Chapter 5

Using Abrasive Grit for Weed Management in Field Crops

Michael Carlson, Frank Forcella, Sam Wortman and Sharon A. Clay

Additional information is available at the end of the chapter

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Abstract

Abrasive grit, applied at high pressure and directed at plant base, can control weeds and increase yield. We evaluated fertilizer [pelletized turkey (*Meleagris gallopavo*) litter] and non-fertilizer [walnut (*Juglans regia*) shell] grits for maize and soybean in-row (IR) weed management. Grits were applied at V1 and V5 of maize, and V1 and V3 of soybean. Between-row weed cultivation was done alone (BR), or in combination with grit (I/B), after grit application. Small weeds (<4 cm) were controlled after grit treatment, but, larger broadleaf weeds, grass weeds (treated when growing points were below ground), and later emerging weeds resulted in IR weed biomass similar between season-long weedy (SLW) and IR treatments by August. In maize, fertilizer and nonfertilizer I/B treatments averaged 44 and 14% greater yields, respectively, than SLW ($p<0.01$) but each was similar to BR which averaged 23% greater yield ($p=0.63$). Maize grain had 16% higher N content in the fertilizer I/B treatment than SLW or nonfertilizer I/B ($p<0.003$). In soybean, I/B increased yield by 17% ($p=0.009$) over SLW yield, but was similar to the BR increase of 22% ($p=0.13$). Maize had a greater positive response to fertilizer than nonfertilizer grit, whereas soybean was less influenced by I/B treatment.

Keywords: maize (Zea mays), soybean (Glycine max), air-propelled grit, weed control

1. Introduction

The number and acreage of organic certified farms across the United States has increased [1] due to expanding organic foods sales [2], which has created premiums for organically grown commodities [3, 4] and alternative income streams for farmers. Crop fertility and weed

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management, within the confines of the certified organic regulations [5], are major concerns in organic production systems, as methods other than synthetic chemicals must be utilized. Alternative organic-approved nutrient sources include manures [6–9] and seed meals [9–11], when derived from certified organic materials.

Weed control repeatedly has been ranked as very to extremely problematic [12–14] and as a top research priority [15] in organic producer surveys. Flexible systems that rely on cultural and mechanical methods are needed to prevent the creation of specialized weed communities [16, 17]. Cultural methods enhance the crop's competitive ability [16], reducing weed impact. Methods include alternating crops that vary in seasonal growth, fertilizing differentially [18], or speeding canopy closure by planting in narrow rows or at high densities [19–24]. Dense cover crop mulches, such as those created by rye grass (*Lolium* sp.) or hairy vetch (*Vicia villosa*), suppress weeds [25–29], although these may become major weed problems or immobilize N, negatively impacting yield, if not carefully managed [26, 28].

The most important time for weed control is during the early growth stages of a crop, also known as the critical weed free period, so that yield is not reduced [30–39]. Careful timing of physical and mechanical weed control operations [40–42], including deeper tillage or seedbed preparation that disturbs newly emerging weed seedlings (i.e. stale seedbed) [43–45] can provide weed control and lower in-season weed density [46, 47]. Burying the weeds to at least 1 cm deep, through rotary hoeing or rod weeding, or mowing the weeds at the surface also provides control [48, 49].

Cultivation, or flaming at high temperatures [50], are effective methods to control between-row weeds, however, in-row weed control is still a problem for organic growers [51]. In-row weeders, including harrows, finger and torsion weeders, and weed blowers, have been developed [52–55]. However, crop burial or injury [56] can result in yield reduction [57] so that accurate steering and slow driving are needed to minimize crop damage [51]. Despite advances in physical weed management, organic growers are not satisfied with the tools available nor the amount of weed suppression achieved [58]. Additional methods would provide alternatives to support these 'traditional' weed control techniques [51, 59–61].

Air-propelled abrasive grit application for weed control by tissue abrasion was proposed by Nørremark et al. [62]. Numerous types of grits made from agricultural (e.g., maize cobs and walnut shells), non-agricultural (e.g., sand), and organic fertilizer (e.g., soybean meal and corn gluten meal) materials controlled weeds in greenhouse and field settings [63–70] when sprayed at high pressure (800 kPa). In the field, two or three in-row grit applications, applied from V1 to V5 growth stage of maize, could reduce weeds and increase grain or silage yields [65, 69, 70].

Although Forcella [66] demonstrated that soybean could tolerate grit applications after the cotyledon (VC) growth stage, the influence of in-row grit application on weed control has not been field tested in this crop. In addition, organic fertilizers, such as pelletized turkey litter [71], have not been tested as abrasive grits for weed control in maize or soybean field studies. The hypotheses of this study were that 1) grits derived from different sources would result in similar weed control when applied at early crop/weed growth stages; and 2) crop yield would be increased by grits containing nitrogen [68, 72, 73].

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2. Air propelled abrasive grit influence on in-row weed control and crop yield

2.1. Materials and methods

2.1.1. Grits

Two grits, made from materials that are approved for organic production and that differ in fertilizer value, were used for in-row application and control of weeds. Sustane® (Sustane Corp., Cannon Falls, MN), is made from pelletized aerobically composted turkey litter [71], and had a fertilizer grade of 8-2-4 ($N\text{-}P_2O_5\text{-}K_2O$). Agra Grit (AgraLife), made from walnut shells, which has a high C:N ratio with little immediate nitrogen availability, provided a low N content comparison. Sustane and Agra Grit products have a hardness value of 3 on the Mohs scale of mineral hardness and varied in size from 0.56 to 0.85 mm.

2.1.2. Field experiments

Maize and soybean were planted from 2015 to 2017 in organic certified production fields at the SDSU Southeast Research Farm (Beresford, SD), in a non-certified transition area at the SDSU Research Field Station at Aurora, SD; and in conventionally managed fields at the at the Swan Lake Research Farm (Morris, MN). Soil types were silt loam complexes (Morris and Beresford) and a silty clay loam at Aurora.

Varieties used, relative maturity (RM), planting and harvest dates varied by year and location (**Table 1**). Swan Lake was the northernmost location and used shorter RM varieties. Southeast was the southernmost location and used longer RM varieties. Maize was seeded at 3.5-cm depth, when soil temperatures were 14°C. Soybean seeding rate varied by location and year (**Table 1**) and was planted at 2.4-cm depth when soil temperatures were 18°C. Row spacing was 0.76 m with four crop rows per treatment (~3-m width). Plot length varied from 3 to 9 m.

Sustane 8-2-4 and Agra Grit were applied in all trials. In-row (IR) grits were applied twice, at the V1 and V5 maize growth stages, and the V1 and V3 soybean growth stages (**Table 1**). About 800 kg ha^{-1} of grit was used for each application, which was applied using a propelled abrasive grit applicator [PAGMan] that sprays four rows simultaneously, with a nozzle on each side of the row [69, 70]. Distance of the nozzle tip to the base of the maize plants was between 10 and 15 cm, at a 45° contact angle. Spray pressure was 690 kPa and tractor speed was 2.5 km $hr.^{-1}$. After the final grit treatment each year, a single cultivation was used for between-row (BR) weed control using a John Deere® 866 spring tine cultivator at 5 km $hr.^{-1}$. In addition, other treatments all years included a single between-row cultivation, as described previously, to determine yield potential with only cultivation, season-long weedy (SLW) to estimate yield in nontreated conditions, and weed-free (hand-weeded weekly until canopy closure) to estimate maximum yield potential under weed-free conditions.

Weed species and density were recorded in each plot prior to and about 1 week after final grit applications. In mid-July to early September depending on crop and year (**Table 1**), weeds,

Year	Location	Crop	Relative maturity	Planting		Grit application		Weed biomass	
				Date	Rate	First	Second	Greenness	Harvest date
					(*1000)				
2015	Aurora	Soybean	1.4	June 9	395	June 30	July 8	September 8	October 22
	Beresford	Soybean	2.1	June 9	395	June 26	July 10	September 2	October 20
	Morris	Corn	93 d	April 16	79	May 16	June 2	August 27	October 1
2016	Aurora	Corn	99 d	May 7	79	May 17	June 15	July 15	October 5
	Aurora	Soybean	1.4	May 19	395	June 8	June 23	July 20	October 14
	Morris	Soybean	1.1	May 4	431	June 1	June 17	July 19	September 9
2017	Aurora	Corn	95 d	May 5	79	June 2	June 23	August 1	November 5
	Aurora	Soybean	1.7	May 30	395	June 15	June 29	July 31	October 11
	Beresford	Soybean	1.9	May 24	420	June 16	June 27	July 28	October 17
	Morris	Corn	93 d	May 11	86	June 6	June 26	July 25	October 31

Table 1. Locations, crops, relative crop maturity rating, planting dates and rates, dates of weed control applications, and measurements.

in- and between-rows, were harvested from 1/10 m^2 areas, separated by functional group (grass vs. broadleaf) and dried at 60°C until constant weight to quantify biomass by treatment. Relative greenness of the newest fully expanded maize leaf (SPAD meter, Konica Minolta, Japan) (10 to 20 plants per plot) was measured in 2016 and 2017 during this sampling time. At crop physiological maturity, the middle two rows of each treatment were harvested, and yield determined. Yield was corrected to 15.5% moisture for maize, and 13% moisture for soybean. Maize grain was tested for % N content, and soybean was analyzed for oil and protein contents.

2.1.3. Statistical analysis

Treatments [grit type followed by between-row treatment (I/B), between-row (BR) only, SLW, and hand-weeded] were replicated four times for each crop, year, and location in randomized complete block designs. Yields in hand-weeded and SLW treatments varied considerably among locations and years. To analyze main effect of grit treatments, the SLW treatment average yield by crop, location, and year was used as the 'base' yield, with grit type and BR treatment average yields for the crop, location, and year divided by the SLW value, providing a relative yield comparison with the SLW. This relative yield approach assisted in evaluating treatment comparisons among years and locations. The treatments by crop were the fixed effects, whereas location, blocks, and years were random effects. One-way ANOVAs (i.e., was the relative treatment yield greater than its SLW?) were calculated with significance of $p = 0.1$. In addition, a sign test for paired comparisons also was used as a non-parametric measure to determine if treatments differed.

2.2. Results

2.2.1. Influence of treatments on in-row (IR) and between-row (BR) weed control

Broadleaf weeds observed in plots during the time of grit applications included common lambsquarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), common purslane (*Portulaca oleracea*); and grass weeds included green and yellow foxtail (*Setaria viridis* and *S. pumila*, respectively). Weed size ranged from <1 cm (V1 maize application), 2- to 6-cm tall (V1 soybean), and >10 cm tall (V3 soybean or V5 maize). Broadleaf weeds were greater in number, making up >60% (and at times, nearly 100%) of the weed profile.

In general at all locations, grit treatments tended to control all weeds in maize after the first (V1) application (data not shown) as weed densities were low, and most were small (<3 cm). When grit was applied in soybean, plots at Aurora and Beresford already had high weed densities (~700 plants m^{-2}) and weed height ranged from 2- to 6-cm at V1 and, while grits abraded leaf tissue, control ranged from 0- to 50%. Plots at Morris were rotary hoed prior to grit application and no weeds were present. Examining weeds before and after the second application indicated that emerged broadleaf weeds again were injured by abrasion, but if >4-cm tall, they were not controlled. Grass weeds, if emerged, were injured, but growing points were still below the soil surface, so that although defoliated, they were not controlled well.

Grit application, generally, did not influence IR weed biomass measured at R4, with weights similar to those recorded in SLW plots. At Aurora IR weed biomass was found to be nearly 100% grass in 2016 and averaged 300 kg ha^{-1} (SLW averaged 400 kg ha^{-1}), and in 2017, was about 60% grass and averaged about 4500 kg ha^{-1} (SLW averaged 4300 kg ha^{-1}). In Morris maize plots, nearly 100% of biomass was attributed to broadleaf species and averaged 100 kg ha^{-1} (SLW averaged 140 kg ha^{-1}) in 2015, and 2200 kg ha^{-1} (SLW averaged 2600 kg ha^{-1}) in 2017.

Total IR weed biomass in soybean treated with grit did not differ from the location/year SLW treatment except at Aurora in 2016, where grit treatments had reduced broadleaf biomass that ranged from 20 to 80% less (220 kg ha^{-1} in SLW) and about 50% less grass biomass (1100 kg ha^{-1} in SLW).

The BR cultivation in maize and four of six soybean site-years had few if any weeds remaining between rows and remained nearly weed-free through harvest. The exceptions were the 2015 soybean plots in Aurora where the BR treatment had 11,000 kg ha^{-1} between row weed biomass with grass weeds contributing about 80% of the total biomass, and 2015 soybean plots in Beresford, where BR weed biomass was 105 kg ha^{-1} with grass weeds accounting for all the biomass.

2.2.2. Crop yield

Maize yields in weed-free areas differed by location and year and ranged from 7588 (Aurora, 2017) to 12,690 (Morris, 2015) kg ha^{-1} in weed-free treatments. Yield losses in SLW compared

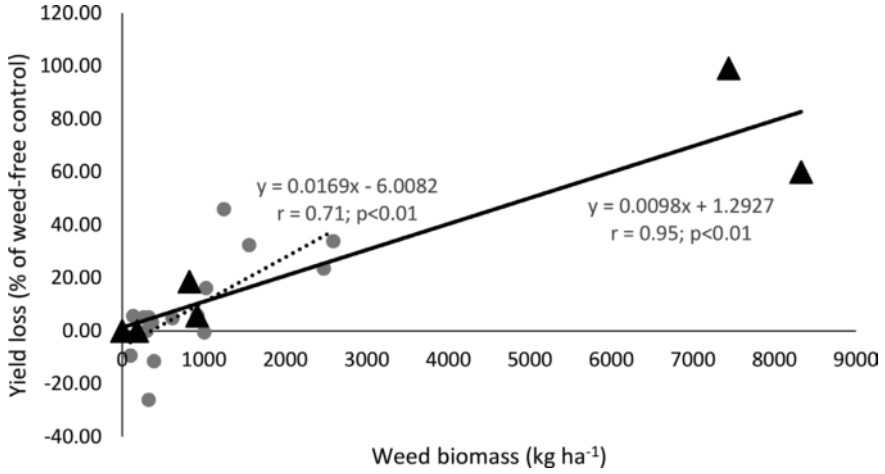

Figure 1. Maize yield loss (% of weed-free control) by total weed biomass at all locations and treatments. Triangles represent the season-long weedy treatments and the regression is shown by the solid black line ($r = 0.95$; $p < 0.01$). Circles represent yield loss based on weed biomass compared with the weed-free control plots of the I/B and BR treatments with the regression shown in the dotted line ($r = 0.71$; $p < 0.01$).

to the weed-free check ranged from 5% to nearly 100%. Maize yields in the SLW, I/B, and BR treatments were almost all lower than the weed-free check. In the SLW vs. weed-free treatments, the percent yield loss was positively correlated with total weed biomass (in-row plus between-row weeds) when examined across all studies ($r = 0.93$; $p = 0.008$) (**Figure 1**). Because the I/B and BR treatments had few between row weeds, the yield losses in these treatments were positively correlated with in row weed biomass ($r = 0.71$; $p = 0.001$). The slopes of each regression line were similar ($m \sim 0.01$), which indicated that percent yield loss was about 1% for each 100 kg ha^{-1} of weed biomass present at R4.

Although weeds were present in the row after I/B treatments, maize yields across years and locations were greater than the SLW, except in one case. On average, there was a 30% yield increase in grit application treatments compared within a year and location to its companion SLW treatment. Sustane treatments averaged 44% greater yield than SLW, whereas Agra Grit averaged 14% greater yield ($p = 0.1$). In addition, maize grain had 16% higher N content than grain from either the SLW or Agra Grit treatments ($p<0.003$). Sustane appeared to provide some nitrogen to the crop [74], as relative greenness, measured at R4 of maize, was similar to the weed-free check, and averaged 44% ($p < 0.01$) higher than greenness of plants in the SLW treatment. Agra Grit has a high C/N ratio, and actually slowed soil nitrogen mineralization in laboratory studies [74], although greenness values at R4 were about 30% greater than SLW plants. The BR treatment and I/B treatments averaged over all grits, however, had similar maize yield increases (23% vs. 30%, respectively; $p = 0.63$) compared to the SLW.

Soybean yield in weed-free treatments ranged from 1626 (Aurora, 2015) to 4856 (Aurora, 2016) kg ha^{-1}. Yield losses compared to weed-free treatments within location and year ranged from 2 to 43%. However, unlike maize yield losses, which were linearly related to total weed

biomass, soybean yield loss in SLW compared with weed-free was not correlated to total weed biomass ($r = 0.16$; $p = 0.69$), but was more correlated to in-row weed biomass ($r = 0.58$; $p = 0.12$). When examining relative yield compared with the SLW treatment, I/B treatments increased yield on average by about 16% ($p = 0.004$), which was similar to the BR treatment alone ($p = 0.48$). Soybean yield increases due to Agra Grit treatments compared with Sustane treatments were similar. Protein and oil content of soybean grain were similar among treatments as well. These data indicate that grit applications applied at V1 and V5 of soybean had minimal impact on soybean yield and weed biomass. Indeterminate growth of soybean may have been partially responsible for the inconsistency between weed biomass and soybean yield loss.

3. Conclusion

Weed management using grits was more effect on small broadleaf weeds than larger broadleaf or grass weeds. While the larger weeds and grasses were defoliated with the grit treatment, these regrew and by late season, biomass was similar in-row as the season-long weedy treatment. The in-row treatment, followed by cultivation between rows, tended to increase maize yield compared to no management, and grit with a higher N content tended to increase maize yield and nitrogen content more than a low N grit. Weed control in soybean was more challenging and, due to the size of the weeds even at V1 (one expanded trifoliate leaf), did not control weeds well, and by the second application (V5), weeds were likely too large for meaningful injury. Soybean yield loss was more related to in-row weed biomass than between row weed biomass. Thus, more research is needed to better control in-row weeds in soybean to limit yield loss.

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Author details

Michael Carlson[1], Frank Forcella[2], Sam Wortman[3] and Sharon A. Clay[1]*

*Address all correspondence to: sharon.clay@sdstate.edu

1 Department of Agronomy, Horticulture, and Plant Science, South Dakota State University, Brookings, SD USA

2 USDA-ARS, Morris, MN, USA

3 University of Nebraska-Lincoln, Lincoln, NE USA

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