Do soil characteristics influence weed seed mortality?

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Introduction & Objectives

In the seedbank, seed dormancy and quiescence promote temporal dispersal of viable weed seeds, allowing for successful seedling recruitment from a single cohort over many years [1]. The seedbank is the source from which weed populations are dispersed over timescales. Certain soils result in greater weed seed mortality [2]. However, ***the characteristics that comprise a weed seed-suppressive soil, and how these characteristics could be managed, remain unclear***. Understanding which soil characteristics are associated with weed seed mortality could ***elucidate novel tactics for weed management*** at the source of temporal dispersal, thereby facilitating management of weed populations. The ***objectives*** of this study were to **(*a*)** determine the effect of soil texture on survival of canola (*Brassica napus* L.) seed in the soil seedbank and **(*b*)** establish associations among soil and microclimate characteristics and survival of canola seeds in field soils.

Materials & Methods

Panel 1. Mesocosms

a.

b.

Field Study - Southern Manitoba 2015-2016, 2 sites

- **RCBD common garden soil experiment**
- **9 field soils (treatments) collected from southern Manitoba**
- **Weed species: volunteer canola**
- **150 viable canola seeds buried in mesocosms @ 10 cm depth (Panel 1a)**
- **Bottoms of mesocosms were replaced with 1 mm fibreglass mesh (Panel 1b)**
- **Mesocosms buried in the field in Nov 2015, level with the soil surface**
- **Proc MIXED & partial least squares (PLS) analysis in SAS 9.4**

Seed measurements

- **% seed survival (Fig. 1)**
  - Growth chamber seedling recruitment followed by elutriation
    - Seed survival over winter (Nov-Apr)
    - Seed survival over summer (Apr-Sep)
    - Annual seed survival (Nov-Sep)

Microclimate measurements (sub-annual)

- **Soil temperature (T) @ 10cm depth** (iButtons)
  - **Mean diurnal range in soil temp.**
    - Mean T_{max} - T_{min}
  - **Number of days mean temp.**
    - < -3°C in Winter
  - **Number of days diurnal soil temp. range**
    - > 4°C in Winter, > 8°C in Summer
  - **Thermal time** [3]
    - T_b = 3°C in Winter, 15°C in Summer
- **Volumetric water content @ 10 cm depth** (EC-5)
  - **Hydro time** [3]
    - Ψ_b = -0.03 MPa in Summer
  - **Hydrothermal time** [3]
    - T_b = 5°C, Ψ_b = -0.03 MPa in Summer

Table 1. Soil characteristic measurements

Soil characteristic	Observed range
Mineral particle density	%sand/silt/clay (Fig. 2)
Organic matter (OM)	2.1 - 6.2%
Bulk density (BD)	0.91 - 1.50 g cm^{-3}
Carbonate	0.0 - 1.6 % CCE
pH	5.0 - 7.6
Electrical conductivity (EC)	0.07 - 0.68 dS m^{-1}
Cation exchange capacity	7.4 - 37.8 meq
NO_3^- - Nitrogen (N)	3 - 33 ppm
Olsen - Phosphorus (P)	14 - 45 ppm
Potassium (K)	166 - 652 ppm
Calcium (Ca)	174 - 1,393 ppm
Magnesium (Mg)	1,041 - 4,886 ppm
Sodium (Na)	18 - 45 ppm

Soil mineral particle densities, OM, BD and EC were used to determine soil water retention characteristics and convert volumetric water content to soil water potential (Ψ) [4]. Soil water potential was used to determine hydro and hydrothermal time to seed exhumation [5]. The PLS model was saturated with all soil (Table 1) and microclimate characteristics and pruned iteratively to remove unimportant variables and achieve model parsimony [6].

Results

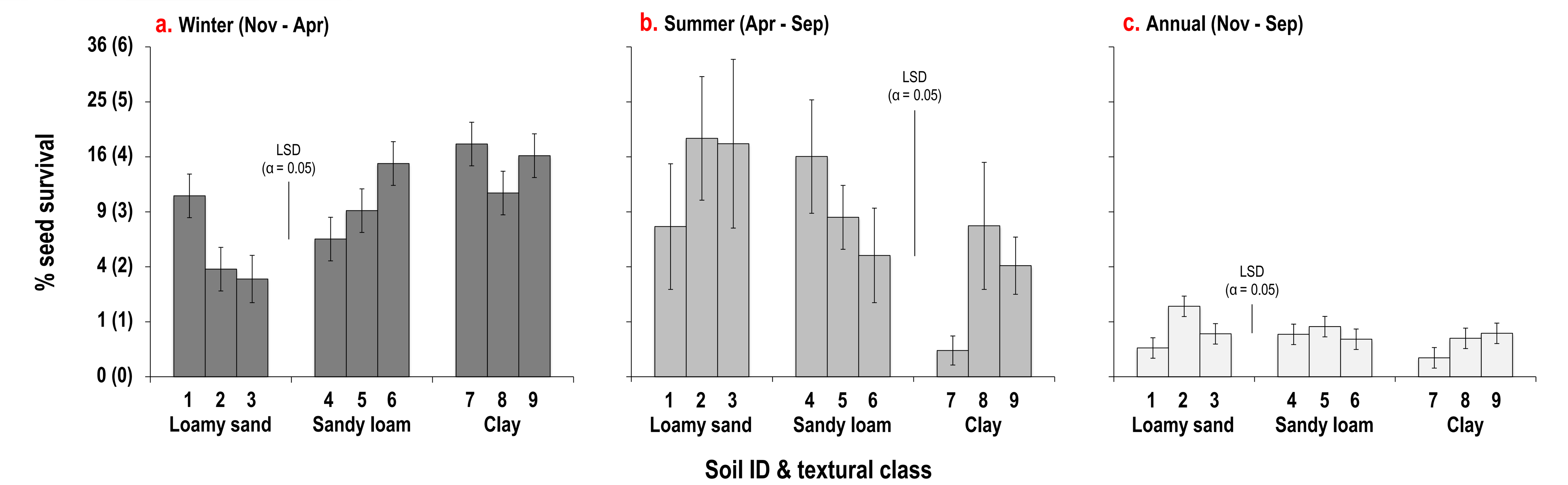

Figure 1. The percentage of canola seed that survived over (a) winter, (b) summer, or (c) winter/summer combined (annual) buried at 10 cm depth in nine different soils. Y-axis values are back-transformed means with square root-transformed means in parentheses. Error bares indicate ± SE. Within each sub-figure, vertical lines indicate Fisher's protected LSD (α = 0.05).

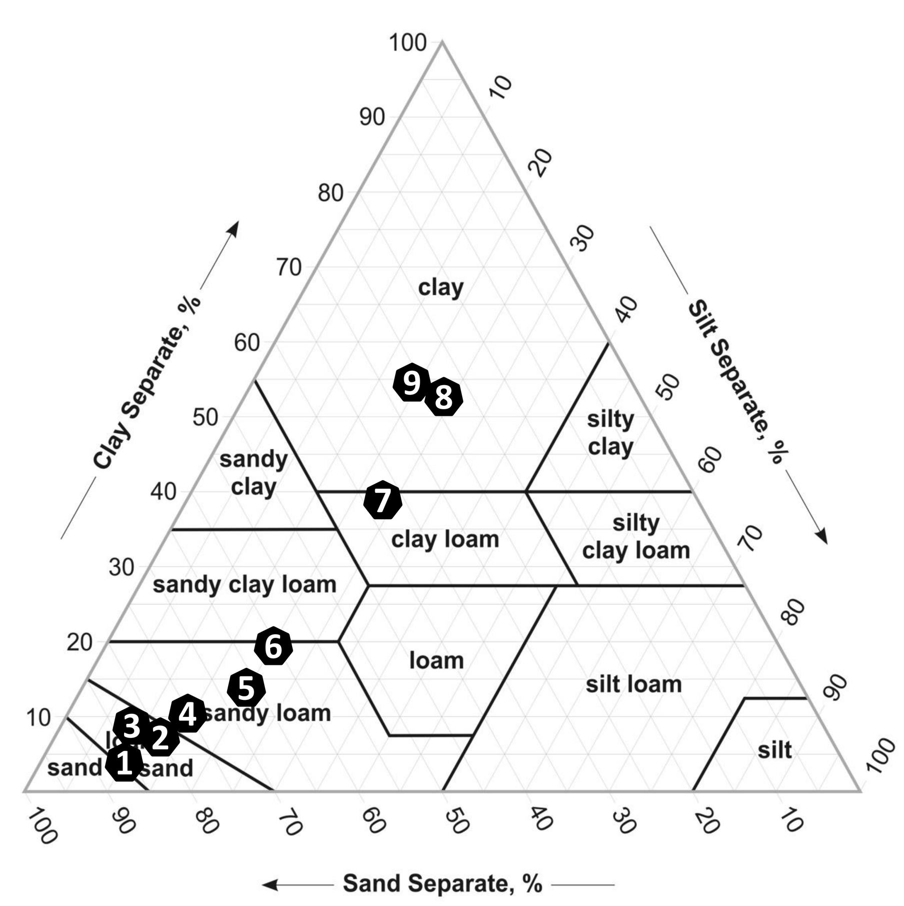

Figure 2. Mineral particle densities (%) of the nine soil treatments overlaid on the soil textural triangle. Soil identification numbers correspond with those in Fig. 1.

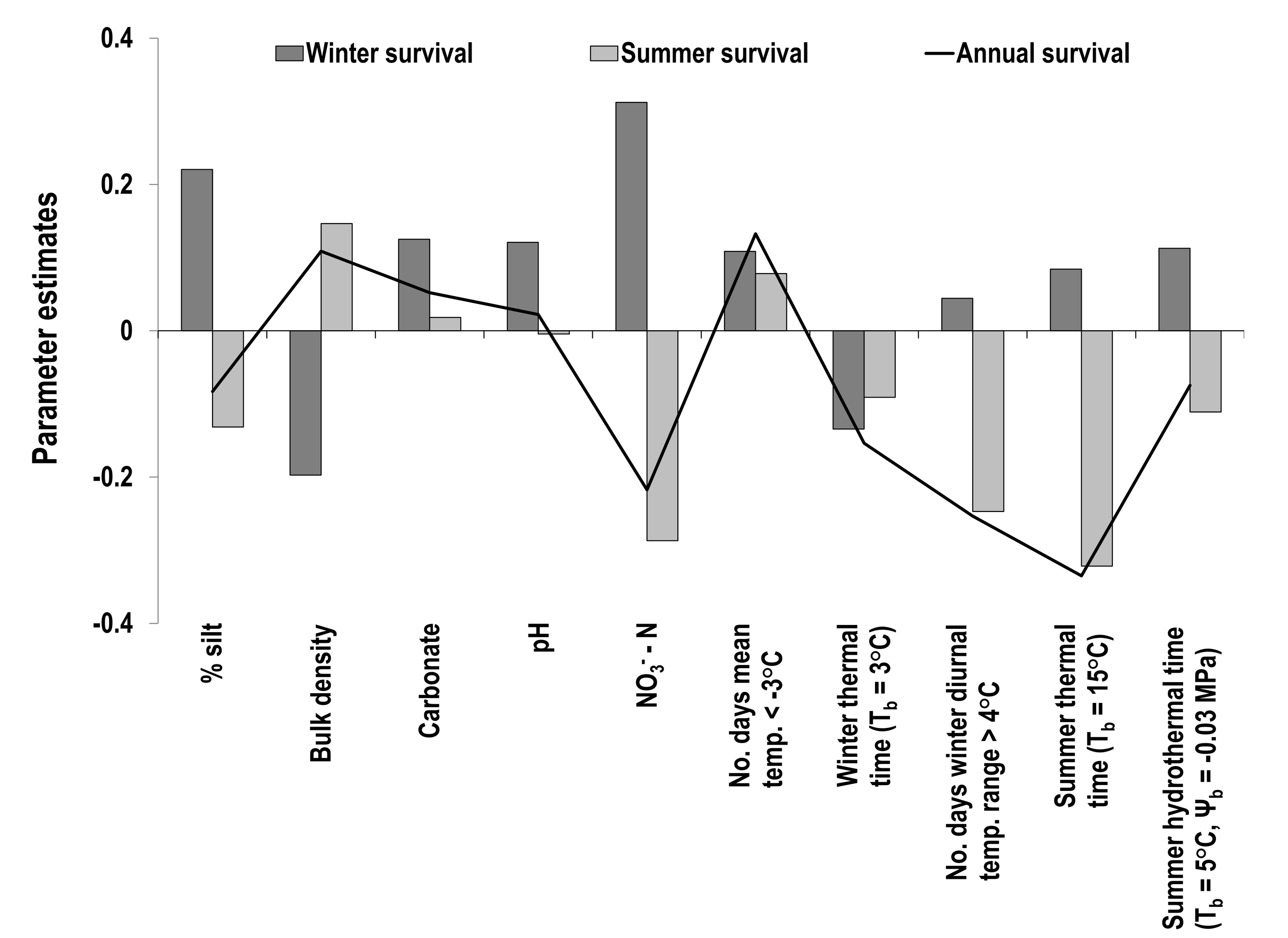

Figure 3. Parameter estimates of explanatory variables contributing to survival of volunteer canola seed in nine different soils over winter, summer, or winter/summer combined (annual) using centered and scaled data in PLS analysis.

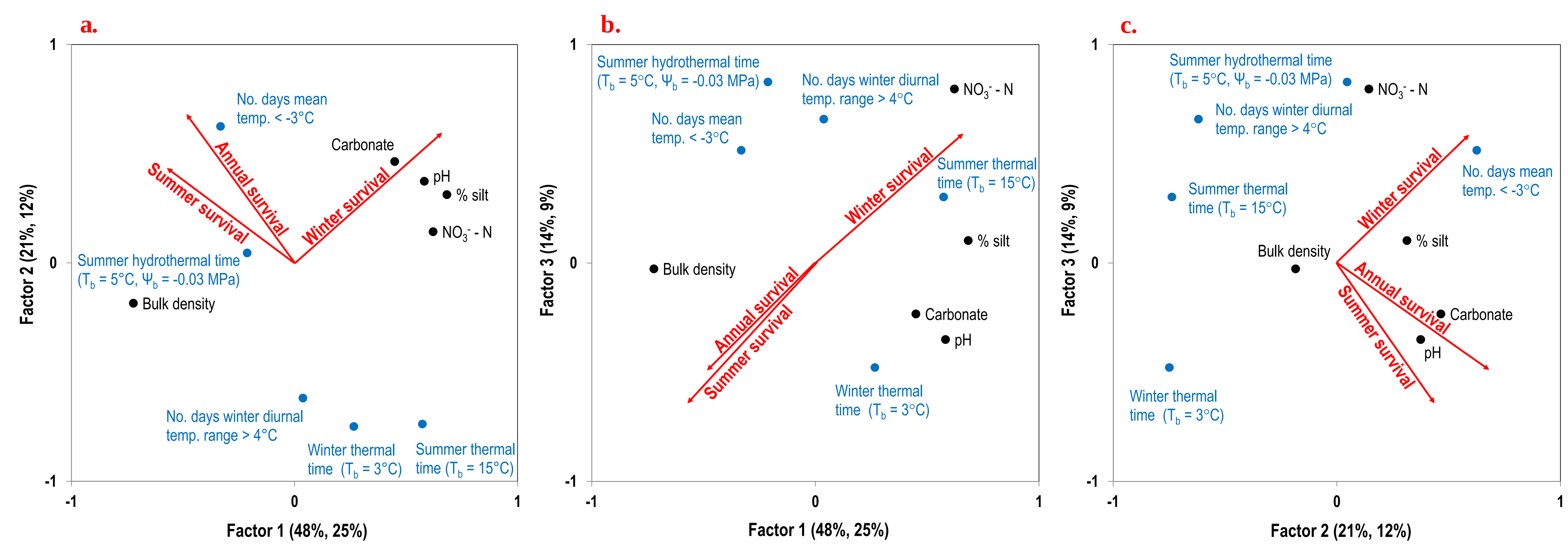

Figure 4. Ordination biplots displaying the relative weights of explanatory (*black circles* indicate soil characteristics; *blue circles* indicate microclimate characteristics) and response (*red vectors* indicate seed survival) variables for the three factors extracted using partial least squares analysis. Biplot (a) represents factors 1 vs. 2, biplot (b) represents factors 1 vs. 3, and biplot (c) represents factors 2 vs. 3. Parenthetical values indicate the respective percentage variation in explanatory and response variables explained by each factor.

Results & Discussion

Soil texture contributed to divergent sub-annual canola seedbank dynamics. Over winter, survival of canola seed was greater in fine textured soils (clays; 15% survival) compared with coarse textured soils (loamy sands; 4% survival) (Fig. 1). This result agrees with research from Germany, where a greater number of oilseed rape seeds survived over winter in a clay and a clay loam soil compared with a sandy loam soil [2]. In the current study, the opposite effect was observed over summer, where fine textured soils (6% survival) resulted in reduced survival of canola seed compared with coarse textured soils (15% survival). Medium textured soils (sandy loams) resulted in intermediate seed survival over both sub-annual time periods.

Partial least squares analysis revealed that soil characteristics including the mineral particle densities of silt and clay, BD, carbonate, pH and NO_3^- - N were associated with survival of canola seed (Fig. 3). Soil microclimate characteristics including the number of days mean soil temperature was below -3°C, the number of days during winter where the diurnal temperature range was greater than 4°C, winter and summer thermal time, and hydrothermal time over summer also were associated with canola seed survival. The three extracted factors explained a total of 82% of the variation in explanatory variables (soil and microclimate characteristics) and 45% of the variation in response variables (seed survival) (Fig. 4). Of the soil characteristics, NO_3^- - N had the strongest association with seed survival and was associated positively with seed survival over winter and negatively with seed survival over summer (Fig. 3). Annual seed survival was associated more closely with seed survival over summer than over winter. These results agree with previous research showing that soil enriched in inorganic N resulted in greater mortality of velvetleaf (*Abutilon theophrasti* Medik.) seed [7]. The negative associations of NO_3^- - N and hydrothermal time with survival of canola seed over summer suggests that secondary dormancy in canola seed was alleviated over summer. Potentially greater microbial activity as a result of greater NO_3^- - N and moisture availability likely caused canola seed to be utilized as a carbon source for microbes, resulting in seed decay.

In conclusion, soil texture and associated edaphic factors influence survival of canola seed in the soil seedbank. Further research is warranted to elucidate potential management strategies that could be used to induce mortality of weed seeds in soil by promoting soil and microclimate characteristics that result in weed seed demise.

[1] Fenner & Thompson (2005) The Ecology of Seeds. 250p
[2] Gruber *et al.* (2014) Plant Soil Environ 6:280-284
[3] Bradford (2002) Weed Sci 50:248-260
[4] Saxton & Rawls (2006) Soil Sci Soc Am J 70:1569-1578
[5] Davis *et al.* (2005) Weed Sci 53:860-868
[6] Sawatsky *et al.* (2015) Quant Meth Psych 11:52-62
[7] Davis (2007) Weed Sci 55:123-128

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