

NEMATOCIDAL AND HERBICIDAL PROPERTIES OF 2-PROPENAL [ACROLEIN]: A POTENTIAL ALTERNATIVE TO METHYL BROMIDE FOR SOIL FUMIGATION

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ABSTRACT

2-propenal [acrylaldehyde, acrolein] effectively controlled the reniform nematode [*Rotylenchulus reniformis*] in a greenhouse experiment with a soil from a cotton field naturally infested with the nematode. The compound was applied in an aqueous emulsion to soil at rates of 0-300 mgs/Kg soil in 25 mgs increments and after thorough mixing the soil was covered with a polyethylene tarp. The compound reduced exponentially populations of reniform and microbivorous nematodes in pre-plant soil samples. A dose of 50 mgs/kg soil equivalent to 100 lbs a.i./A resulted in >90% reduction in these populations. Soil and soybean [test plant] root samples at the end of the experiment revealed the same pattern of response for the reniform nematode as in the pre-plant samples; however, microbivorous populations had recovered in response to applications of ≤ 100 mgs/Kg soil and were even stimulated by the 75 mgs rate. In another experiment 2-propenal applied post-emergence at rates of 0-800 mgs/Kg soil in 100 mgs increments resulted in sharp declines in the number of yellow nutsedge [*Cyperus esculentus*] and other weeds in a manner proportional to the doses; doses ≥ 200 mgs/kgs soil applied post-emergence resulted in practical elimination of all weed. Results indicate that acrolein can be developed as an alternative to methyl bromide for soil fumigation.

Key Words: soil disinfection, nematocide, herbicide, fumigant, pest management, soil-borne pathogens, nematode control, chemical control.

INTRODUCTION

2-propenal [$\text{CH}_2=\text{CH}-\text{CHO}$; acrylaldehyde] is one of the oldest organic compounds synthesized by man. It was obtained by Redtenbacher in 1843 from dry distillates of fats and glycerol [Smith, 1961; WSSA, 1979]. It occurs widely in nature and is produced by *Bacillus amaracrylus* from glycerol and by *B. welchii* [Merck, 1989]. 2-propenal melts at -86.95°C , has a boiling point of 52.69°C and a vapor pressure at $30^\circ\text{C} = 325.70$ mm Hg. It is a fumigant, lachrymatory compound, moderately soluble in water and completely miscible in most organic solvents [Merck, 1989; Smith, 1962]. Some biological properties of 2-propenal have been known for over half a century. The herbicidal properties of the compound are utilized in control of aquatic weeds under the common name of acrolein and it is also used as a rodenticide [Meister, 2003]. The nematicidal properties of the compound have not been studied even though its fumigant and chemical properties suggest that it could be useful for injection into soil to control phytopathogenic nematodes and other soilborne pests. This paper reports results from a greenhouse study conducted to evaluate the nematicidal and herbicidal properties of these compounds.

MATERIALS AND METHODS

The nematicidal properties of 2-propenal [; acrolein], were studied in a greenhouse experiment with soil severely infested with the reniform nematode [*Rotylenchulus reniformis*]. The soil was collected from a cotton field and was a sandy loam with pH 6.2, organic matter content <1.0% and cation exchange capacity <10 meq/100 gms soil. The soil was mixed 50:50 by volume, with washed fine siliceous river sand and the mixture, here-from referred to as soil. The moist soil [50% field capacity] was apportioned in 1 Kg quantities contained in 4L polyethylene bags. The compounds were applied to the soil in the bags, and after thorough mixing the treated soil was transferred to 1L capacity, 4-inch-diam. plastic [PVC] pots which were then covered with a polyethylene bag [1 mil] held tightly to the outside wall of the pot with a rubber band. The covered pots were placed on a greenhouse table and after 10 days the bags were removed and soil samples for nematode analyses were collected from each pot. The pots were planted with 'Young' soybean [5 seed/pot]. Soybean plants were grown for 8 weeks when they were removed, soil samples taken for nematode analysis [salad bowl incubation technique, Rodriguez-Kabana & Pope, 1981], and data were collected on shoot height, and fresh weights of shoots and roots. The relative health of the root systems was determined using a subjective scale. In the scale values ranged from 1 to 5. A value of 1 corresponded to healthy, well develop and clean looking root systems without necrotic area and no disease symptoms; a value of 5 represented roots with severely reduced development and obvious disease symptoms including large portions with necrotic and/or rotten tissue. Values between 1 and 5 represented intermediate degrees of damage. The roots were incubated to assess nematode populations in them.

Herbicidal properties of the compound were studied as described for the experiment on nematicidal activities. The soil was a silt loam from a cotton field with the normal complement of annual grass and broadleaf weed species, with no nematode problems, and similar characteristics as the one used for the nematode experiments. It was artificially seeded with 5 yellow nutsedge tubercles/pot. Nutsedge plants and other weeds were grown for a month, and the pots were then treated with 2-propenal and covered with polyethylene bags for 10 days, when the bags were removed and weed counts taken one month after treatment. An emulsifiable concentrate [EC's] was prepared containing 10% [w/w] emulsogen and the EC was used to make aqueous emulsion containing 2.5% active ingredient; the emulsions was then used to deliver the compound to soil. Application rates for the nematicide experiment were: 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300 mgs/Kg soil and those for the herbicide trial: 0,100, 200, 300,400, 500, 600, 700, and 800 mgs/Kg soil. In each experiment there were 6 replications [pots] per treatment arranged in a randomized complete block design.

All data were analyzed according to standard procedures for analyses of variance. Fisher's Least Significant Differences [FLSD] were calculated when F values were significant and are included in the graphs. Curvilinear analyses were conducted according to standard procedures using TableCurve 2D program.

RESULTS

Nematicidal Activity. 2-propenal. Data obtained from the experiment with 2-propenal are presented in Figs. 1. The compound reduced exponentially populations of reniform and microbivorous nematodes in pre-plant samples [Figs. 1A]. A dose of 50 mgs/Kg soil equivalent to 100 lbs a.i./A resulted in >90% reduction in these populations. Soil and root samples at the end of the experiment revealed the same pattern of response for the reniform nematode [Fig. 1 B-C] as in the pre-plant samples; however, microbivorous populations had recovered in response to applications of ≤ 100 mgs/Kg soil and were even stimulated by the 75 mgs rate.

Sharp increases in shoot height and weights were observed in response to dosages ≤ 50 mgs [Figs. 2A]; this was followed by gradual decline in values for the two variables. The overall response was typical of a log-normal model. Root weights increased gradually [Figs. 2B] in response to rates up to 175 mgs and declined with higher dosages in a typical Gaussian symmetrical pattern.

Root condition was improved by all but the highest dose of 2-propenal [Fig. 2B].

Herbicidal Activity

Application of 2-propenal resulted in sharp declines in the number of yellow nutsedge and other weeds in response to increasing doses of the chemical as illustrated for nutsedge in Fig. 3. The relation between dose and weed population adjusted well to an inverse cubic model indicating that doses ≥ 200 mgs/Kg soil applied post-emergence resulted in practical elimination of the weed.

CONCLUSIONS

2-propenal is a powerful nematicidal and herbicidal compound with long-term effects against plant pathogenic nematodes but with no long lasting negative effects on beneficial microbivorous nematodes. Application rates 50-100 mgs/kg soil equivalent to 100-200 lbs a.i./A on a broadcast basis eliminate plant pathogenic nematodes, retain microbivorous nematodes, and increase growth of plants. Yellow nutsedge, a hard-to-kill species, and other weeds were practically eliminated with rates ≥ 200 mgs/Kg soil [≥ 400 lbs a.i./A]. These rates are very practical and are considerably below those used with methyl bromide [400-800 lbs/A] for soil fumigation. The fact that 2-propenal is a precursor for the synthesis of many other organic compounds and is already registered for use as a herbicide to control aquatic weeds makes this chemical available in adequate quantities and at reasonable price compared with current prices for methyl bromide.

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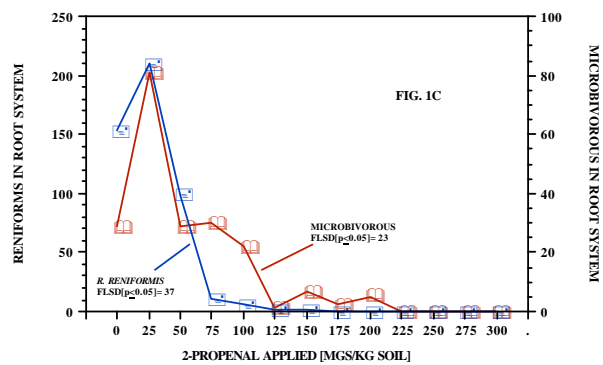
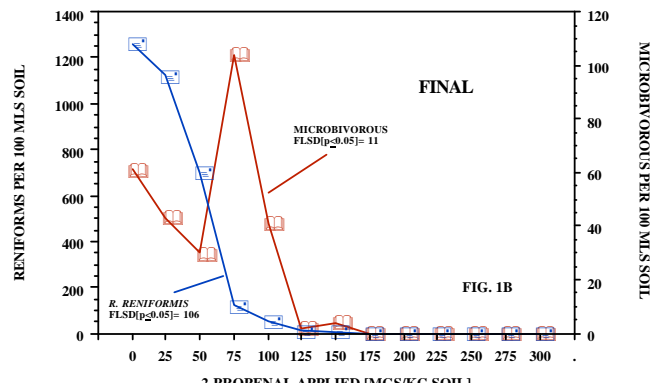
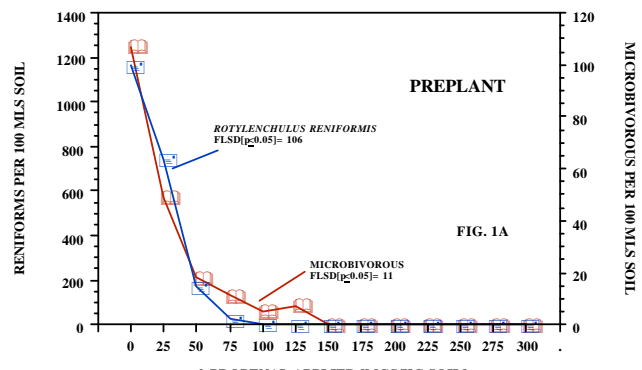
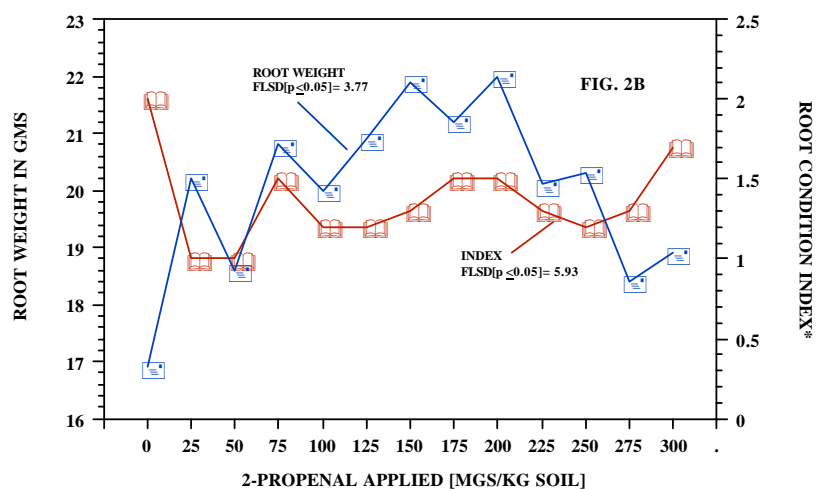
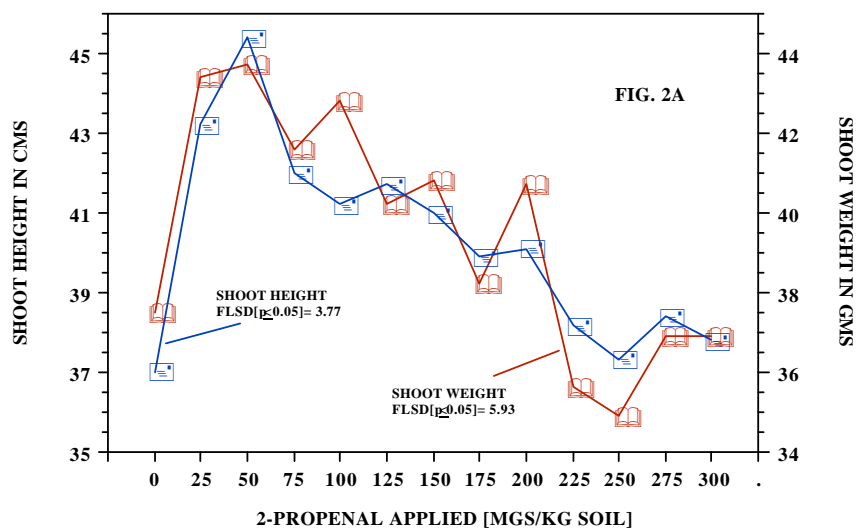


Figure 1. Effect of applications of 2-propenal [acrolein] on populations of reniform and microbivorous nematodes in a soil from a cotton field. A. Pre-plant populations 10 days after treatment; B & C soil and root populations 8 weeks after planting of 'Young' soybean.



*ROOT CONDITION SCALE: 1= BEST TO 5= WORST

Figure 2. Growth response of 'Young' soybean to pre-plant applications of 2-propenal in an experiment with soil from a cotton field infested with the reniform nematode.

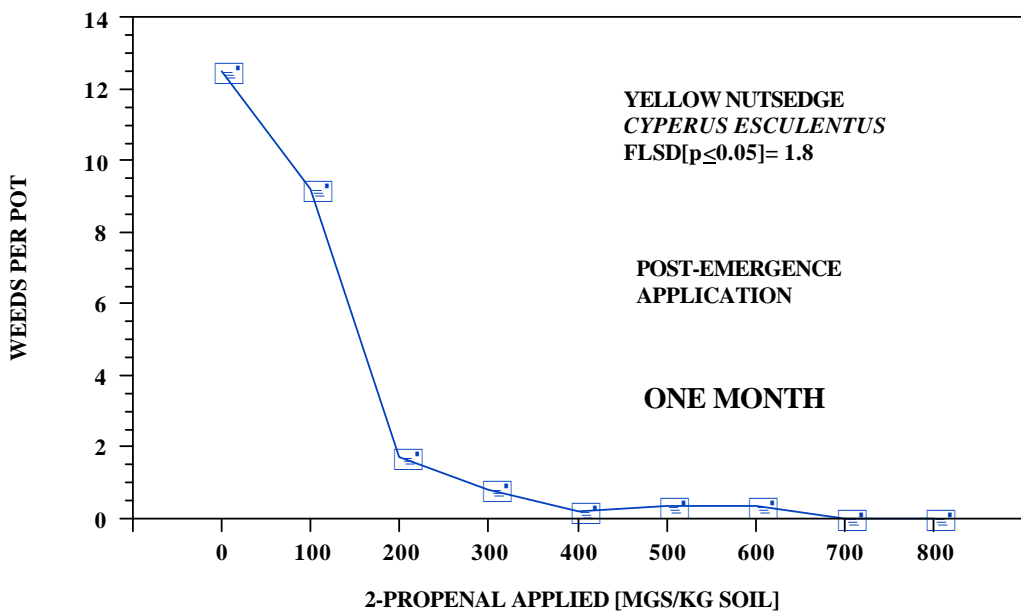


Figure 3. Control of yellow nutsedge [*Cyperus esculentus*] with post-emergence applications of 2-propenal in an experiment with soil artificially infested with the weed.