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Broadleaf weed control with abrasive grit during raspberry establishment

Frank Forcella[1], Steven Poppe[2], Emily Tepe[3] and Emily Hoover[4]

[1]Adjunct Professor (retired), Department of Agronomy and Plant Genetics, University of Minnesota, St, Paul, MN, USA; [2]Senior Horticulture Scientist, West Central Research and Outreach Center, University of Minnesota, Morris, MN, USA; [3]Research Fellow, Department of Horticultural Science, University of Minnesota, St. Paul, MN, USA and [4]Professor, Department of Horticultural Science, University of Minnesota, St. Paul, MN, USA

Research Article

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Author for correspondence:
Frank Forcella, 23028 470th Avenue, Morris, MN 56267. Email: forcellafrank@gmail.com

Abstract

Growers desire more techniques to control weeds in horticultural crops that are grown organically and consumed directly, such as red raspberry. Abrasive grit emited via high air pressure is a new method for controlling weeds. Grit derived from corn cobs was examined for its efficacy during the year of raspberry establishment for 2 to 3 years at three sites (seven site-years) and compared with efficacy of hand-weeding as well as no weed control. Grit was applied once or twice weekly after raspberry transplantation in spring until weed emergence ceased in mid to late July. Weeds and raspberry growth were assessed in August. Grit was effective in controlling broadleaf weeds, averaging 94% control across site-years, but control of grass weeds was less than 10%. Total weed (broadleaf plus grass) control across site-years ranged from 51% to 96% and averaged 78%. Raspberry cane growth was affected by weeds, and grit-weeding at least partially alleviated these effects. Thus, abrasive grit allows growers to manage broadleaf weeds effectively without herbicides or soil tillage. However, additional research is needed to determine the correct amounts and timing of grit applications, as well as more efficacious types of grit, to control grass weeds.

Introduction

Few options exist for nonchemical control of weeds during raspberry establishment (Mitchell et al. 2018). Current options typically involve repeated soil cultivation (including hand-hoeing) to kill weeds and various types of mulches (including weed mats) to suppress weed emergence and growth. Specific information for these management techniques is limited. For instance, depth of soil cultivation should not exceed 5 cm to prevent damage to developing roots and cane buds (Barney et al. 2007), but specific methods of cultivation usually are not stated in raspberry production guides. In contrast, more information is available regarding mulches, which can be based on shredded plant materials, woven plant-based (biodegradable) and synthetic fabrics, and polyethylene films (Barney et al. 2007; Hammermeister 2016). Although mulches can control weeds effectively, they also are associated with a wide variety of production issues, both physical and biological. For instance, soil cultivation is incompatible with mulches of all types, and polyethylene and biodegradable mulches may increase levels of deleterious nematodes in raspberry plantings (Zhang et al. 2019). Polyethylene mulches also present an eventual disposal problem for growers. Another nonchemical form of management, thermal weed control (flaming and steaming), is not common in raspberry production.

Although a few herbicides are labeled for use during raspberry establishment (Peachey 2019), new weed control techniques are needed for growers and consumers who desire fruit produced without the use of synthetic herbicides (Mitchell et al. 2018). Furthermore, given the rapid and extensive evolution of herbicide resistance in recent decades, new strategies of weed control are needed (Beckie et al. 2019). One possibility for this is the application of abrasive grits for POST weed control. Grits applied at high air pressures (Forcella 2009) can eliminate weed seedlings entirely and abrade and damage larger weeds. Several types of plant- and animal-derived products can be used as abrasive grits, including nitrogen-rich materials such as pelletized poultry manure (Braun et al. 2019) and corn gluten meal (Forcella et al. 2011), as well as many carbon-rich residues like corn cobs, grape pomace, olive pits, and spent coffee grounds (Forcella 2017, Perez-Ruiz et al. 2018). To date, abrasive grits have been used successfully to control weeds in agronomic crops such as corn and soybean (Erazo-Barradas et al. 2018, 2019) and horticultural crops like tomato and pepper (Braun et al. 2019; Wortman 2014, 2015). However, the usefulness of this new technique in high-value, perennial crops such as red raspberry is unknown. Accordingly, we explored the use of corn-cob grit to control weeds during the establishment year of red raspberry over 2 to 3 years at three sites in Minnesota.

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Materials and Methods

Field experiments were established during May in the following years and sites. Site 1, used in 2017, 2018, and 2019, was at the West Central Research and Outreach Center (WCROC), Stevens County, MN (45.59°N, 95.87°W), which is an experiment station operated by the University of Minnesota. Soil type was a McIntosh silt loam (fine-silty, mixed, superactive, frigid Aquic Calciudoll) in 2017 and an adjacent complex of Langhei loam (fine-loamy, mixed, superactive, frigid Typic Eutrudept) and Barnes loam (fine-loamy, mixed, superactive, frigid Calcic Hapludoll) in 2018 and 2019. Previous crops were grass-based pasture and strawberry [*Fragaria* × *ananassa* (Weston) Duchesne ex Rozier ssp. *ananassa*]. Site 2, used in 2018 and 2019, was at the Fairhaven Farm, Stearns County, MN (45.32°N, 94.22°W), which is a privately owned commercial farm that emphasizes a wide variety of traditional and exotic horticultural crops that can be grown in the region. Soil type was an Arvilla sandy loam (sandy, mixed, frigid Calcic Hapludoll). Previous crops were cucurbits. Site 3, used in 2018 and 2019, was at the Prairie Horizons Farm, Pope County, MN (45.46°N, 95.55°W), which is a certified organic farm specializing in cattle production with incipient interests in organic fruit production. Soil type was a Langhei-Barnes loam. Previous crops were garlic (*Allium sativum* L.).

Soil was cultivated to produce residue-free beds for transplanting raspberry canes in May each year. Plots were 300 cm long and contained four 30-cm-tall transplants spaced at 75-cm intervals and planted at 10-cm soil depth. Raspberry rows were separated from other rows by at least 200 cm. The raspberry cultivar was 'Caroline,' and clonal materials were supplied each year by Nourse Farms, South Deerfield, MA.

Three treatments were implemented: a weedy check, hand-weeded, and grit-weeded, all of which are described in detail in the following paragraphs. Treated plots were arranged in a randomized block design with four replications. Treated areas of each plot were 300 cm long and 60 cm wide.

In the weedy check treatment, weeds grew unimpeded from the transplant date until late July. Weeds in the hand-weeded treatment were hoed manually or pulled by hand semiweekly to biweekly; time spent hand-weeding was recorded with stop watches.

Grit-weeding consisted of applying commercially available corn-cob grit at 700 kPa using a portable grit applicator (Figure 1). The applicator was mounted on a small, hand-pulled, garden wagon. It consisted of a gasoline-powered air compressor, wand tipped with a single nozzle, and grit tank with a battery-powered grit metering system. Flexible nylon tubes connected the air compressor to the nozzle and the grit tank and meter to the nozzle. A vacuum created by air flowing through the nozzle drew grit from the grit tubes into the nozzle. This dual-tube system helped prevent clogging of the air tube by grit.

For WCROC and Fairhaven Farm, grit particles were approximately 0.5 mm in diameter and had a specific gravity (±SE) of 0.43 ± 0.005 g cm^{-3}; these characteristics matched corn-cob grits used by others (Erazo-Barradas et al. 2018, 2019, Forcella et al. 2017). At Prairie Horizon Farm, however, organically certified grit was used, which had a particle diameter of 1 mm and specific gravity of 0.54 ± 0.005 g cm^{-3}.

At all sites, the nozzle of the grit applicator was positioned approximately 30 cm from the target weeds. Time spent applying grit and the amount of grit applied in each plot were recorded. Dates of grit weeding were identical to those of hand-weeding.

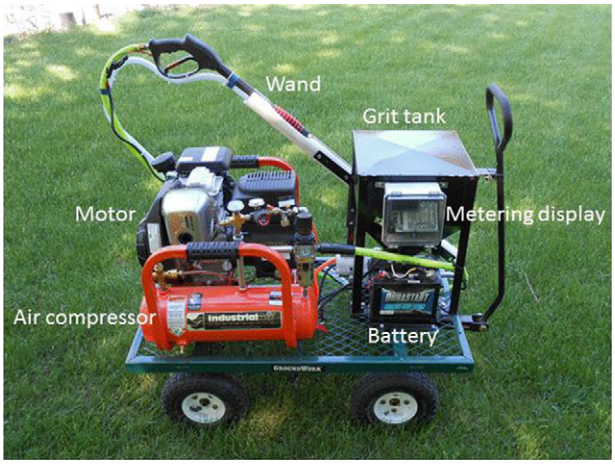


Figure 1. Single-nozzle grit applicator comprises a gasoline-powered motor and air compressor, a grit tank, and a meter that regulates the amount of grit dispensed to an air stream created by the compressor, which passes through the hand-held wand tipped by a single nozzle.

Weeds were harvested by clipping at ground level in late July from the entire area of each plot. Weeds were sorted into two groups (grasses and broadleaf plants), and dried at 60 C for 1 wk, and weighed. Number and lengths of raspberry canes were recorded in each plot in late summer of 2018 and 2019. Canes arising from aboveground buds on original transplants and new canes arising from belowground buds were recorded separately. Dry weights of canes also were recorded after clipping at the soil surface and drying at 60 C for 1 wk in late summer of 2017 and 2019.

All data were tested for homogeneity of variances, and treatment means and variances were calculated. Because of significant variation among years and sites for weed biomass data, year- and site-specific means were separated through single-factor ANOVA, with P level set at 0.05, and LSDs calculated. For raspberry cane data, years varied significantly but not sites. Thus, biomass data were combined across sites for 2019, and cane length data were combined across sites for 2018 and 2019. Aggregate means were separated through two-factor ANOVA for 2018 and 2019, whereas single-factor ANOVA was used for 2017 data. P levels were set at 0.10, and LSDs were calculated.

Results and Discussion

Weed control

Hand-weeding and grit-weeding occurred six to 10 times (Table 1) during spring to mid-summer, depending on individual plot needs, duration of weed emergence, and weed growth. As expected, hand-weeding nearly eliminated all weeds (Table 2). Grit-weeding also reduced weed biomass appreciably, but some species clearly tolerated abrasion more than others. Dry weights of broadleaf weeds, which were the predominate weeds at all sites, were reduced significantly ($P < 0.01$) compared with the weedy check treatments in each of the seven site-years (Table 2). Prominent broadleaf species found in the weed-control treatments included primarily annual plants such as common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), hairy galinsoga [*Galinsoga ciliata* (Raf) S.F. Blake], common mallow (*Malva neglecta* Wallr.), wild buckwheat (*Polygonum convolvulus* L.),

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Table 1. Number of weeding events per season, cumulative time spent weeding, and total amount of corn-cob grit applied in red raspberry at three sites in central Minnesota over 2 or 3 y.

Site and year[a]	No. of hand-weeding events	Time, mean ±SE (n = 4)	No. of grit-weeding events[b]	Time, mean ± SE (n = 4)	Grit amount, mean ± SE (n = 4)
WCROC (Stevens County)		min m^{-2}		min m^{-2}	kg m^{-2}
2017	6	2.4 ± 0.18	7	5.4 ± 0.58	2.5 ± 0.17
2018	7	6.6 ± 0.07	6-7	13.3 ± 0.88	4.4 ± 0.14
2019	8	4.7 ± 0.42	8	10.6 ± 0.32	3.8 ± 0.04
Fairhaven Farm (Stearns County)					
2018	10	6.2 ± 0.08	10	32.5 ± 1.13	8.6 ± 0.07
2019	9	4.9 ± 0.34	8	16.7 ± 0.19	5.7 ± 0.13
Prairie Horizon Farm (Pope County)					
2018	8	8.0 ± 0.02	8	23.8 ± 2.16	4.7 ± 0.17
2019	8	5.8 ± 0.38	8	26.6 ± 1.86	4.7 ± 0.31

[a]Abbreviation: WCROC, West Central Research and Outreach Center of the University of Minnesota.
[b]Grit used at WCROC and Fairhaven Farm was from conventionally grown corn; grit diameter was 0.5 mm. At Prairie Horizon Farm, grit was from organically grown corn, and grit diameter was 1.0 mm.

Table 2. Dry weights of broadleaf, grass, and total weeds as influenced by three treatments across seven site-years.

	Weed dry weight				
Site-year[a]	Hand-weeded	Grit-weeded	Weedy control	$LSD_{0.05}$[b]	P[b]
	g m^{-2}				
Broadleaf					
WCR-2017	6	3	849	211	<0.01
FHF-2018	11	63	951	261	<0.01
PHF-2018	1	63	307	164	0.02
WCR-2018	1	41	888	122	<0.01
FHF-2019	14	38	1,095	218	<0.01
PHF-2019	9	31	663	277	<0.01
WCR-2019	1	3	1,540	402	<0.01
Grass					
WCR-2017	2	30	74	19	<0.01
FHF-2018	0	221	240	120	<0.01
PHF-2018	1	228	509	196	<0.01
WCR-2018	0	4	4	ns	0.17
FHF-2019	5	228	357	201	0.03
PHF-2019	26	454	326	136	<0.01
WCR-2019	8	337	156	202	0.04
Total					
WCR-2017	8	34	923	198	<0.01
FHF-2018	12	284	1,191	224	<0.01
PHF-2018	7	291	816	228	<0.01
WCR2018	1	44	892	119	<0.01
FHF-2019	19	266	1,452	178	<0.01
PHF-2019	34	485	989	312	<0.01
WCR-2019	8	340	1,696	440	<0.01

[a]Abbreviations: FHF, Fairhaven Farm (Stearns County, MN); PHF, Prairie Horizon Farm (Pope County, MN); WCR, West Central Research and Outreach Center (Stevens County, MN).
[b]LSD and *P* values derived from ANOVA.

Table 3. Raspberry cane growth as affected by three treatments.

Year	Hand-weeded	Grit-weeded	Weedy	$LSD_{0.10}$	P
Raspberry cane dry weight, g m^{-2}[a]					
2017	125	121	76	29	0.08
2019	192	76	57	18	<0.01
Cumulative raspberry cane length, cm[b]					
2018	162	168	128	26	0.09
2019	135	86	80	19	<0.01

[a]Dry weight data for 2017 are for canes from only the West Central Research and Outreach Center (WCROC; Stevens County, MN), whereas those for 2019 are for values averaged across three sites in central Minnesota (WCROC and Fairhaven Farm, both in Stearns County; and Prairie Horizon Farm in Pope County).
[b]For 2018 and 2019, data are for cumulative growth of canes within plots averaged across the same three sites.

and Venice mallow (*Hibiscus trionum* L.), as well as a perennial, Canada thistle [*Cirsium arvense* (L.) Scop.].

Surviving plants in the grit-weeding treatments were grasses (Table 2). Grit-weeding significantly reduced grass biomass in only two of seven site-years. Surviving grasses included perennials, especially bluegrass (*Poa pratensis* L.), smooth brome (*Bromus inermis* Leyss.), and quackgrass [*Elytrigia repens* (L.) Desv. ex Nevski]. Annual grasses, such as foxtails (*Setaria* spp.), crabgrass [*Digitaria sanguinalis* (L.) Scop.], and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] also survived abrasion but typically were stunted compared with those in the weedy-check treatment. In some cases (e.g., Prairie Horizon Farm in 2019), control of broadleaf weeds by grit-weeding apparently released grasses from competition so that grass biomass in the grit-weeded treatment was significantly greater than in the weedy check treatment.

Total weed biomass was consistently and significantly reduced by grit-weeding (Table 2). Overall, in terms of weed biomass reduction and when averaged across sites and years (±SE), grit-weeding provided 94% ± 2.5% broadleaf weed control, 6% ± 25.9% grass control, and 78% ± 6.1% total weed control. Last, although supporting data do not exist, observations suggested that the larger diameter (1 mm) organic corn-cob grit used at the Prairie Horizons Farm was not as effective as the smaller diameter (0.5 mm) grit used at Fairhaven Farm and WCROC. These observations are consistent with the comparatively higher weed biomasses in grit-weed treatments at Prairie Horizons Farm, relative to the weedy controls, compared with other sites.

Raspberry growth

Growth of raspberry canes was affected by weeding treatments (Table 3). Raspberry growth in hand-weeded treatments always was significantly greater ($P = 0.10$) than that in the nonweeded (control) treatment, and it usually was greater than that in the grit-weeded treatment. The latter treatment also usually allowed

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significantly greater raspberry cane growth than in the control treatment, but less than in the hand-weeded plots. Thus, grit-weeding usually prevented weeds from reducing raspberry growth, but abrasion by grit may have curtailed cane growth somewhat compared with hand-weeding. Excessive amounts of grit needed for grass suppression (discussed in the next section) may have contributed to reduced cane growth.

Weeding times and grit amounts

Both hand-weeding, which consisted of hoeing and hand-pulling, and grit-weeding were performed six to 10 times each season across site-years (Table 1). Cumulative work times (±SE) averaged 6 ± 0.7 min m^{-2} of plot area for hand-weeding and 18 ± 3.6 min m^{-2} for grit-weeding. Grit-weeding also resulted in the use of 5 ± 0.7 kg m^{-2} of corn cob grit. The large amounts of time and grit used for grit-weeding reflected the efforts expended to suppress abrasion-resistant grass weeds. Weeding times and required grit amounts for control of only broadleaf weeds in raspberry remain unknown.

In corn, only two to three grit-weeding events, and considerably less grit, were needed for season-long weed control (Erazo-Barradas et al. 2018, 2019). This probably occurred because corn canopies develop quickly and suppress the growth of many weeds, especially late-germinating species. In contrast, horticultural crops, such as raspberry, grown in widely spaced rows separated by alleys composed of mown grass, do not shade weeds as effectively as narrow-row crops like corn. Consequently, physical weed-control efforts are likely to be correspondingly greater in crops such as raspberry.

Grit-weeding clearly has potential to control broadleaf weeds in horticultural crops such as transplanted raspberry. However, it was not effective for controlling grass weeds. Lack of effectiveness for grass control possibly reflected the use of low-density corn-cob grit in these experiments. Denser and more sharply angled grit, such as walnut (*Juglans regia* L.) shell grit or quartz sand likely would effect better control of grass weeds (Perez-Ruiz et al. 2018). Corn-cob grit was used because of its availability in the Upper Midwest, but in high-value horticultural crops, the substitution of walnut-shell grit may be justified. (The retail price for bulk corn-cob grit can be as low as \$1 kg^{-1}, whereas 22.7-kg [50-lb] bags of walnut-shell grit are valued at approximately \$2 kg^{-1}.) Alternatively, some grits may have little cost for the grower. For instance, quartz sands possibly could be mined on-farm and used to control weeds. Last, grit-weeding leaves soil undisturbed, which may have beneficial effects on growth of crops emanating from rhizomes or root buds.

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Conflicts of interest. The authors declare no conflicts of interest.

References

Barney DL, Bristow P, Cogger CG, Fitzpatrick SM, Hart JM, Kaufman DM, Miller C, Moore PP, Murray T, Rempel H, Strik BC, Tanigoshi LK (2007) Commercial Red Raspberry Production in the Pacific Northwest. Washington State University Extension Bulletin PNW598. https://ir.library.oregonstate.edu/concern/administrative_report_or_publications/jm214p441. Accessed: June 29, 2020

Beckie HJ, Ashworth MB, Flower KC (2019) Herbicide resistance management: recent developments and trends. Plants 8:161

Braun EE, Lovell ST, Babadoost M, Forcella F, Clay S, Humburg D, Wortman SE (2019) Abrasive grit application in organic red pepper: an opportunity to integrate nitrogen and weed management. HortSci 54:1509–1516

Erazo-Barradas M, Forcella F, Humburg D, Clay S (2018) Air-propelled abrasive grit for weed control in organic silage corn. Agron J 110:632–637

Erazo-Barradas M, Friedrichsen CN, Forcella F, Humburg D, Clay SA (2019) Propelled abrasive grit applications for weed management in transitional corn grain production. Renew Agric Food Syst 34:33–40

Forcella F (2009) Potential use of abrasive air-propelled agricultural residues for weed control. Weed Res 49:341–345

Forcella F (2017) Spent coffee grounds as air-propelled abrasive grit for weed control in organic production. Weed Technol 31:769–772

Forcella F, Humburg D, Wortman S, Clay SA (2017) Air-propelled abrasive grit can damage the perennial weed, quackgrass. Can J Plant Sci 98:963–966

Forcella F, James T, Rahman A (2011) Post-emergence weed control through abrasion with an approved organic fertilizer. Renew Agric Food Syst 26: 31–37

Hammermeister AM (2016) Organic weed management in perennial fruits. Scientia Hort 208:28–42

Mitchell C, Hawes C, Iannetta P, Birch ANE, Begg G, Karley AJ (2018) An agroecological approach for weed, pest and disease management in *Rubus* plantations. Pages 63–81 *in*: Graham J, Brennan R (eds.) Raspberry: Breeding, Challenges, and Advances. Heidelberg, Germany: Springer Nature

Peachey E (2019) Pacific Northwest Weed Management Handbook. Oregon State University https://pnwhandbooks.org/weed. Accessed: June 29, 2020

Perez-Ruiz M, Brenes R, Urbano JM, Slaughter DC, Forcella F, Rodríguez-Lizana A (2018) Agricultural residues are efficient abrasive tools for weed control. Agron Sustain Dev 38:18

Wortman SE (2014) Integrating weed and vegetable crop management with multifunctional air-propelled abrasive grits. Weed Technol 28:243–252

Wortman SE (2015) Air-propelled abrasive grits reduce weed abundance and increase yields in organic vegetable production. Crop Protect 77:157–162

Zhang H, Miles C, Ghimire S, Benedict C, Zasada I, DeVetter L (2019) Polyethylene and biodegradable plastic mulches improve growth, yield, and weed management in floricane red raspberry. Scientia Hort 250:371–379

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