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THE REGULAR, AND NOT SO REGULAR, NEWSLETTER OF THE GARLIC SEED FOUNDATION

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#30

Mycorrhizae — The Fungi That Make Life (and Garlic) Possible!

By Christine Gruhn

Literally "fungus-roots," mycorrhizae are a beneficial association between specific types of fungi and the roots of green plants, and most of the plants on the earth harbor mycorrhizal fungi within their roots. Why? It's fairly easy to figure out what the fungus is getting out of the association; as fungi are not green, they cannot make their own food, and these mycorrhizal fungi can get food that the host plant makes through photosynthesis. What about the plant? Why not kick out these photosynthate free-loaders and grow larger? Mycorrhizal fungi have threads of fungal tissue, called hyphae (pronounced Hi-Fee, definitely ripe for a play on words here, David), that extend out from the root and into the soil. When colonized by the fungi, the plant roots can gain essential nutrients, especially phosphorus, from a much larger volume of soil than they can through their roots alone. Mycorrhizal fungi may also benefit their host plants by improving water relations, producing antibiotics or plant growth hormones, which stimulate cell division. They also help improve soils and prevent erosion by binding soil particles together. Most of us who can conduct research on mycorrhizae believe that this relationship is an obligate one in most natural ecosystems, that is, the fungi cannot live without the plants, and the plants cannot survive and compete in the low-nutrient soils found in nature without their mycorrhizal partners.

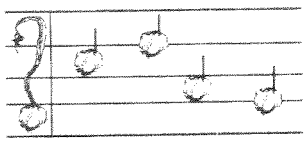
And what about garlic? Garlic with onions, leeks, and most of its other relatives, is highly mycorrhizal. We have seen up to 70% of a garlic's root system colonized by mycorrhizal fungi. In onion, the presence of mycorrhizae can sometimes be detected with the naked eye. After a thorough washing of onion roots, note that some of them appear much more yellow than others—the yellow color indicating a root filled with mycorrhizal fungi. The next question—"Mushrooms are fungi, right? When can I go mushroom hunting in my garlic fields?" Sorry. There are two types of mycorrhizal fungi. Ectomycorrhizae, which produce both edible and poisonous mushrooms above ground while aiding plants below ground, form associations with trees, mostly pines. Arbuscular mycorrhizae, which are found with virtually all other plants, produce only microscopic spores in the soil. We are only now learning how to identify these spores in order to understand which arbuscular mycorrhizal fungi are present in a given ecosystem.

Think you could use less phosphorous fertilizers if you encouraged the native mycorrhizal fungi in your garlic? Yup. This has been proven through over 30 years of experimentation. How can you encourage beneficial mycorrhizal fungi to form associations with your favorite crop? Think sustainably. Low levels of phosphorus fertilization will encourage root colonization by fungal partners that will most benefit the plants. Be wise here—do not expect to immediately stop heavy phosphorus fertilization and be ready for a bonanza crop the next year while you let the mycorrhizal fungi do their thing. There are many different strains of the fungi, and after a few years of high fertilization, the strains that thrive and promote plant growth in low-nutrient soils will be gone from the soil, out-competed by those that can survive under the new conditions. These new residents generally do not improve plant growth, and experiments in tobacco have shown that they actually inhibit growth if low-nutrient conditions are again imposed. Why? They still take food from the plant, but without bringing in soil nutrients. Fungicides are definitely to be avoided, although other agricultural chemicals have also been shown to inhibit mycorrhizal fungi.

We are currently conducting research at Rose Valley Farm in upstate New York to look at another potential benefit of growing garlic. Our preliminary work shows that garlic becomes so heavily mycorrhizal that it does not care (at least in terms of mycorrhizae) what crop preceded it in a field, even if it was one of the rare nonmycorrhizal crops that are found among the brassicas and the crucifers. Upcoming experiments will ask if garlic can be used to "fire up" the levels of mycorrhizae in a field after a crop such as broccoli, and then plant a crop such as lettuce, that is highly dependent on mycorrhizal fungi? Stay tuned!

[Note: for the past couple of summers, Dr. Christine Gruhn (a member of our CSA and Assistant Professor of Biology at Nazareth College in Rochester, NY) has been walking about this farm with a small shovel and paper bags. Either with a student assistant or by herself, she's collected all types of plants, roots, soil, and compost, and taken them back to her lab for study. This work with mycorrhizal fungi is exciting stuff, and the garlic seems to be an important player. As more is known, Christine will keep us informed. D.S.]

Director's Notes



Without garlic: The dogs know. As soon as I grab my heavy socks and gaiters from the drying rack next to the stove ... they know. By the time I sit to put on my ski boots "Brandy Rose" is scratching at the door; "Shadow" is prancing about the room, my boot in his mouth; "Ren" is lying directly at my feet, her head *on* my foot; and "Birdseed" is giving me his "woo-woo-woo" raz while wiggling his bouncing body in all crazy directions. We've all been cooped up too long today, so now with a couple of hours of daylight remaining, I'll get to ski hard before I go into jail tonight.

It's not cold, maybe 20°, but no wind and a sweater and hat are all that's needed. We haven't had good snow this year and temperatures comparatively warm. Fifty miles to the west they had 36" one night. We got half an inch. Fifty miles northeast they got 98" in a 24-hour period (a new record). We got nothing. But it snowed a couple of inches today and it's fast on the ice base. These are the times I get to enjoy this farm, when I can travel about at leisure, taking in the beauty without the head-list of chores to get done or farm tools in my greasy, dirty, sweaty hands.

I ski through the orchard and nut tree plantations looking at the leafless configuration of branches and think about pruning design, ski through the 50' pine barriers I planted 20+ years ago, and travel west to the compost and windows that appear to be these igloos for caterpillars at 100' long by 6' wide and 5' high, horizontal wind silos. I ski out to the farm equipment and enjoy the fascinating snow drifts imitating desert dunes about the functional shapes of structural steel. Save for the brown carcasses in the fall broccoli field, the cover crops are doing their job holding the snow on the top soil, preventing wind erosion. There are hundreds of small birds in the Russian Olive — chickadees, sparrows, nuthatches bouncing about, a couple of loud jays, and a brilliant male cardinal. The contoured beds of the garlic field, mirrored by perfectly symmetrical drifts of that parallel pattern, allow me to ski west to east, then north.

Out along the N/S hedgerow/rockwall the dogs go wild chasing squirrels up trees, mice into borrows, pheasant to wing, and a rabbit into the field. Shadow's first out as he's the fastest, but heavy, and his paws break through the snow in pursuit. As the rabbit makes its first jag, Ren is close, as she's lighter and on top of the snow. She's also low to the ground and very quick and agile. Birdseed has prevented a second jag, and the rabbit's indecision allows Ren to make the kill. She's efficient, then prances about displaying her trophy and growling at old lazy Brandy Rose as she picks up the blood scent. Birdseed dances back to me: "woo-woo-woo" and I grab for a snowball to throw at his wiggling butt. I call him Dancing Bird.

I'm in search of open water. The one pond is frozen, as is the other, but the outflow is clear and the creek is flowing. I'm looking for tracks of the native, non-hibernating critters that need drink to fuel up their metabolism furnace to live in the northern winter. I come across signs of many wild turkey; several deer traveled in the creek for some 30', browsing on the twig of maple and beech along the way ... more rabbit tracks, and mice coming from one hole to water and into another hole. I find signs of another rabbit kill: its tracks, then wing imprints like a snow angel (made by kids) and specks of blood, then nothing. Owl? The long shadows tell me I need to get moving and, returning to the trail, go west onto Paul's land for his loop, then north over to Doug's. He skis often and maintains his wood trails beautifully, as good as a manicured park! There is a tree in these woods where owl or raptor perch to enjoy their prey. I can always find remains of fur, fin or feather — and do today. My clothes are wet with sweat as I return to Paul's for a go on his "downhill." I go *down*, swish — thud! Here comes Birdseed: "woo-woo-woo." The bastard! I *hit* his butt this time!

Dry clothes, hot coffee and warm fire. "Frank-lynn" the cat is catching the melting snow drops from the socks and gaiters on the rack. Three wet, smelly dogs fast asleep on the floor and the fourth crunching on her hors d'oeuvre in the driveway. I've got an hour before jail, so I'll start my Director's notes. (D.S.)

With Garlic: This is very decadent. I'm sitting here in a lawn chair in a t-shirt, my feet propped up on a crate, drinking this fancy coffee I was given. It's about 10° out, clear air and bright sun, with good winds off Ontario at 12 to 20. Inside this plastic hoophouse/greenhouse it's 90°. I could take all my clothes off and call it July! This is a secret joy of owning one of these structures. We built a 12' x 5' 2 x 12 growing box in here and filled it with compost and transplanted all these greens — bok choy, mizuna, spinach, red/green chard, red/green kale, collards, stuck in some leeks, onions, and yes, garlic bulbs. The green tips are just now emerging. I should dig one up for study, but I'd rather eat them.

Some big California garlic factory farm called today. I really don't like talking to them. "Is this the G-S-F?" "Hi, who's this?" "Gilroy megabucks 3000-acre garlic ranch." "What do you want?" They're looking for varieties. They've got disease. I got no tears for them. I ask why they are

(continued on back page)

COMMON SENSE
PEST CONTROL QUARTERLY

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A Note to GSF Members:

I put together this research on garlic because garlic is readily available, organic farmers and gardeners grow and use a lot of it, and I like it! Though not much of a cook, I use garlic in everything but desserts.

The scope and amount of research worldwide into uses of garlic surprised me. There are many more controlled studies done abroad than in the United States. Much of the work is published in esoteric journals that would be difficult for garlic growers to find. For some of the results, I had to rely on abstracts, but I was able to get the Indian and Pakistani papers.

— William Quarles, Managing Editor

BIRC, the Bio-Integral Resource Center, is a non-profit corporation which does research and education in integrated pest management. It runs an experimental organic farm, participates in the worldwide effort to eliminate the use of methyl bromide, and is an important part of the movement for a sustainable agriculture. BIRC offers two kinds of membership: for those interested in pest control around the house, they publish the *Common Sense Pest Control Quarterly*. A subscription costs $30 a year. For profession IMP managers or farmers, they publish *The IPM Practitioner*. A subscription costs $35 a year. A dual membership provides both publications for $55 a year. The BIRC staff will also answer members' pest management questions and help them search for information.

TERMINOLOGY

Where the article doesn't give "common-names," we thank Abby Seaman, Entomologist, Cornell Cooperative Extension for the following: The bacteria and fungi themselves don't have common names, but their related diseases do. When they just use the Genus name as below, there are a number of different diseases on different crops that are caused by the different species in that Genus.

- *Puccinia sp.*: causes rust on cereals and other plants.
- *Collectotrichum sp.*: Anthracnose diseases.
- *Botrytis sp.*: gray mold on various fruits and vegetables.
- *Gleosporium sp.*: same as *Collectotrichum*.
- *Erwinia sp.*: bacterial wilt of curcurbits, Stewarts wilt of corn, fire blight of fruit trees, etc.
- *Phytophthora drechsleri*: blight on tropical crops
- *Fusarium Oxysporum f. sp. niveum*: vascular wilt of curcurbits.
- *Stagonospora curtisii*: causes red discoloration (spurs) on ornamental bulbs. No common name.
- *Sclerotinia sclerotiorum*: white mold in many vegetables.
- *Curvularia sp.*: causes leaf spots on grasses, cereals, corn.
- *Fasciola hepatica and F. gigantica*: liver fluke in sheep causes fascioliasis in sheep, cattle, horses, etc.
- *Aphis gossypii*: cotton aphid.
- *Myzus persicae*: green peach aphid.
- *Henosepilachna sparsa*: Epilachna Beetle, tropical, feeds on solanaceous crops.

In Press #28 (Summer 1996) "Allio-phile" I mentioned the attached article related to garlic. I distributed copies to GSF contact folks across the country (and Canada) and when their response was enthusiastically positive, decided to share it with all members. We contacted Mr. Quarles at BIRC and thank him for his permission to reprint it, and his above remarks, (without cost to GSF) as Press #30. We'd be interested in your comments on the use of the Press for this purpose and hope you enjoy this article. Next issue we'll go back to our regular format with "Out Of My Head," "Chef Ed," "Allio-phile," recipes, "Ask Alice," and the usual collection of worthless information and lousy humor. [D.S.]

Garlic Can Protect Your Garden

By William Quarles

Garlic, *Allium sativum*, evolved as a wild plant in Asia thousands of years ago. It is now found all over the world and is widely used as a spice and as a food. Garlic also has a reputation in herbal folklore as a curative for a number of medical problems, including hemorrhoids, rheumatism, dermatitis, abdominal pain, cough, loss of appetite, and loss of weight. The medical properties of garlic were recognized at least 5000 years ago, and it was used specifically in the treatment of heart disease by the East Indians and Egyptians of 1500 BC (Kritchevsky 1991).

Garlic also has a folk history as an antibiotic and antifungal agent. This folk history was formalized when tincture of garlic was recommended for cholera in 1758 in the *Codex Medicamentarius* (Stoll and Seebeck 1951). The antimicrobial properties of garlic were investigated more systematically in the early 1900s by chemists and pharmacologists. The antibiotic effect was substantiated first, with early reports by Dombray and Vlaikovitch appearing in 1924. Fungicidal effects were reported by biologists and pharmacologists in the 1940s (Leshnikov 1947).

Wonder Drug

Starting with the isolation of the antibiotic allicin from garlic by Cavallito et al. in 1944, the pharmacology of garlic has been actively investigated. According to a recent review of studies with humans, garlic lowers blood pressure, lowers cholesterol, inhibits blood clot formation, and lowers serum lipids (Kritchevsky 1991). In Europe, garlic has been registered as a drug for the prevention of cardiovascular disease (Grunwald 1993). Garlic is also antiprotozoal, antiviral and may boost the human immune system (Weber et al. 1991).

Perhaps the most amazing property of garlic is its anticancer action. According to Stoll and Seebeck (1951) complete regression of tumors of the type caused by benzpyrenes were achieved by injections of the amino acid alliin into the tumor. Alliin is a precursor of the pharmacologically active components of garlic (see Chemistry Box A). Garlic may also act to *prevent* cancer, possibly due to its antioxidant effect (Yang et al. 1994; Imai et al. 1994; Ip et al. 1992).

Type of Preparation

Garlic is also a pesticide. The pesticidal content of garlic varies with the genetics of the plant and where it is grown (Stoll and Seebeck 1951). Intact garlic contains the amino acid alliin, which is the precursor of all the pesticidal compounds. Alliin is soluble in water and has no odor, but when garlic is crushed, chopped, blended or otherwise damaged, the characteristic odor is released, as alliin is enzymatically converted to allicin, the primary pesticidal substance (see Chemistry Box A). Thus, the smellier the garlic, the more potential it has as a pesticide.

The type of effect depends partly on the type of preparation. Cold-pressed garlic juice, extracts with organic solvents, extracts with water, and steam distilled oil have all been used. Confusion sometimes arises because the term such as "10% aqueous extract" can have more than one meaning. Unless otherwise specified, this term means that 1 part by weight of garlic or garlic powder is mixed or homogenized with 9 parts by weight of water, the solids are filtered off, and the liquid is sprayed.

Alternately, garlic can be extracted by a garlic press, by an organic solvent, or by steam distillation. A 10% aqueous solution or extract can be formulated when 1 part by weight of the oil thus obtained is added to 9 parts water by weight. When the solvent or method of extraction is other than water, it is given in parentheses. Thus, a 10% aqueous extract (MeOH) means garlic was extracted with methanol (MeOH), then added to water to make a 10% spray by weight. [Occasionally the solutions were formed by volume. Since garlic oil has a density nearly the same as water, little error is involved by treating this as a percent by weight.]

Controls Plant Pathogens

Ark and Thompson (1959) found that cold-pressed garlic juice was an effective inhibitor of a number of plant pathogens, including *Erwinia*, *Botrytis*, *Gleosporium*, *Colletotrichum*, *Puccinia* and others. When extracts were used, water extracts of garlic powder gave better pathogen control than extracts of alcohol, ether, or chloroform.

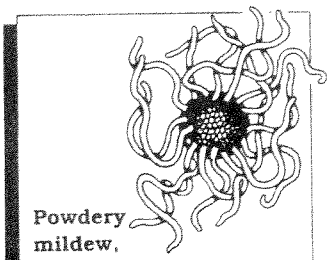
Aqueous extracts of garlic powder were tested on bean, cucumber, radish, spinach, almonds, cherries and apricots in greenhouse tests. Spraying with 10-20% aqueous extracts of garlic powder controlled downy mildew of cucumber, *Pseudoperonospora cubensis*. Dusting with 50% garlic powder mixed with 50% diatomaceous earth (Cellite 500) gave "perfect control" of radish and spinach downy mildews. Sprays of 2-10% aqueous garlic extracts gave "excellent control" of cucumber scab, *Cladosporium cucumerium*. Complete control of bean anthracnose, *Colletotrichum*

lindemuthianum, was effected by 10-20% aqueous garlic powder extracts (Ark and Thompson 1959).

Garlic sprays also protected against bacterial diseases, although these diseases required higher concentrations than some of the fungal diseases. "Good control" of bean blight, *Pseudomonas phaseolicola*, and angular leaf spot of cucumber, *P. lachrymans*, was achieved with 10-20% aqueous garlic sprays.

Fruit trees and fruit were protected against the rot fungus, *Monilinia fruticola*. Apricot seedlings sprayed with 10% aqueous garlic sprays showed no sign of infection after inoculation. Peaches, either dipped in 20% aqueous extracts or fumigated with garlic volatiles showed no signs of infection after inoculation (Ark and Thompson 1959).

Qvarnstrom (1992) found that a 5% aqueous garlic emulsion controlled powdery mildew, *Erysiphe cichoracearum*, when sprayed on greenhouse cucumber crops. Cucumber leaves were sprayed on both sides every 7 days with a high pressure sprayer. Untreated cucumbers showed 83-85% infection. Those sprayed with 5% garlic emulsion had a 10% infection rate in one crop, and a 2% infection rate in another.


Powdery mildew, *Erysiphe sp.*

Qvarnstrom and Ramert (1992) applied 5% aqueous garlic sprays to roses for control of blackspot, *Marssonia [Diplocarpon] rosae*. Three cultivars were tested, the susceptible 'Allotria' and 'Super Star' and the more resistant 'Peace'. Garlic sprays gave satisfactory control only on 'Peace'.

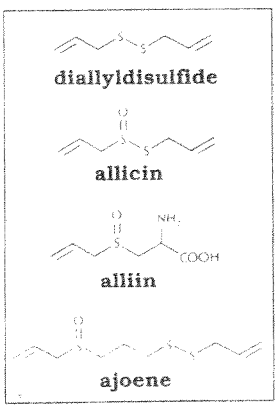
Box A. Chemistry

Intact garlic bulbs are chemically different from crushed garlic bulbs, which also differ from extracts, which especially differ from commercial garlic oils. The parent substance in garlic is the amino acid alliin, which chemically is an oxidation derivative of the amino acid S-allylcysteine.

The allylsulphoxide group is very important in garlic chemistry. Alliin may be thought of as the allylsulfoxide derivative of the amino acid alanine. When garlic is damaged or crushed, water-soluble alliin is enzymatically converted to allicin, which is the allylsulfoxide derivative of allylsulfide, and is nearly insoluble in water. All the other garlic sulfides may be derivatives or decomposition products of allicin, and most are insoluble in water (Stoll and Seebeck 1951; Block et al. 1986; Cavallito and Bailey 1944).

Fresh aqueous extracts contain mostly allicin, which is a potent fungicidal and antibacterial agent, and may be insecticidal (Cavallito and Bailey 1944; Amonkar and Reeves 1970; Stoll and Seebeck 1951). Allicin also produces the characteristic garlic smell. Upon sitting in water, allicin reacts to form ajoene and other sulfur compounds. The basic structural unit of alliin, allicin, and ajoene is allylsulfoxide (Kritchevsky 1991; Block et al. 1986).

When aqueous extracts are distilled, 1% to 2% of a commercially available volatile oil is produced containing very little allicin. Instead, the major products are diallyl sulfide, diallyldisulfide, and diallyltrisulfide (Frazao et al. 1994). Heating garlic, or extracting garlic into hot oil quickly decomposes allicin into these complex sulfides (Laakso et al. 1989).



Different Pesticidal Effects

Because of the dynamic chemistry in garlic, an aqueous extract has different pesticidal properties than a MeOH extract or steam-distilled oil. Intact garlic cloves contain about 0.2-0.3% alliin, most of which is converted to allicin when garlic is crushed. When garlic is homogenized in water, the major chemical component is allicin, which has a water-solubility of 2.5% (w:w). As solutions sit, further reaction occurs and oily substances separate. Thus, much of the effectiveness of an aqueous extract depends on dispersing or emulsifying the oily allicin and its degradation products (Stoll and Seebeck 1951; Cavallito and Bailey 1944).

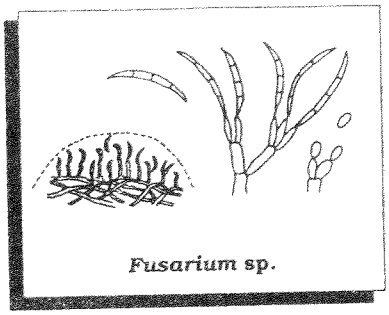
A methanol or ethanol extract of crushed cloves or powder removes all the allicin present. If the solvent is evaporated and the result emulsified in water, the result can be a more potent insecticide, fungicide, and bactericide than obtained with water only.

Garlic oil obtained by steam distillation is not an antibiotic, is only weakly antifungal, but may be a more potent insecticide than solvent-extracted oil, at least for larval flies and mosquitoes (Cavallito and Bailey 1944; Amonkar and Banerji 1971; Saniewska 1995). This oil contains mostly diallyl di- and trisulphides. It is too volatile, however, to be very useful as a crop protectant, as 80% disappears within 24 hours of spraying (Ramakrishnan et al. 1989).

Methanol or ethanol extracts applied directly in the solvent to the insect or the plant are very potent insecticides. Although giving high mortalities to aphids, this extract is very broad spectrum and may be a hazard to beneficials such as syrphids and lacewings, but less so for lady beetles (Stein and Klingauf 1990; Nasseh1982)

Mode of Action

The positive cardiovascular effects of garlic, as well as the fungicidal and insecticidal properties, might be partly due to enzyme inhibition. Garlic extracts and allicin inhibit a number of enzymes in vitro, including cholinesterase. Generally, common enzymes involved in human digestion and respiration are unaffected (Wills 1956). Of the 29 enzymes tested by Wills (1956), those most strongly inhibited by allicin were succinic dehydrogenase, which is involved in Krebs cycle energy production; triose phosphate dehydrogenase, which is important for carbohydrate metabolism; and xanthine oxidase, which converts xanthines into uric acid. Garlic may also inhibit the enzymatic conversion of acetate to cholesterol in the rat liver (Kritchevsky 1991).



Fusarium sp.

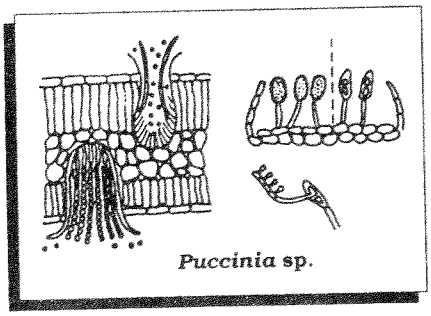
Chauhan and Singh (1991) found that the volatiles from crushed garlic at 5000 ppm stopped spores of *Phytophthora drechsleri* from germinating. Garlic had twice the activity of onion extracts.

Garlic in some cases is more effective than chemical fungicides. Shami et al. (1985) found that when watermelon seeds were soaked for 12 hours in 100% cold-pressed garlic juice only 25% of the seedlings wilted after they were planted in *Fusarium oxysporum* f.sp. *niveum* infested soil. Standard treatments with benomyl (Benlate®) and other fungicides gave 40-70% wilted seedlings.

Lower concentrations are needed to inhibit spore germination (50 ppm garlic oil in the culture media) of *Fusarium oxysporum* than are required for complete inhibition of mycelial growth (250 ppm garlic oil in the culture media) (Tariq and Magee 1990).

Active Compound

When garlic is chopped or crushed, many compounds are produced after the enzymatic conversion of alliin to allicin. One of these compounds is ajoene (see Box A). Allicin and ajoene are major antifungal agents in garlic, and garlic extracts (ethanol) contain 0.3% to 0.5% allicin as measured by antibiotic action (Cavallito et al. 1944; Barone and Tansey 1977).



Puccinia sp.

Saniewska (1992) found that 0.25% (2500 mg/liter) homogenized garlic in a growth medium inhibited, and 1.0% killed the plant pathogen *Stagonospora curtisii*. Pure ajoene inhibited this fungus at 30 mg/liter.

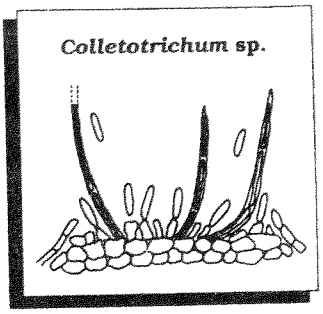
Singh et al. (1990) found that a number of plant pathogens including *Alternaria* spp., *Colletotrichum* sp., *Curvularia* sp. and *Fusarium* spp. could not germinate in 100 mg/liter concentrations of ajoene.

Singh et al. (1995) found that 1000 ppm of ajoene controlled powdery mildew, *Erysiphe pisi*, on growth chamber pea plants as well as the fungicides sulfur (Sulfex®) and carbendazim (Bavistin®). Singh et al. (1992) found that ajoene at 2.5 ppm inhibited sporangium formation and germination of metalaxyl resistant *Phytophthora drechsleri* f.sp. *cajani*. Complete inhibition was seen at 20 ppm.

Ajoene and allicin also kill viruses, but garlic oil from steam distillation does not (Weber et al. 1992). For instance, aqueous garlic extracts inhibit tomato mosiac virus (Othman et al. 1991).

Steam-Distilled Oil Less Effective

Garlic oil obtained by steam distillation of crushed garlic or garlic powder has little or no effect on the dogwood anthracnose pathogen, *Discula* sp. However, 5-10% aqueous extracts of garlic cloves or powder completely inhibited the pathogen. This experiment suggests that allicin and ajoene available in water extracts are more potent fungicides than the di- and triallyldisulphides available in steam-distilled garlic oil (MacElreath et al. 1991).



Colletotrichum sp.

This observation is consistent with Saniewska's (1995) report that ajoene inhibited *Stagonospora* sp. at 30 mg/liter while diallyldisulfide required 50 mg/liter.

Garlic Leaves Also Active

In some cases, garlic leaves are cheaper and more readily available than garlic cloves. Misra and Dixit (1976) found that garlic leaf extracts inhibited a number of plant pathogens, but they did not publish the concentrations.

Singh et al. (1979) showed that 7000 ppm of leaf extract could inhibit *Fusarium oxysporum* f. sp. *ciceri* while *Sclerotinia sclerotiorum* required only 5000 ppm. Treated seeds of gram, *Cicer arietinum*, did not produce wilted seedlings when sown in infested soil.

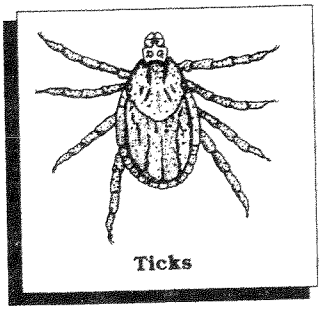
Nematicide

Garlic also kills pest nematodes. A 5% aqueous garlic extract killed 88% of exposed root knot nematode, *Meloidogyne incognita*, juveniles within 24 hours and 100% within 72 hours. When the extract was applied to soil containing the nematodes, 100% mortality was seen in 72 hours (Rakesh et al. 1995). Rakesh et al. (1992) also found a 5% aqueous solution killed 100% of 2nd stage *M. incognita* juveniles when applied to soil. Populations of fungi and bacteria were dramatically reduced. Actinomycetes were unaffected.

Gupta and Sharma (1993a) found that 5% aqueous garlic was more effective than 5% extracts of onion and that the active component was probably allicin. When 5 ppm of this compound was tested, 100% of *M. incognita* were dead after 72 hours. The 5 ppm concentration reduced the number of viable eggs by about 92%. *M. incognita* on tomatoes was controlled by 25 ppm root dips of allicin; however, 100 ppm was lethal to the plants (Gupta and Sharma 1993b).

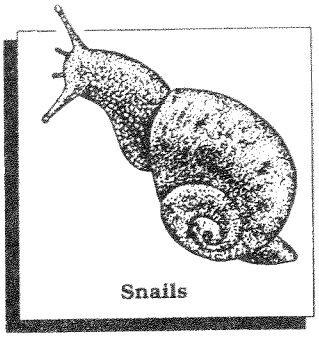
Aquatic Snails

Even snails can be stopped by garlic. Raw garlic was homogenized in water, then chemically fractionated. The allicin fraction proved toxic to the aquatic snails *Lymnaea acuminata* and *Indoplanorbis exustus*.



Ticks

Allicin was more potent than the synthetic molluscicides carbaryl (Sevin®) or phorate (Granutox®), and the LC50 in 96 hrs was 8 mg/liter. Control of these snails in India is important, as they carry the parasites *Fasciola hepatica* and *F. gigantica* that sicken and kill cattle (Singh and Singh 1995). Effects on garden snails, *Helix* sp., apparently have not been published.

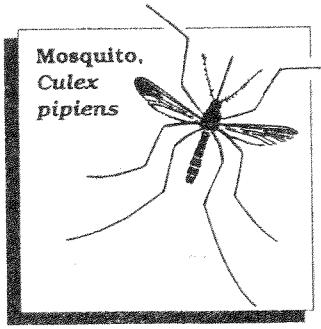

Snails

Insects

Intercropping of garlic with crops such as potato to reduce insect pests is a centuries-old practice (Potts and Gunadi 1991). However, use of garlic extracts and garlic oil to fight insects seems to be a relatively modern practice. Catár (1954) reported that the blacklegged tick, *Ixodes ricinus*, could be killed within 30 minutes by application of aqueous or alcoholic garlic extracts.

Amonkar and Reeves (1970) prepared garlic insecticide by extracting dehydrated garlic with methanol and with steam distillation. Both the extract and the steam-distilled oil were toxic to 5 common pest mosquito species. The steam-distilled oil was about 4 times more potent, giving 100% mortality at 50 ppm. Amonkar and Banerji (1971) confirmed that garlic oil (steam-distilled) was lethal at 5 ppm to the *Culex pipiens* mosquito. They determined the active components of the oil were diallyl disulfides and trisulfides.

Bhatnagar-Thomas et al. (1974a) found that the housefly, *Musca domestica nebulo*, was knocked down within 6 minutes and killed within 60 minutes by fumes from (steam-distilled) garlic oil. Housefly larvae had 100% mortality after a 180 minute exposure. Khapra beetle larvae, *Trogoderma granarium*, needed a 7 hr exposure for 100% mortality within 48 hours of treatment. Symptoms were hyperexcitability, drunkeness, salivation and excretion. Bhatnagar-Thomas and Pal (1974b) found the insectidal action was not caused by interference with the respiratory chain. They suspected, but could not confirm garlic oil obtained by steam distillation was an acetylcholinesterase inhibitor.


Mosquito, *Culex pipiens*

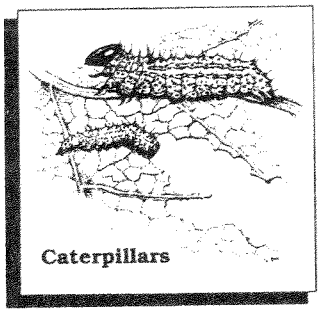
Caterpillars

Endersby et al. (1992) tried a number of alternate approaches to control the cabbage pests diamondback moth, *Plutella xylostella* and cabbage white butterfly, *Pieris rapae*, on cabbage. Pyrethrum, pyrethrum/garlic, soap, BT, BT-soap, and fenvalerate were used. Of the biorational treatments, highest marketable yields were given by BT or rotenone. Pyrethrum/garlic (unknown extracting solvent) treatments gave higher yields than soap or pyrethrum alone.

Topical treatments of 10 g/liter (1%) of garlic (water extract), 10 g/liter of *Melia azedarach* (H_2O), and 1 ml/liter of fenitrothion (Sumithion®) killed 3rd-instar larvae of the potato tuber moth, *Phthorimaea operculella*, in laboratory experiments. Mortality was assessed at 24 hrs, then daily until moth emergence. Mortalities before emergence were 100% for Sumithion, 91.7% for *M. azedarach* and 85% for garlic. The biorationals caused a considerable delay in adult emergence, and there was little mortality during the first 3 days, except Sumithion® killed all the larvae within this time (Nasseh and Furassy 1992).

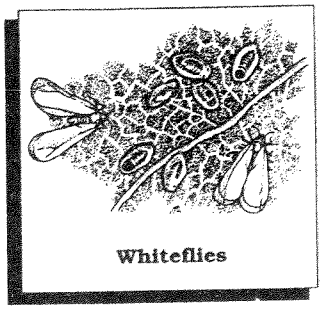
Krishnaiah and Mohan (1983) applied weekly sprays of 0.5% aqueous garlic oil (probably steam-distilled) and 14 synthetic pesticides to cabbage in tropical field trials. Garlic sprays had no effect on cabbage leafwebber, *Crocidolomia binotalis*. Sprays reduced numbers of the diamondback moth, *Plutella xylostella*, for 4 days.

Fresh garlic fumes are ovicidal to a number of economically important caterpillars and bugs. When eggs of the moth, *Earias vittella*; cotton stainer bug, *Dysdercus koenigii*; the armyworm, *Spodoptera litura*; and the tomato fruitworm, *Helicoverpa armigera* were exposed to garlic fumes in the laboratory at 28°C (82.4°F) and 80% RH, *S. litura* eggs did not hatch. *D. koenigii* hatching was impaired and egg survivors died in the larval stage. *H. armigera* egg survivors died in the large and pupal stages. *E. vittella* was the most resistant, as 30% of the eggs survived to the adult stage, compared to 73% of the controls (Gurusubramanian and Krishna 1996).


Caterpillars

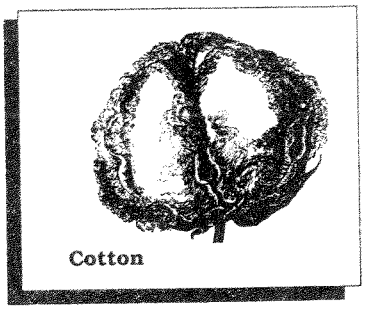
Whiteflies

Garlic products have been extensively tested against the silverleaf whitefly, *Bemisia argentifolii*, on cotton plants by Flint et al. (1995) of the USDA Cotton Research Laboratory in Phoenix, Arizona. Four garlic products were tested: chopped garlic extract, garlic oil, and the commercial products Garlic Barrier® and ENVIRepel® (see Resources). The extract was produced by blending 125 g of chopped garlic with 1 liter of water (10% by weight) and 0.05% Tween-80 surfactant in a high speed homogenizer for 10 minutes. The mixture was then strained through cheesecloth and formulated into aqueous sprays by adding water. For tests on cotton, 10% aqueous sprays were used. Garlic Barrier and ENVIRrepel are both water extracts of garlic that are sold as insect repellents (see *Common Sense Pest Control Quarterly* 9(4):18 for a review of these products).


Whiteflies

Garlic oil (steam-distilled) was purchased from a commercial supplier (see Resources). The garlic oil had a different smell than the extract, reflecting probable chemical differences between the two products (see Chemistry Box A). Sprays were made by adding garlic oil to water containing 0.05% Tween-80 by volume. Sprays of 2% garlic oil in water caused plant damage, but 1% sprays did not.

In all cases, cotton plants were sprayed and monitored weekly for nymphs, adults and egg masses. Garlic oil sprays gave no protection at all, possibly because of volatility. ENVIRepel diluted 1:10 in water provided no protection. There was no effect on numbers of adults, no significant effect on egg numbers, no significant reduction of the nymph population. Garlic Barrier diluted 1:10 in water was more successful, reducing egg and adult numbers at 3 and 4 weeks and nymphs at 2 and 3 weeks.


Cotton

The 10% aqueous spray of chopped garlic gave the best protection, reducing eggs, nymphs and adults over a 14-day period. Though garlic repelled whiteflies on sprayed leaves, adults colonized new leaves as the plants grew. The best protection given by the garlic products was similar to that obtained with 2% aqueous soybean oil sprays.

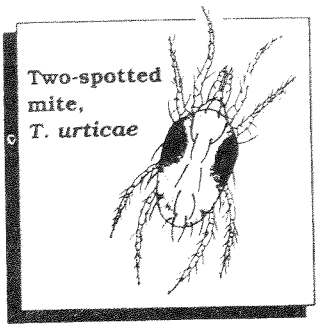
Flint et al. believe that garlic intercrops would be ineffective against silverleaf whitefly because the insect completed its lifecycle on garlic plants in greenhouse tests.

Garlic might be less effective on tomato plants than on cotton. Liu and Stansly (1995) found that 10% aqueous (v:v) Garlic Barrier did not repel silverleaf whitefly adults on tomato in laboratory and greenhouse tests. However, 1% aqueous Sunspray® oil (see Resources) gave control equal to the pyrethroid bifenthrin.

Aphids

Field tests in cabbage with 0.5% garlic oil (steam) in water gave no protection against the green peach aphid, *Myzus persicae*, or the mustard aphid, *Lipaphis erysimi* (Krishnaiah and Mohan 1983). On the other hand, intercropping garlic and potatoes reduced populations of *Aphis gossypii* and *Myzus persicae* on potatoes (Potts and Gundai 1991).

Ethanol extracts (20 g fresh garlic/150 ml ethanol; 14% (w:w)) when sprayed in ethanol directly onto infestations of the peach aphid, *Myzus persicae*, gave about 78% mortality within 24 hours. This is about the same effectiveness as sprays of alcoholic basil extracts (see *Common Sense Pest Control Quarterly* 11(3):12-18 for a review of basil as a pesticide). Aqueous extracts of garlic gave little mortality under these conditions. Also oil extracts of garlic subsequently emulsified with water were relatively ineffective (Stein and Klingauf 1990).


Aphids

Two-spotted mite, *T. urticae*

Thrips and Mites

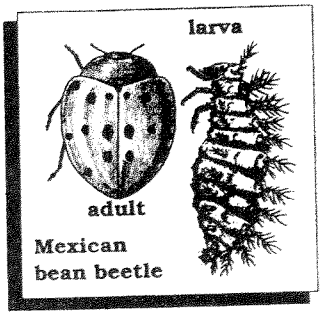
Garlic extracts are not effective for control of onion thrips, *Thrips tabaci* (Bhardwaj and Gupta 1992). In fact, thrips are attracted to interplants of garlic with potatoes (Potts and Gundai 1991).

Garlic extracts also do not kill the two-spotted mite, *Tetranychus urticae*, but sprays reduce the number of eggs laid on bean leaves and prolong development times (Barakat et al. 1986).

Beetles

Application of 5% garlic sprays (extracted with, and applied in methanol) directly to larvae of the Mexican bean beetle, *Epilachna variestis*, led to a strong antifeedant effect. When 5% methanolic extracts (MeOH) were sprayed on bean leaves that were then dried and fed to the larvae, only 12 of 50 became adults, and 7 of 50 were deformed. All untreated larvae became adults. Since this result implies that MeOH extracts of garlic might have insect growth regulator effects, the experiment should be repeated for confirmation (Nasseh 1981).

Intercropping potatoes with garlic led to reductions of the pest beetle, *Henosepilachna sparsa* (Potts and Gundai 1991).



Stored Product Beetles and Weevils

In some cases, garlic can protect stored products from beetles and weevils. Javaid and Poswal (1995) tried to protect beans against the bean weevil, *Callosbruchus maculatus*, with plant products and spices. Spices were applied as 2% powders to beans. Cloves and black pepper protected beans as well as malathion. Garlic powder was not effective. Cloves and black pepper powder were freshly prepared, but other spices might have been old. Aguiar et al. (1994) also found garlic extracts ineffective for control of the rice weevil, *Sitophilus oryzae*, on rice.

Garlic powder (2%) gave some protection of corn against the khapra beetle, *Trogoderma granarium*. However, after 4 months the infestation reached intolerable levels. Neem oil (1.0%) gave complete protection for 6 months (Jood et al. 1993).

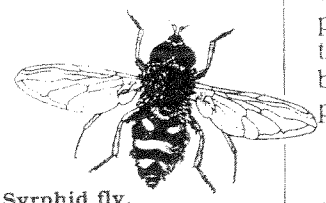
Locusts

When 1% aqueous garlic sprays (steam distilled) was applied to foliage, dried and fed to

the desert locust, *Schistocerca gregaria*, no toxic or repellent effects were seen (Thapar and Chandra 1981). [This is not too suprising as the steam-distilled oil would evaporate rather quickly.]

Laboratory Tests of Beneficials

Nasseh (1982) found a dose-related mortality of methanolic garlic sprays (MeOH extract) to larvae and pupae of the syrphid fly *Syrphus corollae*, the lacewing *Chrysopa carnea*, and the lady beetle, *Coccinella septempunctata*. Insects, however, were directly sprayed with methanolic solutions of the extract, then confined on the residues in a small dish. Under these conditions, a 5% extract caused 50-60% of the syrphid or lacewing larvae to die before becoming adults, and lady bug larvae showed about 8-20% pre-adult mortality. Lacewing pupae showed about 30%, and syrphid pupae about 70% mortality. Lady beetle pupae showed only 8% mortality. Under these extreme conditions, developmental effects were seen, with some surviving adults showing misshapen wings. This possibly hormonal effect of methanol solutions and extracts has not been confirmed by other workers.

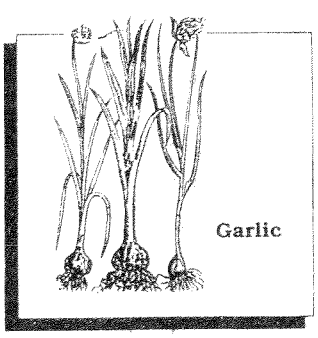


Syrphid fly, *Syrphus* sp.

Safety

Cavallito and Bailey (1944) reported the LD50 of allicin in mice was 60 mg/kg intravenously and 120 mg/kg by subcutaneous administration. At best, garlic contains 0.5% allicin, corresponding to an LD50 of 1200 mg/kg if a garlic extract was applied intravenously. Perrin et al. (1924) reported that about 0.8 ml/kg (900 mg/kg) of garlic oil (steam distilled) was lethal to rabbits. They classed garlic oil as "excito-stupefactive."

Clinical experiments of 5 g fresh garlic, 800 mg of powder or 3.75 g of garlic oil daily have lowered human cholesterol without toxic effects. However, there have been reports of anemia, weight loss and dermatitis with large doses (Kritchevsky 1991).

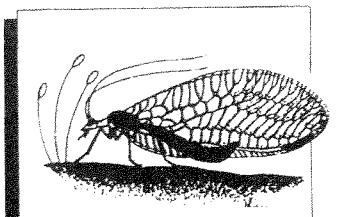


Garlic

Conclusion

A stock solution of garlic spray can be made by homogenizing 2 bulbs of garlic (about 1/4 lb, 114 g) 5-10 minutes in a blender with a quart of water containing a few drops of liquid soap. The liquid is collected after squeezing through cheesecloth to remove solids.

The stock solution should be diluted 1:10 with water just before spraying. Such a solution contains very roughly 25-50 ppm of allicin. Such aqueous sprays applied to foliage will control many fungal and bacterial plant diseases, and might prevent virus diseases. The extract can be applied as a soil drench for nematode control. Soil drenches involve a trade-off, however, as beneficial soil microbes might be killed. Seed soaks with pure garlic juice give more direct protection with fewer possible negative effects.



Lacewing adult

This aqueous extract should also repel whiteflies, caterpillars, beetles, and possibly aphids. Direct hits on insects can also kill them. According to the literature, this kind of spray may be less useful for locusts, thrips, and mites. However, the published reports should be confirmed with further work.

Sprays made from steam-distilled garlic oil are too volatile to be very effective, and alcoholic extracts applied in ethanol or methanol, though giving high mortality to aphids and other insects might also harm beneficials. Such sprays are more detrimental to syrphids and lacewings than to ladybugs.

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Resources

Chopped Garlic—Sunfresh, Ltd., 6220A Young, North York, Ontario, CANADA M2M 3X4; 416/218-7700

Garlic Barrier®—Garlic Research Labs, 624 Ruberta Ave., Glendale, CA 91201; 818/247-9600; FAX 818/247-9600.

ENVIRepel®—American Biochemical Co., 4210 Cloud Way, Paso Robles, CA 93346; 805/237-8394; FAX 805/237-8397.

Sunspray® Oil—Mycogen, Inc., 501 Overlin Dr., San Diego, CA 92121; 800/745-7476; 619/453-8030.

Garlic Oil—Vegetable Juices, Inc., 6135 South Nottingham, Chicago, IL 60638; 312/586-6800.

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Director's Notes (continued)

polluting the deserts. I ask about the thousands of Mexican laborers. I ask about their cheap prices and why they are putting small family farmers, in the rest of this country, out of business. 5-gallon buckets of "WHOLE-PEALED" at $1.00/#. (They pay 60¢/# harvested).

But this is a person, a research chemist, who is looking for varieties, and a paycheck. I finish with my explanation of industrial espionage. They end with a "thank-you," they'll join. All the big groups have over the years. I wonder if we ever make it on any Boardroom agendas?

My truck garlic is starting to get ripe. I keep a few bulbs on the dash. I bet it's thawed/frozen — thawed/frozen — thawed/frozen a hundred times. It stinks. Gave a friend a ride home the other day: HAD to roll the window down! Truck gets hot in the sun and that old garlic just cooks!

In closing, I'll share a new notion of mine, an "Alias." Why not be 2 of you — another. This week I received a wonderful letter and photos from Joe Greathouse in Central Pennsylvania. One photo showed Joe and his Weeny-Wagon set up for business. The sign read: "WADE'S WEENY WAGON." So every time Joe steps in the wagon, he becomes Wade, then back to Joe.

Think of the possibilities! We can each have complimentary or contrary I.D.s. Guys in jail do it all the time. There was a time years ago when a special woman friend called me "Buck," and I called her "Dixie" (but that was hormonal and geographic). What's your alias?

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Let's get working on those garlic art projects!

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Washington, DC Garlic Festival	June 28-29	Margaret Leitch 215-340-3593
Gilroy Garlic Festival (California)	July 25-27	Festival Association 408-842-1625
Fox Run Vineyards Garlic Festival Penn Yan, NY	August 2-3	Wendy 315-536-4616
Western N.Y. Garlic Harvest Fest Batavia, NY	August 9	Gary Skoog 716-637-6586
Adams Garlic Fest Pawcatuck, CT	August 16-17	Audrey Adams 860-599-4241
Southern VT Garlic/Herb Festival Wilmington, VT	August 30 Rain: August 31	Steve Wrathall 802-368-7147
Celebrated Clove Garlic Festival Lincoln (Boston), MA	September 6 Rain: September 7	Bruce Bickford 508-369-5329 (PM)
Northern Ohio Garlic Festival Wellington (Cleveland), OH	September 6-7	Bob and Wendy 303-855-1141 (PM)
Peconic River Herb Farm-Garlic Day Calverton, NY	September 20 Rain: September 21	Cris 516-364-0058
Hudson Valley Garlic Festival Saugerties, NY	September 27-28	Kiwanis Club 914-246-3090
Virginia Garlic Festival Amherst, VA	October 11-12	Richard Hanson 804-946-5168