Rapeseed (*Brassica napus*) Green Manure Crop Suppresses Weeds in Potato (*Solanum tuberosum*)[1]

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Abstract. Fall-planted rapeseed and sudangrass were evaluated for weed control in potato during a two-year study. Rapeseed incorporated in the spring in a loamy sand soil reduced weed density 85 and 73% in 1992 and 1993, respectively, and reduced weed biomass 96 and 50% in 1992 and 1993, respectively, in following potato crops compared to potato after fallow. Potato following rapeseed yielded 25% and 17% more total tuber weight than potato following sudangrass in 1992 and fallow in 1993, respectively. In greenhouse trials, rapeseed tissue added to a loamy sand soil at 20 g fresh weight per 400 g dry soil reduced biomass of hairy nightshade and longspine sandbur by 90 and 83%, respectively. Similarly, white mustard tissue added at 20 g fresh weight per 400 g dry soil reduced biomass of hairy nightshade and green foxtail by 83 and 70%, respectively. **Nomenclature:** Green foxtail, *Setaria viridis* (L.) Beauv. #[3] SETVI; hairy nightshade, *Solanum sarrachoides* Sendtner # SOLSA; longspine sandbur, *Cenchrus longispinus* (Hack.) Fern. # CCHPA; potato, *Solanum tuberosum* L. 'Russet Burbank'; rapeseed, *Brassica napus* 'Jupiter,' sudangrass, *Sorghum sudanense* (P.) Stapf 'Trudan 8'; white mustard, *Brassica hirta* Moench 'Martigena.'

INTRODUCTION

Potato production is heavily reliant on pesticide inputs and herbicides are used on about 90% of the fall potato acreage (12). Future public policies may mandate reduction in pesticide inputs on numerous crops. Effective weed control practices that reduce reliance on herbicides need to be developed if reduction in pesticide use is to be achieved.

Brassica species are important oil seed crops in North America and Europe, and have potential for use as a green manure crops (18, 40). A green manure crop planted in the fall may prevent soil erosion and reclaim leachable nutrients. *Brassica* green manure crops have shown potential for controlling several common potato pests, including soilborne diseases (30, 41), insects (44), nematodes (28, 29), and weeds (2). Growth of numerous crop and weed species have been suppressed by adding rapeseed residues to soil (18, 20, 26, 27, 31, 42).

All *Brassica* species contain glucosinolates, which are hydrolyzed to isothiocyanates (ITC)[4] (commonly referred to as mustard oils), thiocyanates, and nitriles in the soil (4, 5, 6, 15, 16, 39). At least nine different glucosinolates have been found in rapeseed which hydrolyze to their respective ITC's (15).

There are numerous examples of ITC's inhibition of plant growth or seed germination. Allyl-ITC and β-phenylethyl-ITC were known to inhibit seed germination as early as 1949 (14). Methyl-ITC is a breakdown product of metham sodium, a commercial fumigant which suppresses nematodes, diseases, and weeds (11, 32, 35, 38, 43). Benzyl-ITC, a breakdown product of white mustard (21, 37), is phytotoxic to velvetleaf (*Abutilon theophrasti* Medicus), sicklepod (*Senna obtusifolia* L. formerly *Cassia obtusifolia* L.), and sorghum [*Sorghum bicolor* (L.) Moench] (8, 45). Black mustard [*Brassica nigra* (L.) W.J.D. Koch] residues inhibited establishment of grass species in a natural grassland community and allyl-ITC isolated from *Brassica nigra* was shown to inhibit *Bromus rigidus* seed germination (1). Aqueous extracts from decaying residues of wild mustard [*Brassica kaber* (D.C.) L. C. Wheeler] were highly toxic to Japanese millet [*Echinochloa crus-galli* var. *frumentacea* (Roxb.) W. F. Wight] (13). Ionic thiocyanate (SCN–), another product of glucosinolate breakdown (3, 4), inhibited the root or shoot growth of several crop species (23, 34). Isoprenoid and benzenoid volatile compounds are also released from decaying *Brassica* tissue and may play a role in weed suppression (37).

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

[4]Abbreviations: CRD, completely randomized design; ITC, isothiocyanate; WAE, weeks after emergence.

Recent work has demonstrated that a fall-planted green manure crop of rapeseed incorporated in the spring before planting suppresses nematodes (*Meloidogyne chitwood*] in potato (28, 29). Sudangrass has also been used successfully as a green manure crop to suppress nematodes in potato[5].

This research was conducted to evaluate weed suppression in potato following fall-planted green manure crops of rapeseed and sudangrass. Plant residues of rapeseed and white mustard were also evaluated for suppression of weed emergence and growth in greenhouse studies.

MATERIALS AND METHODS

Field trials. Studies were conducted on a Hezel (Typic Torriorthents) loamy sand soil containing 0.9% organic matter, pH 6.7, in 1991 near Prosser, WA, and on a Quincy (Typic Torripsamments) sand soil, containing 0.5% organic matter, pH 7.0, in 1992 near Paterson, WA. A high glucosinolate variety rapeseed, Jupiter, and sudangrass, Trudan 8, were seeded at 6 and 28 kg/ha, respectively, Aug. 22, 1991, and Aug. 28, 1992. Fallow plots were included which were kept weed-free with glyphosate [*N*-(phosphonomethyl)glycine].

Rapeseed biomass was determined by drying and weighing plants clipped from a 1-m^2 quadrat per plot just before incorporation. Sudangrass biomass samples were collected similarly following the first hard frost each fall. Two methods of residue incorporation were tested. The first consisted of rototilling sudangrass 10 cm deep on Oct. 25, 1991, and Nov. 19, 1992, and rapeseed on Mar. 13, 1992, and Mar. 18, 1993. Rapeseed was just beginning to flower when incorporated. The second consisted of killing the rapeseed with glyphosate at 1.1 kg ae/ha and strip-tilling to incorporate the rapeseed in bands 40-cm wide centered every 86 cm in the potato row several days before planting. Sudangrass was strip tilled similarly in the fall, but had already died from winter kill. Fallow controls were strip tilled in the spring similar to rapeseed plots. All strip tilled plots were treated with glyphosate at 1.1 kg/ha before tillage.

Russet Burbank potato was planted on Apr. 22, 1992, and Apr. 20, 1993 in rows spaced 86 cm apart. Pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] and metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] were applied at 1 and 0.5 kg ai/ha, respectively, to half of each main plot on May 6, 1992, and May 5, 1 993.

In 1991, 21 kg N/ha was applied to all plots before planting green manure crops. An additional 174 kg N/ha was applied to the potato crop on Apr. 9, 1992, and 235 kg N/ha on May 28, 1992. In 1992, 74 kg N/ha was applied to all plots just before planting green manure crops in the fall and potato received an additional 325 kg N/ha applied over 8 wk through sprinkler irrigation water during the growing season in 1993.

Weeds were counted by species in early July each year after the potato canopy had closed. Weeds visible above the potato canopy were counted in the entire plot. Weed biomass, by species, was determined by drying and weighing excised plants just before potato harvest from two 1-m^2 quadrats per plot in 1992 and three 1-m^2 quadrats per plot in 1993.

Potato tubers were harvested from the center 6 m of the middle row of each 3-row plot on Sept. 20, 1992, and Oct. 7, 1993. Tuber size distribution and grading was determined from a 40-kg subsample from each plot and specific gravity was measured on ten, 230- to 280-g tubers in each treatment.

The experiment was a split plot, randomized complete block design with five replications. Main plots were a factorial combination of three green manure crops (sudangrass, rapeseed, and fallow) by two methods of incorporation (strip tilled or all tilled) and were 2.6 by 18.2 m. Subplots were herbicide or no herbicide and were 2.6 by 9.1 m. Data were subjected to analysis of variance and treatment means separated by the LSD test at the 5% level. Error A and error B terms were pooled to calculate LSD to compare weed control for green manure crops within herbicide treatments.

Greenhouse. *General.* Experiments were conducted in a greenhouse at 28/21 C day/night and daylength extended to 16 h with sodium vapor lamps delivering a PPFD of 700 μE/m^2/s. Jupiter rapeseed or Martigena white mustard was planted in 23-cm diam fiber pots containing equal volumes of a Quincy loamy sand soil, sand, and peat. Pots were watered daily and fertilized weekly with 50 ml of solution containing 0.6 g N/L, 0.2 g P/L, 0.4 g K/L with micronutrients. Rapeseed and white mustard were thinned to four plants per pot 1 week after emergence (WAE)[4].

Shoots and leaves of rapeseed were harvested 8 WAE when plants were 40 cm tall and had eight leaves. White mustard was harvested 4 WAE when plants were 80 cm tall with 12 leaves and just beginning to flower. Plant tissue

[5]Santo, G. 1994. Personal communication. Washington State University, Prosser, WA 99350.

was chopped into 0.5-cm² pieces and 20 g fresh plant material were uniformly mixed into 400 g dry Quincy loamy sand soil in 500-ml plastic pots. Nonamended soil was included for comparison. Pots were watered immediately and weed seed were placed on the soil surface. An additional 1 mm of soil was added to cover the seeds. Pots were watered daily with a fine mist so as not to disturb the shallowly planted seeds. Plants were fertilized weekly with 20 ml of the fertilizer solution mentioned previously.

Glucosinolate concentration was determined on one plant from each harvest date. The procedure was a modification (36) of the trimethylsilyl method (9, 10, 19). Harvested plants were stored at –20 C until freeze-dried, ground, and passed through a 1-mm screen. A 150-mg sample of the dried ground plant tissue was heated to 90 C for 10 min in a test tube at which time two 2-ml aliquots of boiling water were added, were shaken after adding water, and left for a total of 4 min. The sample was then cooled to room temperature and 100 µl of a 1.5 M lead acetate and 1.5 M barium acetate solution were added, mixed, and centrifuged at 2000 × *g* for 10 min. The supernatant was applied to a preconditioned DEAE-sephadex A-25 anion exchange column. The column was washed with 0.02 M pyridine acetate solution. Purified sulfatase solution was applied to the column and the column was left covered overnight. Desulfoglucosinolates were eluted with 1.75 ml water into a 2-ml vial and dried under a stream of air. Trimethylsilyl derivatives of the desulfoglucosinolates were formed by adding 0.75 ml of a mixture of dry acetone, *N,N*-dimethylformanide, bis trimethylsilyl trifluoroacetamine, *N*-trimethylsilylimidazole, and trimethylchlorosilane. Vials were tightly capped and shaken well before incubating at 37 C for 10 min. A 1-µl sample was injected into a gas chromatograph with the injector and detector set at 280 C. Column temperature was programmed to increase 5 C/min from 235 C to 280 C.

All experiments were repeated at least twice. Data were subjected to analysis of variance within and across experiments and were averaged across experiments where appropriate. Treatment means were separated using Fisher's protected LSD test at the 5% level.

Test 1. Fifty hairy nightshade or 10 longspine sandbur seeds were planted in 400 g soil amended with 20 g of rapeseed tissue, 20 g of potato leaf and stem tissue, or nonamended soil. Weed seedlings were counted 3 WAE, and above ground tissue was cut and weighed. Each treatment was replicated eight times in a completely randomized design (CRD)[4] and the experiment was repeated.

Test 2. Fifty hairy nightshade or 25 green foxtail seeds were planted in white mustard-amended soil and nonamended soil. Weed seedlings were counted 3 WAE and above ground tissue was cut and weighed. Treatments were replicated nine times with hairy nightshade and six times with green foxtail in a CRD. Hairy nightshade experiments were repeated four times and green foxtail experiments repeated three times.

RESULTS AND DISCUSSION

Field trials. Fall-planted rapeseed produced 5800 and 4100 kg/ha dry weight in 1991–92 and 1992–93, respectively. Sudangrass produced 1900 and 95 kg/ha dry weight in 1991 and 1992, respectively. Sudangrass growth was severely limited in the fall of 1992 by cool temperatures in September and an early frost.

Incorporating the entire area vs. strip-tilling after killing with glyphosate had no effect on weed control, weed biomass, or potato yield in 1992 and 1993 (data not shown). The hilling disc on the potato planter left very little plant residue between the rows and negated any possible differences between incorporation methods. Residue incorporation method by herbicide interaction effect on weed control, weed biomass, or potato yield was not significant in either year.

There was a significant green manure by herbicide interaction effect on weed density and biomass in both 1992 and 1993. In 1992, common lambsquarters (*Chenopodium album* L. # CHEAL) was the major weed present with lesser amounts of redroot pigweed (*Amaranthus retroflexus* L. # AMARE) and annual grasses. Rapeseed reduced mid-season weed density in potatoes by 85 and 83% compared to fallow and sudangrass, respectively (Table 1). Final weed biomass in potato was reduced by 96 and 98% when rapeseed preceded potato compared to a fallow or sudangrass green manure crop, respectively. Herbicide-treated plots were free of weeds whether a green manure crop was grown or not.

In 1993, redroot pigweed was the dominant weed species. Rapeseed reduced mid-season weed density 73% and final weed biomass 50% in potatoes compared to fallow or sudangrass preceding potato (Table 1). The difference in rapeseed suppression of weeds in 1992 and 1993 may have been due to weed species dominance in the two years or to the greater amount of rapeseed biomass in 1992. As in 1992, all herbicide-treated plots were weed-free.

There was no significant interaction between green

Table 1. Total mid-season weed density above the potato canopy and final weed biomass in potato following fallow, sudangrass or rapeseed in 1992 and 1993 near Prosser, WA[a].

Green manure treatment	1992 Weed density No herbicide	1992 Weed density Herbicide treated[b]	1992 Weed biomass No herbicide	1992 Weed biomass Herbicide treated	1993 Weed density No herbicide	1993 Weed density Herbicide treated	1993 Weed biomass No herbicide	1993 Weed biomass Herbicide treated
	no./100 m^2		g/m^2		no./100 m^2		g/m^2	
None (fallow)	61 a	1 a	386 a	0 a	62 a	0 a	529 a	1 a
Sudangrass	54 a	3 a	560 a	0 a	61 a	0 a	504 a	0 a
Rapeseed	9 b	0 a	14 b	0 a	17 b	0 a	263 b	0 a

[a]Data averaged across methods of incorporation. Means within a column followed by the same letter are not different at P = 0.05 according to LSD test.
[b]Herbicide treated received pendimethalin and metribuzin at 1 and 0.5 kg/ha, respectively.

manure crops and herbicides on potato tuber yield in 1992 or 1993. In 1992, total potato tuber yield following rapeseed was 25% greater than potato following sudangrass, but neither was significantly different from potato following fallow, which yielded 69.6 MT/ha (Table 2). The amount of tubers grading equal to or better than a US #2 was similar between potato following rapeseed or fallow and were greater than potato following sudangrass. Potato following sudangrass were stunted early in the season and the canopy closed 10 d later than potato that followed rapeseed or fallow (data not shown). Potato following sudangrass produced fewer tubers in the 227 to 340 g weight range compared to fallow plots and fewer tubers greater than 340 g compared to potato following rapeseed. Other tuber weight categories and the number of culls were not affected by green manure crop.

Total tuber yield in 1992 increased 15% when preemergence herbicides were applied (Table 2). Potato treated with herbicides had fewer small potato tubers under 227 g and more over 227 g (Table 2). This shift toward larger tubers when using herbicides was paralleled by an increase in the amount of cull tubers (Table 2). Tuber specific gravity averaged 1.08 and was not affected by green manure crop or herbicides (data not shown).

Total potato tuber yield in 1993 was 69.4 and 68.0 MT/ha when potato followed rapeseed and sudangrass, respectively, and was greater than yields of potato following fallow, which yielded 58.9 MT/ha (Table 3). Likewise, the amount of tubers graded equal to or better than a US #2 was greater from potato following rapeseed or sudangrass compared to potato following fallow. Potato following rapeseed produced more tubers in the 113 to 227 g weight category and fewer tubers over 340 g than potato following sudangrass or fallow.

In 1993, potato treated with a herbicide yielded 39% more total tuber weight than potato not treated with a herbicide (Table 3). This increase in yield was due to greater numbers of tubers larger than 113 g. There were no

Table 2. Potato tuber size distribution, culls, and total yield as affected by green manure crop treatment and pre-emergence herbicides in 1992 at Prosser, WA[a].

Treatment	Tuber weight category (g) < 113	113–227	227–340	> 340	Culls	≥ U.S. #2	Total yield
	MT/ha						
Main plots							
None (fallow)	9.3 a	23.5 a	16.9 a	14.1 ab	5.8 a	54.5 a	69.6 ab
Sudangrass	11.8 a	22.4 a	12.9 b	9.7 b	4.6 a	44.9 b	61.4 b
Rapeseed	9.9 a	28.4 a	16.4 ab	15.9 a	5.9 a	60.7 a	76.5 a
Subplots							
No herbicide	11.1 a	26.6 a	13.8 b	9.6 b	3.3 b	50.0 b	64.4 b
Herbicide treated	9.6 b	22.9 b	17.0 a	16.8 a	7.5 a	56.7 a	73.8 a

[a]Data averaged across methods of incorporation. Means within a column and subgroup followed by the same letter are not different at P = 0.05 according to LSD test.

Table 3. Potato tuber size distribution, culls and total yield as affected by green manure crop treatment and pre-emergence herbicides in 1993 at Paterson, WA[a].

Treatment	Tuber weight category[a] (g)						
	< 113	113–227	227–340	> 340	Culls	≥ U.S. #2	Total yield
	MT/ha						
Main plots							
None (fallow)	20.9 a	30.2 c	5.6 a	1.2 a	0.9 a	37.1 b	58.9 b
Sudangrass	23.0 a	34.7 b	7.8 a	1.3 a	1.1 a	43.8 a	68.0 a
Rapeseed	24.6 a	38.9 a	5.2 a	0.2 b	0.4 a	44.4 a	69.4 a
Subplots							
No herbicide	25.8 a	24.9 b	3.1 b	0.2 b	0.8 a	28.1 b	54.8 b
Herbicide treated	19.9 b	44.3 a	9.4 a	1.7 a	0.9 a	55.4 a	76.2 a

[a]Data averaged across methods of incorporation. Means within a column and subgroup followed by the same letter are not different at P = 0.05 according to LSD test.

differences in culls (Table 3). Tuber specific gravity averaged 1.09 and was not affected by green manure crop or herbicide treatments (data not shown).

Greater potato tuber yields following rapeseed compared to sudangrass in 1992 and compared to fallow in 1993 appear to involve factors other than weed suppression since herbicide-treated potato without any weed competition also yielded greater when following rapeseed than when following sudangrass in 1992 or fallow in 1993. Decaying rapeseed residues have been shown to suppress various fungi and may benefit potato growth by suppressing harmful soil pathogens (36). In addition, nitrogen may be mineralized from the decaying rapeseed residues and be utilized by the potato crop during the growing season. Fall incorporation of sudangrass residues may have released nitrogen too soon allowing it to leach before the potato crop could utilize it in the spring[6].

Greenhouse. *Test 1.* Rapeseed tissue added at 20 g per 400 g dry soil reduced hairy nightshade biomass by 90% and emergence by 75% at 3 WAE (Table 4). Hairy nightshade plants that emerged in rapeseed amended soil were stunted and chlorotic compared to plants grown in nonamended soil or in soil amended with potato tissue. Chopped potato tissue added at 20 g per 400 g dry soil reduced hairy nightshade biomass 59% and emergence 47%, compared to nonamended soil. Apparently hairy nightshade emergence and growth are adversely affected by any green plant residue added to the soil. It is unlikely that the reduction in hairy nightshade biomass by rapeseed was due to a high carbon to nitrogen ratio in the soil since plants were fertilized weekly. Additionally, equal amounts of potato tissue added to the soil did not cause similar symptoms and biomass reduction.

When compared to nonamended soil, longspine sandbur biomass and emergence were reduced by 83 and 35%, respectively, by adding rapeseed tissue to soil (Table 4). Adding an equivalent amount of potato tissue had no effect on longspine sandbur biomass or emergence.

Test 2. White mustard tissue added at 20 g per 400 g dry soil reduced hairy nightshade biomass and emergence by 83 and 56%, respectively, 3 WAE (Table 5). Hairy nightshade injury symptoms were similar to those emerging in rapeseed-amended soil. In preliminary studies, white mustard leaves added to soil reduced hairy nightshade emergence and growth more than equivalent amounts of stems or root tissue (Boydston, unpublished results). White mustard residues did not affect seedling emergence but reduced the biomass of green foxtail 70% 3 WAE compared to nonamended soil (Table 5).

Rapeseed and white mustard residues incorporated into the soil reduced emergence and/or biomass of a broadleaf and two grass weed species. These *Brassica* residues added

Table 4. Hairy nightshade (SOLSA) and longspine sandbur (CCHPA) fresh weight and number of seedlings at 3 wk after emergence after adding 20 g rapeseed or potato fresh tissue to 400 g dry loamy sand soil in the greenhouse[a].

Soil amendment	SOLSA		CCHPA	
	Weight	No. seedlings	Weight	No. seedlings
	g/pot	no./pot	g/pot	no./pot
Rapeseed	0.7 c	6.4 c	0.7 b	3.5 b
Potato	4.0 b	13.3 b	4.2 a	5.5 a
None	6.8 a	25.1 a	4.1 a	5.4 a

[a]Means within a column followed by the same letter are not different at P = 0.05 according to LSD test.

[6]Pan, Bill. 1995. Personal communication. Washington State University, Prosser, WA 99350.

Table 5. Hairy nightshade (SOLSA) and green foxtail (SETVI) fresh weight and number of seedlings at 3 wk after emergence after adding 20 g white mustard fresh tissue to 400 g dry loamy sand soil in the greenhouse[a].

Soil amendment	SOLSA		SETVI	
	Weight	No. seedlings	Weight	No. seedlings
	g/pot	no./pot	g/pot	no./pot
White mustard	0.9 b	7.2 b	2.3 b	14.0 a
None	5.4 a	15.8 a	7.6 a	15.7 a

[a]Means within a column followed by the same letter are not different at P = 0.05 according to LSD test.

to soil have also reduced the growth of kochia [*Kochia scoparia* (L.) Schrad.] and shepherd's-purse [*Capsella bursa-pastoris* (L.) Medicus] (2). Whether high glucosinolate content is responsible for the activity of these green manure crops on weed growth has not been determined. Total glucosinolate content of greenhouse grown plants used in these studies averaged 4 and 5 μmol/g dry weight of rapeseed and white mustard, respectively. Research by Teasdale suggests that total glucosinolate content of rapeseed residue added to soil was not correlated with weed suppression[7]. However, specific glucosinolates found in various *Brassica* species may be more critical for weed suppression than total glucosinolate content.

Weed suppression observed in potato following a rapeseed green manure crop may be a result of the breakdown of glucosinolates in the plant tissue to ITC. Both the concentration and length of exposure of weed seeds to methyl-ITC is critical for weed control (35). Soil texture, temperature, and amount of water applied after incorporating rapeseed could affect the breakdown of glucosinolates and subsequent release of ITC. Leachates from dried rapeseed tissue inhibited the growth of velvetleaf and tall morningglory [*Ipomoea purpurea* (L.) Roth] in previous studies (25) and similar leachates may be responsible for the weed suppression observed in these studies.

Growing rapeseed as a green manure crop may suppress certain weed species, but could potentially injure succeeding crops. In these studies, potato was not injured by rapeseed incorporated only several days before planting. Small-seeded crops may be more susceptible to injury from rapeseed than potato.

Growing a rapeseed green manure crop before planting potato may suppress nematodes, certain fungal diseases, and weeds. When used primarily as a method for suppressing nematodes in a potato cropping system, rapeseed may allow growers to reduce preemergence herbicide use or rely on postemergence herbicide applications or cultivation as needed. Even under the low weed populations encountered in these studies, rapeseed weed suppression was commercially acceptable in only one of the two years evaluated. Under heavier weed populations typically encountered in many fields a green manure crop may not be as effective as in these studies.

Glucosinolate content of *Brassica* crops has been increased with sulfur fertilization and water stress (15, 16, 17, 22). In addition, the growth stage of the green manure crop at the time of incorporation could affect the amount of ITC released (7, 24, 33). Therefore, managing glucosinolate content of *Brassica* green manure crops may be possible. The effects of rapeseed planting date, soil moisture and temperature during growth and decay, amount of biomass produced, and time of incorporation on weed suppression all need further study.

[7]Teasdale, J. 1994. Personal communication. USDA-ARS, Beltsville, MD 20705.

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