2})

	No Weed Control			With Weed Control		
	Manure	**No Manure**	**Manure Effect**	**Manure**	**No Manure**	**Manure Effect**
JB I	284.3	440	NS	59.3	1.3	NS
NH I	201.6	72.2	NS	2.5	1.6	NS
RJ I	53.9	37	NS	8.5	1.3	NS
MP I	28	83.4	NS	0.3	11.1	NS
MS I	270.1	253.2	NS	72.6	64.4	NS

Notes: With α = 0.10: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

Table 6: Species Richness and Diversity at approximately 46 DAP

Table 6a: Species Richness (number of spp. m^{-2})

	No Weed Control			With Weed Control		
	Manure	**No Manure**	**Manure Effect**	**Manure**	**No Manure**	**Manure Effect**
JB I	5.4	5.9	NS	1.8	2.1	NS
NH I	3.6	3	NS	1.6	2.4	NS
RJ I †	5.4	7.2	***	2.1	3.1	*
MP I	3.2	3.5	NS	0.7	1.8	NS
MS I	3.8	4.5	NS	2.2	2	NS

Table 6b: Hill's Species Diversity Index, N1‡

	No Weed Control			With Weed Control		
	Manure	**No Manure**	**Manure Effect**	**Manure**	**No Manure**	**Manure Effect**
JB I †	3.4	3.4	NS	1.8	1.9	NS
NH I †	2.3	1.8	NS	1.6	2.2	NS
RJ I	3.4	4.6	**	1.8	2.7	*
MP I	2.0	1.7	NS	1.2	1.8	NS
MS I †	1.3	1.2	NS	1.2	1.2	NS

Notes: With $\alpha = 0.10$: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

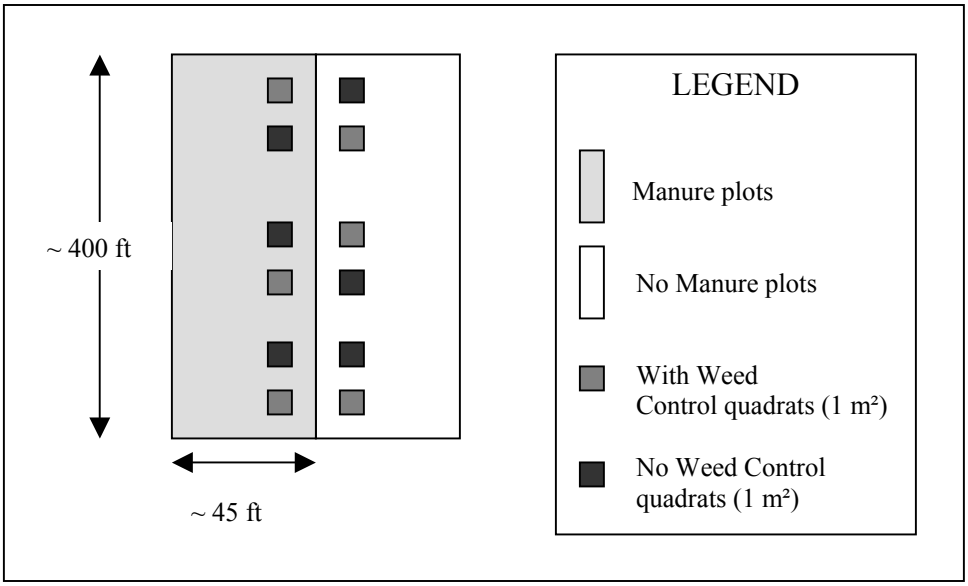
† Raw data set used in analysis (not log-transformed), as the raw data was a better fit to the ANOVA assumptions than the transformed data.

‡ $N1 = e^{H'}$, where $H' = -\sum [(\frac{n_i}{n}) \ln(\frac{n_i}{n}))]$

Table 7: Weed species occurring only in one of the two manure treatments

Site	Broadleaves only in Manure Plots	Grasses only in Manure Plots	Broadleaves only in No Manure Plots	Grasses only in No Manure Plots
JB I	Broadleaf Plantain		Purslane, Wild Buckwheat, Prickly Lettuce, Yellow Wood Sorrel, Shepherd's purse, Fleabane, Canada Thistle	Wheat, Quackgrass
NH I	Knotweed, Purslane		Horseweed	Wild Oat
RJ I	Milkweed, Fleabane		Purslane, Yellow Wood Sorrel, Broadleaf Plantain	
MP		Giant Foxtail, Wild Proso Millet	Velvetleaf, Dandelion	Fall Panicum
MS	Broadleaf Plantain	Green Foxtail		Quackgrass

Figure 1: Typical layout, one repetition (not to scale)



REFERENCES

Blackshaw, R. E. and L. M. Rode. 1991. Effect of ensiling and rumen digestion by cattle on weed seed viability. Weed Sci. 39:104-108.

Cudney, D. W., S. D. Wright, T. A. Shultz, and J. S. Reints. 1992. Weed seed in dairy manure depends on collection site. California Agric. 46:31-32.

Harmon, G. W. and F. D. Keim. 1934. The percentage and viability of weed seeds recovered in the feces of farm animals and their longevity when buried in manure. Agron. J. 26:762-767.

Ludwig, J. A., and J. F. Reynolds. 1988. Diversity Indices. p. 85-92 *in* Statistical Ecology: A primer on methods and computing. Wiley Press, New York.

Mt. Pleasant, J. and K. J. Schlather. 1994. Incidence of weed seed in cow (*Bos taurus* spp.) manure and its importance as a weed source for cropland. Weed Tech. 8:304-310.

Sarapatka, B., M. Holub and M. Lhotska. 1993. The effect of farmyard manure anaerobic treatment on weed seed viability. Biol. Agric. Hort. 10:1-8.

Takabayashi, M., T. Kubota, and H. Abe. 1979. Dissemination of weed seeds through cow feces. JARQ. 13:204-207.

Wagner, C. R. 1992. Soil weed seed bank population dynamics and methods for measuring weed seed populations in soil. M.S. Thesis, Agronomy. University of Wisconsin: Madison.