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MICROWAVE SOIL HEATING FOR CONTROLLING RYEGRASS SEED GERMINATION

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ABSTRACT. *Several studies have evaluated the effectiveness of microwave soil heating to control a range of weed species. Ryegrass species are problematic weeds of cropping systems across many of the major crop production regions of Australia. This study determined the effect of irradiation time, soil moisture, and distance into the soil from the irradiated surface on the efficacy of microwave soil heating in reducing the germination of both perennial (*Lolium perenne*) and annual (*Lolium rigidum*) ryegrass seeds. The study used a horn antenna to apply the microwave energy to the soil. Temperature increased linearly with heating time in dry sand, although the rate of temperature increase depended on distance from the irradiated surface. The rate of temperature increase was highest at 2 cm depth ($\approx$5.6°C min^{-1}) and lowest at 10 cm depth ($\approx$2.6°C min^{-1}). The germination of seeds in the dry sand was unaffected until the microwave treatment time reached 12 min. Even after 12 min of heating in dry sand, only seeds that were close to the irradiated surface were affected, with the germination percentage of seeds on the surface dropping to 2% of the control treatment's germination response. There was no effect on seeds that were 10 cm from the irradiated surface. The rate of temperature increase in wet sand was more complex. The temperature in the first 2 cm of sand rose rapidly ($\approx$18.3°C min^{-1} at 2 cm) during the first 4 min of heating and then stabilized between 80°C and 90°C. As the heating time continued beyond 4 min, the temperature at other locations farther from the irradiated surface also rose and stabilized between 80°C and 90°C; however, the heating rate was slower than near the surface ($\approx$7.8°C min^{-1} at 10 cm). Heating in the wet sand reduced seed germination at all depths to less than 2.5% of the control treatment's germination response after 8 min of microwave treatment. Seeds that were within 5 cm of the irradiated surface of the wet sand were all killed (0% germination) after only 4 min of microwave heating.*

Keywords. *Microwave radiation, Seed germination, Soils, Weed control.*

Lolium spp. (ryegrasses) are diploids native to Europe, Asia, North Africa, and the North Atlantic islands (Kloot, 1983). Three species of the genus, *Lolium perenne*, *Lolium multiflorum*, and *Lolium rigidum*, are wind-polinating outcrossers that often hybridize (Kloot, 1983). These are used for grazing pasture but have been identified as the most significant weeds in Australian cropping systems (Kloot, 1983). *Lolium rigidum* produces up to 45,000 seeds per square meter (Gill, 1996), with *Lolium perenne* appearing to set similar numbers of seeds per plant (Shah et al., 1991; Steadman et al., 2006). *Lolium* seed develops in spring, is shed to the soil surface in late spring, and remains on or near the soil surface during summer (Steadman et al., 2006). *Lolium rigidum* seeds have short-lived innate dormancy, which prevents germination during summer rainfall events, and between 40% and 80% of the seeds may germinate at the start of the growing season in autumn; however, ungerminated viable seeds may persist to germinate later with the crop or in subsequent growing seasons (Gill, 1996).

Gramshaw and Stern (1977) discovered that all except 10% of their *Lolium rigidum* seeds germinated after two weeks of burial at 2 cm below the soil surface. The remaining ungerminated seeds represented the dark dormant seeds. As burial depth increases, induced dormancy of non-dark dormant *Lolium rigidum* seeds ensures that transfer of deeply buried seeds to within 2 cm of the surface by cultivation will promote germination (Gramshaw and Stern, 1977). Because dormant seeds slowly lose dormancy (Gramshaw and Stern, 1977) and progressively germinate if they are near the surface, ongoing recruitment from the weed seed bank can hamper crop production. Depletion of the weed seed bank is critically important to overcoming infestations of various weed species (Kremer, 1993). Mechanical and chemical controls are the most common methods employed for weed control in cropping systems (Batlla and Benech-Arnold, 2007; Bebawi et al., 2007). The success of these methods usually depends on destroying the highest number of individuals during their seedling stage (Batlla and Benech-Arnold, 2007) before they interfere with crop production and subsequently set further seed. These strategies must be employed over several years to deplete the weed seed bank.

Burnside et al. (1986) reported that viable weed seeds in the soil can be reduced by 95% after five years of consistent herbicide management; however, Kremer (1993) pointed out

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