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Within-field soil heterogeneity effects on herbicide-mediated crop injury and weed biomass

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Soil organic carbon (OC), clay content, water content, and pH often influence the bioactivity of soil-applied herbicides, and these soil properties can vary greatly within fields. The purpose of this work was to determine the influence of within-field soil heterogeneity on the efficacy of RPA-201772 where corn, shattercane, and velvetleaf were seeded as bioassays. An experimental approach was developed to quantify RPA-201772 dose–response across a range of soil conditions in an agricultural field. Based on a logistic model, crop injury was quantified with the I_{20} parameter, the dose eliciting 20% greenness reduction, using a series of photographic standards. Weed biomass was quantified with the I_{80} parameter, the dose eliciting 80% biomass reduction, relative to the untreated control. Crop and weed responses varied by two orders of magnitude. Significant correlation, as high as 0.76, was observed between measures of plant response and soil properties, namely particle size and OC. Furthermore, native velvetleaf spatial distribution at the study site was heterogeneous, and seedlings were observed in plots where seeded velvetleaf biomass was high. Spatial heterogeneity of soil affinity for herbicide results in differential weed fitness and contributes to weed "patchiness."

Nomenclature: RPA-201772, 5-cyclopropyl-4-(2-methylsulphonyl-4-trifluoromethyl-benzoyl)isoxazole; corn, *Zea mays* L.; shattercane, *Sorghum bicolor* (L.) Moench. SORBI; velvetleaf, *Abutilon theophrasti* Medik. ABUTH.

Key words: Dose–response, site-specific, spatial.

Soil-applied herbicides are used widely in corn production in the United States, and several factors influence their efficacy. Those factors include pesticide properties, formulation, application technique, agricultural management, characteristics of crops and weeds, climatic conditions, and soil properties (Leistra and Green 1990). Failure to recognize such factors in practice can result in unsatisfactory herbicide effectiveness and nontarget effects such as crop injury.

Soil organic carbon (OC), pH, and particle size can strongly influence soil-applied herbicide efficacy (Blackshaw et al. 1994; Blumhorst et al. 1990; Shea 1989). These soil properties are known to vary within the field. Cambardella et al. (1994) found strong spatial dependence of both OC and pH. Direct measures of herbicide sorption, such as k_d, can vary significantly within fields (Novak et al. 1997; Oliveira et al. 1999). Though these soil properties are known to vary within individual fields, most herbicides are applied uniformly at a constant dose to an entire field. With the advent of within-field mapping of soils, pests, and yield, much has been learned about variation in growers' fields. It is not uncommon for OC to vary from 0.9 to 3.0% or clay from 20 to 40% within individual fields (Cambardella et al. 1994; Khakural et al. 1999).

Weed populations are also known to vary within fields, but the mechanisms giving rise to their spatial heterogeneity are poorly understood. Biotic, abiotic, and anthropogenic processes likely contribute to the expression of weed "patchiness" in agricultural fields. Several reasons for weed patchiness have been proposed, including variability in preferred habitats, propagule dispersal, and weed mortality (Mortensen and Dieleman 1998; Woolcock and Cousens 2000). Associations between soil properties and weed populations led Dieleman et al. (2000) to suggest that variability in plant-available herbicide concentration is one reason weeds are patchy. Studies are needed to move beyond characterization research toward development of a mechanistic understanding of the role of within-field soil heterogeneity on spatial variability of weed fitness.

RPA-201772 is a relatively new preemergence herbicide for corn. RPA-201772 disrupts pigment biosynthesis via an inhibition of *p*-hydroxyphenyl pyruvate dioxygenase (Luscombe et al. 1995) and consequently results in bleaching symptoms (Bhowmik et al. 1996). In both plants and soil, RPA-201772 rapidly converts to a biologically active diketonitrile derivative [(2-mesyl-4-trifluoromethylbenzoyl)-cyclopropylcarbonyl acetonitrile] via cleavage of the isoxazole cycle. Bioactivity of RPA-201772 varies with soils (Bhowmik et al. 1999; Knezevic et al. 1998). To guide decision making for RPA-201772 use, a greater understanding of the role of soil heterogeneity on RPA-201772 bioactivity is needed.

The objectives of this work were to (1) describe an experimental approach aimed at deriving herbicide dose–response functions over a range of soil conditions in a single variable field; (2) use this approach to quantify the influence of within-field soil heterogeneity on RPA-201772 efficacy and crop tolerance; and (3) identify the extent to which soil heterogeneity and soil-applied herbicide use contribute to weed patchiness.

Materials and Methods

Field experiments were conducted in 1999 and 2000 at the University of Nebraska Agricultural Research and Development Center near Mead, NE. The field selected was

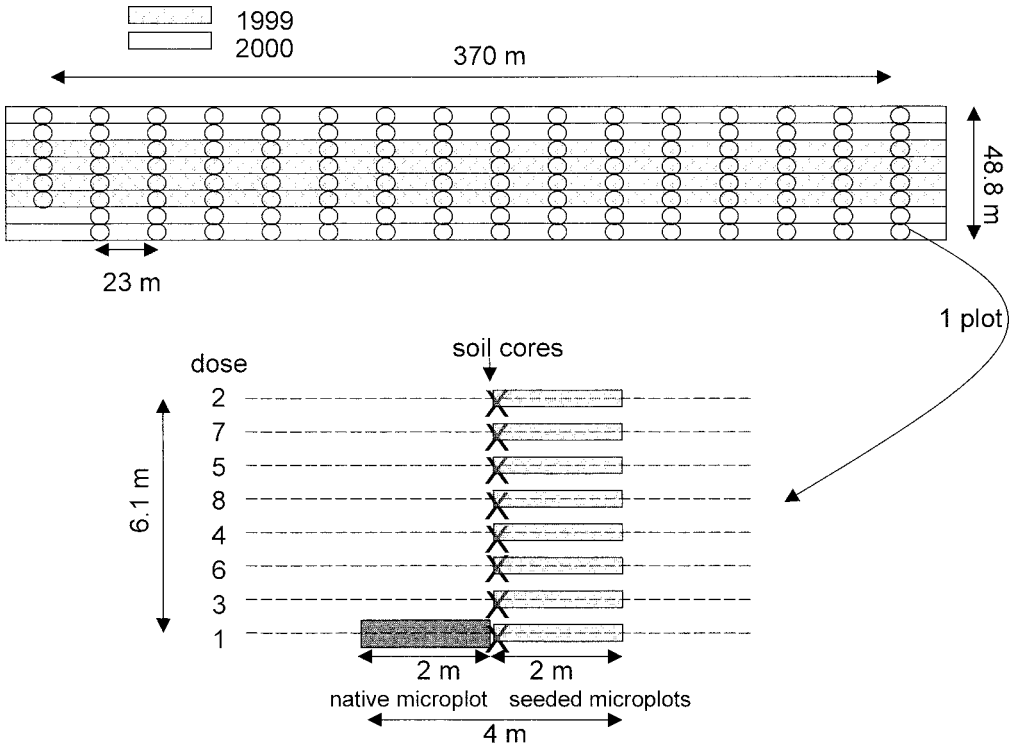

FIGURE 1. Illustration of study site, describing experimental "plot" and "microplot."

identified a priori to have significant variability in particle size and OC and had been in row crop production for at least 20 yr prior to the study. Velvetleaf (*Abutilon theophrasti*) had been observed in this field for at least 10 yr. Experiments were established in 1999 and 2000 so that RPA-201772 dose–response functions could be characterized from early-season weed and crop response data at multiple plots (2.0 by 6.1 m) throughout the field. Soil properties and native velvetleaf densities were also characterized at each plot. The influence of soil variation on herbicide dose–response was determined. In addition, associations among native velvetleaf populations, seeded velvetleaf biomass, and soil properties were evaluated.

Experimental Sites

A gradient from fine-textured to coarse-textured soils was present across the study site (5 ha), where soil series included Tomek (fine, smectitic, mesic Pachic Argiudoll) and Pohocco (fine-silty, mixed, superactive, mesic Typic Eutrudept). Eight parallel east–west transects (6.1 m in width) traversed this gradient, each approximately 370 m in length encompassing eight 76-cm spaced rows (Figure 1). The four center transects were used in the 1999 study and the remaining four transects in the 2000 study. Corn ('Pioneer 34R07Bt') was direct seeded (75,600 seeds ha^{-1}; 3.8-cm depth) on the transects without tillage. On approximately 23-m intervals along each transect, within-field plots were established, consisting of eight rows measuring 4 m in length (Figure 1). Within each plot, two groups of adjoining 2-m-long microplots were established. "Seeded" weedy microplots (2-cm width) were established by planting shattercane (*Sorghum bicolor*; sorghum NK KS711Y as a surrogate) and locally collected velvetleaf seeds to a depth of 1.3 cm directly in the crop row using a research-grade cone planter[1] (Figure 1). Seeding density for shattercane was 53 seeds m^{-1} in 1999 and 56 seeds m^{-1} in 2000. Seeding density for velvetleaf was 200 seeds m^{-1} in 1999 and 750 seeds m^{-1} in 2000. "Native" weedy microplots (38-cm width) were established by selecting a 2-m length of crop row adjacent to the seeded microplots where no weed seeds were planted (Figure 1). Planting dates for crop and weeds were May 10, 1999, and April 28, 2000.

Following planting in each year, eight doses of RPA-201772 were selected and then randomly applied (0.38-m band) to microplots (Figure 1). The dose for each row was constant over the full length of the transect. Herbicide was applied to each microplot with a tractor-mounted compressed-air sprayer through an even flat-fan nozzle delivering 187 L ha^{-1}. In 1999, eight individual microplots received 0, 2, 4, 10, 25, 63, 158, and 247 g ha^{-1} RPA-201772. To increase the range of plant response, the range of RPA-201772 doses was expanded to include 0, 3, 8, 20, 50, 126, 315, and 788 g ha^{-1} RPA-201772 in 2000. A total of 64 and 62 plots (512 and 496 seeded microplots) were established in 1999 and 2000, respectively.

Data Collection

Corn, shattercane, and velvetleaf response was measured 24 d after treatment (DAT) in 1999 and 25 DAT in 2000. A 1-m section of each seeded microplot, representative of local plant growth (< 3 m from microplot), was selected. For corn, a visual rating of crop greenness (0 = total apparent chlorophyll loss, 100 = no apparent chlorophyll loss) was based on a series of photographic standards assembled from a preliminary greenhouse trial. For shattercane and velvetleaf, plants with apparent photosynthetically active tissue were clipped at the soil surface, separated by species, oven dried, and weighed.

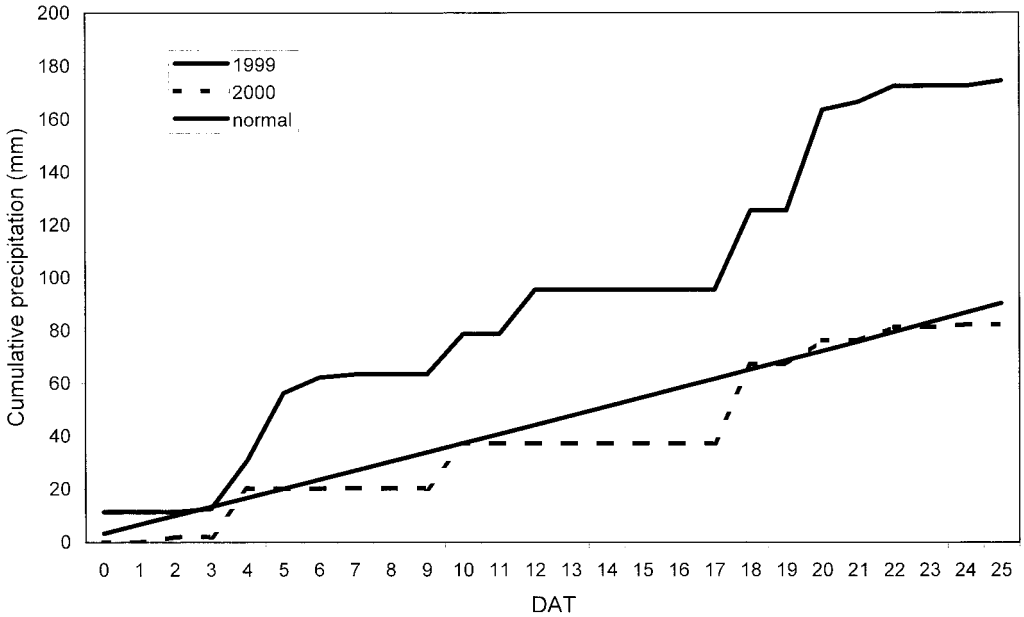

FIGURE 2. Precipitation in 1999 and 2000 and 30-yr normal. The study site was irrigated 4 and 18 d after treatment (DAT) in 2000.

Immediately following assessment of seeded microplots, weed density in the untreated adjacent native microplot was evaluated. A 1- by 0.38-m quadrat frame was centered over the crop row within the native microplots. Seedlings were counted by species.

Within 1 wk of crop and weed sampling, soil cores were drawn for surface soil analysis. Two-centimeter-diameter cores were taken using a hand-held probe inserted to a depth of 5 cm. A single core was taken next to each microplot and composited by plot, for a total of eight cores (Figure 1). Samples were analyzed for OC, pH (Anonymous 1988a), and particle size (Anonymous 1988b).

Soil water content was characterized from crop planting through 24 DAT in 1999 and 25 DAT in 2000. For each transect, two 3- by 3-m plots were selected that had the coarsest and finest soil texture within the transect. Using a 2-cm-diam hand-held probe, eight cores were drawn from 5 cm deep and composited. Soil cores were drawn 2, 4, 7, 9, 11, 14, 18, and 22 DAT in 1999 and 5, 7, 11, 14, and 21 DAT in 2000. Samples were then weighed and oven dried to determine gravimetric water content. Daily precipitation amounts were recorded using rain gauges at the study site and precipitation data from a nearby automated weather station.

A center-pivot irrigation system was used to compensate for subnormal precipitation. Water was applied to approximate the 30-yr precipitation average.

Statistical Analysis

The logistic model was used to quantify plant response over a range of herbicide doses (Seefeldt et al. 1995; Streibig 1988; Streibig et al. 1993). In this study, corn (greenness), shattercane, and velvetleaf (biomass) responses caused by RPA-201772 dose were fit to the following logistic model:

$$y = C + \frac{D - C}{1 + \left(\frac{x}{I_{50}}\right)^b} \qquad [1]$$

where y = plant response, C = lower limit, D = upper limit, I_{50} = dose eliciting 50% response, and b = slope. In this case, C is a measure of plant response at very high doses, D is response of untreated plants, and b is the slope at the I_{50} dose. Equation 1 was simplified by setting parameter $C = 0$, since plant response at high doses was zero. Nonlinear regression methods (PROC NLIN) were used to fit crop and weed responses for each plot (Seefeldt et al. 1995; SAS 1990).

Once model parameters were determined for each plot, two additional biologically meaningful parameters were calculated. One parameter, the crop I_{20}, reflects the dose eliciting a 20% decrease in greenness (hereafter referred to as "crop injury"), a level many growers would prefer to avoid. Also, the weed I_{80} parameter represents the dose eliciting an 80% reduction in biomass, a biologically effective dose for the weed (Dieleman and Mortensen 1998). Assuming a desired level of crop safety and weed suppression is independent of within-field location, these parameters were calculated by choosing a field-wide threshold response in Equation 1 and solving for the dose. The threshold response for crop injury was determined by calculating the mean of the five highest greenness values in the untreated microplots and multiplying that value by 0.8. Likewise, the threshold response for the weed was determined by using the mean of the five highest biomass measurements in the untreated microplots and multiplying that value by 0.2.

Pearson correlation coefficients were calculated between soil properties and logistic model parameters within each plot in order to quantify the correlation between soil properties and measures of corn, shattercane, and velvetleaf response. Furthermore, the relationships among velvetleaf density in native, untreated microplots, seeded velvetleaf biomass, and soil properties were quantified using correlation analysis.

Results and Discussion

The rainfall amount and temporal pattern differed for 1999 and 2000. Normal to above-normal precipitation was observed during the course of the experiment in 1999. Fre-

TABLE 1. Descriptive statistics for pH, percentage organic carbon (OC), sand, coarse silt, fine silt, very fine silt, and clay content at Mead, NE, in 1999 (n = 64) and 2000 (n = 62).

	1999							2000						
	pH	OC	Sand	Coarse silt	Fine silt	Very fine silt	Clay	pH	OC	Sand	Coarse silt	Fine silt	Very fine silt	Clay
	%							%						
Mean	5.9	1.2	54	15	13	2	17	5.9	1.3	48	16	16	2	18
Standard deviation	0.5	0.5	28	12	8	1	8	0.4	0.6	27	10	8	2	7
Minimum	4.8	0.0	7	1	3	1	7	5.0	0.3	8	1	1	1	7
Maximum	6.8	2.4	88	38	28	6	34	6.7	2.8	86	33	32	6	32

quent rains in 1999 resulted in a wetter than normal May and June (Figure 2). At 24 DAT, the cumulative rainfall had reached 175 mm, which was 85 mm above the 30-yr normal. By contrast, in 2000, below-normal rainfall was observed, and the site was irrigated 4 and 18 DAT to bring total precipitation to near-normal levels.

Intense rainfall 5 and 20 DAT in 1999 resulted in a loss of several plots within the field. Because of potential herbicide movement and seed loss, 16 plots were not included in further analyses. Unexpectedly low velvetleaf emergence (mean of 4.1 seedlings m^{-1}) was observed in seeded microplots in 1999. Only seeded microplots with ≥ 10 seedlings m^{-1} receiving the 0 g ha^{-1} dose were included for further analysis. Of the original 64 plots in 1999, 48 corn, 40 shattercane, and 20 velvetleaf were used in the analysis. A minimum of 57 of the original 62 plots were used for any one species in 2000.

The study was located in a field with significant soil heterogeneity. Although mean OC was 1.3%, OC ranged from a low of near 0 to 2.4% in 1999 and from 0.3 to 2.8% in 2000 (Table 1). Particle size also varied considerably; percentage sand varied from 7 to 88%. As expected, clay content varied as well, with more than a four times difference from low to high values. While pH varied, it never exceeded 7.0.

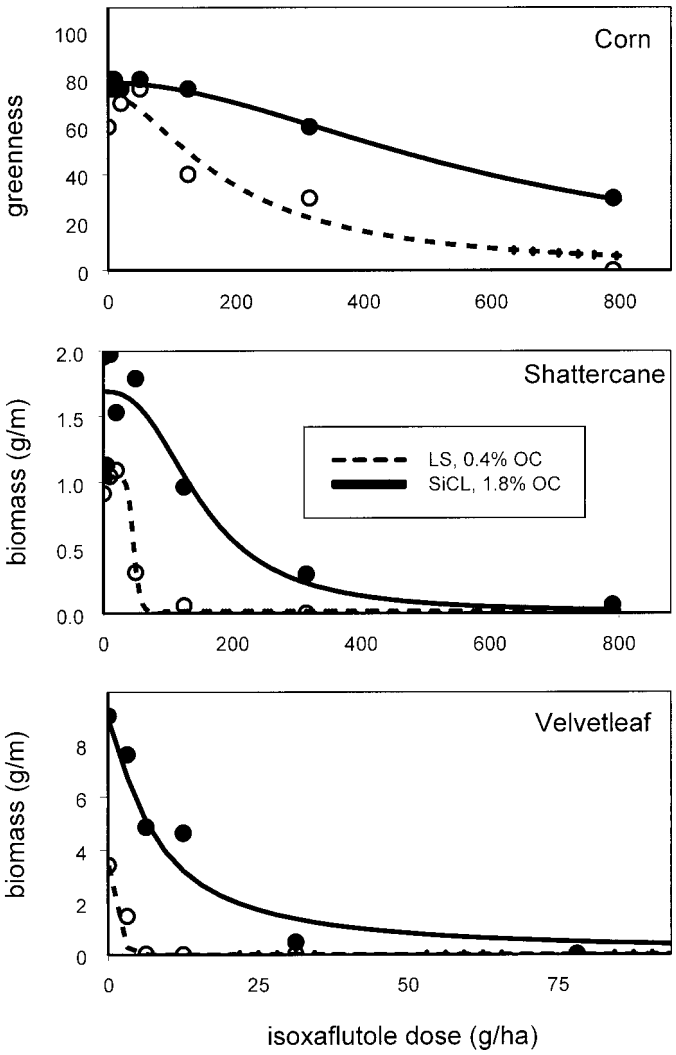

FIGURE 3. RPA-201772 dose–response functions from two plots in the same field for corn, shattercane, and velvetleaf in 2000. One plot has a loamy sand (LS) textural class and 0.4% organic carbon (OC), whereas the other, approximately 300 m away, has a silty clay loam (SiCL) textural class with 1.8% OC.

Species Responses

Several authors have identified the extent of corn tolerance to RPA-201772 (Bhowmik et al. 1999; Knezevic et al. 1998; Sprague et al. 1998), but variable weather makes quantification of the relevance of within-field soil heterogeneity under field conditions difficult. This field study eliminated weather as a confounding variable by characterizing herbicide dose–response functions on a field with markedly different soils (i.e., precipitation and air temperature were relatively consistent across soils). These findings indicate that crop injury to RPA-201772 varied significantly within the field and that variation was correlated with soil heterogeneity. Figure 3 illustrates an example in 2000 of how RPA-201772 dose–response functions typically varied for corn. On a loamy sand plot with 0.4% OC, only 23 g ha^{-1} of RPA-201772 resulted in crop injury. To elicit the same level of crop injury on a silty clay loam soil with 1.8% OC, 172 g ha^{-1} of RPA-201772 were required. Clearly, some plots such as the loamy sand plot were more susceptible to crop injury. In fact, the range of I_{20} parameters extended from < 1 to nearly 243 g ha^{-1} of RPA-201772 (Table 2). Low I_{20} parameters (e.g., < 1 g ha^{-1}) indicated the crop had minor bleaching symptoms at very low doses in a few plots. Averaged over plots and years, 98 g ha^{-1} of RPA-201772 were required to elicit crop injury. Knezevic et al. (1998) observed no grain yield reduction when injury was < 10%. For this field, a dose eliciting no response in one plot could result in > 50% decrease in crop greenness in several other plots.

TABLE 2. Logistic model parameter estimates for crop (greenness) and weed (biomass) responses in 1999 and 2000.

Species	Parameter[a]	Units	1999 Mean	1999 SD	1999 Min	1999 Max	2000 Mean	2000 SD	2000 Min	2000 Max
Corn[b]	D[c]	—	83	5	75	91	77	4	65	87
	b	—	4	3	1	10	3	2	1	10
	I_{50}	(g ai ha^{-1})	276	94	149	563	262	118	73	605
	I_{20}	(g ai ha^{-1})	119	64	< 1	235	77	59	< 1	243
Shattercane[d]	D	(g m^{-1})	1.62	0.58	0.79	2.90	1.91	0.47	1.01	2.77
	b	—	3	2	< 1	7	6	4	1	10
	I_{50}	(g ai ha^{-1})	77	48	4	190	77	41	8	235
	I_{80}	(g ai ha^{-1})	88	51	1	194	96	54	9	262
Velvetleaf[e]	D	(g m^{-1})	0.14	0.16	< 0.01	0.56	8.32	3.21	1.43	15.23
	b	—	3	2	< 1	5	3	3	< 1	10
	I_{50}	(g ai ha^{-1})	5	7	< 1	27	6	5	< 1	23
	I_{80}	(g ai ha^{-1})	5	8	< 1	27	9	9	< 1	32

[a] D = response in untreated plots (dose = 0×); b = slope at I_{50} dose; I_{50} = dose eliciting 50% reduction in response (crop = greenness; weed = biomass); I_{20} = dose eliciting 20% reduction in crop greenness (crop injury); I_{80} = dose eliciting 80% weed biomass reduction (biologically effective dose).
[b] 1999 n = 48; 2000 n = 60.
[c] 0 = total apparent chlorophyll loss; 100 = no apparent chlorophyll loss.
[d] 1999 n = 40; 2000 n = 57.
[e] 1999 n = 20; 2000 n = 57.

While more susceptible to RPA-201772 than corn, shattercane response varied according to soils as well. For instance, shattercane on coarse-textured, low OC soils was much more susceptible to biomass reduction than seedlings on fine-textured, higher OC soils (Figure 3). The RPA-201772 dose resulting in 80% biomass reduction was 45 g ha^{-1} in a loamy sand plot, whereas the I_{80} dose in a silty clay loam plot was more than four times higher. Although the mean biologically effective dose was 88 g ha^{-1} in 1999 and 96 g ha^{-1} in 2000, the range of biologically effective RPA-201772 doses was 1 to 262 g ha^{-1} (Table 2). An average uniform dose applied to this entire field would result in vastly different outcomes. Some plots would have above-average control, while several others would have significantly higher shattercane biomass.

Velvetleaf was very susceptible to RPA-201772, yet much like the other species, its susceptibility was dependent on location within the field. The maximum dose for 80% biomass reduction was 32 g ha^{-1}; however, the average dose was less than 10 g ha^{-1} (Table 2). On a sandy loam plot, the I_{80} parameter was 2 g ha^{-1}, whereas on a silty clay loam plot, the I_{80} parameter was 24 g ha^{-1} (Figure 3). Generally, these biologically effective doses of RPA-201772 are more in agreement with controlled studies by Bhowmik et al. (1996, 1999) than the higher doses found in field studies by Knezevic et al. (1998) and Young et al. (1998). The differences in biologically effective doses found in this study, compared to others, are likely due to variation in climate and soil properties. Processes that influence phytotoxicity of soil-applied herbicides (e.g., plant absorption and growth rate) usually differ under greenhouse vs. field conditions (Frans et al. 1986). Also, OC, the primary absorbent of both RPA-201772 and diketonitrile, was lower in this study than in those soils in studies by Knezevic et al. (1998) and Young et al. (1998).

Relationship of Soil Properties and Plant Response

The variable soils, range of RPA-201772 doses, and multiple species provided a unique study system for examining the associations between soil properties and herbicide efficacy. Laboratory studies indicate soil OC greater than 1.2% is the primary sorbent for both RPA-201772 and diketonitrile, although below 1.2% OC, other soil factors such as clay content regulate its availability (Mitra et al. 1999, 2000). Plant response observed in this study, as reflected in the crop I_{20} and weed I_{80}, correlated highest with particle size (Tables 3 and 4). Although correlations also were observed between plant response and OC, these were usually smaller. For example, the I_{80} parameter of shattercane had a correlation coefficient with clay of 0.74 in 1999 and 0.76 in 2000. Mitra et al. (1999) found that RPA-201772 sorption increased as pH increased above 7.0. No clear associations were observed between plant response and soil pH; however, this is likely the result of a narrow range of pH. Hence, these field-based bioassay findings on soil properties are consistent with laboratory studies (Mitra et al. 1999, 2000).

Several reasons may explain the correlation between RPA-201772 dose–response functions and soil properties. Plant-available herbicide concentration may have varied across the field as a function of soil properties previously discussed. Sorption of RPA-201772 and the diketonitrile derivative in-

TABLE 3. Correlation matrix of selected soil properties and logistic model parameter estimates at 24 days after treatment in 1999.[a]

	Parameter estimate[b]	pH	Organic carbon	Sand	Coarse silt	Clay	Native velvetleaf
							No. m^{-2}
Corn							
(n = 48)	D	0.12	0.03	−0.02	0.01	0.08	—
	I_{50}	0.16	0.20	−0.11	0.07	0.17	—
	I_{20}	−0.26*	0.26*	−0.31*	0.30*	0.30*	—
Shattercane							
(n = 40)	D	0.10	0.40*	−0.43**	0.44**	0.38*	—
	I_{50}	0.29*	0.46**	−0.65**	0.63**	0.65**	—
	I_{80}	0.29*	0.59**	−0.77**	0.75**	0.74**	—
Velvetleaf							
(n = 20)	D	0.01	0.28	−0.33	0.26	0.29	0.45*
	I_{50}	−0.37	0.48*	−0.42*	0.30	0.50*	0.03
	I_{80}	−0.27	0.54*	−0.47*	0.33	0.54*	0.15
Native velvetleaf							
(n = 64)	No. m^{-2}	0.04	0.37**	−0.38**	0.20	0.40**	—

[a] * $P < 0.1$; ** $P < 0.01$.
[b] D = response in untreated plots (dose = 0×); I_{50} = dose eliciting 50% reduction in response (crop = greenness; weed = biomass); I_{20} = dose eliciting 20% reduction in crop greenness (crop injury); I_{80} = dose eliciting 80% weed biomass reduction (biologically effective dose).

creased with increasing OC and clay content (Mitra et al. 1999, 2000). Thus, soils with higher OC and clay content have a higher affinity for these active ingredients, and therefore, less herbicide is available for plant uptake. In addition, the plant-available herbicide concentration may have increased with particle size. In both years, results of the gravimetric water content analyses indicated plots with coarse-textured soils had one-half the water content of fine-textured soils through 25 DAT (data not shown). All else being equal, reducing water content by half would double the concentration of herbicide in soil water solution. Potential for RPA-201772 activity in plants may be further influenced by soil texture. Veerasakaran et al. (1999) reported that RPA-201772 is taken up more rapidly than diketonitrile, and the total conversion from RPA-201772 to diketonitrile increases with soil water content (Taylor-Lovell et al. 2000). Finally, the half-life of both compounds decreases as water content increases (Veerasakaran et al. 1999).

Soils in the field also differed in their early-season productivity. For instance, shattercane biomass in untreated microplots (D) ranged from 0.8 to 2.9 g m^{-1} (Table 2). Furthermore, weed biomass in untreated microplots was positively correlated with OC and clay content (Tables 3 and 4). Observed differences in weed biomass in untreated microplots indicate occurrence of preferential habitats (e.g., higher nutrient or water content) in high OC and clay content soils.

A Contributing Factor to Weed Patchiness

This study provides evidence that variability in plant-available herbicide concentration may be an important mechanism regulating weed patch formation and persistence. Velvetleaf had been observed in this field for at least 10 yr. Figure 4 illustrates the native seedling distribution of velvetleaf at the 1999 and 2000 experimental sites. The highest densities, ranging from 15 to 113 seedlings m^{-2} in 1999 and from 25 to 229 seedlings m^{-2} in 2000, were observed in the eastern end of the field, with few (< 15 seedlings m^{-2}) to no seedlings observed in the western end of the field. Velvetleaf seedling density was highly correlated with OC and particle size (Tables 3 and 4). The spatial distribution of I_{80} RPA-201772 doses was similar to the native velvetleaf population (Figure 4). A high correlation (0.42) was observed in 2000 between native velvetleaf density and the I_{80} dose of RPA-201772 (Table 4). However, this association was not observed in 1999, possibly because the nearly threefold increase in the number of plots from 1999 to 2000 increased the power of this correlation analysis. RPA-201772 use cannot account for the spatial heterogeneity of velvetleaf, because it was not used prior to 1999. However, the influence of soil properties on plant-available herbicide concentration is not unique to RPA-201772. Thus, RPA-201772 may be a potential surrogate for many soil-applied herbicides. For instance, atrazine and metolachlor have been used in this field for weed control in corn since at least 1980. Given a less efficacious herbicide and uniform application, within-field plots with a greater proportion of the herbicide sorbed to the soil matrix would portend higher seedling fitness. Over time, localized seedbank additions would enhance seedling fitness via competition for herbicide (Winkle et al. 1981) and would further define patch boundaries and persistence in time.

Within-field soil variation is important to crop tolerance, herbicide efficacy, and, over time, spatial distribution of the weed. Previous research has documented the influence of varying OC, clay content, and pH on RPA-201772 and diketonitrile sorption (Mitra et al. 1999, 2000). These studies used soils collected from sites throughout the United States, representing a broad range of soils. In this work, crop injury and biologically effective doses of RPA-201772 for shattercane and velvetleaf control were highly correlated with soil particle size within a field. To avoid crop injury or poor weed control, these findings underscore the importance of matching herbicide use to site-specific soil properties. Furthermore, this work demonstrates that, under uniform

TABLE 4. Correlation matrix of selected soil properties and logistic model parameter estimates at 25 days after treatment in 2000.[a]

	Parameter estimate[b]	pH	Organic carbon	Sand	Coarse silt	Clay	Native velvetleaf
							No. m^{-2}
Corn							
(n = 60)	D	−0.31*	−0.04	−0.04	0.03	0.09	—
	I_{50}	−0.22*	0.61**	−0.65**	0.61**	0.67**	—
	I_{20}	−0.15	0.21	−0.31*	0.32*	0.31*	—
Shattercane							
(n = 57)	D	−0.16	0.33*	−0.34*	0.33*	0.32*	—
	I_{50}	−0.22*	0.63**	−0.74**	0.70**	0.76**	—
	I_{80}	−0.27*	0.61**	−0.75**	0.71**	0.76**	—
Velvetleaf							
(n = 57)	D	0.21	0.58**	−0.61**	0.57**	0.59**	0.17
	I_{50}	−0.14	0.63**	−0.75**	0.68**	0.79**	0.62**
	I_{80}	−0.10	0.63**	−0.76**	0.68**	0.76**	0.42**
Native velvetleaf (n = 62)	No. m^{-2}	0.04	0.37**	−0.38**	0.20	0.40**	—

[a] * $P < 0.1$; ** $P < 0.01$.
[b] D = response in untreated plots (dose = 0×); I_{50} = dose eliciting 50% reduction in response (crop = greenness; weed = biomass); I_{20} = dose eliciting 20% reduction in crop greenness (crop injury); I_{80} = dose eliciting 80% weed biomass reduction (biologically effective dose).

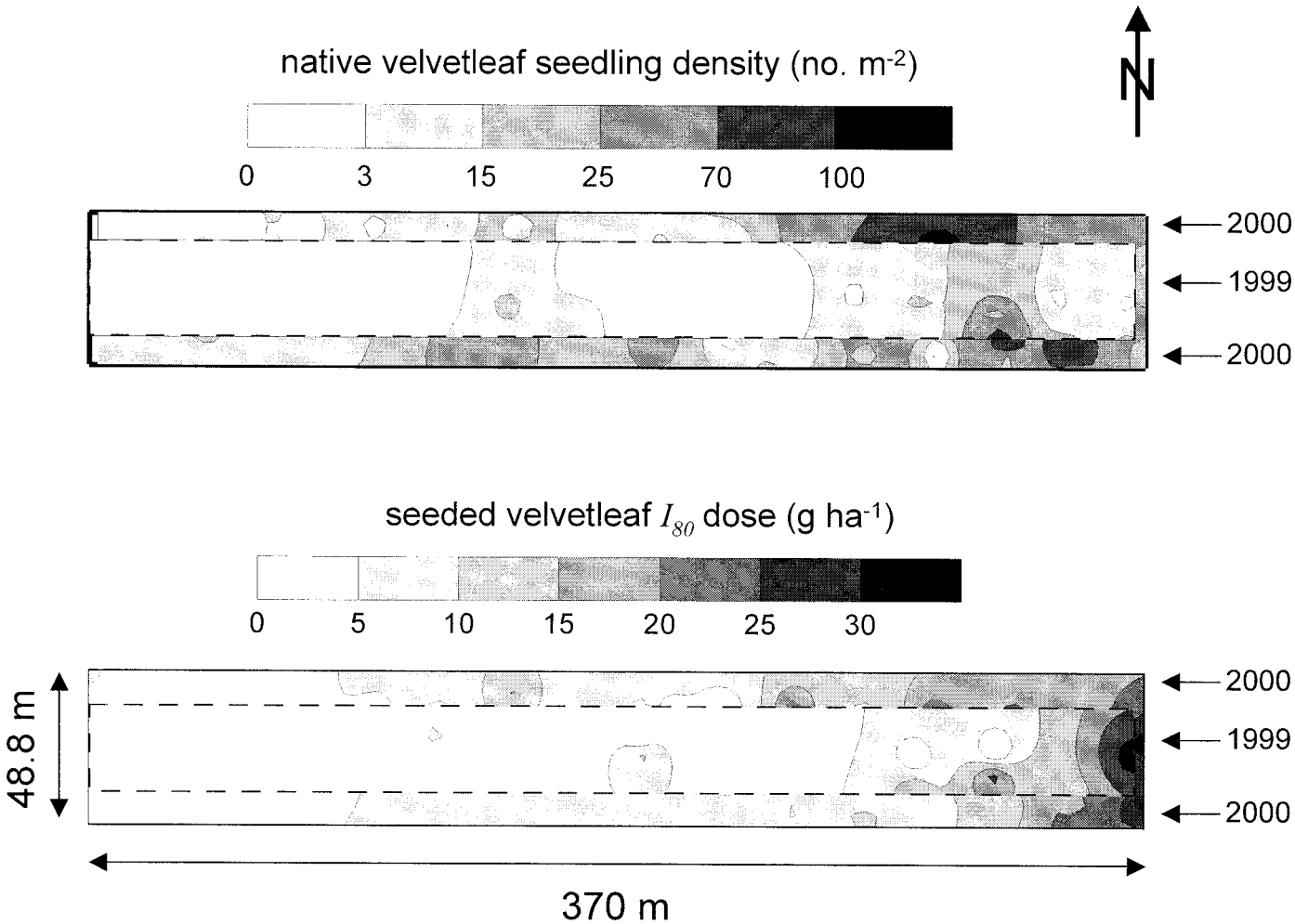

FIGURE 4. Interpolated maps of native velvetleaf seedling distribution and seeded velvetleaf I_{80} doses. The 1999 map (center) overlays the 2000 map.

herbicide applications, some within-field locations offer fitness advantages over other locations due to a lower relative plant-available herbicide concentration. This lower herbicide concentration reduces herbicide uptake and efficacy, thereby favoring seed production and contributing to weed patchiness.

Sources of Materials

[1] Cone planter, ALMACO, 99 M Avenue, P.O. Box 296, Nevada, IA 50201.

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