Allium spp. Amendments, Soil Temperature, and Exposure Time Affect Seed Viability for Weed Management in California

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Summary

A two-year study was conducted during 2000-01 in microcosms to evaluate amendment with onion (*Allium cepa*) and garlic (*A. sativum*) residues as an approach for reducing weed seed numbers in soil. Additional factors, including amendment concentration, soil temperature, and exposure time also were tested for their effects on the amendment treatments. Seeds of barnyardgrass (*Echinochloa crus-galli*), common purslane (*Portulaca oleracea*), London rocket (*Sisymbrium irio*), and black nightshade (*Solanum nigrum*) were used in the study. Results showed that 39 C soil temperature was consistently deleterious to seed survival, as compared to 23 C. Significant effects of the *Allium* spp. amendments on weed seed viability were common, but less consistent than with the other experimental factors. No differences in weed seed viability due to soil amendment with onion versus garlic were found in the 2000 experiment, and only in barnyardgrass and black nightshade in the 2001 experiment. On the other hand, seed viability differences due to amendment concentration (1% versus 3% by weight) were found in barnyardgrass, black nightshade, and London rocket in the 2000 experiment, but no concentration differences were found in the 2001 experiment. In both experiments, barnyardgrass, common purslane, and London rocket seeds were less viable after longer incubation in the microcosms, while black nightshade was not significantly affected by exposure time.

Introduction

Soilborne pests and pathogens, including weed propagules, nematodes, fungi, bacteria, and certain other agents, can be limiting factors in the production of crops. One of the principal strategies used by growers of high-value horticultural crops to combat these organisms is pre-plant soil disinfestation, either with pesticides, or other physical or biological methods. Soil fumigants are the most effective soil disinfestation chemicals, and historically, methyl bromide (MB) has been the most important soil fumigant chemical used by growers in California and around the world[5].

Until recently, consumption of MB for pre-plant fumigation in California was estimated at 16 million pounds annually - nearly 50% of the total amount used in the USA. However, MB was identified as a risk to the stratospheric ozone layer in 1992 and targeted for worldwide phase-out in 1997, by means of the Montreal Protocol, an international treaty. Under the current terms of the agreement and of the federal Clean Air Act, pre-plant consumption of MB in the USA is scheduled to be gradually phased out by 2005[5].

With the impending suspension of methyl bromide for most agricultural uses, and the extremely high cost of methyl bromide fumigation now, there is an urgent need for implementable, alternative methods of soil disinfestation for use in production agriculture. In addition, the increasing acreage devoted to organic production requires the development and implementation of usable tools for soil disinfestation. Biofumigation is one such emerging tool. The term biofumigation refers to the use of organic amendments and crop residues to release biotoxic volatile compounds during degradation in soil. Changes in soil microbiota resulting in biological control of soilborne pests may also contribute to the lethal effects. Biofumigation can be a useful option for soil disinfestation, especially when combined with soil heating (solarization)[2-4].

Most of the previous biofumigation research has focused on use of various cruciferous crop residues, such as broccoli and cabbage, to control pathogens and nematodes[2,3]. To be useful to a larger portion of the agricultural sector, it is important that other rotational crops with high pesticidal activity via the biofumigation process be identified and guidelines for their use in weed management developed. For this reason, the present study evaluated *Allium* spp. amendments, using onion and garlic specifically, for potential as biofumigants for weed management. The additional factors of amendment concentration, soil temperature, and exposure time also were studied for their effects on the treatments. The approach described in this paper could be used by organic as well as conventional producers, and is practicable for fields at the urban-rural interface where chemical fumigants face buffer space restrictions. An earlier, preliminary report was published[1].

Materials and Methods

Soil, weed seeds, and *Allium* amendments. Hanford fine sandy loam soil was collected at the University of California Kearney Agricultural Center in Parlier. Soil was sifted through a 3-mm mesh sieve to remove roots and other surface debris. The four weed species tested in both 2000 and 2001 were barnyardgrass (*Echinochloa crus-galli*), common purslane (*Portulaca oleracea*), London rocket (*Sisymbrium irio*), and black nightshade (*Solanum nigrum*). The *Allium* soil amendments included garlic (*A. sativum* 'California Early') and onion (*A. cepa* 'Mission'), which consisted of culls and residues normally left in the field following harvest in the central San Joaquin Valley. The *Allium* spp. were dried, and ground in a Thomas-Wiley mill using a 1-mm mesh screen prior to use.

Preparation of weed seeds for treatment. Ten seeds (in 2000) or 20 seeds (in 2001) of each species were placed in 3.5-cm diameter nylon organdy bags and tied tightly. Bags of seeds were dipped in deionized water and placed between moist paper towels to imbibe water for 24 hours prior to immersion in water baths. The exception was common purslane, which was dipped only one hour prior to treatment, as it germinates quickly following imbibition.

Preparation of microcosms and treatment. Soil was moistened to approximately field capacity (14-15%) before amendments were added. Samples consisted of 200 g of soil with either 1 or 3%, by weight, of onion or garlic amendments, or nonamended soil. Amended samples were thoroughly mixed, then placed in a 355-ml, ‘Kal-Klear’ plastic cup. Six bags of weed seeds, one of each species, were placed halfway down in the center of the cup and buried in soil. Each cup was covered with 1-mil, clear polyethylene film and secured with a rubber band. Heated microcosms were placed in a 385-l capacity, stainless steel water bath maintained at 39 C using a 'Techne FTE10A' immersion circulator. Unheated samples were kept in a smaller water bath maintained at ambient temperature (22-23 C). Temperatures of soil samples and water baths were monitored with 'HOBO' data loggers.

Germination and viability testing. At intervals of 2, 4, and 7 days of incubation, microcosm samples of each amended or nonamended treatment were removed from baths. Following removal, weed bags were extracted from soil, opened and weed seeds were checked for germination and viability. Additional samples of each species were placed in the incubator according to the germination protocol to serve as the time '0', nontreated control.Seeds from each bag were placed in 100 x 15 mm petri dishes on 70 mm Whatman #1 filter paper moistened with 1.4 ml deionized water. Petri dishes were placed in crispers and incubated in a 'Revco' incubator on a cycle of 8 hours at 20 C and 16 hours at 30 C, and exposed to a fluorescent, plant growth light during the 30 C cycle. Water was added to petri dishes as needed during the incubation period. Weed seeds were checked for germination at regular intervals of 3-5 days. Germinated seeds were counted and discarded. Seeds were counted as germinated if the radicle had emerged and the plumule emerged to a length of 3 mm. Nongerminated seeds were gently squeeze-tested to determine viability. Tetrazolium testing was done on nongerminated black nightshade seeds. Percentage of seed viability was determined for each species.

Results and Discussion

Results of the two-year study showed both similarities and differences in weed species seed viability response to the experimental treatments.

As described in a previous, preliminary report[1], the effect of temperature (39 C versus 23 C) in the 2000 experiment was consistently significant for the four weed species tested, indicating that the higher soil temperature was deleterious to seed survival over the course of the seven-day incubation period. This finding was confirmed during the 2001 experiment (Table).

Significant effects of the *Allium* spp. amendments on weed seed viability were common, but less consistent than with the other experimental treatments. No differences in weed seed viability due to soil amendment with onion versus garlic were found in the 2000 experiment, and only in barnyardgrass and black nightshade in the 2001 experiment. On the other hand, seed viability differences due to amendment concentration (1% versus 3% by weight) were found in barnyardgrass, black nightshade, and London rocket in the 2000 experiment, but no concentration differences were found in the 2001 experiment (Table).

Consistent differences in seed viability attributable to length of exposure to the treatments were found. In both the 2000 and 2001 experiments, barnyardgrass, common purslane, and London rocket seeds were less viable after longer incubation in the microcosms, while black nightshade was not significantly affected by exposure time. These results were duplicated in the 2001 experiment (Table). Several significant and consistent treatment interactions also were found during the study. These will be discussed in subsequent publications.

Conclusions

Results of this study showed that exposure to 39 C soil temperature was consistently deleterious to seed survival in barnyardgrass (*Echinochloa crus-galli*), common purslane (*Portulaca oleracea*), London rocket (*Sisymbrium irio*), and black nightshade (*Solanum nigrum*), as compared to 23 C. Significant effects of the *A. cepa* and *A. sativum* amendments on weed seed viability were common, but less consistent than with the other experimental factors. No differences in weed seed viability due to soil amendment with onion versus garlic were found in the 2000 experiment, and only in barnyardgrass and black nightshade in the 2001 experiment. On the other hand, seed viability differences due to amendment concentration (1% versus 3% by weight) were found in barnyardgrass, black nightshade, and London rocket in the 2000 experiment, but no concentration differences were found in the 2001 experiment. In both experiments, barnyardgrass, common purslane, and London rocket seeds were less viable after longer incubation in the microcosms, while black nightshade was not significantly affected by exposure time. The results indicate that the *Allium* spp. amendments, especially when combined with elevated soil temperature (solarization), may contribute to effective weed management strategies for both conventional and organic production.

Significance of experimental factors on weed seed viability (2000-01).

Factor, Year	Weed species			
	E. crusgalli	*P. oleracea*	*S. irio*	*S. nigrum*
	Statistical Significance Level			
Soil amendment				
2000	ns*	ns	ns	ns
2001	<0.0001	ns	ns	0.0005
Amendment concentration				
2000	<0.0001	ns	<0.0001	0.0037
2001	Ns	ns	ns	ns
Soil temperature				
2000	<0.0001	<0.0001	<0.0001	0.0072
2001	<0.0001	<0.0001	<0.0001	0.0036
Exposure time				
2000	<0.0001	<0.0001	<0.0001	ns
2001	<0.0001	0.0021	<0.0001	ns

*ns = not significant at $P<0.05$.

References

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