

all counties, indicating the parasite had survived the summer, when suitable host stages were rare.

In the second season, with improved rearing techniques, 22,000 parasites were produced and released in Fresno (1,500), Madera (3,050), Tehama (8,200), and Tulare (9,250) counties. Recoveries increased, especially in northern release orchards where *M. zebratus* was often as numerous as *Metaphycus bartletti* and *Scutellista cyanea*, the two most common parasites of the later host stages. Recovery in Tulare County has not been as promising. Release orchards had large black scale populations; recovery is thus difficult until parasite numbers increase in the field. Also, many release sites were chemically treated when scale numbers threatened production.

Conclusions

Parasite establishment in the southern San Joaquin Valley is impeded by black scale's development pattern. A combination of weather patterns and cultural methods cause the population to develop uniformly with little overlap of stages. Parasites are

specific to one or two host stages; when these are not available, the parasites cannot become established in the orchard. Uniform development may also increase economic damage, because most scale growth and honeydew production occur in the spring, when conditions favor sooty mold growth.

While climate-related mortality depends on summer temperatures, cultural practices can create a shelter within the canopy even during very hot years. Until natural enemies are established, the most dependable control strategy would seem to be frequent pruning to increase heat-caused mortality.

Sacramento Valley orchards have a good combination of biological and cultural controls. Black scale becomes troublesome only when the canopy becomes too dense and a mild summer allows the pest to increase faster than the natural enemies.

Metaphycus zebratus has become established in northern orchards, confirming that this area is more favorable to biological control. We will follow the effect of this parasite on scale incidence and the competitive interactions with resident natural

enemies. While recoveries in Tulare County have not been as promising, the parasite has been recovered and time is needed to determine its effectiveness.

In both northern and central regions, monitoring of scale populations is recommended to help in timing cultural or chemical control measures. A sampling program with control action thresholds is being developed for olive growers. We are also studying methods to increase biological controls through manipulation of cultural methods and inoculation or augmentative release programs with resident natural enemies.

Kent Daane is Post-Doctoral Researcher, and Leopoldo Caltagirone is Entomologist, Division of Biological Control, University of California, Berkeley. Funding for this research was provided by the California Olive Committee and the Division of Biological Control. The authors thank L. Ferguson, K. Hagen, C. Hill, C. Kennett, E. Kinsel, B. Krueger, M. Martin, F. Schiro, and S. Sibbett for assistance in project development and locating grower collaborators.

Garlic weed competition

Harry S. Agamalian □ Edward A. Kurtz



Garlic yields from weed-free rows (center) were as much as 50% greater than in rows in which weeds were not removed (left and right).

If not controlled with chemicals or by costly hand removal, weeds can cut garlic yields in half and lower the quality of the crop.

Field trials comparing chemical and hand removal showed that judicious use of selective herbicides combined with good cultural practices will achieve best results.

Garlic is grown on 15,000 to 17,000 acres in California for processing (dehydration) and fresh market use. It is a long-season annual crop (230-250 days), planted in the fall and harvested in the late summer of the following year. Consequently, the crop is vulnerable to competition from winter and summer annual weeds. Some of the more troublesome are Russian thistle (*Salsola australis*), little mallow (*Malva parviflora*), shepherd's purse (*Capsella bursa-pastoris*), London rocket (*Sisymbrium irio*), common groundsel (*Senecio vulgaris*), sowthistle (*Sonchus oleraceus*), and many grass species.

Early growth of garlic provides little shading to suppress weeds. In addition, all garlic for processing is mechanically harvested, and weeds interfere with equipment operation and bulb recovery.

Although several herbicides are registered for weed control in garlic, their value compared with removing weeds by mechanical or physical means is often questioned. However, garlic is planted at a high density of 16 to 22 plants per linear foot, and hand-weeding can be extremely costly.

Research in 1983 showed that it took 38 to 56 hours to hand-weed one acre. Workers invariably remove crop plants along with weeds. The loss of one plant per bed-foot can reduce yield by as much as 1,000 pounds per acre. We conducted research to learn more about the effects of weeds on garlic quality, crop yield, and the time required to remove weeds by hand.

The variety California Late garlic was planted in late October 1985 near Salinas on a Chualar clay loam. The crop was grown under sprinkler irrigation. Fertilizer, insecticides, and fungicides were applied in keeping with the regular practices followed in the commercial field in which the trial took place.

Of the native weed populations in the experimental site, the two major species were little mallow (80%), and shepherd's purse. There was a minor population of chickweed (*Stellaria media*). All weeds germinated in the fall and winter. Shepherd's purse and chickweed completed their life cycles in early spring, but little mallow, which is a biennial weed, remained competitive throughout the garlic crop's active growth period.

Six treatments were included in a randomized complete block design. Each consisted of four replications in one bed (3.3 feet by 50 feet long). The treatments were: complete removal of weeds by hand as they emerged, through harvest, starting at 0, 60, 90, and 120 days after garlic emergence; hand weed removal at harvest (230 days); and a preemergence herbicide application of Dacthal (DCPA) plus Furloe (chlorpropham) at planting time.

Garlic and weed populations were counted at regular intervals during the experiment and at harvest. Weed biomass dry weights were collected periodically, along with garlic bulb weights and bulb yields at maturity. Garlic stand counts taken 5 weeks after planting (December 1985) and before removal of weeds were uniform for all treatments (table 1). Garlic populations in all treatments in May were compared with the maximum established populations counted in December. The following stand reductions were recorded for the indicated treatments: Dacthal plus Furloe, 1.4%; 0 days, 4.5%; 60 days, 13.3%; 90 days, 13.9%; 120 days, 21.9%; and 230 days, 28.2%. Loss of garlic plants at the above intervals were directly related to plant removal during the weeding process.

The garlic crop was harvested 230 days after planting. After mechanical topping, all bulbs, regardless of size, were harvested. Yield included total bulb counts (bulbs per 150 square feet), average bulb weight in grams, and yield in tons per acre (table 1). The three best treatments in all treatment categories were Dacthal plus Furloe and the 0- and 60-day weed removal plots. The other three treatments (weed removal starting at 90, 120, and 230 days) provided significantly lower bulb counts, bulb weights, and yield per acre than did the three best treatments.

Weed removal

Weeds were removed from the 0-day treatment as they emerged to maintain a weed-free condition throughout the experiment. The preemergence herbicide treat-

ment was also weed-free. Weed populations, biomass in tons per acre, and hours per acre required to remove weeds were recorded at the time of removal. Density of shepherd's purse ranged from 9 to 12 plants per square foot, and little mallow 6 to 8 plants (table 2). At the 60-day removal point, the weeds weighed 1.66 tons per acre, and it took 100 hours to weed 1 acre. When weeds were removed starting at 90 days, they weighed 2.73 tons per acre, and it took 190 hours to weed an acre. The weed biomass, when removal began at 120 days, was 2.92 tons per acre, and it took 211 hours to weed an acre. Weed biomass and weeding time were not recorded at the 230-day (harvest) weed removal period.

Conclusions

There is a close relationship between reduced stands, final harvested bulbs, bulb weights, and yields of garlic. Plant counts at emergence, before weed removal, were virtually the same in all treatments. Garlic was able to compete with little mallow and shepherd's purse for the first 60 days of growth, but after 90 days significant yield reductions and smaller individual bulbs were evident.

Yield reductions occurred in all periods of weed competition compared with the weed-free (removal beginning at day 0) and herbicide treatments. Using 11 tons as a base harvest yield, the yield reductions were: 60 days, 11.8%; 90 days, 31.8%; 120 days, 48.2%; and 230 days, 52.7%. Without adequate weed control, competition from little mallow and shepherd's purse significantly reduced garlic yields when weed removal began at 90, 120, and 230 days.

The figures in table 2 show the value of removing weeds from garlic during the growth period. They also show the relationships between weed populations, weeding time, and cost for weed removal. Assuming hourly wages (including benefits) of \$4.50 to \$6.25, costs per acre for weed removal for the indicated treatments are: 60 days, \$450.00 to \$625.00; 90 days, \$855.00 to \$1,187.50; and 120 days, \$949.50 to \$1,318.75.

These trials show that weed populations and time of weed removal can significantly affect garlic yield. They also show that the time and costs to remove weeds can be significant and should be considered when selecting available weed control programs. Based on these experiments, garlic growers should continue to use selective herbicides judiciously in combination with good cultural practices to obtain top yields and best quality.

Harry S. Agamalian is Farm Advisor-Weed Scientist, Monterey-Santa Cruz Counties, and Edward A. Kurtz is Technical Consultant, American Dehydrated Onion and Garlic Association, Salinas, California.

TABLE 1. Effects of various periods of weed competition or herbicide treatment on garlic emergence and yield

Treatment	Stand count/ sq ft row*		Bulbs/ 150 sq ft	Harvest*	
	12-18-85	5-12-86		Bulb weight grams	Yield tons/acre
Herbicide ^a	28.9 a	28.5 a	1191 a	31.9 a	11.1 a
Hand-weeding ^b :					
0 days	30.9 a	29.5 a	1201 a	32.2 a	11.0 a
60 days	29.4 a	25.5 b	1105 ab	29.4 a	9.7 a
90 days	28.1 a	24.2 c	1030 b	24.8 b	7.5 b
120 days	27.8 a	21.7 c	861 c	23.0 b	5.7 c
230 days	28.0 a	20.1 c	833 c	21.3 c	5.2 c

*Means in each column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

^a Preemergence application of Dacthal plus Furloe.

^b Hand weed removal, through harvest, starting at indicated days after garlic emergence.

TABLE 2. Effects of various periods of weed competition or herbicide treatment on weed density, biomass, and weeding time

Treatment	No. weeds/sq ft		Weed biomass* tons/ac	Weeding time* hr/ac
	Little mallow	Shepherd's purse		
Herbicide	0	0	0	0
Hand-weeding:				
0 days	0	0	0	x
60 days	7.5	9.2	1.66 a	100 a
90 days	6.2	10.0	2.73 b	190 b
120 days	8.1	12.1	2.92 b	211 b
230 days	7.3	10.3	x	x

* See table 1 footnote (*). x No values obtained.