Screening Cool-Season Legume Cover Crops for Pecan Agroecosystems

Michael W. Smith, Raymond D. Eikenbary, Don C. Arnold, B. Scott Landgraf, Glenn G. Taylor, Gordon E. Barlow, Becky L. Carroll, Becky S. Cheary, Natasha R. Rice, and Robert Knight

---

Approved for publication by the Director of the Oklahoma Agricultural Experiment Station.

Michael W. Smith, Professor, Becky L. Carroll and Becky S. Cheary, Research Technicians, and Natasha R. Rice, graduate student, Department of Horticulture and Landscape Architecture, Oklahoma State University, Stillwater, OK 74078. Raymond D. Eikenbary, Professor and Don C. Arnold, Survey Entomologist, Department of Entomology, Oklahoma State University, Stillwater, OK 74078. Scott Landgraf, Soil Scientist, and Glenn G. Taylor and Gordon E. Barlow, Horticulturists, Samuel Roberts Noble Foundation, P.O. Box 2180, Ardmore, OK 73402. Robert Knight, pecan grower located at Sapulpa, OK.

Abstract. Selected cool-season annual and perennial legumes were evaluated as potential ground covers to supply nitrogen and increase beneficial arthropod populations in a pecan (*Carya illinoensis* (Wangenh.) C. Koch) orchard. Aphid (Homoptera: Aphididae), lady beetle (Coleoptera: Coccinellidae), damsel bug (Hemiptera: Nabidae), green lacewing (Neuroptera: Chrysopidae), brown lacewing (Neuroptera: Hemerobiidae), hover fly (Diptera: Syrphidae), spined soldier bug and other stink bugs (Hemiptera: Pentatomidae), and spider (Araneida) populations were monitored at 7-14 day intervals during the growing season for three years. Biomass production and nitrogen content in the legume tops was measured for two years. Aphid populations peaked during the early spring each year with the highest populations usually on 'Dixie' crimson clover and 'Kenland' red clover. Lady beetle populations were positively correlated with aphid populations. Spider populations were not correlated with aphid populations. There were usually low populations of the other arthropods monitored. Nitrogen contained in the tops of the annual legumes ranged from 20 kg/ha to 89 kg/ha (single harvest at anthesis), and from 108 kg/ha to 179 kg/ha (two harvests, June and September) for the perennial legumes. Two annual legumes ('Dixie' crimson clover and hairy vetch) and two perennial legumes ('Louisiana S-1' white clover and 'Kenland' red clover) were chosen for further evaluation.

Key words: aphid, Aphididae, Araneida, biological control, *Carya illinoensis*, cover crops, Chrysopidae, Coccinellidae, Hemerobiidae, Insecta, Leguminosae, Nabidae, Pentatomidae, Syrphidae

Introduction

Legumes and mixtures of legumes and grasses as the ground cover in pecan orchards offer certain advantages compared to grass sod, such as supplying nitrogen and increasing beneficial arthropods in the orchard that may aid in control of certain pecan pests. Legumes were once commonly grown as cover or green manure crops in orchards until the arrival of inexpensive synthetic nitrogen fertilizers during the 1940's and 1950's (Tedders, 1983). Interest in the use of legumes has increased recently because of higher nitrogen costs, acquired pesticide resistance by certain insects (Boethel, 1981; Dutcher and Htay, 1985), and to avoid pesticide loading in the environment.

There are two types of commercial pecan orchards in the United States. One is based on wild trees that have been cleared of competing vegetation, with the trees periodically thinned to the correct tree spacings for optimum production (these trees and nuts are called natives) (Harris, 1983). Management of native orchards ranges from those receiving complete fertility and pest management programs to those that receive little management, and are only harvested on an irregular basis. Native pecans from 1970 through 1990 accounted for 38% of the U.S. production, and for 92% of Oklahoma's production (Napper, 1991). In Oklahoma about 70% of the native pecan orchards are combined with cattle grazing (Mitchell and Wright, 1991). This requires managers to minimize pesticide use and choose pesticides for pecans that are compatible with cattle grazing.

The second orchard type is planted to a few improved cultivars. There are >1000 pecan cultivars (Thompson and Young, 1985), but only about 40 cultivars are common in the United States (Thompson, 1990). In the southeastern U.S. 'Stuart', 'Schley' and 'Desirable' are the principal cultivars, and in the west 'Western Schley' and 'Wichita' are the major cultivars. In the central pecan belt about 20 cultivars dominate the pecan plantings. Cultivar orchards are usually not grazed, and ground covers are closely mowed grass sods. The lack of genetic diversity among trees in these plantings compared to native orchards coupled with a more aggressive management style has led to frequent pesticide applications. These conditions have resulted in acquired pesticide resistance of aphids (Dutcher and Htay, 1985) and mites (Boethel, 1981), and have caused outbreaks of secondary pests (Mizell III, 1991) because natural enemies were eliminated, necessitating additional pesticide applications.

In both orchard types legume ground covers may be beneficial. Erdman (1967) showed estimates of nitrogen fixed by several legumes ranging from 57 to 207 kg/ha N. Wood et al. (1983) reported that 'Amclo' arrowleaf clover (*Trifolium vesiculosum* Savi) added about 112 kg/ha N to the pecan orchard.

Certain legumes harbor large aphid populations which tend to attract aphid predators and parasitoids. These aphids feeding on the legumes will not attack pecan trees; however, the predators and parasitoids which amass to feed on these aphids attack aphids and other pests in the pecan trees. Three aphid species attack pecan: yellow pecan aphid (*Monelliopsis pecanis* Bissell), blackmargined aphid (*Monellia caryella* (Fitch)), and black aphid (*Melanocallis caryaefoliae* (Davis)) (Tedders et al., 1982). Yellow pecan aphid and blackmargined aphid cause damage to the foliage at the feeding site by clogging phloem, inducing chlorosis, irreversibly suppressing photosynthesis, and reducing nut size (Wood and Tedders, 1982; Wood et al., 1988). Black aphid feeding causes necrosis in the surrounding mesophyll cells and can cause premature leaf abscission (Lakin, 1972; Tedders et al., 1982).

Bugg et al. (1991) proposed a cover crop management system for pecans to enhance beneficial arthropods in the orchards. Several cool-season and warm-season cover crops have been evaluated in Georgia and Massachusetts to increase aphidophagus insects and other entomophaga to enhance biological control in vegetable and pecan agroecosystems (Bugg and Dutcher, 1989; Bugg and Ellis, 1990; Bugg et al., 1990; Wood et al., 1983). Among several potential cool-season crops screened, certain legumes were promising candidates to increase beneficials.

This study was undertaken to evaluate several cool-season annual and perennial legumes as potential ground covers in pecan orchards. Their ability to attract beneficial insects into the orchard and supply nitrogen were the primary characteristics evaluated.

Materials and Methods

The site

The study was conducted in a commercial native pecan orchard near Sapulpa, in central Oklahoma. The soil was a Port loam (fine-silty, mixed, thermic; Cumulic Haplustoll; Mollisols), a deep, well-drained, nearly level soil with high available water-capacity. These soils occur on bottom land, and are typical pecan soils in this region.

Pest management

In 1991 and 1992 *Bacillus thuringiensis* var. kurstaki was applied during early June for first generation pecan nut casebearer (*Acrobasis nuxvorella* Niunzig). In 1993, chlorpyrifos was applied on 21 April and 3 May for phylloxera (*Phylloxera notabilis* Pergande, *P. russelae* Stoetzel, and *P. devastratrix* Pergande) and on 17 June for pecan nut casebearer. Carbaryl was applied for pecan weevil (*Curculio caryae* (Horn)) control on 18 August, and 7 and 27

September 1991, 15 September and 1 October 1992, and 28 August and 15 September 1993. No other insecticides were used in the orchard.

Soil preparation and planting

Existing vegetation was killed during August 1990 with glyphosphate. The soil was cultivated with a rotary tiller during late September. Seed were inoculated with the appropriate commercial *Rhizobium* culture then distributed with a broadcast planter, and the area was packed with a roller. Perennial legumes were established once during 1990, and the annual legumes were reseeded during September each year. Seeding rates for each legume are listed in Table 1. In 1992, 'Yuchi' arrowleaf clover, rose clover, hairy vetch and 'Mt. Barker' subterranean clover were not included in the trial, and in 1993 rose clover, hairy vetch and 'Mt. Barker' subterranean clover were not included. Each plot consisted of a single tree with the legumes extending about 50% beyond the drip-line on all sides of the tree (plot sizes were about 1000 m^2).

Arthropod sampling

Arthropod populations were sampled during 1991 through 1993 at seven to 14 day intervals using a sweep net. Each sweep net sample consisted of ten sweeps per plot. The collected material was transferred to plastic bags with "kill-strips", transported to the laboratory and frozen until the arthropods of interest could be identified and counted. The arthropods monitored were aphids (Homoptera: Aphididae), lady beetles (*Hippodamia convergens* Guerin, *Coccinella septempunctata* L., *Coleomegilla maculata lengi* Timberlake, *Cycloneda munda* (Say), Coleoptera: Coccinellidae), damsel bugs (*Nabis* spp., Hemiptera: Nabidae), green lacewings (*Chrysopa* and *Chrysoperla* spp., Neuroptera: Chrysopidae), brown lacewings (Neuroptera: Hemerobiidae), hover flies (Diptera: Syrphidae), spined soldier bug (*Podisus maculiventris* (Say), Hemiptera: Pentatomidae), stink bugs (Hemiptera: Pentatomidae), and spiders (Araneida). Aphids were divided into alatae, and apterae plus nymphs to determine trends during the growing season. Lady beetle adults were counted by species, and larval counts were pooled over species. Both larvae and adult green lacewings, brown lacewings, and hover flies were counted. Counts of spined soldier bugs and stink bugs did not distinguish between adults and nymphs.

On 19 April 1991 and 23 April 1993, aphids were identified by species, and the population percentage of each species was calculated.

Nitrogen analysis

In 1991, two 1-m^2 legume biomass samples (tops only) were harvested from each plot at the edge of the tree canopy. The legumes were harvested once at the beginning of anthesis. In 1992, the annual legumes were harvested once at anthesis and the perennial legumes were harvested twice, during June and September, which coincided with mowing the rest of the plot. The samples were sorted into legume and non-legume (primarily grasses), oven-dried at 70°C, weighed, and the legumes analyzed for N using the macro-Kjeldahl (Horowitz, 1980). Total N in the tops was calculated from the dry weight of the legumes in each sample and the N concentration in the legume tops.

Statistical design and analysis

Each legume plot was replicated three times in a completely randomized design. Data were analyzed using analysis of variance with mean separation by the protected LSD or Duncan's multiple range test.

Results

Arthropod populations

The aphid population during 1991 peaked during late April and early May, then declined (Fig. 1). The decline in the aphid population coincided with the onset of frequent rainfall. 'Dixie' crimson clover had completed flowering and plants were senescing by 14 May. Peak aphid populations were greatest on 'Dixie' crimson clover and 'Yuchi' arrowleaf clover followed by 'Kenland' red clover and 'Mt. Barker' subterranean clover, and least on rose clover and the three white clover cultivars. The aphid population on hairy vetch was low until an increase on 14 May, which coincided with the onset of flowering. However, on the next sampling date (29 May) no aphids were collected from hairy vetch or the other legumes. In 1991, the alatae population never exceeded 9% of the total aphid population (Fig. 2).

In 1992, the aphid population tended to be associated with rainfall patterns. Rainfall was infrequent during early spring, and the first two samples (14 and 21 April) yielded the highest aphid populations (Fig. 3). Aphid populations were greater on 'Dixie' crimson clover and 'Kenland' red clover than on the other legumes. Frequent rainfall began about 1 May and continued until late June. The aphid population was low on all legumes from May through mid-September, then increased on all legumes on 28 September. The alatae population rose to 18% of the aphid population during April, was near zero through the rest of summer, then reached 18% of the population again during late September (Fig. 4).

In 1993, the aphid population was erratic (Fig. 5). For instance, on crimson clover the initial sample on 8 April showed a medium aphid population followed by a sharp decline, then a population increase. Chlorpyrifos was applied to the pecan trees for phylloxera control on 21 April and 3 May 1993, which accounts for the sudden decrease in the aphid population. During the previous two years no insecticide applications were necessary during the early season. Aphids were highest during the spring, with none or low populations throughout the summer which agrees with observations the previous two years. The maximum alatae population was 17% of the total aphids present (22 May) (Fig. 6).

Aphid species identified on the legumes were blue alfalfa aphid (*Acyrthosiphon kondoi* Shinji), pea aphid (*Acyrthosiphon pisum* (Harris)), and cowpea aphid (*Aphis craccivora* Koch). In 1991 blue alfalfa aphid was the dominant species on 'Yuchi' arrowleaf clover, 'Mt. Barker' subterranean clover, and 'Kenland' red clover (Table 2). 'Dixie' crimson clover and 'Osceola' white clover had similar populations of blue alfalfa aphids and pea aphids. Pea aphids were the dominant species on rose clover, hairy vetch, 'Regal' white clover and 'Louisiana S-1' white clover. Although cowpea aphids were not the dominant species on any of the legumes, three legumes, rose clover, hairy vetch, and 'Regal' white clover had more cowpea aphids than the other legumes. In 1993, pea aphids were the dominant species on the legumes evaluated, although 'Kenland' red clover had a relatively large blue alfalfa aphid population.

The lady beetle larval population in 1991 peaked during late April and early May, then declined (Fig. 7). This population trend was strongly correlated with aphid population trends (Table 3). The greatest lady beetle larval population was on 'Dixie' crimson clover followed by 'Kenland' red clover (Fig. 7). There were few differences in the lady beetle larval populations among the other legumes.

In 1991, the adult lady beetle population generally rose from early April until mid-May, then declined abruptly (Fig. 8). The adult lady beetle population was strongly correlated with the aphid population (Table 3). As the lady beetle population increased during late April and May, the population on 'Dixie' crimson clover was consistently among the highest (Fig. 8). Other legumes that occasionally had a high adult lady beetle population were 'Kenland' red clover, 'Yuchi' arrowleaf clover and hairy vetch. Other legumes either had intermediate or low populations. *Hippodamia convergens* was the dominant lady beetle species in 1991 followed by *Cycloneda munda, Coccinella septempunctata,* then *Coleomagilla maculata lengi.* No differences were detected between lady beetle species among the different legumes (data not shown).

In 1992, the lady beetle larval population was relatively high during April, then declined sharply in May and remained low through September (Fig. 9). This population trend was weakly correlated with the aphid population (Table 3). There were few differences in lady beetle larval populations among the legumes in 1992. The adult lady beetle population had a distinct peak on 5 May, then a second high population during mid-June through late July (Fig. 10). However, there were few aphids present or other arthropods that might serve as a food source and little egg laying was observed. The species distribution in 1992 was substantially different than in 1991. *Coleomagilla maculata lengi* accounted for 50% of the lady beetles collected followed by *Coccinella septempunctata, Hippodamia convergens,* and *Cycloneda munda.* In 1990, *Hippodamia convergens* was the dominate species (72% of the population), and *Coleomagilla maculata lengi* only made up 2.7% of the lady beetle population (Fig 8).

In 1993, few lady beetle larvae were observed on the legumes, except on 'Yuchi' arrowleaf clover sampled on 5 May (Fig. 11). The lower aphid population than the previous two years and the early-season chlorpyrifos application probably account for the low lady beetle larval population. The adult lady beetle population was similar to 1992. The population peaked from early May through early June (Fig. 12). Few significant differences in lady beetle population levels were observed among legumes. Species distribution was similar to 1992, with 68% of the population being *Coleomegilla maculata lengi*, followed by *Hippodamia convergens, Coccinella septempunctata* and *Cycloneda munda.*

In 1992, the spider population peaked during August then declined (Fig. 13). The population trends were not associated with the aphid population (Table 3). Similarly, the spider population in 1993 was relatively low during spring and early summer, then peaked during August when aphid populations were low (Fig. 14). Spiders are general predators and their feeding activity was associated with activity of arthropods other than aphids. Although there were some significant differences in spider populations among the legumes, differences were neither large nor consistent.

The damsel bug population was low in 1991, and there were no significant differences in populations among the legumes (data not shown). In 1992, the damsel bug population peaked (Fig. 15) immediately after the aphid population crashed (Fig. 3). The damsel bug population was low and somewhat erratic in 1993 (Fig. 16). There was a population peak on most legumes during late April. During 1991-93 there were few significant differences in damsel bug populations among the legumes.

Green lacewing, brown lacewing, hover fly, and spined soldier bug were collected each year in the legume plots. However, populations of each were low, and consistent population trends or differences in populations among the legumes could not be identified (data not shown).

Stink bug populations were low (peak population each year was 1 stink bug/10 sweeps) on all legumes during the three years of the study (data not shown). There were no consistent population trends or differences among the legumes.

Nitrogen in legume tops

Legume biomass from a single harvest in 1991 was greater from 'Yuchi' arrowleaf clover, 'Dixie' crimson clover, rose clover and 'Kenland' red clover than the other legumes (Table 4). These legume plots also tended to have the least non-legume biomass. In 1992, when the four perennial legumes were harvested twice, 'Kenland' red clover and 'Louisiana S-1' white clover produced more legume biomass than the other legumes. There were no significant differences in the amount of non-legumes or total biomass produced during 1992.

In 1991, nitrogen concentration in legume tops ranged from 2.22% in rose clover to 3.61% in 'Osceola' white clover. The three white clover cultivars had higher N concentrations than 'Yuchi' arrowleaf clover, 'Dixie' crimson clover, rose clover, or 'Mt. Barker' subterranean clover. Hairy vetch and 'Kenland' red clover were intermediate in N concentration. In 1992, the three white clover cultivars ranged from 3.6% to 3.8% nitrogen during the first harvest and 3.2% to 3.6% during the second harvest. Nitrogen concentrations in the white clover cultivars were higher than in the other legumes during the first harvest, but there were no significant differences in nitrogen concentration among the legumes during the second harvest.

A single harvest of legume tops in 1991 showed from 20 kg/ha N in 'Mt. Barker' subterranean clover to 82 kg/ha N in 'Dixie' crimson clover. In 1992, annual legumes were harvested once at anthesis, and perennial legumes were harvested twice to coincide with mowing. Total nitrogen in the legume tops ranged from 89 kg/ha N for 'Dixie' crimson clover to 179 kg/ha N for 'Kenland' red clover. 'Kenland' red clover and 'Louisiana S-1' white clover produced more N in the tops than the other legumes evaluated in 1992.

Conclusions

Four legumes were chosen for evaluation in large scale plots. These are the perennials 'Kenland' red clover and 'Louisiana S-1' white clover and the annuals 'Dixie' crimson clover and hairy vetch.

Each legume chosen has certain strengths and weaknesses. 'Kenland' red clover was among the highest in nitrogen production and attraction of certain beneficial arthropods. However, we observed that the stands began to decline during the third year. Also pure stands of red clover may prove to be excessively competitive with the trees for water. 'Louisiana S-1' white clover was the best adapted of the three white clover cultivars evaluated. It produced large quantities of nitrogen, but attracted few beneficial arthropods. 'Louisiana S-1' was aggressive, and we observed that the stands improved each year during the study. 'Louisiana S-1' becomes relatively quiescent during the summer, minimizing competition for water, and provided an excellent harvest surface during the fall. Therefore, we chose these two perennial legumes for planting as a mixture in large plots for further evaluation.

'Dixie' crimson clover consistently had larger aphid populations and attracted more beneficial arthropods than the other legumes evaluated. It also produced relatively large quantities of nitrogen. The major disadvantage of 'Dixie' crimson clover is that plants mature and senesce while the trees are foliating, at which time there are usually few arthropod pests in the tree canopy. Planting crimson clover with another annual legume may extend the time that the ground cover will hold beneficial arthropods in the orchard. We observed that hairy vetch began rapid growth about the time crimson clover declined. Therefore, a mixture of crimson clover and hairy vetch could be utilized to extend the ground cover growing season.

References

Boethel, D.J. 1981. Resistance in the pecan leaf scorch mite, *Eotetranychus hicoriae* (McGregor) (Acari: Tetranychidae): implications in pecan pest management. Misc. Publ. Entomol. Soc. Amer. 12:31-44.

Bugg, R.L. and J.D. Dutcher, J.D. 1989. Warm-season cover crops for pecan orchards: horticultural and entomological implications. Biological Agricultural and Horticulture 6:123-148.

Bugg, R.L. and R.T. Ellis. 1990. Insects associated with cover crops in Massachusetts. Biological Agriculture and Horticulture 7:47-68.

Bugg, R.L., S.C. Phatak and J.D. Dutcher. 1990. Insects associated with cool-season cover crops in southern Georgia: implications for pest control in truck-farm and pecan agroecosystems. Biological Agriculture and Horticulture 7:17-45.

Bugg, R.L., M. Sarrantonio, J.D. Dutcher and S.C. Phatak. 1991. Understory cover crops in pecan orchards: possible management systems. American Journal of Alternative Agriculture 6:50-62.

Dutcher, J.D. and U.T. Htay. 1985. Resurgence and insecticide resistance problems in pecan aphid management. In W.W. Neel, W.L. Tedders, and J.D. Dutcher (eds.). Aphids and Phylloxeras of Pecan. Special Publication 38. University of Georgia Experiment Station. pp. 17-29.

Erdman, L.W. 1967. Legume inoculation. USDA Farmers Bul. No. 2003.

Harris, M.K. 1983. Integrated pest management of pecans. Annual Review of Entomology 28:291-318.

Horowitz, W. 1980. Fertilizers, p. 15, section 205. In: S. Williams (ed.). Official methods of analysis of the Association of Analytical Chemists. 13th ed. Association of Official Chemists, Washington, D.C.

Lakin, K.R. 1972. An investigation of the damage associated with *Tinocallis caryaefoliae* (Davis) feeding on pecan leaves. Masters Thesis, Auburn University. 47p.

Mitchell, R.L. and J.C. Wright. 1991. Experiences in pecan orchard floor vegetation management: two years of stocker steer performance and evaluation of grazing management. Annual Report of the Northern Nut Growers' Association 82:72-79.

Mizell, R.F. III. 1991. Pesticides and beneficial insects: application of current knowledge and future needs. p 47-54. In B.W. Wood and J.A. Payne (eds.). Pecan Husbandry: challenges and opportunities. First National Pecan Workshop Proceedings. U.S. Department of Agriculture, Agricultural Research Service, ARS-96,

Napper, W.P. 1991. Fruit and tree nuts situation and outlook report yearbook. U.S. Department of Agricultural Economic Research Service, TFS-258.

Tedders, W.L. 1983. Insect management in deciduous orchard ecosystems: habitat manipulation. Environmental Management 7:29-34.

Tedders, W.L., B.W. Wood and J.W. Snow. 1982. Effects of feeding by *Monelliopsis nigropunctata, Monellia caryella,* and *Melanocallis caryaefoliae* on growth of pecan seedlings in the greenhouse. Journal of Economic Entomology 75:287-291.

Thompson, T.E. 1990. Pecan cultivars:current use and recommendations. Pecan South 24(1):12-17, 20.

Thompson, T.E. and F. Young. 1985. Pecan cultivars - past and present. Texas Pecan Growers Association, Inc., College Station, Texas.

Wood, B.W. and W.L. Tedders. 1982. Effects of an infestation of blackmargined aphid on carbohydrates in mature 'Stuart' pecan. HortScience 17:236-238.

Wood, B., W. White and W.L. Tedders. 1983. Use of legumes in pecan orchards. Annual Report of the Northern Nut Growers' Association 74:147-150.

Wood, B.W., W.L. Tedders and C.C. Reilly. 1988. Sooty mold fungus on pecan foliage suppresses light penetration and net photosynthesis. HortScience 23:851-853.

Table 1. Legumes and seeding rates.

Legume	Scientific name	Seeding rate (kg/ha)
Annuals		
'Yuchi' Arrowleaf clover	*Trifolium vesiculosum* Savi	9.1
'Dixie' Crimson Clover	*T. incarnatum* L.	18.3
Rose clover	*T. hirtum* All.	9.1
'Mt. Barker' subterranean clover	*T. subterraneum* L.	9.1
Hairy vetch	*Vicia villosa* Roth.	18.3
Perennial		
'Kenland' red clover	*T. pratense* L.	9.1
'Osceola' white clover	*T. repens* L.	3.7
'Regal' white clover	*T. repens* L.	3.7
'Louisiana S-1' white clover	*T. repens* L.	3.7

Table 2. Influence of legume on aphid species in 1991 and 1993.

Legume	Aphid species (%)					
	19 April 1991			21 April 1993		
	Blue alfalfa aphid	Pea aphid	Cowpea aphid	Blue alfalfa aphid	Pea aphid	Cowpea aphid
'Yuchi' arrowleaf clover	94.8	9.4	0.8			
'Dixie' crimson clover	51.5	48.3	0.2	0.5	99.0	0.5
Rose clover	4.9	73.0	22.0			
'Mt. Barker' subterranean clover	62.3	36.0	1.7			
Hairy vetch	8.8	73.5	17.7			
'Kenland' red clover	92.6	6.9	0.5	16.3	82.9	0.8
'Osceola' white clover	53.0	40.4	6.5	1.8	96.5	1.7
'Regal' white clover	19.0	63.5	17.5	0	100	0
'Louisiana S-1' white clover	6.7	91.3	2.0	8.4	90.8	0.8

Table 3. Correlations of aphid populations with lady beetle adults and larvae, spiders and damsel bugs.

	Pearson correlation coefficient (r)			
	Lady beetle			
	Adult	Larvae	Spider	Damsel bug
		1991		
Aphid	0.578***	0.599***	0.364***	---
		1992		
Aphid	-0.131^{NS}	0.255*	0.099^{NS}	-0.298*

^{NS},*,***Non-significant (NS) or significant at 5% (*) or 0.1% (***).

Table 4. Nitrogen concentration and total nitrogen in the tops of selected legumes.

Legume	Biomass dry weight			Harvest 1 (May/June)		Harvest 2 (Sept.)		
	Legume (kg/ha)	Non-legume (kg/ha)	Total (kg/ha)	N conc. (%)	N in tops (kg/ha)	N conc. (%)	N in tops (kg/ha)	Total N in tops (kg/ha)
			1991					
'Yuchi' arrowleaf clover	4104a	994bc	5099a	2.43c[z]	80a	---	---	---
'Dixie' crimson clover	4135a	442c	4577ab	2.54c	82a	---	---	---
Rose clover	3799a	1426abc	5226a	2.22c	65ab	---	---	---
'Mt. Barker' subterranean clover	732c	787bc	1519c	2.45c	20c	---	---	---
Hairy vetch	2285b	879bc	3164b	2.92abc	75a	---	---	---
'Kenland' red clover	3475a	1497abc	4973a	2.78bc	82a	---	---	---
'Osceola' white clover	1108c	3354b	2246ab	3.47ab	34c	---	---	---
'Regal' white clover	1498bc	2903a	4401ab	3.61a	44bc	---	---	---
'Louisiana S-1' white clover	1790bc	1430abc	3220b	3.46ab	52ab	---	---	---
			1992					
'Dixie' crimson clover	3445b[y]	1742a	5187a	2.59b	89ab	---	---	89b
'Kenland' red clover	5745a	928a	6674a	2.86b	104a	3.49a	75a	179a
'Osceola' white clover	2593b	2290a	4884a	3.71a	61b	3.48a	52ab	108b
'Regal' white clover	2712b	2209a	4922a	3.77a	58b	3.61a	42b	100b
'Louisiana S-1' white clover	4634a	800a	5434a	3.61a	90ab	3.29a	70ab	160a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

[y]Total biomass from two harvests.

Fig. 1. Aphid populations on legumes during 1991. Vertical bars represent the protected LSD value, 5% level.

Fig. 2. Alatae and apterae plus nymph population trends pooled over legumes during 1991.

Fig. 3. Aphid populations on legumes during 1992. Vertical bars represent the protected LSD value, 5% level.

Fig. 4. Alatae and apterae plus nymph population trends pooled over legumes during 1992.

Fig. 5. Aphid populations on legumes during 1993. Vertical bars represent the protected LSD value, 5% level.

Fig. 6. Alatae and apterae plus nymph population trends pooled over legumes during 1993.

Fig. 7. Lady beetle larvae populations on legumes during 1991. Vertical bars represent the protected LSD value, 5% level.

Fig. 8. Lady beetle adult populations on legumes and distribution of lady beetle species during 1991. Vertical bars represent the protected LSD value, 5% level.

Fig. 9. Lady beetle larvae populations on legumes during 1992. Vertical bars represent the protected LSD value, 5% level.

Fig. 10. Lady beetle adult populations on legumes and distribution of lady beetle species during 1992. Vertical bars represent the protected LSD value, 5% level.

Fig. 11. Lady beetle larvae populations on legumes during 1993. Vertical bars represent the protected LSD value, 5% level.

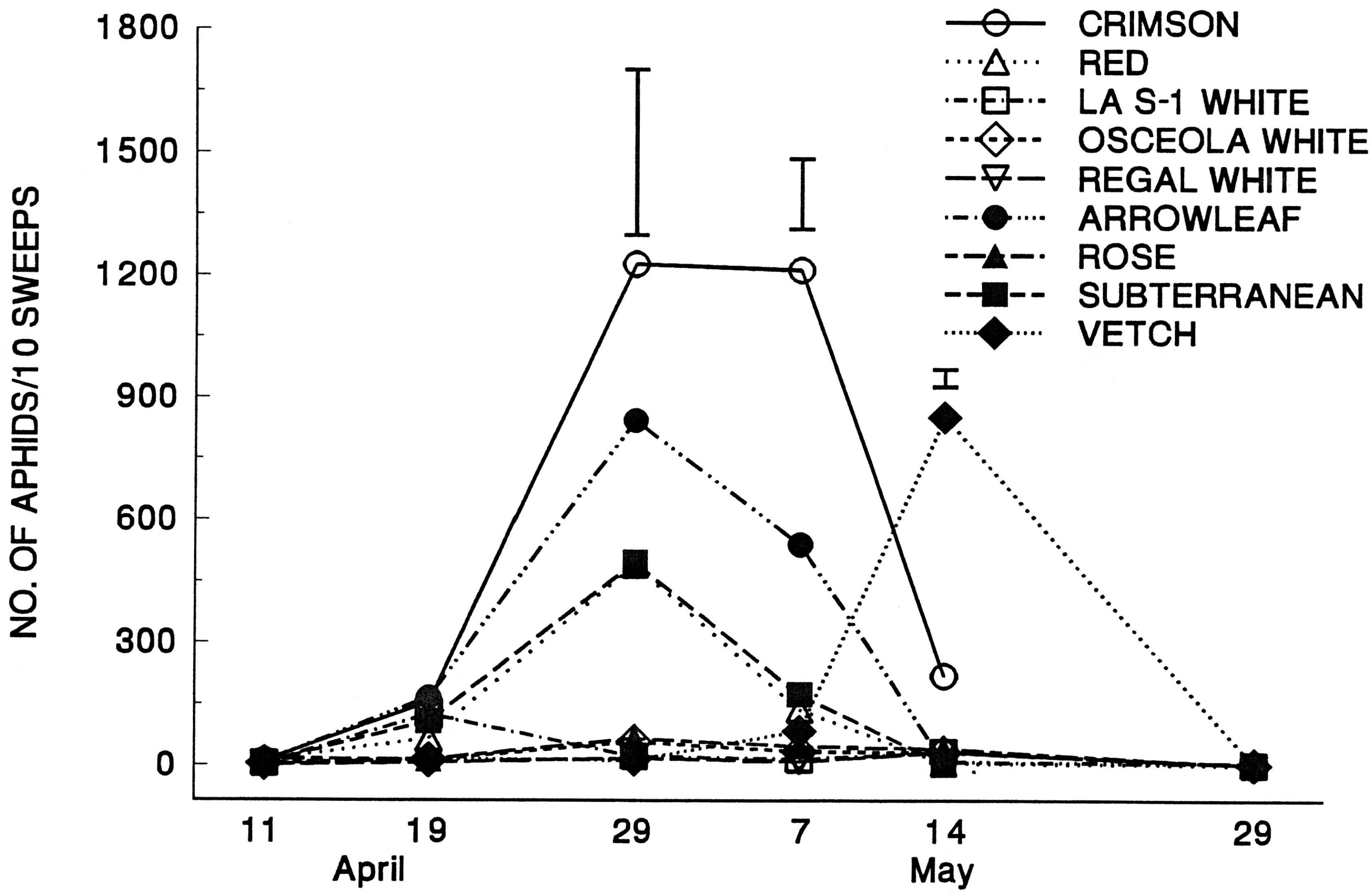
Fig. 12. Lady beetle adult populations on legumes and distribution of lady beetle species during 1993. Vertical bars represent the protected LSD value, 5% level.

Fig. 13. Spider populations on legumes during 1992. Vertical bars represent the protected LSD value, 5% level.

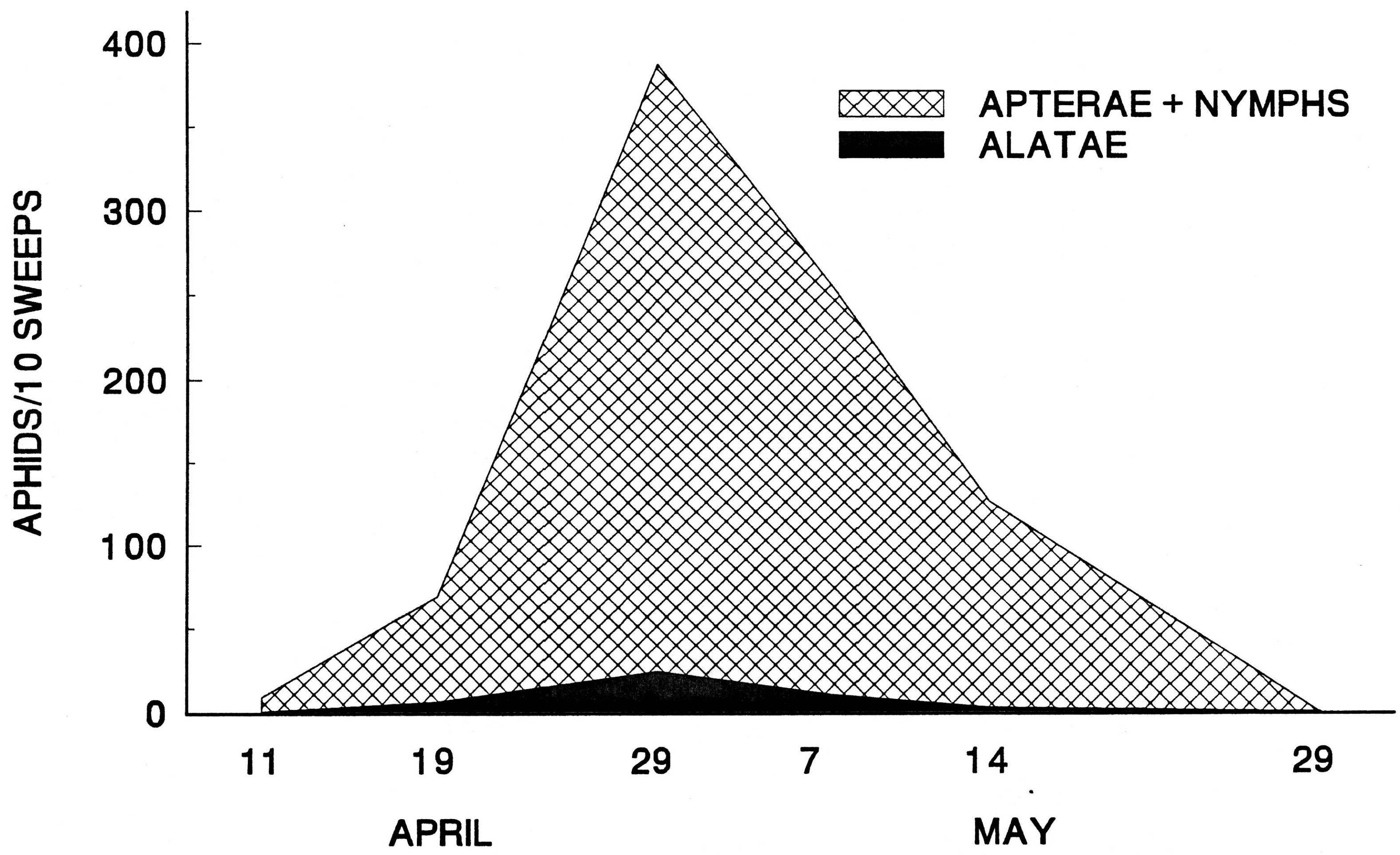
Fig. 14. Spider populations on legumes during 1993. Vertical bars represent the protected LSD value, 5% level.

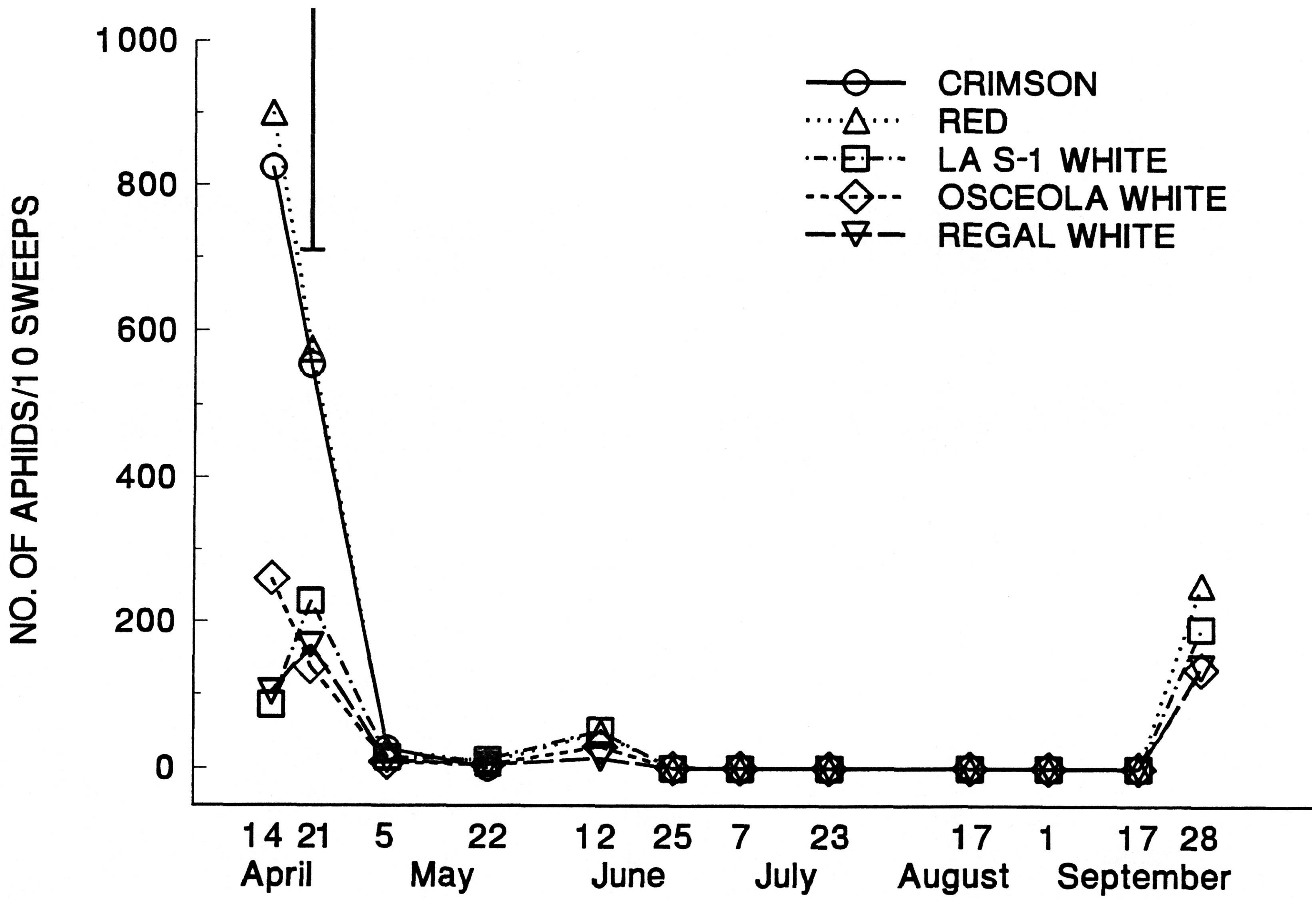
Fig. 15. Damsel bug populations on legumes during 1992. Vertical bars represent the protected LSD value, 5% level.

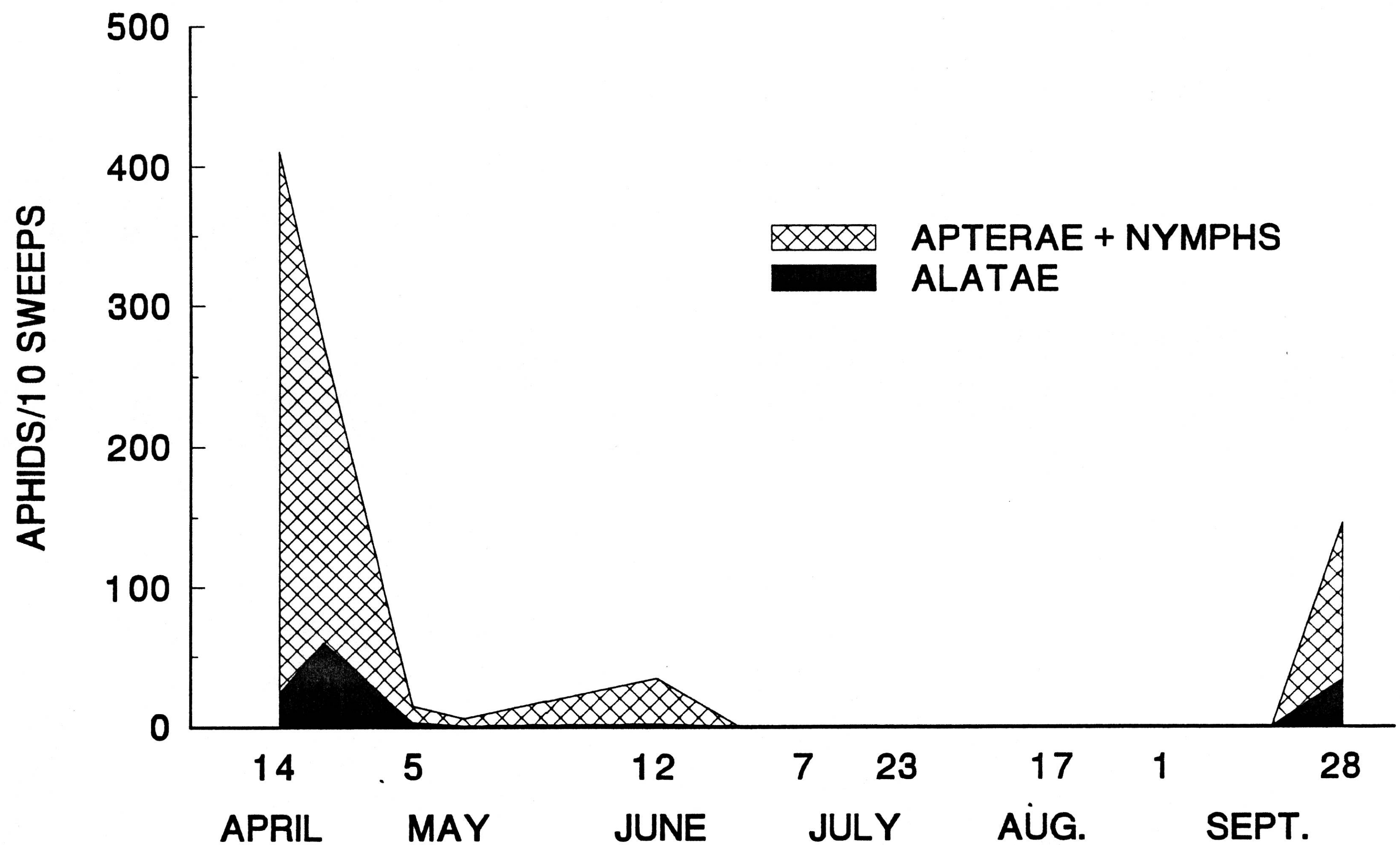
Fig. 16. Damsel bug populations on legumes during 1993. Vertical bars represent the protected LSD value, 5% level.

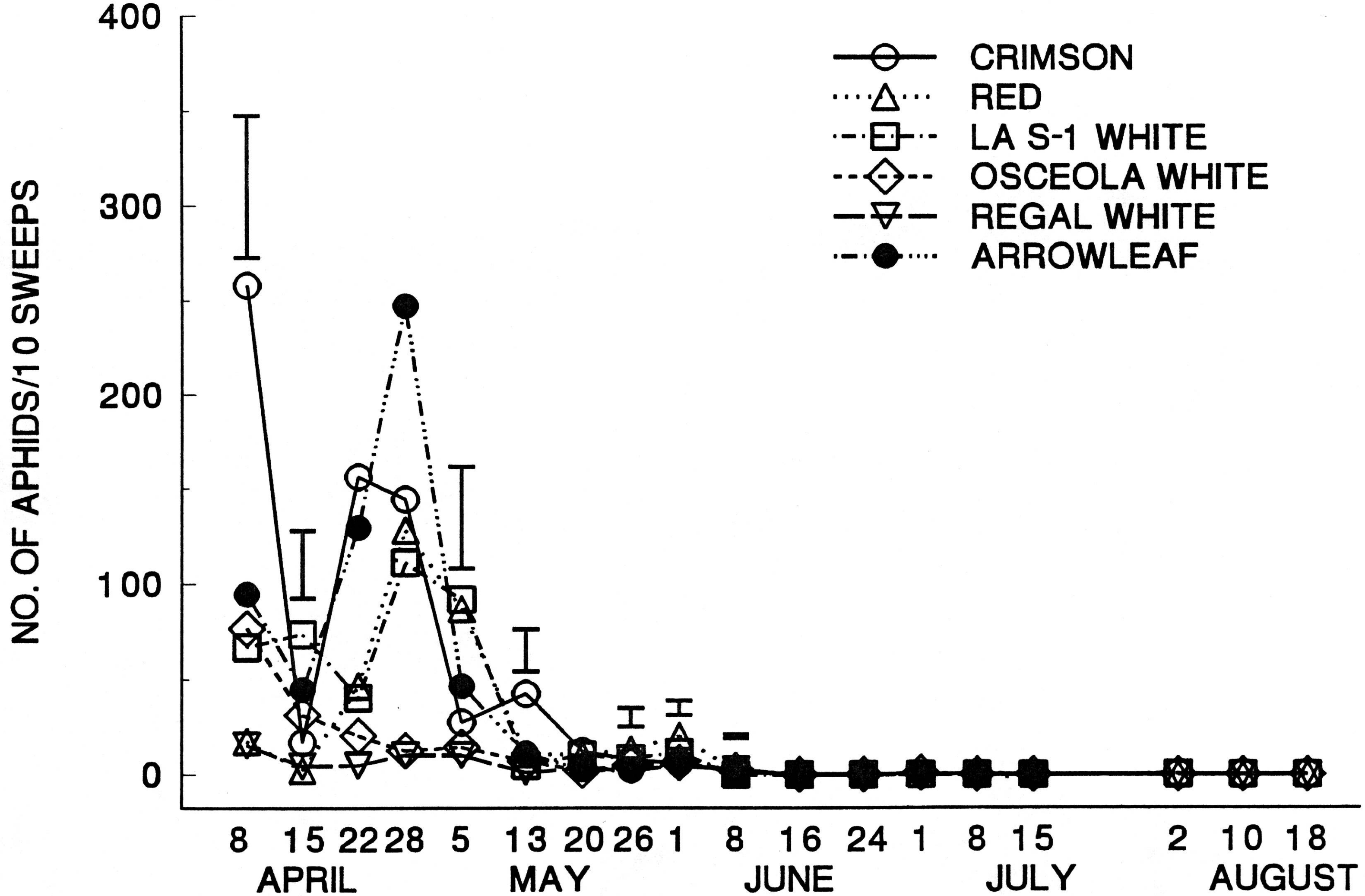


NO. OF APHIDS/10 SWEEPS
1800
1500
1200
900
600
300
0
11
19
29
7
14
29
April
May
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
ROSE
SUBTERRANEAN
VETCH

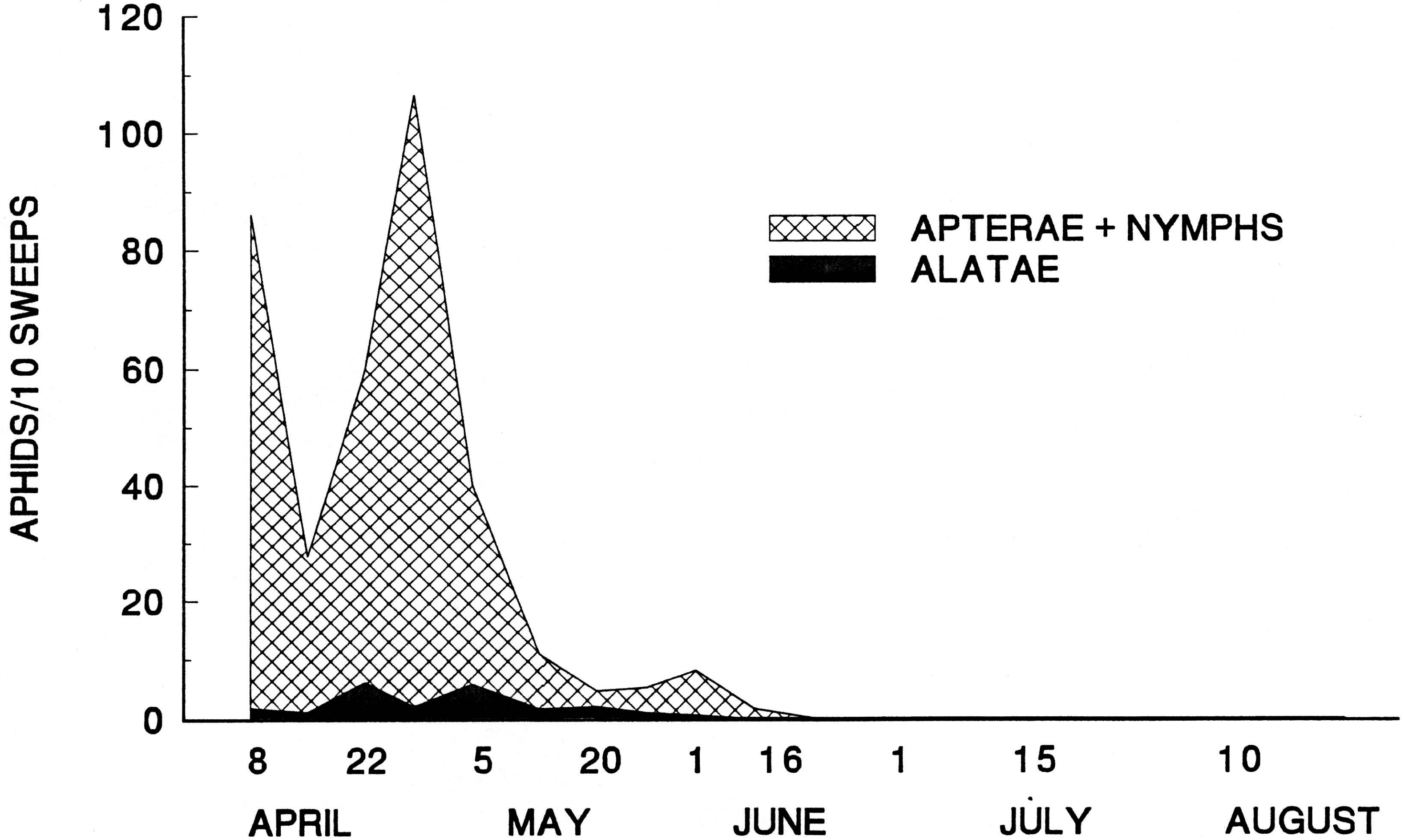

APTERAE + NYMPHS
ALATAE
APHIDS/10 SWEEPS
400
300
200
100
0
11
19
29
7
14
29
APRIL
MAY

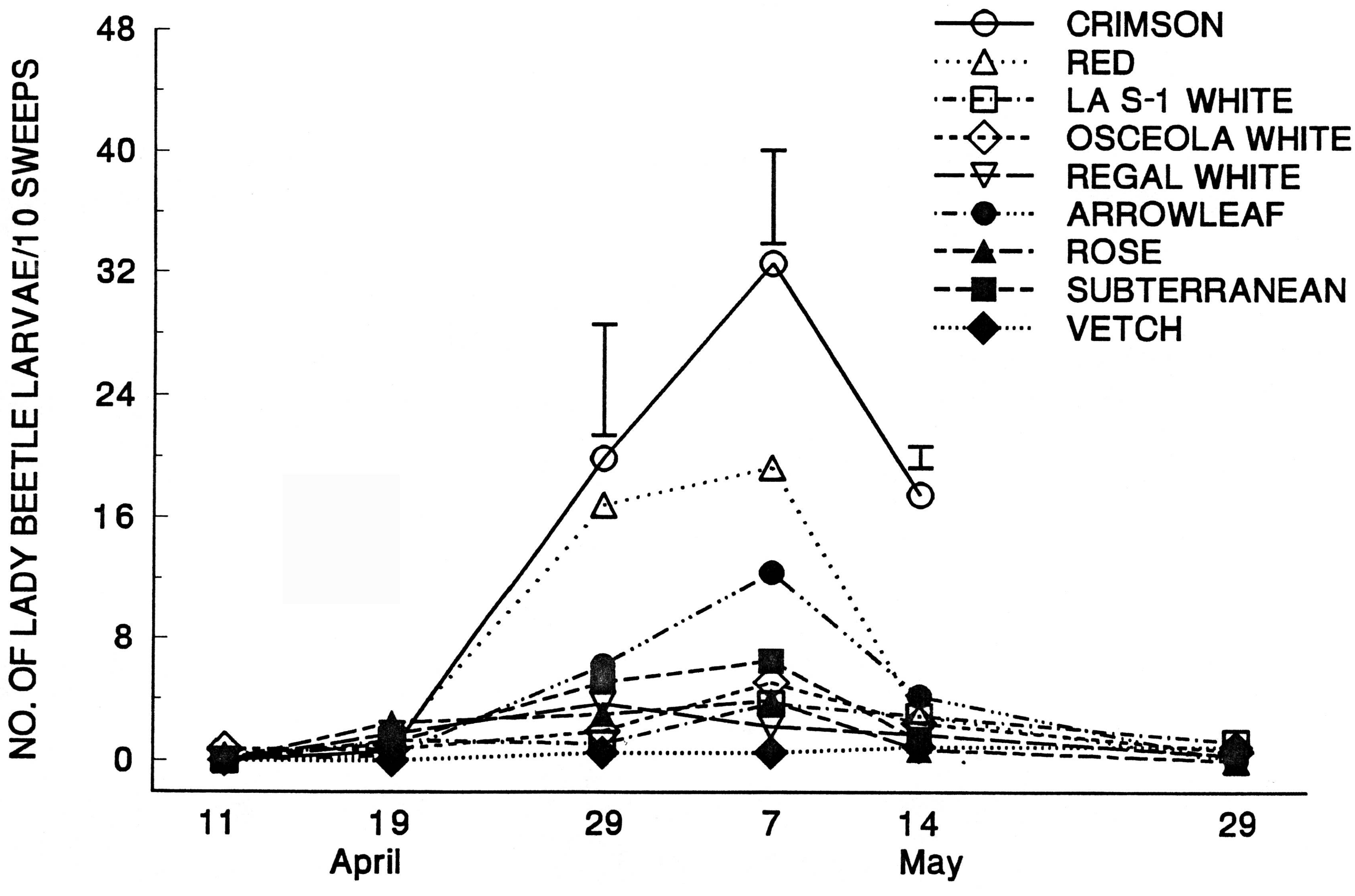

NO. OF APHIDS/1 0 SWEEPS
1000
800
600
400
200
0
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
14 21
April
5
May
22
12
June
25
7
July
23
17
August
1
17 28
September


APHIDS/10 SWEEPS
500
400
300
200
100
0
APTERAE + NYMPHS
ALATAE
14
5
12
7
23
17
1
28
APRIL
MAY
JUNE
JULY
AUG.
SEPT.

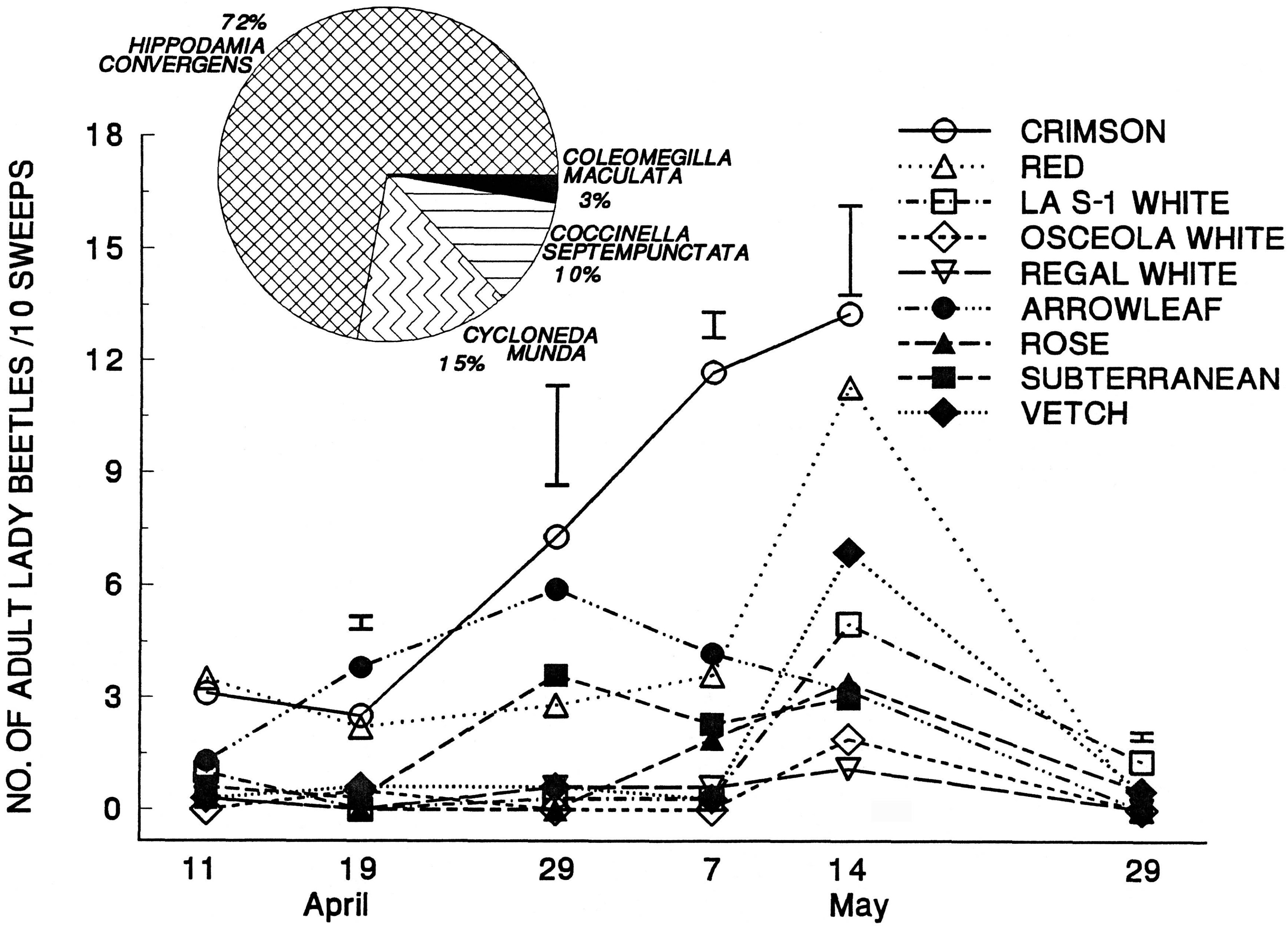


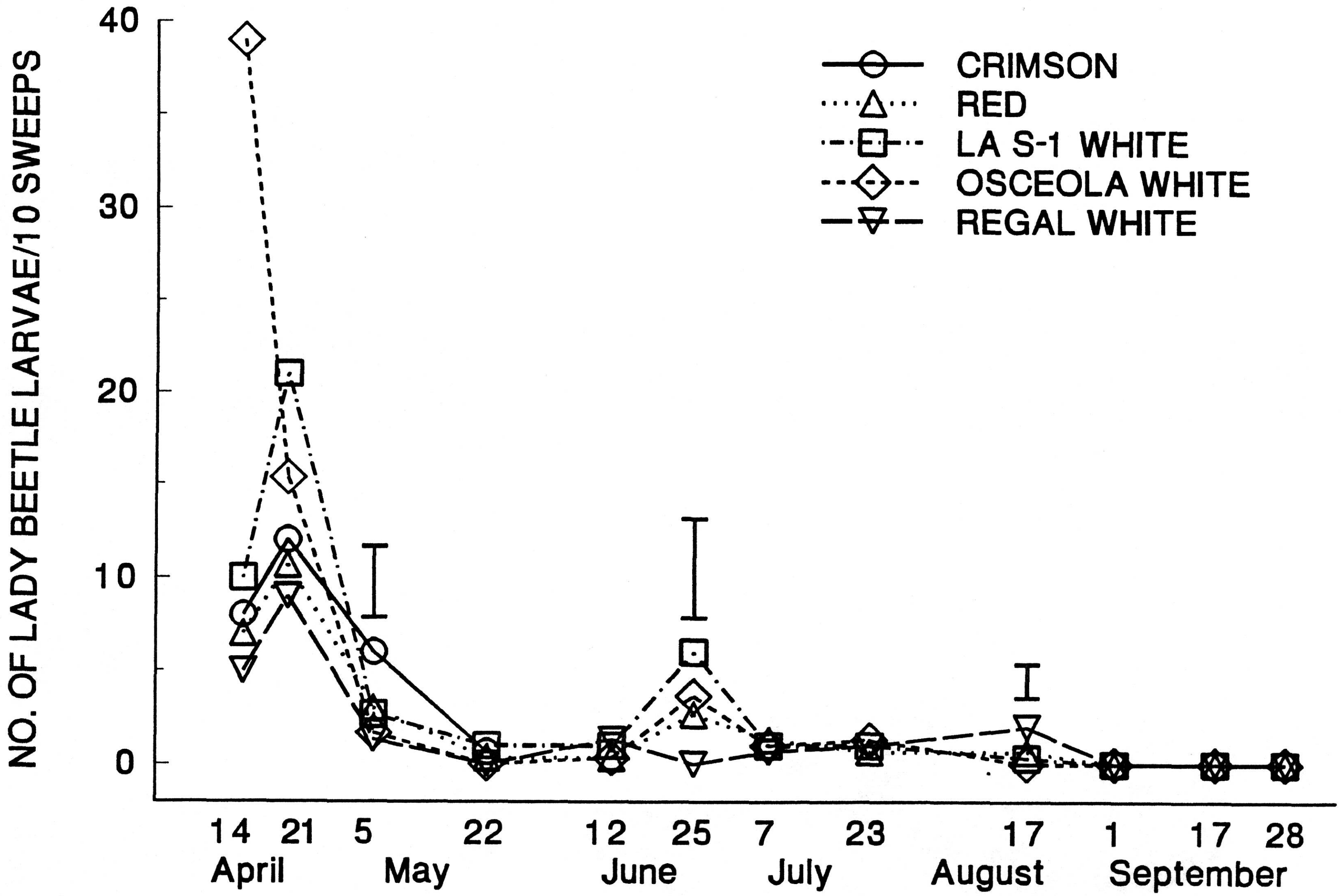
NO. OF APHIDS/10 SWEEPS
400
300
200
100
0
8 15 22 28 5 13 20 26 1 8 16 24 1 8 15 2 10 18
APRIL
MAY
JUNE
JULY
AUGUST
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF

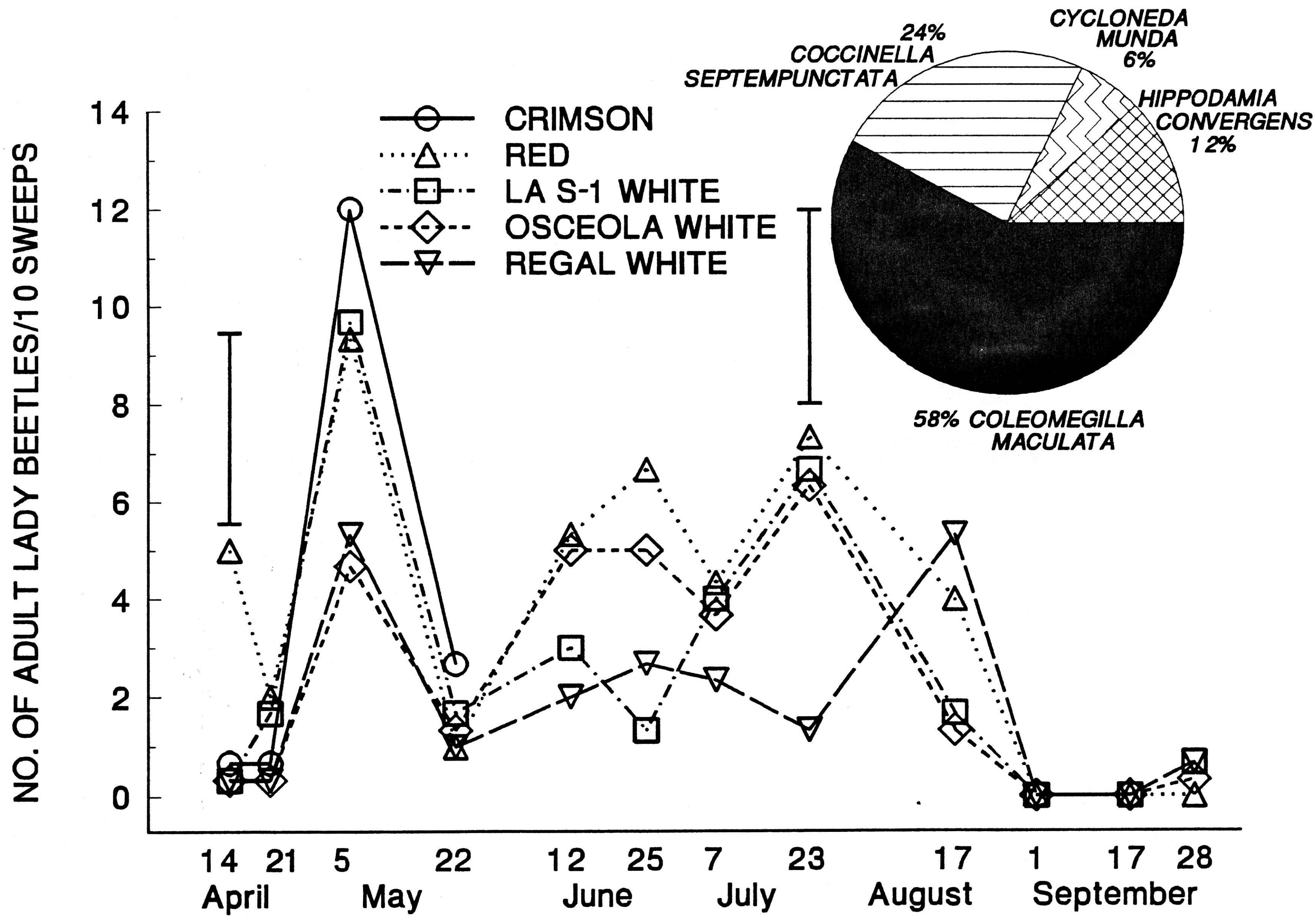

APHIDS/1 0 SWEEPS
120
100
80
60
40
20
0
APTERAE + NYMPHS
ALATAE
8
22
5
20
1
16
1
15
10
APRIL
MAY
JUNE
JULY
AUGUST



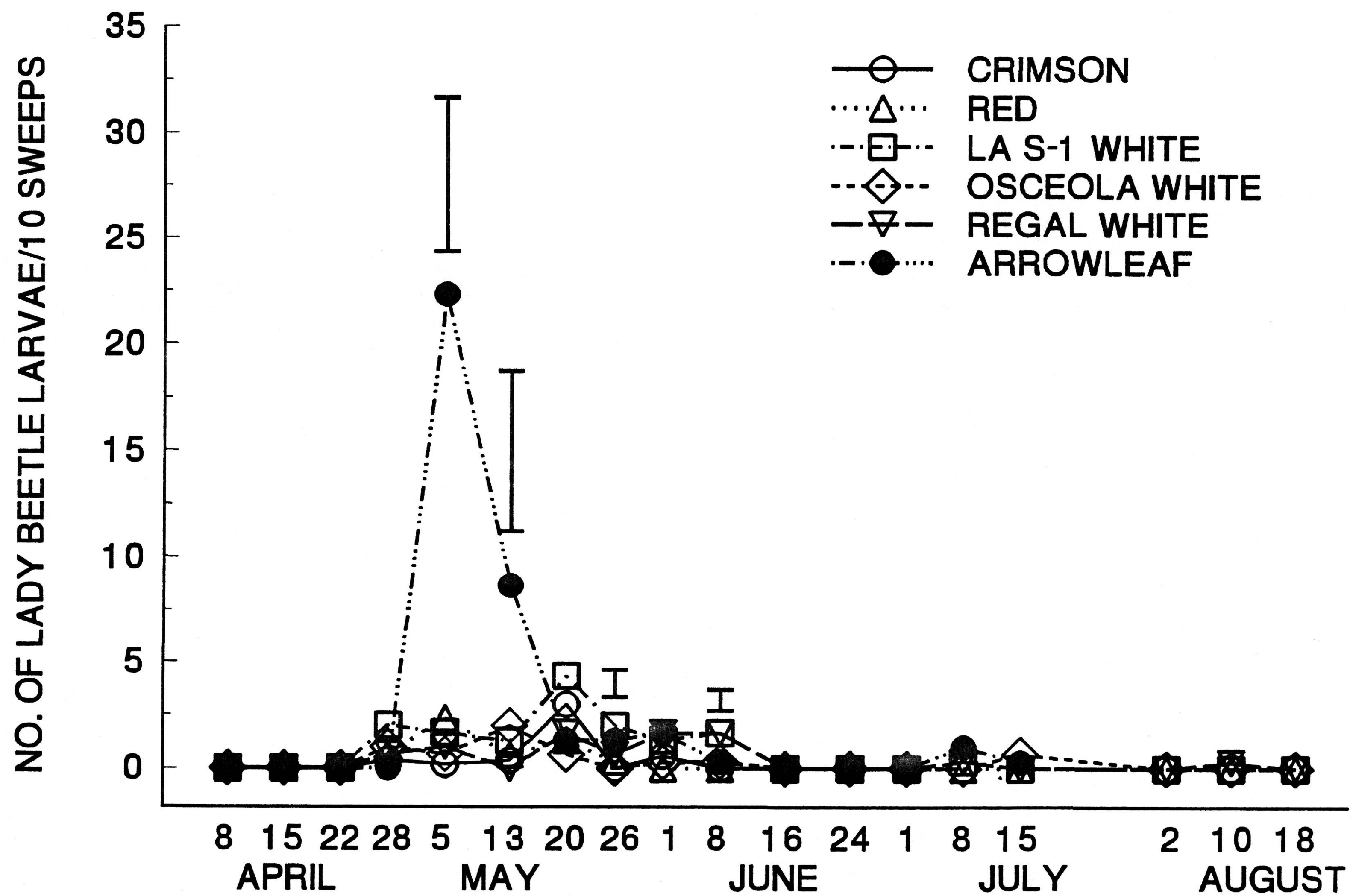
NO. OF LADY BEETLE LARVAE/10 SWEEPS
48
40
32
24
16
8
0
11
19
April
29
7
14
May
29
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
ROSE
SUBTERRANEAN
VETCH

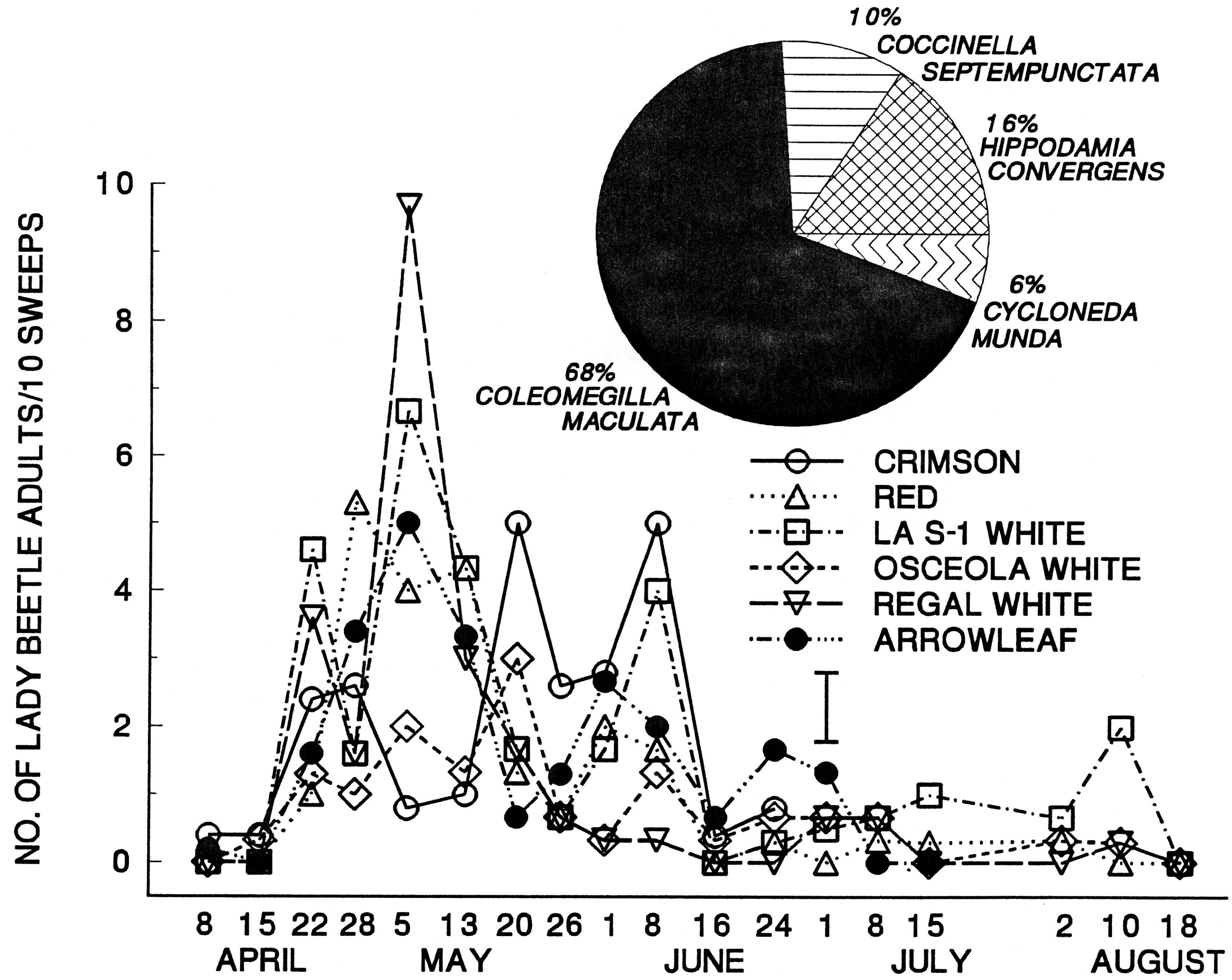

72%
HIPPODAMIA CONVERGENS
COLEOMEGILLA MACULATA
3%
COCCINELLA SEPTEMPUNCTATA
10%
CYCLONEDA MUNDA
15%
NO. OF ADULT LADY BEETLES /10 SWEEPS
18
15
12
9
6
3
0
11
19
April
29
7
14
May
29
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
ROSE
SUBTERRANEAN
VETCH


NO. OF LADY BEETLE LARVAE/10 SWEEPS
40
30
20
10
0
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
14 21 5 22 12 25 7 23 17 1 17 28
April May June July August September

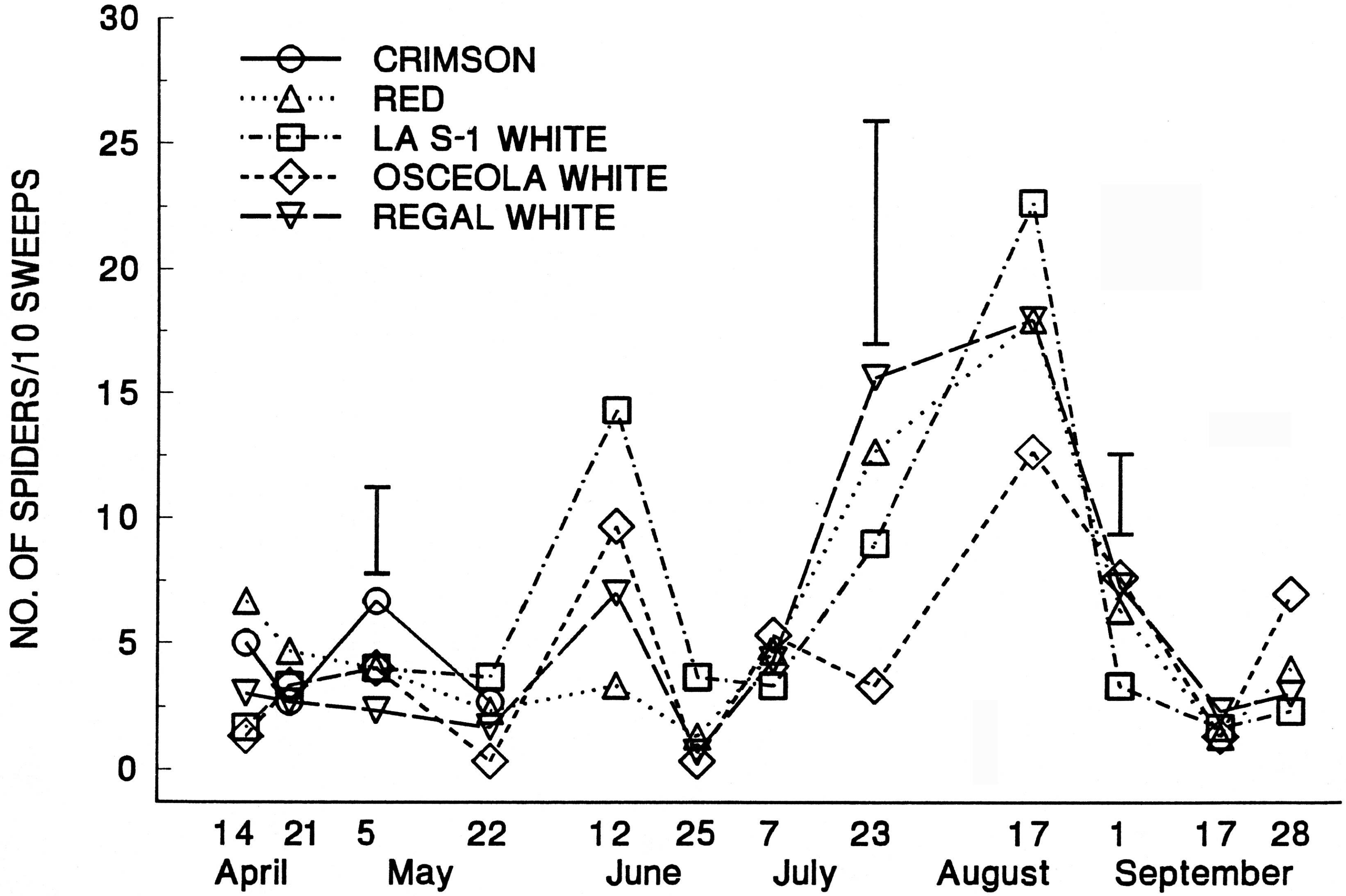


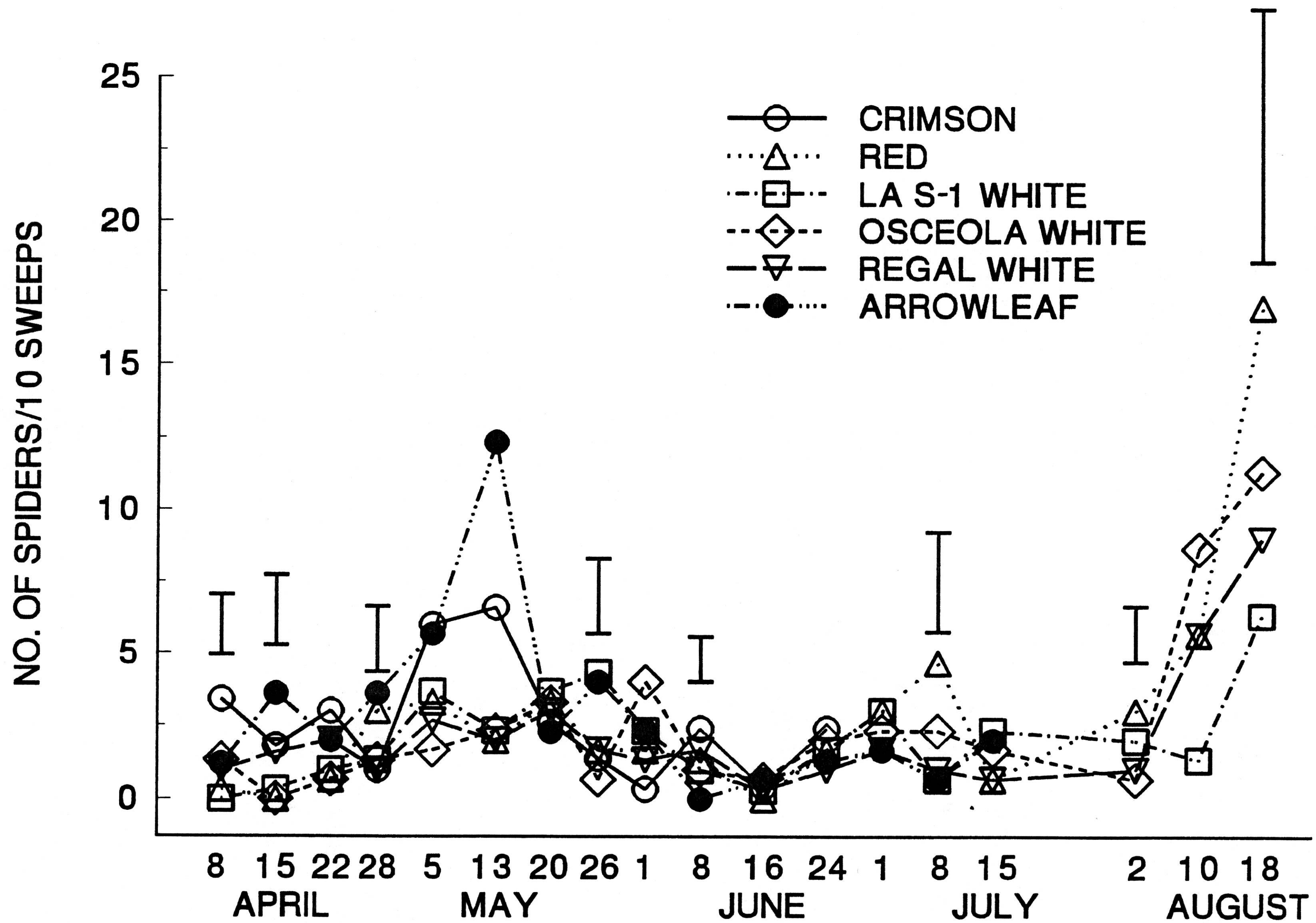
NO. OF ADULT LADY BEETLES/10 SWEEPS
14
12
10
8
6
4
2
0
14
21
5
22
12
25
7
23
17
1
17
28
April
May
June
July
August
September
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
24%
COCCINELLA
SEPTEMPUNCTATA
CYCLONEDA
MUNDA
6%
HIPPODAMIA
CONVERGENS
1 2%
58% COLEOMEGILLA
MACULATA

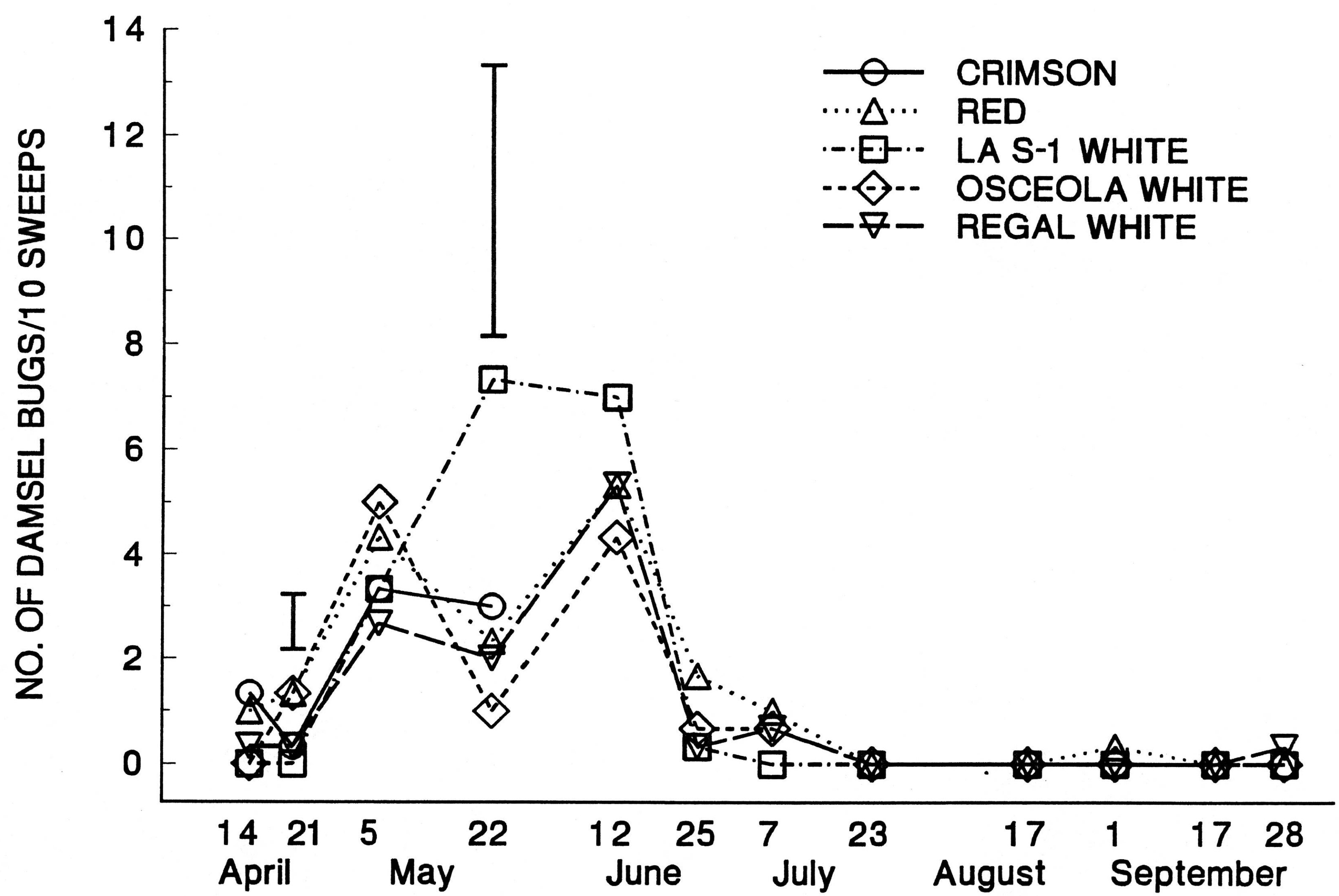

NO. OF LADY BEETLE LARVAE/10 SWEEPS
35
30
25
20
15
10
5
0
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
8 15 22 28 5 13 20 26 1 8 16 24 1 8 15 2 10 18
APRIL
MAY
JUNE
JULY
AUGUST

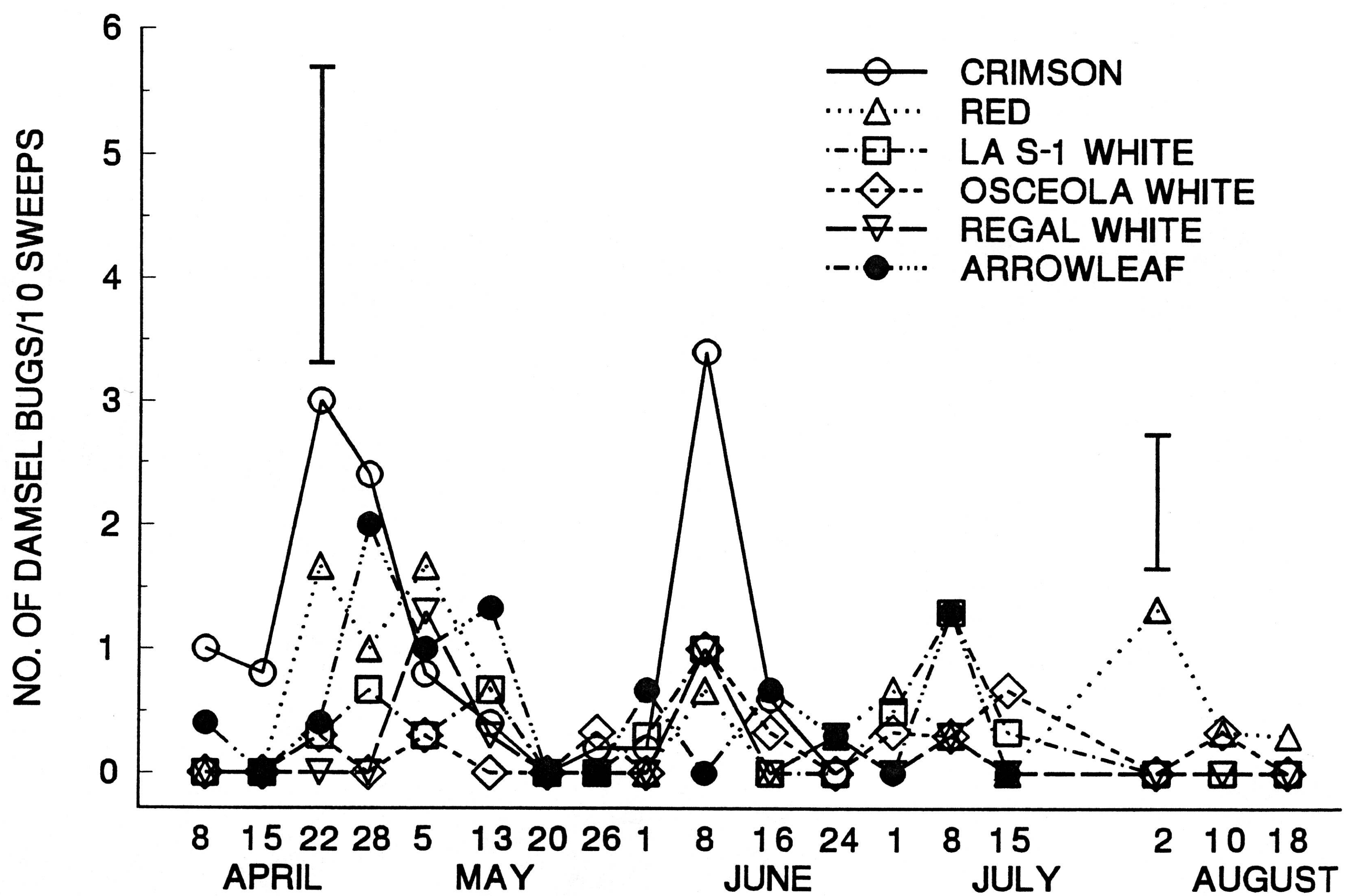


NO. OF LADY BEETLE ADULTS/10 SWEEPS
0
2
4
6
8
10
8 15 22 28 5 13 20 26 1 8 16 24 1 8 15 2 10 18
APRIL
MAY
JUNE
JULY
AUGUST
10%
COCCINELLA SEPTEMPUNCTATA
16%
HIPPODAMIA CONVERGENS
6%
CYCLONEDA MUNDA
68%
COLEOMEGILLA MACULATA
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF


NO. OF SPIDERS/10 SWEEPS
30
25
20
15
10
5
0
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
14 21 5 22 12 25 7 23 17 1 17 28
April May June July August September


NO. OF SPIDERS/10 SWEEPS
0
5
10
15
20
25
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
8 15 22 28
APRIL
5 13 20 26
MAY
1 8 16 24
JUNE
1 8 15
JULY
2 10 18
AUGUST


NO. OF DAMSEL BUGS/10 SWEEPS
0
2
4
6
8
10
12
14
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
14
21
5
22
12
25
7
23
17
1
17
28
April
May
June
July
August
September


NO. OF DAMSEL BUGS/10 SWEEPS
0
1
2
3
4
5
6
CRIMSON
RED
LA S-1 WHITE
OSCEOLA WHITE
REGAL WHITE
ARROWLEAF
8 15 22 28 5 13 20 26 1 8 16 24 1 8 15 2 10 18
APRIL
MAY
JUNE
JULY
AUGUST