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ANNUAL RESEARCH REPORT TO THE ALMOND BOARD
Project Year 1992

Project No. 91-ZG2- (a) Relationship of Irrigation and N fertilization to Occurrence of Hull Rot
(b) Survey of Mycoflora Inhabiting Almond Fruit and Leaves
(c) Bloom Disease Control
(d) Effect of Shot Hole Infection on Almond Fruit

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A. Relationship of Irrigation Cut-off Date to Occurrence of Hull Rot

Objectives:

1) Determine the relationship of various irrigation and nitrogen fertilization regimes on natural occurrence of hull rot.

2) Observe the effect of these same irrigation and fertilization practices on loosening of the hull.

3) Determine the effect of inoculum concentration and hull loosening on severity of hull rot caused by *Rhizopus stolonifer*.

4) Same as (3) but using *Monilinia fructicola*.

Hull rot develops in late summer and causes death of fruiting wood and small branches. It is most severe on vigorous, heavily-cropped Nonpareil trees. The disease results from infection of the hull by any of these fungi: *Monilinia fructicola*, *M. laxa* (the brown rot fungi), *Rhizopus stolonifer*, or *R. arrhizus* (bread mold fungi). *R. stolonifer* and *M. fructicola* are the most frequent incitants of hull rot. Hulls are susceptible to infection as soon as they begin to split. The fungi enter through the natural opening, invade the inner hull surface and apparently produce a toxin that is transported into the spur or twig causing death of those tissues.

The incidence of hull rot may be reduced by reducing the interval

between hull split and harvest (early harvest). Chemical control of the disease is not available and most likely will not be an acceptable option. Manipulation of cultural practices may prove to be the best chance for management of this disease.

GENERAL PROCEDURES

Kearney Agricultural Center

Experiments were conducted on Nonpareil almond trees grown at the Kearney Agricultural Center. These trees were 16 years old and uniformly flood-furrow irrigated.

Nitrogen trials--The details of this experimental design may be found in the report by Dr. Steve Weinbaum who is the principle investigator. Generally, there are six treatments: control, oat cover crop, clover cover crop and 125, 250, and 500 lbs N per year. There are four replications of these six treatments in a randomized complete block design. The experiment utilizes cultivar Nonpareil and is located in two orchards in Stanislaus County.

Irrigation experiment--The details of this experiment may be found in the report by Dr. Terry Prichard who is the principle investigator The experiment uses cultivar Nonpareil planted at the Delta College agricultural area in San Joaquin County. The treatments include two levels of deficit irrigation applied as mid and late season stresses, a plant based irrigation schedule and a full ET treatment as control. There are four replications in a completely randomized designed.

Inoculum

The fungi used were isolates of *R. stolonifer*, *M. fructicola* and *M. laxa* obtained from almond. They were grown on acidified potato dextrose agar (aPDA) and inoculum was prepared by collecting spores in sterile deionized water containing a wetting agent (Tween 20). Spore concentration was adjusted to 10^3, 10^4, and 10^5 spores/ml, and an average of .25 to .50 ml inoculum was delivered to each test fruit using an artists air brush. Percent germination was measured by counting germinated conidia in three groups of 100 conidia sown onto three aPDA plates and incubated at room temperature for 8 to 12 hours. Percent germination ranged from 87 to 100 percent.

Inoculation of fruit

Twenty-five fruit associated with healthy leaves, per replication, were inoculated for each treatment. All fruit were removed from the tree preceding harvest. Each fruit was examined for presence of lesions, pathogens identified and leaves associated with each fruit were scored as dead or alive.

Effect of hull split size on infection was examined by inoculating fruit having small, medium and large hull splits. Small split hulls were fully and firmly attached to the pedicel, medium hulls had begun to dehisce and large split hulls were separated by at least half of the circumference of the attachment area of the hull. Hulls of each size were inoculated with *R. stolonifer* and *M. fructicola* at 10^4 conidia per ml using an artists airbrush. The experiment was conducted twice.

Effect of inoculum concentration on infection was examined by inoculating fruit with small hull splits with each of the three fungi at concentrations of 10^3, 10^4, and 10^5 conidia per ml using an artists airbrush.

Nitrogen and irrigation trials--Natural infection was evaluated at each location by counting the number of strikes and estimating the inches dead wood in each tree soon after harvest. A random sample of fruit beneath each tree was collected and 100 fruit per treatment examined for presence of lesions an the hull rot pathogen identified.

RESULTS

Hull split size--Similar percentages of hulls were infected regardless of split size but percentage dead leaves decreased as hull size (and therefore attachment) decreased (Table 1). *R. stolonifer* and *M. fructicola* infected hulls equally but *M. fructicola* caused greater percentage leaf death.

Inoculum concentration--No differences in percent infected hulls occurred among the three pathogens or the three inoculum concentrations (Table 2). *M. laxa* caused the greatest leaf death followed by *M. fructicola* then *R. stolonifer*. Percent leaf death was not affected by inoculum concentration.

Nitrogen trials--Number strikes per tree and estimated inches dead wood increased with increasing levels of applied nitrogen in one orchard (number 1) but not the other (number 2) (Table 3). The percentage infected hulls increased with increasing levels of nitrogen only for *R. stolonifer* in orchard 1.

Irrigation trial--No differences among treatments were measured for number strikes per tree (Table 4). Significantly higher percentages *R. stolonifer* were found in hulls collected from beneath trees watered at 70% ETc and 30% ETc + 20% postharvest than the other treatments. Incidence of *M. fructicola* did not differ among treatments.

DISCUSSION

Hull split size, or more likely the degree of attachment of the hull to the tree, played a large role in the amount of damage

caused by hull rot. Hulls firmly attached when infected resulted in greater leaf death, presumably because the toxin was translocated to the leaves and shoots. The amount of inoculum at the time of infection did not appear to affect the amount of leaf death thus reduction of inoculum may not be a factor in disease control (unless of course inoculum could be reduced below some unidentified critical level). The brown rot fungi caused more damage that *Rhizopus*, and in these tests *M. laxa* was the most effective in causing leaf death. Fortunately, *M. laxa* also is the least common incitant of hull rot.

The nitrogen trials were preliminary to the beginning of experiments next year. It is encouraging that differences in natural infection were measured in the orchard in which leaf nitrogen levels also were detected.

The incidence of hull rot was too low to produce reliable counts in the Delta College irrigation experiment. Inoculations of fruit next year should provide better results.

Overall, the results of this season's work helped confirm information gathered inthe irrigation cut-off experiments and to affirm several aspects of the techniques used. We thus are better equipped to begin the work next year.

Note: We will begin work on objective 2 (effect of irrigation and nitrogen regimes on hull loosening) next year. No work was done on this objective in 1992.

B. Survey of Mycoflora Inhabiting Almond Fruit and Leaves

Objectives:

1) Describe the naturally-occurring mycoflora (fungi and yeasts) inhabiting almond fruit and leaves in organically and traditionally farmed orchards.

2) Monitor culture plates for occurrence of antagonistic bacteria or other microorganisms and, if found, screen against major bloom disease pathogens.

Almond culture in California includes one to several annual applications of fungicides during and shortly after bloom. The fungal diseases controlled include brown rot (Monilinia laxa), shot hole (Wilsonomyces carpophilus), green fruit rot (Botrytis cinerea), scab (Fusicladium carpophilus) and leaf blight (Hendersonia rubi). Recently, much interest has developed in organic or sustainable systems which do not include use of disease control materials. Differences in the amount of disease might be expected between organically and conventionally farmed orchards and these farming systems also may affect the population of naturally occurring microorganisms which inhabit almond

flowers and fruit. Because pathogens operate within this population of naturally occurring microorganisms, effects on the mycoflora may influence pathogens and disease development. Furthermore, biological control agents may be present which could aid in disease control.

We monitored populations of fungi and yeasts on flowers and fruit of almond trees grown using organic and conventional farming practices. Our objective was to detect differences in the mycoflora populations on these tissues between the two orchards and to identify any bacterial or fungal antagonists that might be present.

PROCEDURES

The observations were made in two commercial almond orchards in Merced County, California. The orchards were adjacent (separated by a county road), planted with alternate rows of cultivars Nonpareil and Carmel, flood irrigated and had cover crops. Irrigation water was drawn from wells and canals and contained about 100 units of nitrogen per four acre-feet of water. The conventionally farmed orchard (conventional orchard) was planted in 1978, regularly pruned, fertilized with composted chicken manure, treated annually with one zinc nutrient spray and one dormant application of copper, oil and diazinon and one or two bloom sprays of Rovral. The tree rows were strip sprayed with herbicide and the cover crop consisted of annual bluegrass, clover, filaree, and chickweed, and reached a height of 8 to 12 inches before mowing. The organically farmed orchard (organic orchard) was planted in 1980, lightly pruned every few years and was not fertilized or treated with other nutrients or pesticides. The cover crop was primarily vetch and ripgut brome with some chickweed and mustard, and attained a height of 18 to 24 inches prior to mowing.

Each orchard was divided into four quadrants, each quadrant containing five rows each Nonpareil and Carmel, each row was ten trees long. Every other Carmel tree was tagged (twenty five trees per quadrant), and samples were collected from these trees at approximately three-week intervals, beginning at petal fall and ending in mid July. Fifty fruit (two per tree) and 100 leaves (four per tree) per quadrant were collected in plastic bags and transported to the laboratory. Within two hours of collection, samples were placed in plastic wash bottles, covered with 100 to 500 mls sterilized deionized water to which 0.1ml per 100 ml wash water of 0.1% tween 20 was added, and shaken on a rotary shaker for 30 minutes. Three 10-fold serial dilutions were made of the wash water and 0.1 ml of each dilution spread over each of three acidified potato dextrose agar culture plates. Similar aliquots of the most dilute wash water were seeded onto three nonacidified potato dextrose agar culture plates to detect presence of antagonistic bacterial growth. Plates were incubated at room

temperature (20 to 23C) for 5 to 7 days. Fungal and yeast colonies were counted on plates of the dilution that produced the greatest number of discrete colonies. The average number of colonies from the three plates of that dilution was used to calculate the number of propagules per fruit. Rainfall data were obtained from a weather station operated at Cressey, California, approximately ten miles from the orchards.

Disease assessments were made by examining trees for symptoms of brown rot or green fruit rot in April and May during routine sample collections. Sample fruit were inspected each collection date for symptoms of shot hole and scab. Severity of shot hole was measured by counting the number of spots per fruit and leaves were rated as healthy, moderately or severely infected. Scab was evaluated by calculating the percent diseased fruit.

RESULTS

Cladosporium was the most common fungal genus found and yeasts were the most numerous members of the populations on fruit on leaves in both orchards (Table 5 and 6). Other fungal genera encountered frequently were *Alternaria, Aspergillus* and *Penicillium*. *Botrytis, Stemphyllium, Epicoccum,* and *Mucor*, were present infrequently. There were fewer fungi and yeasts on leaves than on fruit. Populations were very low at the beginning of the growing season and increased through mid July. Shot hole incidence on leaves and fruit was greater in the organic than in the conventional orchard; scab incidence was about the same (Table 7). Brown rot was not observed in either orchard.

Naturally-occurring antagonists were not observed on the bacterial or fungal agar media plates at any collection date.

DISCUSSION

The mycoflora populations in the two orchards were remarkably similar in number and composition. This has been true for the three years we have sampled the orchards. In 1992, fewer fungal genera were observed than in previous years. The conventional grower has altered his cultural practices to more closely approximate the practices of the organic grower and the increase in insect and spider activity in his orchard was very apparent. The single application of Rovral during bloom is the remaining pesticide used by the conventional grower; the lower incidence of shot hole in the conventional orchard may be attributed to this treatment.

That we did not find any antagonists during the course of these collections is both surprising and disappointing. However, collections mae more for the direct purpose of finding such microorganisms may prove more fruitful for this endeavor.

C. Bloom Disease Control

Objectives:

1) Evaluate several treatment programs for control of bloom diseases and effects on yield.

Bloom diseases, brown rot, shot hole and jacket rot, occur in years or areas of high spring rainfall and can cause serious loss in yield. Usually, fungicide efficacy trials examine the effects of individual materials on one disease. Although this provides much needed information about the activity of the fungicides and aids in decisions on which materials are useful in combating which diseases, most growers apply more than one fungicide during a season. There are several registered materials and thus several possible combinations to choose from. Our intent with this experiment was to compare the disease control capabilities and effects on yield of several combinations of treatments that might be used by growers.

PROCEDURES

The experiment is located in a commercial orchard in Kern County. The trees are mature, about 10 years old, and are planted 1 Merced:2 Nonpareil:1 Mission:2 Nonpareil. Six fungicide combinations were selected on the basis that any may be expected to provide some control of the three major bloom diseases and all the materials are registered. The combinations and a nontreated control comprised seven treatments which were replicated four times and arranged in a randomized complete block design. There were approximately 50 Merced and 100 Nonpareil trees pre replication (one and two rows of Merced and Nonpareil, respectively). Trees will be treated with the same materials every year for five consecutive years, beginning in 1989. Disease and yield measurements are taken each year.

RESULTS

No significant differences among treatments were found in pounds nutmeats per tree (Table 9). Shot hole incidence was significantly greater in the nontreated controls but differences among treatments did not occur. Brown rot was present in the Merced cultivar but at extremely low levels.

Combined analysis of the data taken over the four years also shows no differences in yield among treatments (Table 9). However, trends in shot hole control emerge: the Kocide-Captan-Captan-Captan, Topsin+Captan-Rovral-Ziram and Captan-Captan-Captan have numerically superior disease control followed by Rovral-Rovral-Ziram and Rovral-Rovral-Rovral. The Kocide dormant followed by only two bloom treatments of Rovral was the poorest treatment aside from the nontreated control. There was a

significant increase in the amount of shot hole over time.

DISCUSSION

The final year of this project will be 1993. If rains occur during the critical stage of fruit development perhaps we will be able to measure differences in yield then. The cumulative data on shot hole incidence may nonetheless point to good choices for bloom disease control programs.

D. Effect of Shot Hole Infection on Almond Fruit

Objectives:

1) Determine the stage of fruit development susceptible to susceptible to damage by the shot hole fungus.

2) Determine the importance on inoculum density on fruit infection and damage.

Shot hole, caused by the fungus *Wilsonomyces carpophilus* (aka *Stigmina carpophila*), produces lesions on leaves, fruit and occasionally young shoots of almond trees. When severe, leaf drop ensues, which may lead to fruit drop and chronic weakness. Fruit may bear many lesions on the hull without sustaining any apparent damage. Gumming is associated with fruit infection, but often the nutmeats of fruit with gumming hulls are healthy. The direct effect of shot hole infection on fruit has not been investigated.

PROCEDURES

The experiments were conducted on cultivar Mission almond trees at the Kearney Agricultural Center, Parlier, California. An environment of free moisture on fruit surfaces, a condition favorable to infection, was provided using an automatic misting system. Mist was produced for 1 to 5 minutes (longer periods were needed in late spring) at 10 to 15 minute intervals for 48 hours unless otherwise specified. Although some run-off from leaves was observed, in most instances the fruit surfaces were wet but water did not drip.

The fungus was grown on acidified potato dextrose agar for four to six weeks. On the day of inoculation, conidia were collected in sterile deionized water and concentrations adjusted to 10^3, 10^4, and 10^5 conidia/ml. Two 1.5 percent water agar plates were seeded with 0.1 ml of the 10^4 conidial concentration and incubated for 24 to 48 hours at room temperature. The number of germinated conidia in three groups of 100 were counted. Germination ranged from 83 to 98 percent.

Approximately 0.50 and 1.00 ml of inoculum was applied to young

fruit and expanded fruit, respectively, using a hand-held hand pump spray bottle. These inoculum concentrations and a noninoculated control comprised the treatments in each experiment. There were four replications, one in each of the four quadrants of a tree, 55 to 60 fruit per replication. These were located on one to three branches depending upon availability of fruit. Misting began immediately after inoculation. The length of 20 fruit taken randomly from the experimental tree was measured at each inoculation date. Test trees were located in one row, and one tree, randomly assigned, was used on each inoculation date. Inoculated fruit were observed weekly for evidence of infection, and on 19 June, remaining fruit were counted, and shot hole lesions counted on ten fruit from each replication.

RESULTS

Fruit drop was significantly greater in inoculated than in noninoculated treatments on 30 March an 7 April when average fruit length was 18 to 20 mm (Table 10). The highest inoculum concentrations, 10^5 conidia per ml, resulted in the greatest fruit drop on 23 March and 7 April when average fruit length was 15 and 20 ml, respectively. A linear relationship among the three inoculum concentration levels occurred on 23 March and 7 April but not on 30 March. The number of lesions per fruit differed significantly on 23, 30 March and 7 April for inoculated versus noninoculated controls, 10^5 conidia per ml versus the lower inoculum concentrations and for linerarity among the inoculum concentration levels.

The percentage fruit remaining decreased significantly as durations of the wetness period and inoculum concentration increased (Table 11).

DISCUSSION

Fruit were susceptible to increased drop when inoculated with the shot hole fungus shortly after emergence from the jacket and drop was generally greater where the highest inoculum concentration was used. In previous work, the susceptible period was about two weeks long and encompassed the time when fruit were approximately 15 to 30 mm in length. In 1992, the time span during which fruit were vulnerable extended for three weeks, but fruit did not expand as rapidly this year. This was followed by a substantial growth spurt which was accompanied by reduced fruit drop. In general, more fruit dropped in the experiment this year than in previous years. The overall effect was not as dramatic in 1992 as in 1990 but the pattern remained the same: young fruit wee vulnerable to increased drop when challenged with high levels of inoculum.

Table 1. Effect of hull split size on infection of almond hulls and leaf death inoculated with two hull rot pathogens. Cultivar Nonpareil, Kearney Agricultural Center, 1992.

	Avg. % Infected hulls	Avg. % Dead leaves	Avg. % Healthy leaves
Size			
small	60.1	46.0	45.5
medium	71.0	34.4	47.5
large	65.1	19.5	58.2
Pathogen			
Monilinia fructicola	73.3	47.8	33.7
Rhizopus stolonifer	83.7	32.3	53.0
Control	39.2	19.8	64.5
Inoculation			
Date 1	68.1	34.8	50.0
Date 2	62.7	31.8	50.8
Significance of F, P =			
Date	.034	-	-
Size	.072	.000	.005
Pathogen	.000	.000	.000
Date X size	.048	.260	.051
Date X pathogen	.220	.003	.000
Size X pathogen	.93	.000	.000
Date X size X pathogen	.141	.075	.328

Table 2. Effects of inoculum concentration on infection of almond hulls and leaf death inoculated with three hull rot pathogens. Cultivar Nonpareil, Kearney Agricultural Center, 1992.

	Avg. % Infected hulls	Avg. % Dead leaves	Avg. % Healthy leaves
Pathogen			
Monilinia fructicola	76.1	45.8	26.5
Monilinia laxa	82.5	59.7	22.8
Rhizopus stolonifer	76.8	38.3	30.0
Concentration			
10^5	83.9	46.8	30.3
10^4	75.2	45.3	27.8
10^3	76.3	51.7	24.2
Inoculation Date			
1	82.7	49.0	22.1
2	74.3	46.9	32.8
Significance of F, P =			
Inoculation Date	.131	-	179
Pathogen	.110	.000	.040
Concentrate	.029	.283	-
Date X pathogen	-	-	-
Date X concentration	.140	-	-
Pathogen X concentration	.180	.170	-
Date X pathogen X concentration	.039	.155	.355

Table 3. Natural incidence of hull rot in trees fertilized with varying amounts of nitrogen. Cultivar Carmel, Stanislaus County, 1992.

Nitrogen	Avg. Number strikes per tree		Avg. Inches dead wood per tree	
	Orchard 1	Orchard 2	Orchard 1	Orchard 2
Control	22.5	62.0	0	23.0
Oats	21.2	67.7	4	21.5
Clover	20.7	46.7	0	22.5
125 N	19.7	92.2	5.5	63.5
250 N	36.2	181.7	6.2	109.2
500 N	34.5	191	5.5	241

Treatment	Avg. Percent hulls infected with Monilinia		Rhizopus		Either or Both Fungi	
	Orch 1	Orch 2	Orch 1	Orch 2	Orch 1	Orch 2
Control	10.5	7.8	6.5	28.3	17.0	35.3
Oats	17.5	6.2	4.2	26.7	21.8	33.0
Clover	9.7	10.3	6.7	20.8	16.5	31.0
[illegible] N	8.5	5.0	10.7	19.5	19.2	24.5
250 N	7.7	8.5	14.2	27.5	22.0	36.0
500 N	8.8	13.8	16.5	23.8	22.8	37.5
liner P	NS	NS	++	NS	NS	NS

Table 4. Effect of several deficit irrigation regimes on incidence of hull rot. Cultivar Nonpareil, San Joaquin County, 1992.

Treatment	Average Percent Hulls Rotted	*M. fructicola*	*R. stolonifer*	Average # strikes per tree
100% ET_c	7.0	1.7	6.5	5.2
70% ET_c	14.0	1.0	13.7	4.5
50% ET_c + 20% postharvest	1.5	0.7	7.0	2.5
50% ET_c	2.0	0.7	1.5	2.7
30% ET_c + 20% postharvest	13.7	0.0	13.7	3.2
Plant indicated ($\simeq$ 67% ET_c)	5.3	1.7	4.8	4.3
P =	+++	NS	+++	NS

Table 5. Survey of mycoflora inhabiting almond fruit. Merced County, 1992.

Avg. Number ($X10^5$) colony-forming units/fruit

ORGANIC

Date Collected	Alt.	Asp.	Clad.	Pen.	Other	Yeast	Total Total fungi	Total fungi & yeast
3/10	0	0	1.16	0	.015	5.65	1.175	6.825
4/1	0	0	46.0	0	1.49	399.9	47.49	447.39
4/20	.083	0	26.29	.083	0.166	297.9	26.62	324.52
5/11	.1033	0	23.74	0	0.207	155.5	24.05	179.55
6/2	9.38	0	161.88	4.158	3.13	1489.2	178.55	1667.75
6/25	10.31	17.81	145.0	0	32.72	799.4	205.84	1005.24
7/14	3.13	0	1125.9	0	0	2235.7	1129.03	3364.73

TRADITIONAL

Date Collected	Alt.	Asp.	Clad.	Pen.	Other	Yeast	Total fungi	Total fungi & yeast
3/10	.01005	0	.467	.005	.0199	28.81	.50195	29.312
4/1	0	0	33.5	0	0.505	581.45	34.005	615.455
4/20	.25	0.083	17.09	0	0.334	308.18	17.757	325.937
5/11	.2065	.1034	18.96	0	0.5203	255.22	19.7902	275.01
6/2	0	0	155.0	3.128	2.1	2983.48	160.228	3143.708
6/25	10.31	.1034	83.44	0	11.483	1966.63	105.336	2071.966
7/14	13.53	0	725.03	0	0	2971.9	738.56	3710.46

200 fruit/orchard, cultivar Carmel
Alt. = *Alternaria*
Asp. = *Aspergillus*
Clad. = *Cladosporium*
Pen. = *Penicillium*

Table 6. Survey of mycoflora inhabiting almond leaves. Merced County, 1992.

Avg. Number ($X10^5$) Colony-Forming Units/Leaf

ORGANIC

Date Collected	Alt.	Asp.	Clad.	Pen.	Other	Yeast	Total fungi	Total fungi & yeast
3/10	.0017	0	3.32	.055	0.3534	3.993	3.6784	7.6714
4/1	0	0	3.01	0	1.017	98.0	4.027	102.027
4/20	0	0	2.43	0	0.298	87.4	2.728	90.128
5/11	0.1	0	3.70	0	0.067	38.54	3.867	42.407
6/2	3.65	0	23.47	.165	0.33	366.0	27.615	393.615
6/25	0	1.34	213.5	0	40	537.7	218.84	756.54
7/14	0.83	0	213.5	0	0.83	397.7	215.16	612.86

TRADITIONAL

Date Collected	Alt.	Asp.	Clad.	Pen.	Other	Yeast	Total Total fungi	fungi & yeast
.0	.0017	0	.110	.0017	0.0134	3.27	0.1251	3.3951
4/1	0	0	3.0	0	0.5	94.49	3.5	97.99
4/20	.017	0	1.67	0	.083	88.35	1.77	90.12
5/11	.034	0	1.41	0	.05	45.34	1.494	46.834
6/2	0	0	27.17	0	0	533.2	27.17	560.37
6/25	.17	1.17	33.35	0	1.0	316.9	35.69	352.59
7/14	.83	0	56.0	0	0	112.7	56.83	169.53

200 fruit/orchard, cultivar Carmel
Alt. = *Alternaria*
Asp. = *Aspergillus*
Clad. = *Cladosporium*
Pen. = *Penicillium*

Table 7. Incidence of shot hole and scab in organic and conventional orchards. Cultivar Carmel, Merced County, 1992.

	Disease Evaluation							
	ORGANIC				TRADITIONAL			
	Leaves		Fruit		Leaves		Fruit	
	% disease	# spots	% disease	# spots	% disease	# spots	% disease	# spots
Shot Hole (20 Apr)	18.2	.36	15.5	0.44	.05	.01	3.0	0.04
Scab (14 July)	8.0	-	-	-	13.5	-	-	-

200 fruit and 400 leaves/orchard

Table 8. Comparison of several disease control programs for effects on yield and efficacy. Kern County, 1992.

MERCEDS

Treatment	Nutmeats per tree, lb.	% healthy fruit April	% healthy fruit June	No. lesions per fruit April	No. lesions per fruit June	Brown rot strikes/plot April
Kocide-Captan-Captan-Captan	24.11	97.0 a	83.5 a	.08 b	.41 b	1.7 b
Topsin+Captan-Rovral-Ziram	24.11	95.5 a	84.3 a	.11 b	.39 b	2.0 b
Captan-Captan-Captan	20.66	95.8 a	81.1 a	.11 b	.47 b	1.2 b
Rovral-Rovral-Ziram	18.60	94.7 a	81.3 a	.21 b	.51 b	2.0 b
Rovral-Rovral-Rovral	22.79	87.0 a	81.0 a	.52 b	.64 b	4.7 ab
Kocide-Rovral-Rovral	17.93	85.5 a	69.0 a	.62 b	1.30 b	5.8 ab
Control	22.93	25.2 b	16.0 b	10.51 a	9.06 a	7.5 a
P =	N.S.	.000	.000	.000	.000	.035

NONPAREIL

Treatment	Nutmeats per tree, lb	% healthy fruit April	% healthy fruit June	No. lesions per fruit April	No. lesions per fruit June
Kocide-Captan-Captan-Captan	13.08	95.8 a	75.8 a	.11 d	0.8 b
Topsin+Captan-Rovral-Ziram	14.29	95.3 a	75.8 a	.12 b	0.8 b
Captan-Captan-Captan	9.53	92.8 a	72.8 a	.18 d	1.1 b
Rovral-Rovral-Ziram	13.63	92.5 a	80.2 a	.22 b	0.8 b
Rovral-Rovral-Rovral	12.31	83.0 ab	75.2 a	.61 bc	1.30 b
Kocide-Rovral-Rovral	12.11	74.2 b	62.5 a	1.81 c	2.10 b
Control	14.08	44.5 c	28.0 b	4.80 a	8.35a
P =	N.S.	.000	.001	.000	.002

Treatments:
Kocide 101 applied delayed dormant. All other materials applied, in the order given, at 5-10% bloom, full bloom to petal fall and five weeks after petal fall; treatments timed for Nonpareil bloom. All treatments made with airblast sprayer by the grower.

Disease data:
30 April: shot hole and brown rot
19 June: shot hole

Table 9. Comparison of several bloom disease control programs for control of shot hole. Kern County, 1989-1992.

Treatment	Average % healthy fruit		Average no. lesions/fruit	
	Merced	Nonpareil	Merced	Nonpareil
Kocide-Captan-Captan-Captan	91.3 a	92.5 a	0.28 d	0.24 c
Topsin + Captan-Rovral-Ziram	91.2 ab	92.3 a	0.24 d	0.25 c
Captan-Captan-Captan	89.9 abc	91.7 a	0.31 d	0.31 c
Rovral-Rovral-Ziram	83.8 abcd	86.0 ab	0.61 cd	0.72 b
Rovral-Rovral-Rovral	81.9 abcd	83.7 ab	0.83 bc	0.82 b
Kocide-Rovral-Rovral	75.5 cd	77.6 b	1.11 b	1.34 b
Control	40.9 e	57.4 c	5.25 a	3.93 a
Year				
1989	87.1	96.1	0.85	0.32
1990	94.8	97.1	0.16	0.08
1991	64.0	71.6	2.10	1.77
1992	71.0	67.2	1.83	2.18
Significance of F from Factor analysis of variance and contrasts (for year).				
Treatment	.000	.000	.000	.000
Year	.000	.000	.000	.000
Linear	.000	.000	.000	.000
eatment vs. year	.000	.000	.000	.000

Kocide 101 8.0 lbs/acre
Captan 50W 8.0 lbs/acre
Rovral 50W 1.0 lbs/acre
Ziram 76W 8.0 lbs/acre

laterials applied by air-carrier ground rig, 80 gpa.

pplications made in late January (dormant) 5-10% bloom, full bloom to petal fall and five eeks after petal fall; applications timed for Nonpareil bloom.

hot hole evaluations made each year in late May or early June. 100 fruit/plot, 10 fruit from ach of 10 trees/plot.

Table 10. Effect of shot hole infection of almond fruit on fruit drop. Cultivar Mission, Kearney Agricultural Center, 1992.

Fruit length, mm when inoculated:	9.5 16 Mar	15.2 23 Mar	18.4 30 Mar	20.1 7 Apr	31.5 14 Apr	33.2 21 Apr	34.1 28 Apr	33.9 5 May
	Average percent fruit remaining 19 June							
Conidia/ml								
10^5	16.7	20.2	33.6	33.2	41.5	55.4	62.5	62.7
10^4	22.2	38.2	31.3	42.8	51.8	54.8	54.9	56.6
10^3	27.2	44.1	38.6	45.9	54.4	50.7	54.6	64.2
Control	20.4	44.8	57.0	56.5	61.4	59.5	66.5	65.9
Significance of F from analysis of variance and contrasts:								
Treatment	NS	NS	+	++	NS	NS	NS	NS
Treatment vs.								
Control	.072	NS	++	++	NS	NS	NS	NS
Linear	NS	+	NS	+	NS	NS	NS	NS
10^5 vs. 10^4 and 10^3	NS	+	NS	+	NS	NS	NS	NS
	Average number lesions/fruit 19 June							
10^5	1.2	6.4	15.6	24.1	3.7	4.6	0.6	0.6
10^4	0.1	3.1	6.0	11.5	1.6	3.0	0.4	1.7
10^3	0.4	3.4	3.4	10.8	2.1	2.8	0.1	1.2
Control	0.3	0.3	0.5	3.3	1.1	1.7	0.1	0.6
Significance of F from analysis of variance and contrasts:								
Treatment	NS	+++	++	++	NS	NS	NS	NS
Treatment vs.								
Control	NS	+++	++	++	NS	NS	NS	NS
Linear	NS	++	+	+	NS	NS	+	NS
10^5 vs. 10^4 and 10^3	NS	++	+	+	NS	NS	NS	NS

Four replications of 55-60 fruit each, each replication located in one of the four quadrants of a tree. Immediately after inoculation, treated areas were misted for 48 hours.

All fruit remaining in each replication were counted on 19 June. Ten fruit from each replication were collected and number lesions per fruit counted.

Table 11. Effect of wetness period on drop of almond fruit inoculated with *Wilsonomyces carpophilus* (shot hole fungus). Cultivar Mission, Kearney Agricultural Center, 1992.

Conidia/ml	Average Percent fruit remaining 19 June
10^6	21.7
10^4	30.3
Control	42.6
P = 0.05	+
Wetness period	
8 hr	37.7
24 hr	33.1
48 hr	23.7
P = 0.05	+++

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KEARNEY AGRICULTURAL CENTER
9240 South Riverbend Avenue
Parlier, California 93648
(209) 891-2500

August 18, 1993

Ms. Susan McCloud
Almond Board of California
1104 12th Street
Modesto, CA 95354

Dear Susan:

Enclosed please find our report on the dust (PM_{10}) study we performed at Steffan Ranch in Fresno County in 1992. This report was forwarded to Dr. Flocchini at Davis some time ago, for inclusion with his report to you (since our Almond Board funding in 1992 was a subcontract with the Davis group). I am sending this directly to you since you recently indicated that there had been some delay in receiving the combined report from Davis.

Please note that the PM_{10} concentrations and total fluxes to the atmosphere in this current version have been revised downward slightly since we sent the original report to Dr. Flocchini. This corrects a small error in subtracting background from the filter weights. The conclusions are unchanged, but the older version (should you receive it from Davis) is no longer valid and should be discarded.

Our 1993 study is going well and I hope to see you in the orchard in the next few weeks. Give me a call if I may provide further information.

Sincerely,

Dave Grantz

David A. Grantz
Air Quality Specialist

DAG/dcm

Enclosure

Particulate Exchange (PM_{10} and $PM_{2.5}$) Between the Atmosphere and an Almond Orchard: An Agrometeorological Approach

Fresno County, October 8-22, 1992

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Summary

PM_{10}, or respirable particulate matter, is a serious health risk and degrades visibility. The San Joaquin Valley currently violates federal and state PM_{10} standards. We investigated the effect of an almond orchard on PM_{10} levels by measuring transport of PM_{10} between the upper canopy of an orchard in Fresno County and the atmosphere. The total flux of PM_{10} during the day was determined from bulk eddy diffusivity (derived with a Bowen ratio-energy balance technique), gravitational setting rate (derived from particle diameters) and the distribution of PM_{10} concentrations above the canopy (determined using sequential filtration). This daily flux of 2.75×10^5 $\mu g\ m^{-2}\ day^{-1}$ (9 am-5 pm) was dominated by turbulent diffusion processes, and was upward from canopy to atmosphere. These results may be valid only for the post-harvest period when leaves are particularly dusty. The measured particle fluxes represent a tiny contribution to the San Joaquin Valley air basin PM_{10} levels.

Introduction

Respirable atmospheric particles, ranging from 0-10 μm in aerodynamic diameter (PM_{10}), have been recognized as an environmental pollutant with harmful effects on human health and visibility. Concentrations of PM_{10} have increased during recent years in the San Joaquin Valley of California, where agricultural practices may contribute significantly to ambient PM_{10} levels. Regulations established and under consideration by the United States Environmental Protection Agency and the California Air Resources Board, to measure and control atmospheric PM_{10} concentrations, have made it necessary for the agricultural industry to assess which farming-related activities and managed environmental factors contribute to emissions of PM_{10}, and which may contribute to deposition and removal of PM_{10}.

Large acreages of the San Joaquin Valley are planted to permanent tree or vine crops, and it has been suggested that the large leaf surface areas in orchards and vineyards may act as a sink for fine atmospheric particulates transported from upwind or generated on the orchard floor, effectively decreasing the level of PM_{10} in the atmosphere. Leaves act as a surface for deposition of particulates, as confirmed by visual examination of any leaf surface. Dust deposition onto leaves is likely a function of both leaf and canopy characteristics and environmental conditions. Dust emission from leaves to the atmosphere depends on environmental conditions and the degree of dust loading. An annual dust or PM_{10} budget for an almond orchard requires assessment throughout the growing season, from the time of leaf expansion, when leaves are free of dust, through the (dust-generating) harvest period, and beyond to leaf-fall.

The objectives of this limited study were to assess the exchange of PM_{10} between an almond orchard and the atmosphere during the period immediately following harvest.

Theoretical background

By measuring net radiation, soil heat flux, and temperature and water vapor pressure at two heights, we calculate surface sensible and latent heat fluxes and their bulk eddy diffusivities, using the Bowen ratio-energy balance technique (Bowen, 1926). Flux of particles to or from the almond canopy surface (an imaginary plane near the top of the canopy) can then be calculated from knowledge of 1) median particle diameter (to enable calculation of a sedimentation velocity), 2) eddy diffusivity for water vapor for estimation of the eddy diffusivity for particles, 3) mean particle concentration, and 4) the gradient in particle concentration above the canopy. The gravitational sedimentation and turbulent eddy transport are added together to calculate total PM_{10} flux.

Materials and Methods

Site description

The experiment was conducted between 8 October and 22 October, 1992 in Fresno County in an almond orchard (cv. 'Mission' and cv. 'Thompson'; Steffen Ranch) located on Jensen Avenue 8 miles west of State Route 99. The instrument tower was located approximately 20 m inside the East (downwind) edge of the orchard along West Lawn road, 1 mile South of Jensen Avenue. The orchard was mature (20 yrs.), with a mean canopy height of 6.3 m. Length of upwind fetch from the tower was greater than 1500 m.

Instrumentation

Sensors were installed on a 9.25 m triangular radio mast (Universal Mfg. Co., Warren, MI). All micrometeorological sensors were controlled and data collected and processed with a datalogger (Model 21X; Campbell Scientific Inc., Logan UT). Data were stored in solid state storage modules (SM192; Campbell Scientific Inc., Logan, UT).

Micrometeorological instrumentation. The Bowen ratio was determined using the system packaged by Campbell Scientific. The water vapor gradient above the canopy was measured with a single chilled mirror dew point hygrometer (Model Dew-10, General Eastern Corp., Watertown, MA). Air was drawn continuously from 0.5 m and 2.5 m above the mean canopy height of 6.3 m (6.8 m and 8.8 m above ground level), through inverted 25 mm filter holders fitted with 25 mm teflon filters (1 μm nominal pore size). These filters were changed twice per week. A pump, powered by a deep cycle 12 V marine battery, aspirated the system and drew the air through mixing reservoirs and through the chilled mirror. Every 120 s the sampling air was switched from one height to the other by a solenoid valve controlled by the datalogger. The mirror was allowed to stabilize at the new dewpoint for 40 seconds, and then sampled for 80 seconds at 1 Hz for each level. Vapor pressures were calculated from dew point and reported as 20 min average differences.

The air temperature gradient above the canopy was measured at the two heights by 76 μm (.003 in) chromel-constantan thermocouples. Temperature was sampled at 1 Hz and differences (lower minus upper) between the two heights reported as 20 min average differences.

Net radiation was measured above the canopy with a Fritschen-style net radiometer (Q-6; Radiation Energy Balance Systems, Seattle, WA) at 8.85 m. Soil heat flux was measured at two locations with soil heat flux plates (HFT-1; Radiation Energy Balance Systems, Seattle, WA) and spatially averaging thermocouple probes (TCAV; Campbell Scientific Inc., Logan, UT). One soil heat flux plate was installed within, and one between, the rows of almond trees, to obtain an average representation of the area under study, at a depth of 8 cm. The TCAV was installed such that two thermocouples were used to obtain the average soil temperature above one soil heat flux plate and the other two above the second plate, at depths of 2 cm and 6 cm. The net radiometer, soil heat flux plates, and soil thermocouples were sampled

every 10 s by the datalogger, and recorded as 20 minute averages.

All micrometeorological data were averaged over 2 h periods centered at 10:00, 12:00, 14:00, and 16:00 PST. Unrealistic Bowen ratios and eddy diffusivities were excluded from averages.

Particulate sampling instrumentation. Respirable particulates were sampled over these same 2 h periods. Dichotomous samplers based on sequential filtration (stacked filter units (SFU); Cahill et al., 1977) were deployed with size-selective (<10 μm) inlets at the same heights above the canopy as those used for determining water vapor and temperature gradients.

The particle sampling system consisted of a vacuum pump (Gast model RAA-V110-EB, Gast Mfg. Corp., Benton Harbor, MI) connected to a SFU fitted with 8.0 μm and 0.4 μm (nominal pore sizes) polycarbonate filters (Nuclepore; Costar Inc., Pleasanton, CA) in series. The 8.0 μm filters were precoated with a 0.45% w/w solution of Apiezon grease and toluene (Cahill et al., 1990, Feeney et al., 1984), to give a 50% cut size of 2.5 μm when operated at 10 l min^{-1}, and to increase particle adhesion. The SFU was connected to a certified PM_{10} size-selective inlet (Rupprecht and Patashnik Co., Inc., Albany, NY) that exhibited a 50% cut size of 10 μm when operated at 16.7 l min^{-1}. The transition from 16.7 l min^{-1} to 10 l min^{-1} was accomplished with a laboratory-designed flow splitter. The 10 l min^{-1} and 6.7 l min^{-1} flows were monitored with 65 mm rotameters (model FL 3617, Omega Engineering Inc., Stamford, CT). Calibration of the rotameters was verified with mass flow controllers (Tylan model FC-261, Tylan Corp., Carson, CA). Flow through the SFU was maintained at ± 2% of the required 10 l min^{-1}, and flow through the size selective PM_{10} inlet was maintained at ± 5% of the required 16.7 l min^{-1}.

Particulate loading on the filters was determined gravimetrically from the difference in filter weight before and after exposure. Filter handling procedures followed published protocols (Feeney et al., 1984) with

the additional step of a 24-hour humidity equilibration in a controlled humidity chamber (Auto-Dessicator, Bel-Air Products, Pequannock, NJ) immediately prior to both pre- and post-weighing. All filters were weighed on a mechanical microbalance (M-5, Mettler, Inc.) to the nearest 1.0μg. Weight changes in unexposed control filters, (Feeney et al., 1984) of 40.08 ± 6.80 μg and 19.08 ± 3.35 μg (mean ± SE for 0.4 μm and 8.0 μm filters, respectively; n = 12) were subtracted from the mass gain of exposed filters.

Data presentation

For all 12 days of the experiment, 20-minute averages of each micrometeorological variable were averaged over each 2 h period (n = 72), and presented in figures as diurnal courses. The 2 h average PM_{10} and $PM_{2.5}$ concentrations from all 12 days were averaged over the same 2 h intervals (n = 12). Average (2 h) data were used to calculate all particulate fluxes.

Results

Wind speed and direction, temperature and humidity

Figure 1 presents the means and standard errors of wind direction (1A) and speed (1B) during each 2 h (daytime) period, over all sampling days. In the San Joaquin Valley, wind speeds are generally quite low. The wind speed during this experiment did not suspend large amounts of dust from soil, storage piles, roadways, etc., and extreme turbulence within the canopy was not observed. Mean wind speeds above the canopy gradually increased from 1.5 m s^{-1} in the morning to 2.5 m s^{-1} in the late afternoon.

Wind direction exhibited a consistent diurnal change, from NNW (345°) in the morning, shifting counterclockwise to NW (305°). This prevailing wind direction provided adequate upwind fetch over a uniform almond orchard for greater than 1500 m. Downwind lay a fallow field.

Relative humidity and air temperature are presented in Figures 2A and

2B. As expected, the air temperature gradually increased until late afternoon, while the relative humidity decreased, corresponding to the temperature change. These two variables exhibited consistent patterns from day to day, as represented by the relatively small standard error bars.

Energy flux

The components of the surface energy balance, required for the Bowen ratio-energy balance calculation, are presented as two-hour averages (Figures 3, 4). Incoming solar radiation and net radiation both exhibited typical "bell shaped" curves. Variations about the means were extremely small, reflecting the consistent radiation environment during the experiment, though a small amount of cloudiness was observed on a few days late in the experimental period. The net radiation between 11:00 and 13:00 was reduced slightly due to the shadowing of the net radiometer by the instrument tower (Fig. 3A).

The soil heat flux at the surface (ground heat flux, Fig. 3A) was obtained by adding the heat storage in the upper 8 cm soil, based on the soil temperature changes at 2 and 6 cm, to the soil heat flux at 8 cm. The soil heat flux obtained in this way is positive, indicating downward transfer of energy into the soil during the day. The maximum occurs around 4 pm, which is later than in many field environments, due to shading of the soil surface by the almond trees in the morning and early afternoon. Direct sunlight on the soil surface in late afternoon, when the air temperature was already high, resulted in a large temperature gradient near the soil surface, and maximum transfer of energy into the soil at this time.

Subtracting the soil heat flux from the net radiation yields the available energy in the canopy, (Fig. 3B). This available energy is partitioned into sensible heat flux (H) and latent heat flux (Le), with $H/Le=\beta$, the Bowen ratio. The sensible heat flux is maximal in the early afternoon because of strong heating of the almond canopy. The latent heat

flux increased with time in the morning and remained high during the rest of the day. The small decline in Le the early afternoon is probably attributable to a mid-afternoon decline in stomatal conductance in response to falling humidity (Grantz, 1990) which would limit evapotranspiration and increase the Bowen ratio.

Bowen ratio and bulk eddy diffusivity

The Bowen ratio (β, Fig. 4C) ranged from 0.3 in the morning to 1.1 in the early afternoon. The Bowen ratio was greatest in the early afternoon, when sensible heat flux was largest, though more energy went into latent than sensible heat flux over most of the day in this irrigated orchard.

Average and standard error values for bulk eddy diffusivities (K, Fig. 5) are presented for each two hour period. The magnitude of K indicates the efficiency of turbulent transport in the canopy. Eddy diffusivity was generally about 1.0 $m^2 s^{-1}$, with a maximum of 1.6 $m^2 s^{-1}$ between 11:00 and 13:00.

The standard errors of the Bowen ratio and bulk eddy diffusivities were small near midday, but relatively large in early morning and late afternoon. Large variation of calculated β and K during those periods resulted from small temperature and water vapor pressure gradients between the two measurement heights, which were difficult to measure accurately in the early morning and late afternoon.

Both Bowen ratio and bulk eddy diffusivity depend upon solar energy-driven transport processes, and were weakly dependent on incoming solar radiation during the day (Fig. 6).

PM_{10} mass concentration, gradient and flux

The average and standard error of particulate matter concentrations for three size ranges (0-2.5 μm, 2.5-10 μm, 0-10 μm in diameter) are shown in Fig. 7. The mass concentrations presented here are the average of

measurements made at upper and lower levels above the canopy and show a gradual decrease with increasing time of the day. The cause of this pattern remains to be clarified. The lower afternoon concentrations may result from stronger mixing processes due to surface heating, which dilute air pollutants into a thicker boundary layer at greater elevation above the almond canopy. There was consistently more mass in the smaller size range (0-2.5 μm aerodynamic diameter) than in the larger size range (2.5-10 μm diameter). The average total PM_{10} concentration reached a maximum of around 130 μg m^{-3} in the morning. The small standard errors indicate little variation from day to day. These values approach the Federal 24 h PM_{10} standard of 150 μg m^{-3}. These measured concentrations above the canopy may reflect localized resuspension from leaf surfaces, and may not reflect regional values of PM_{10}.

Figure 8 presents averages and standard errors of particulate concentration gradients for the two size ranges and for total PM_{10}. The gradients were generally negative with a few exceptions in the smaller size range (0-2.5 μm in diameter). A negative gradient means that particulate mass concentrations at the lower height (0.5 m above mean canopy height) were greater than at the upper height, indicating that the almond canopy was a weak source, rather than a sink, for PM_{10} during the measurement period.

Bulk eddy diffusivity, PM_{10} concentration, and eddy flux of PM_{10} were essentially independent of wind speed (Fig. 9) and direction (Fig. 10) over the period of observation.

Eddy particulate fluxes for two size ranges and their sum were generally positive from canopy to air, (Fig. 11). Turbulent activity and mixing caused by surface heating of the almond canopy and the atmospheric surface layer tended to dilute the particulate matter from the zone of greater concentration near the canopy (the source) into higher atmospheric zones of reduced concentration (the sink).

Gravitational settling

In addition to turbulent diffusion, the movement of atmospheric particulates is subject to gravitational settling at a rate, the terminal settling velocity (V_s), that is proportional to the square of particle diameter. We used the midpoint of each size range (1.25 μm and 6.25 μm) to approximate particle diameter in calculation of terminal settling velocity. These "typical" settling velocities are 5.36×10^{-5} m s^{-1} for smaller particles (0-2.5 μm), and 1.22×10^{-3} m s^{-1} for larger particles (2.5-10 μm).

Multiplying these settling velocities by the corresponding particulate matter concentrations (Fig. 12, open circles) yields the particulate fluxes due only to gravitational settling. The maximum possible rates of particulate gravitational settling for the three size ranges (Fig. 12, solid circles) represent the upper bound for transport by this mechanism. The fluxes for fine particles (0-2.5 μm) were only about 10% of the fluxes for larger particles (2.5-10 μm), as expected due to size and concentration differences. Generally, the magnitude of these fluxes (Fig. 12) were insignificant relative to turbulent transport (Fig. 11).

Total particulate flux

The particulate fluxes were generally positive, indicating upward transfer of particulate matter, from canopy to air (Fig. 13). The total net particulate fluxes in terms of μg m^{-2} over different lengths of time (1 s, 1 hr, 2 hr, and 8 hr respectively) between 09:00 and 17:00, are presented in Table 1. The arithmetic average of particulate fluxes for each two-hour period was used in these calculations. The almond orchard contributed relatively low levels of daytime PM_{10} emissions (275 mg m^{-2} day^{-1}).

Discussion

The behavior of the almond canopy as a source of PM_{10}, and the higher concentrations of PM_{10} at the lower levels near the canopy, may only reflect conditions immediately after the harvest, during which large amounts of dust are deposited on leaf surfaces. Resuspension of this material may occur only for a limited period. Further measurements over the entire season will be required to full evaluate the role of almond cultivation in regional PM_{10} budgets.

The limited objectives of the present study were to obtain an estimate of exchange of PM_{10}, respirable particulate matter, between an almond orchard in Fresno County and the atmosphere, and to characterize the time course and mechanism of that transport. The total contribution of PM_{10} to the airbasin during the day, 2.75×10^5 $\mu g\ m^{-2}\ day^{-1}$ (9:00-17:00) was dominated by turbulent diffusion rather than gravitational settling, and was upward from canopy to atmosphere during the post-harvest period.

Approximations and assumptions made during this study include: 1) eddy diffusivity for PM_{10} is assumed equal to that for sensible heat and water vapor; 2) eddy diffusivity for small particles is assumed equal to that for large particles; 3) night-time particle fluxes are ignored since eddy diffusivity calculated from the Bowen ratio-energy balance method is limited to periods of sunlight; and 4) arithmetic median diameter is assumed to represent each size class in the calculation of particle settling velocity. These assumptions are expected to have little impact on the conclusions.

References

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Cahill, T. A., R. A. Eldred, P. J. Feeney, P. J. Beveridge, and L. K. Wilkinson. 1990. The stacked filter unit revisited. In: Visibility and fine particles. Trans. Air Waste Mgt. Assoc. C. V. Mathai. ed.

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Table 1. Total net particulate emission from canopy surface for different time periods for three size ranges.

Duration (9am-5pm)	Total amount per meter square (μg)		
	0-2.5 μm	2.5-10 μm	0-10 μm
1 second	1.61×10^{0}	7.93×10^{0}	9.55×10^{0}
1 hour	5.81×10^{3}	2.86×10^{4}	3.44×10^{4}
2 hour	1.16×10^{4}	5.71×10^{4}	6.87×10^{4}
8 hour	4.64×10^{4}	2.28×10^{5}	2.75×10^{5}

List of Figures

Figure 9. Scatter diagrams of bulk eddy diffusivity, PM_{10} concentration and eddy PM_{10} flux against mean wind speed over the period of observation. Each data point represents a 2-hour period average.

Figure 10. Scatter diagrams of bulk eddy diffusivity, PM_{10} concentration and eddy PM_{10} flux against mean wind direction over the period of observation. Each data point represents a 2-hour period average. The convention used for wind direction is 0 and 360 represent North.

Figure 11. Daytime pattern of the average and standard error of the mean of eddy particulate flux for each 2-hour period.

Figure 12. Daytime pattern of the average and standard error of particulate gravitational settling flux for each 2-hour period. Circles and dots represent the fluxes calculated using the arithmetically averaged particulate diameters and maximum size particulate diameters for corresponding size ranges, respectively.

Figure 13. Daytime pattern of the average and standard error of total particulate fluxes, including both eddy flux and gravitational settling fluxes, for each 2-hour period.

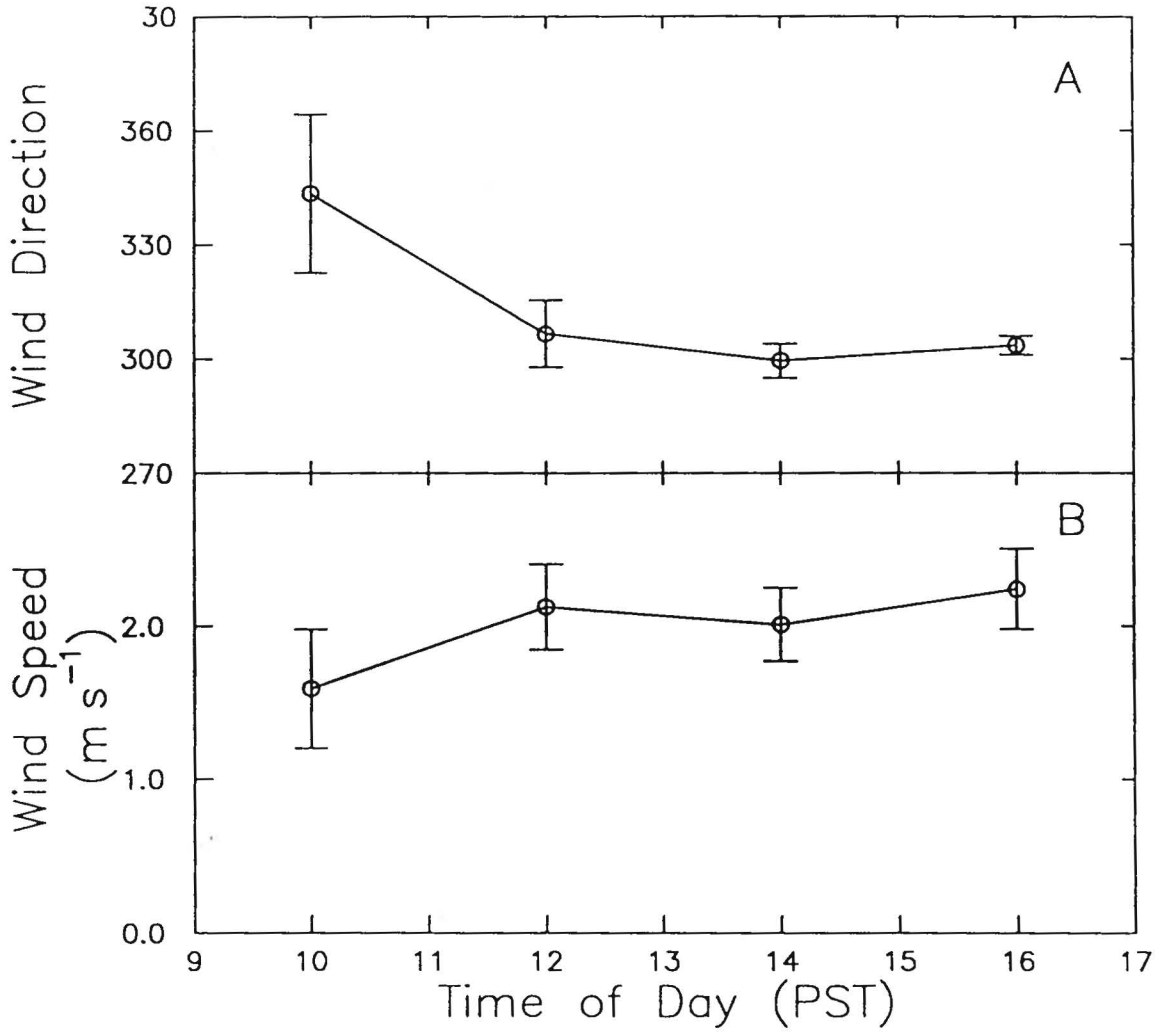

Figure 1. Daytime pattern of the average and standard error of wind speed and mean wind direction for each 2-hour period. The convention used for wind direction is 0 and 360 represent North.

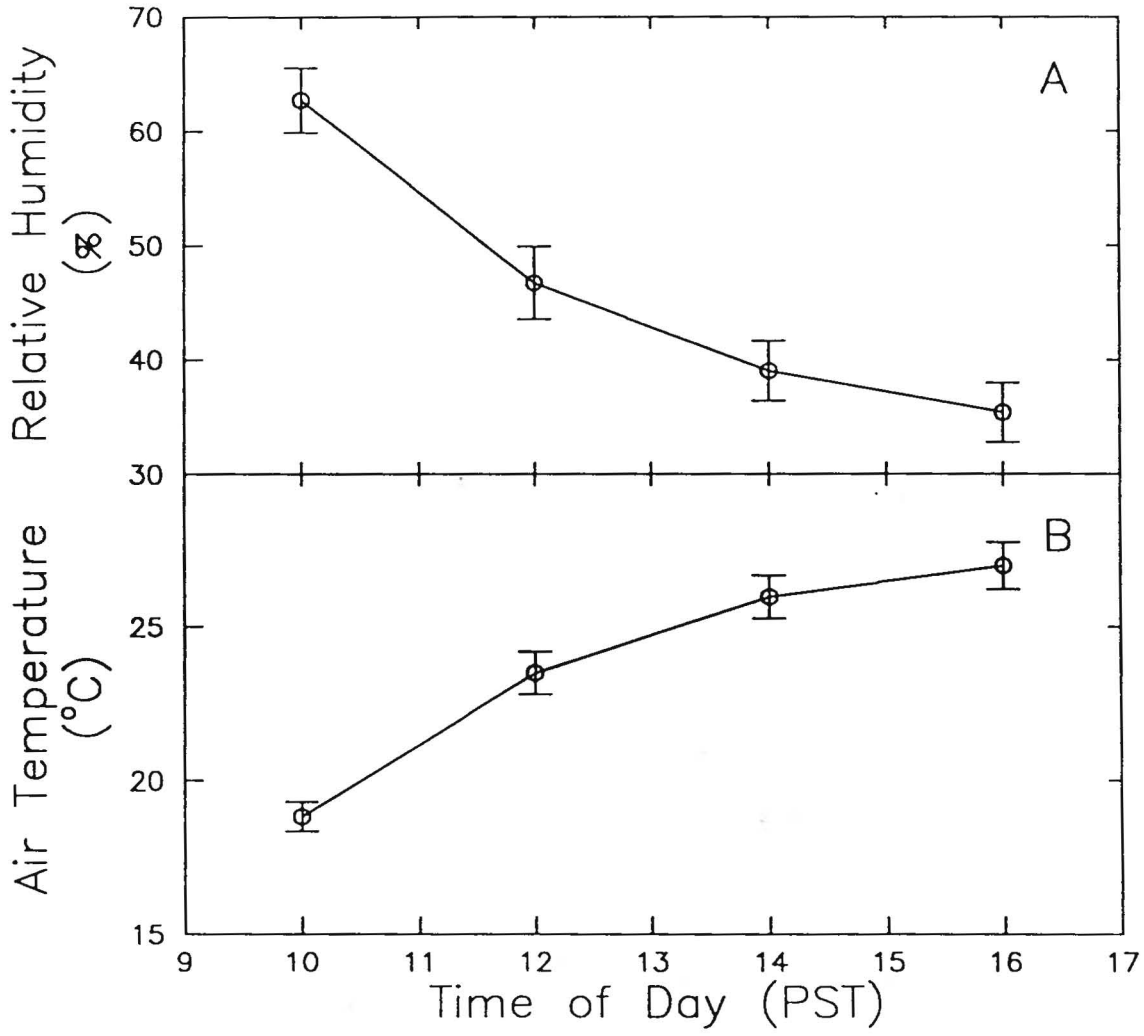

Figure 2. Daytime pattern of the average and standard error of relative humidity and air temperature for each 2-hour period.

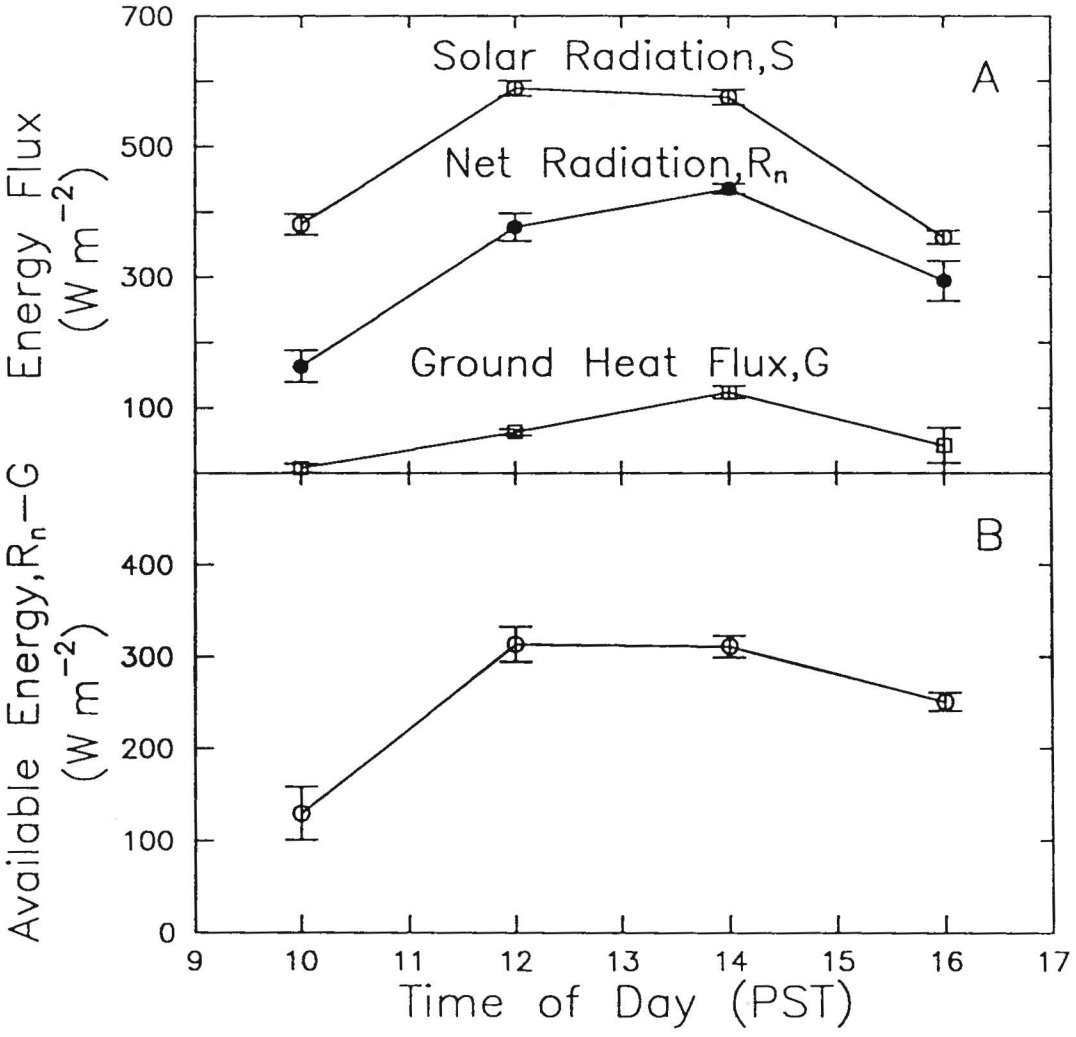

Figure 3. Daytime pattern of the average and standard error of solar radiation, net radiation, ground heat flux and available energy for each 2-hour period.

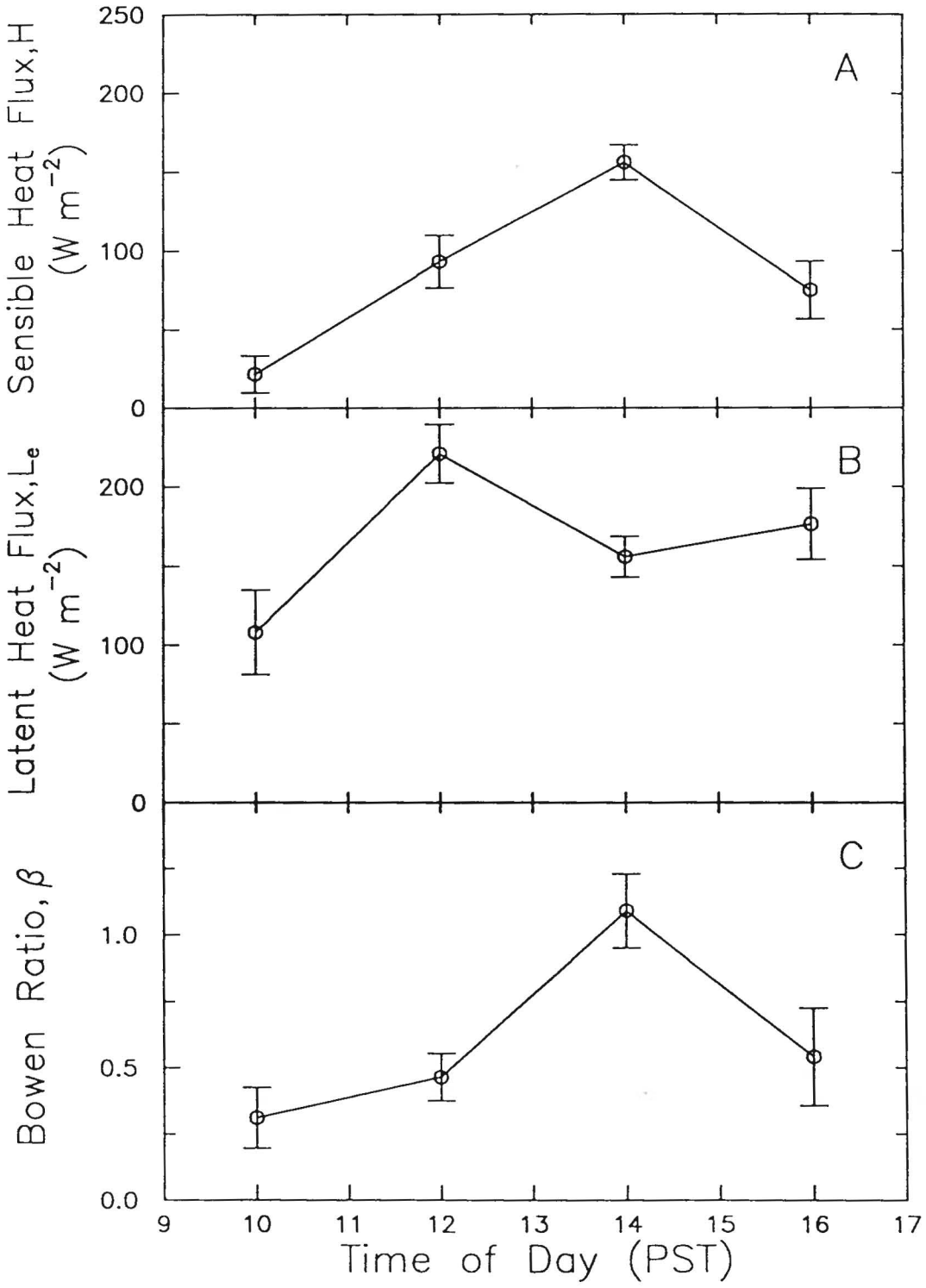

Figure 4. Daytime pattern of the average and standard error of sensible heat flux, latent heat flux and Bowen ratio for each 2-hour period.

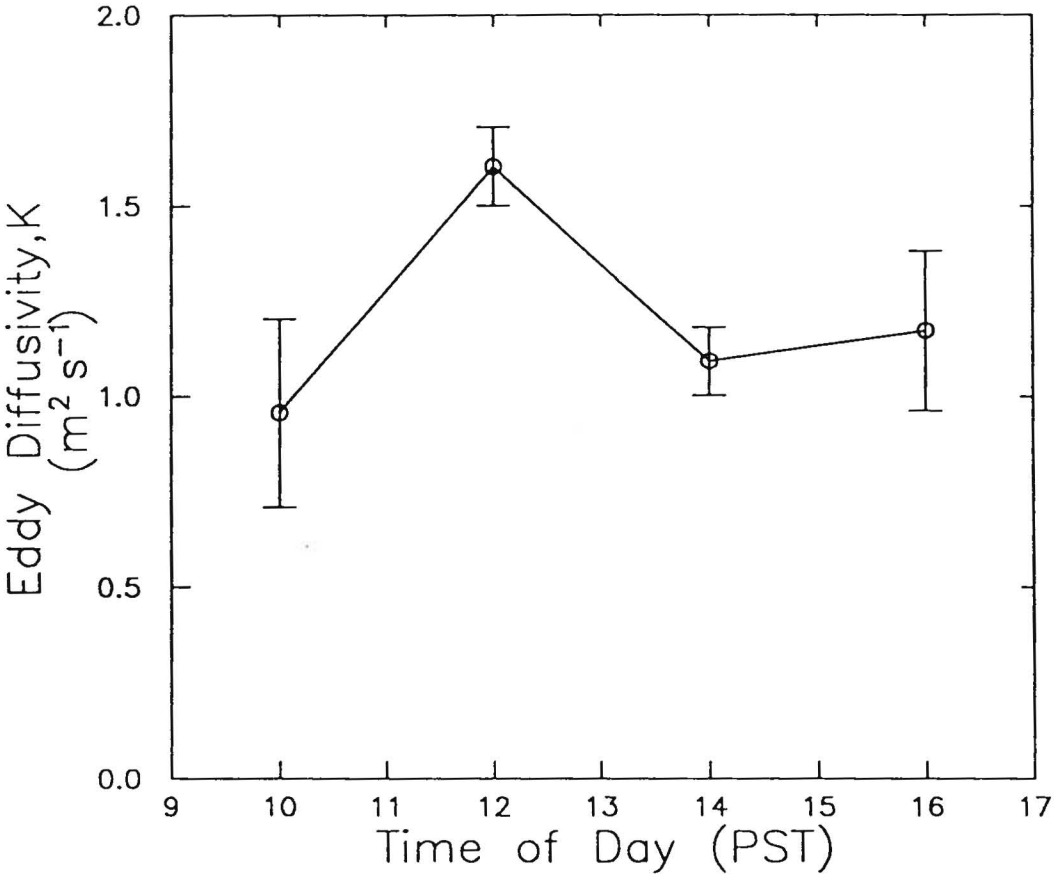

Figure 5. Daytime pattern of the average and standard error of bulk eddy diffusivity for each 2-hour period.

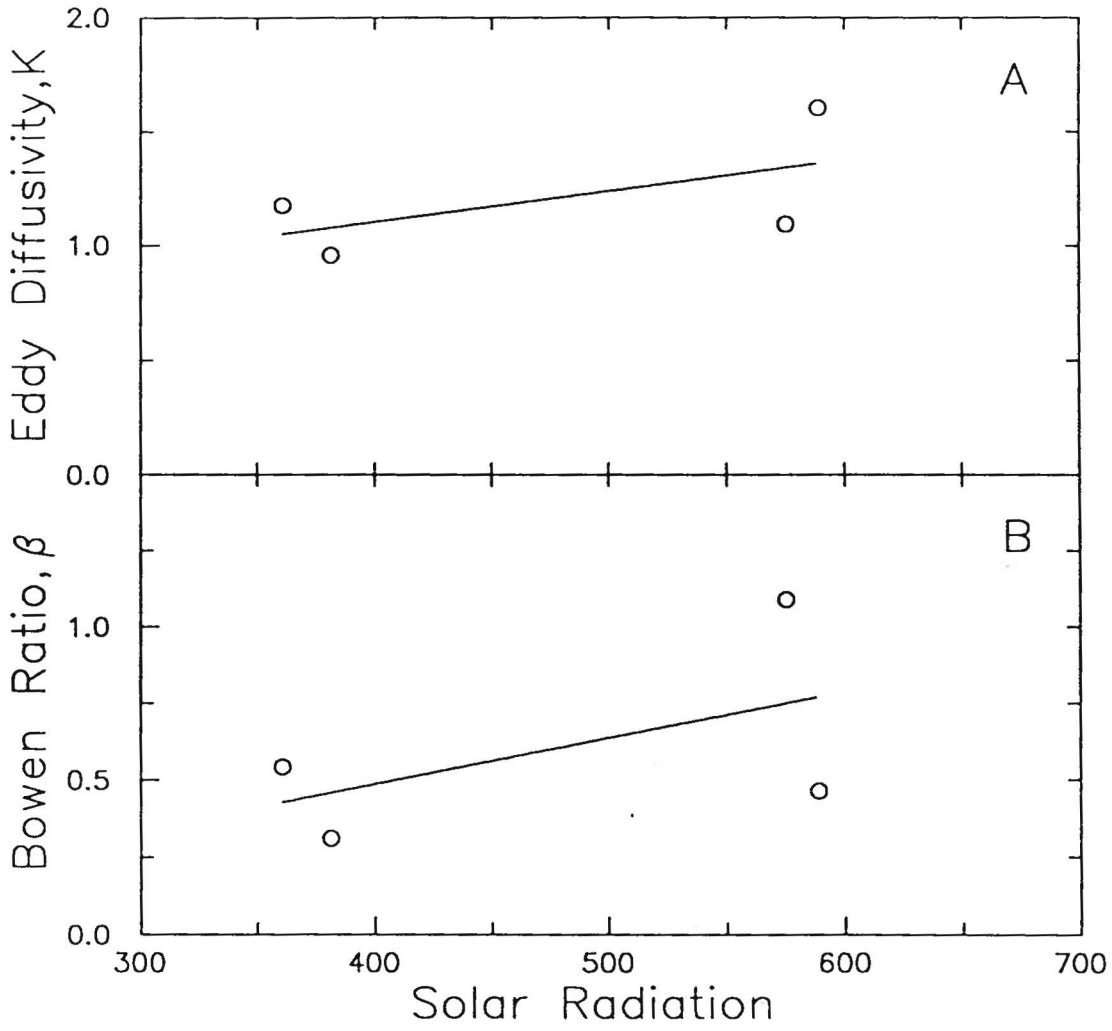

Figure 6. Scatter diagrams of bulk eddy diffusivity and Bowen ratio against incoming solar radiation. Each point represents a 2-hour period average, ensemble averaged over the period of observation.

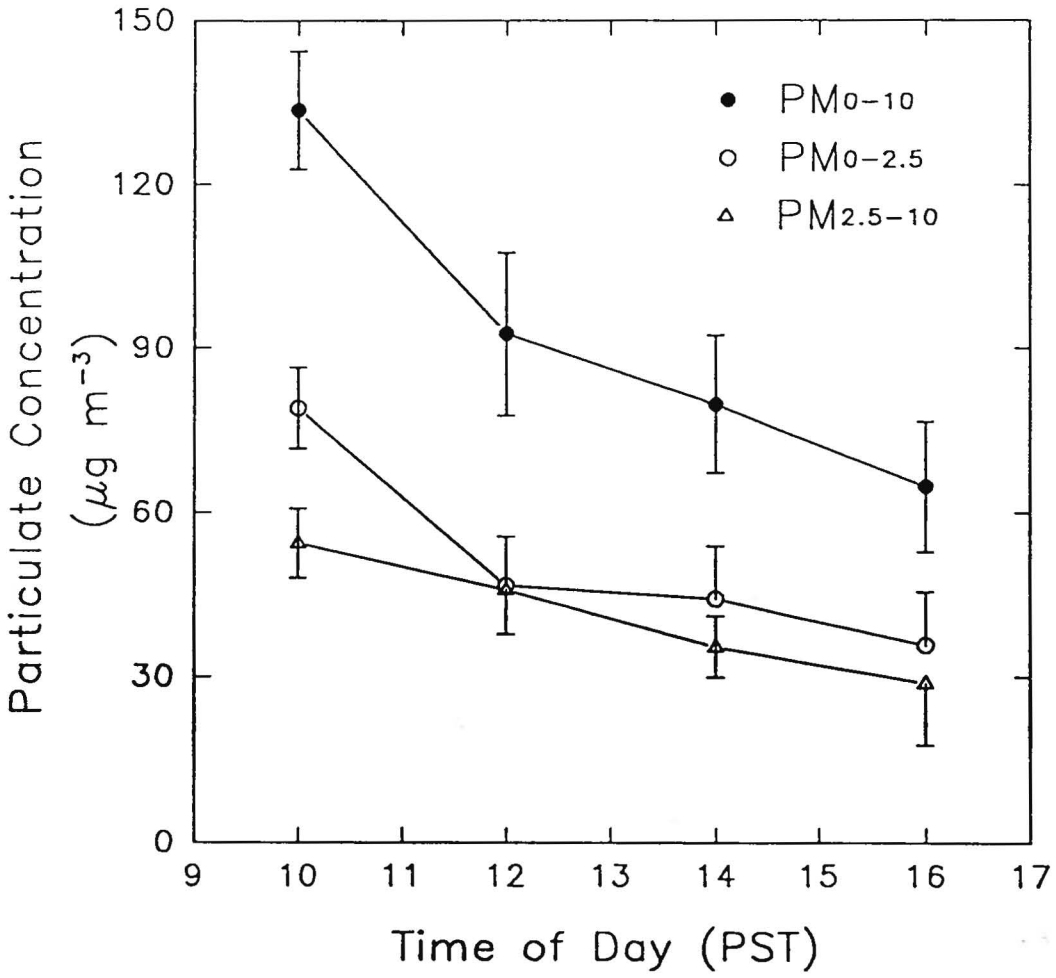

Figure 7. Daytime pattern of the average and standard error of particulate mass concentration for each 2-hour period.

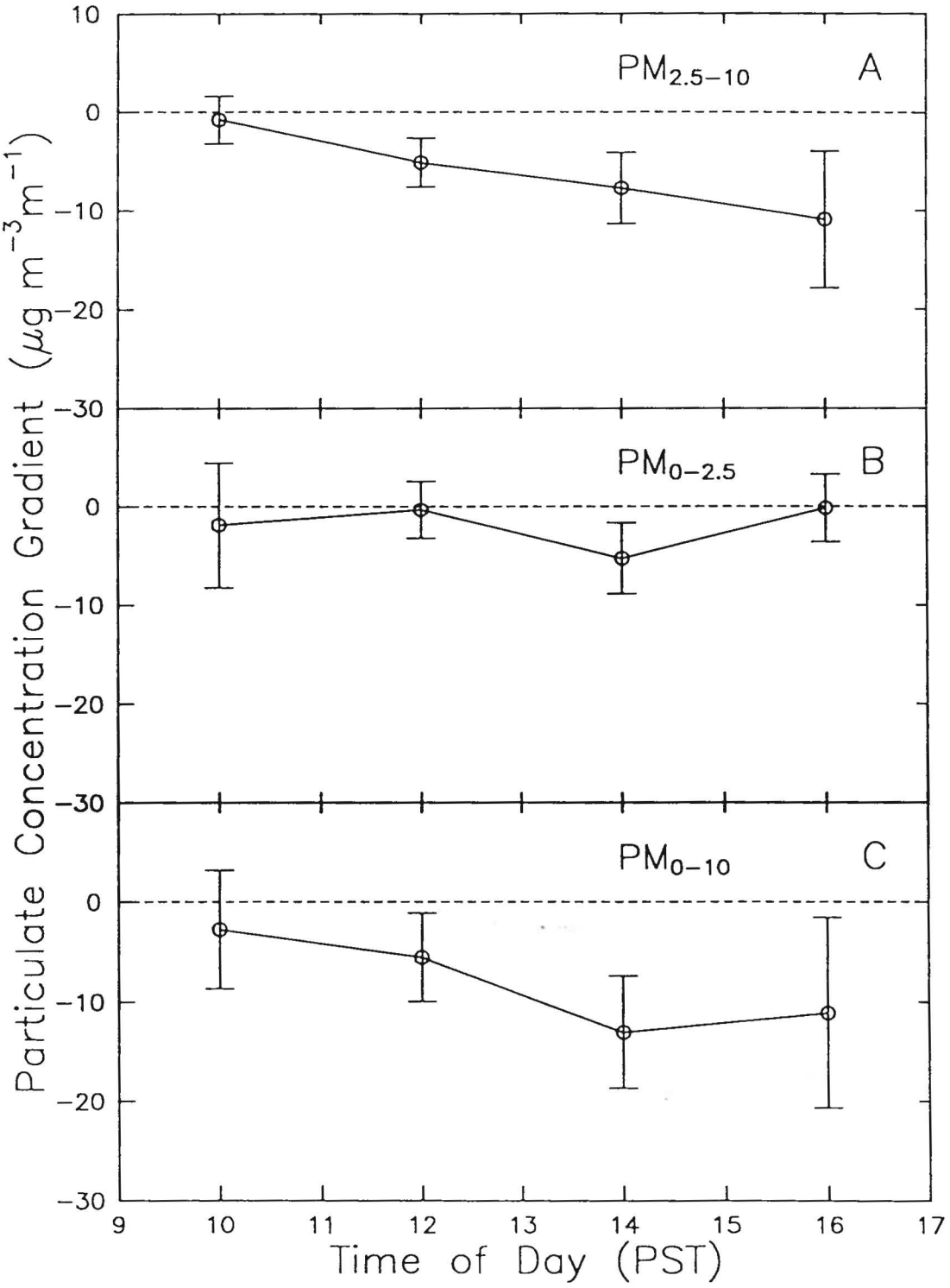

Figure 8. Daytime pattern of the average and standard error of particulate mass concentration gradient for each 2−hour period.

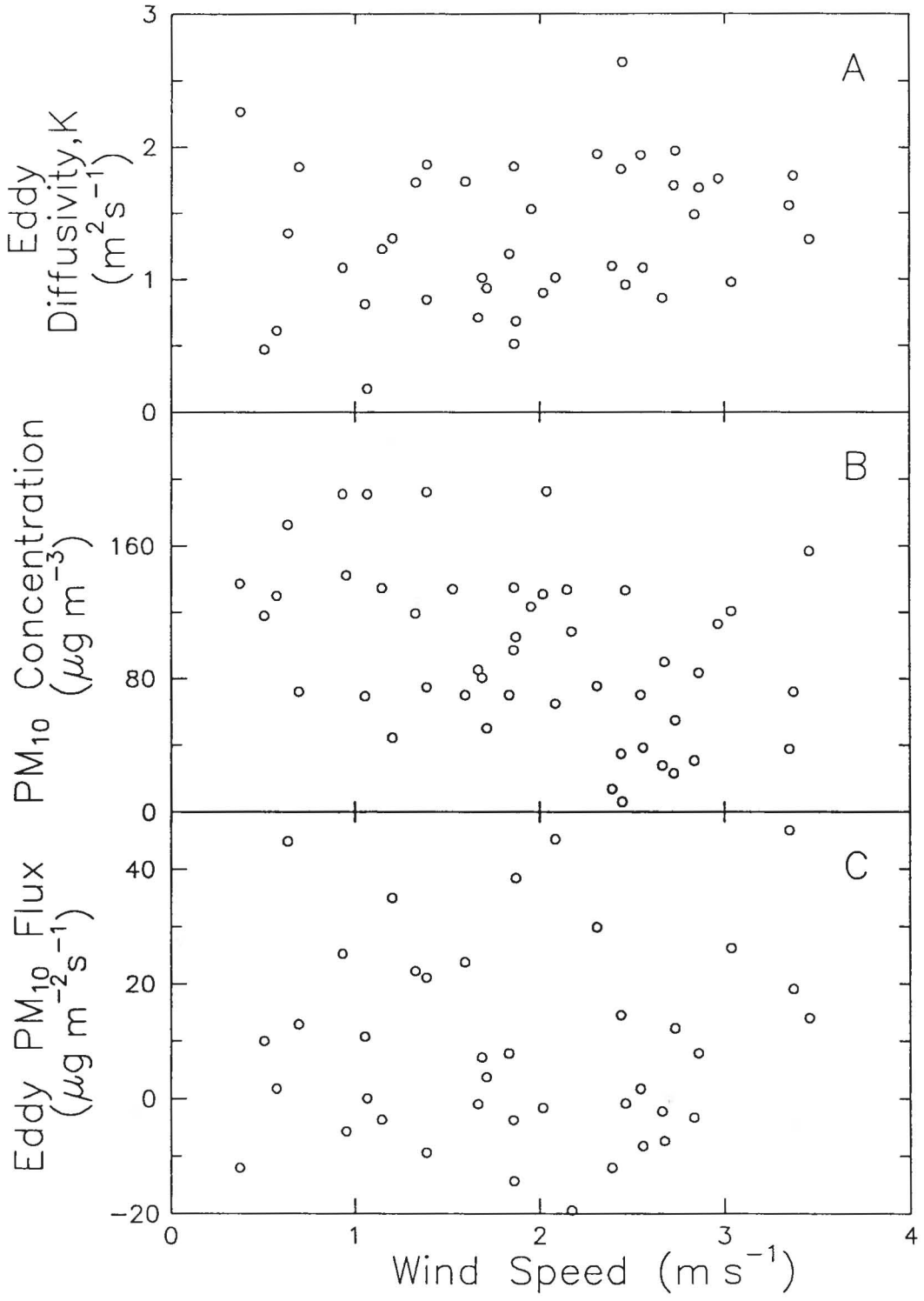

Figure 9. Scatter diagrams of bulk eddy diffusivity, PM_{10} concentration and eddy PM_{10} flux against mean wind speed over the period of observation. Each data point represents a 2−hour period average.

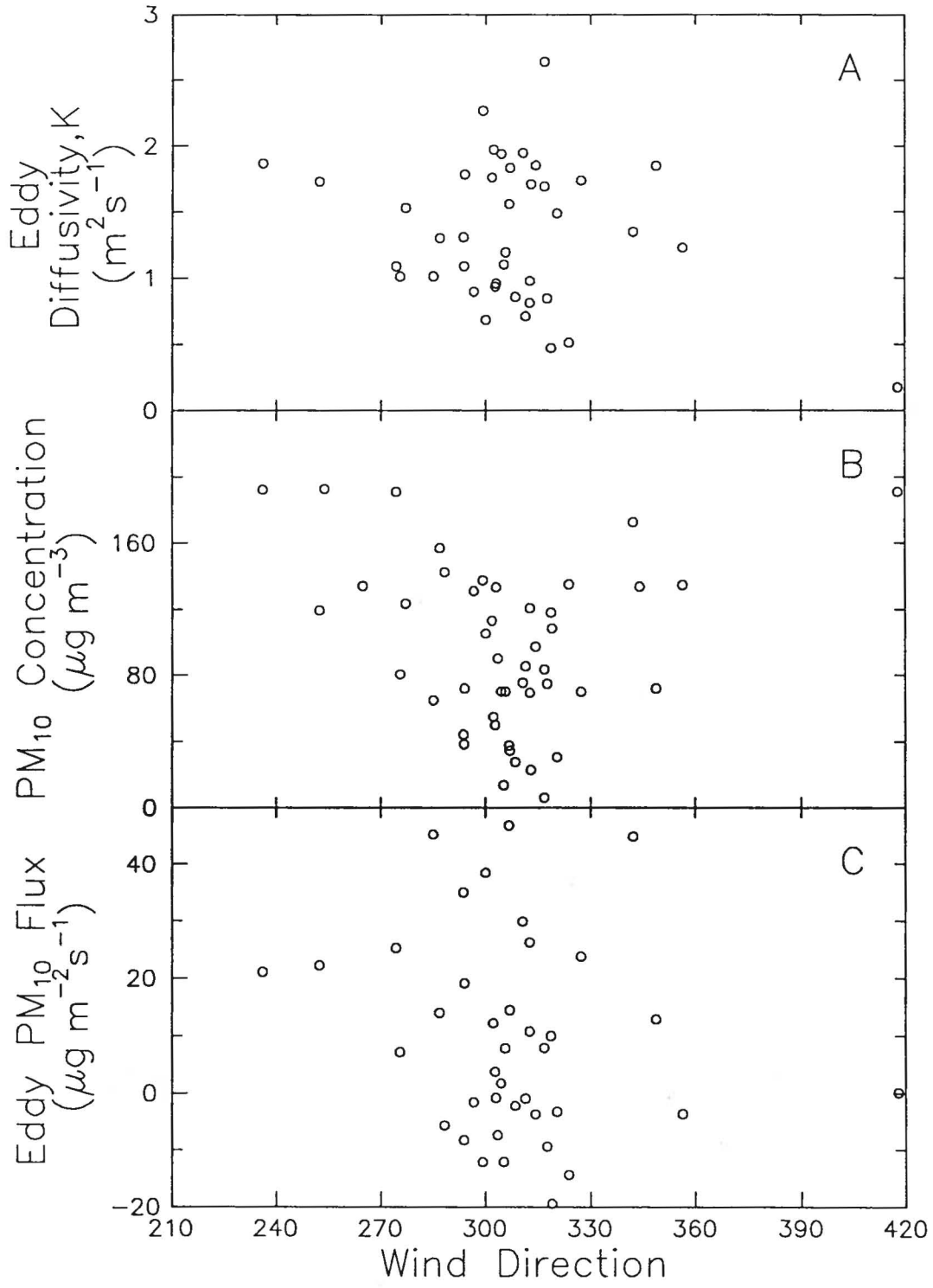

Figure 10. Scatter diagrams of bulk eddy diffusivity, PM_{10} concentration and eddy PM_{10} flux against mean wind direction over the period of observation. Each data point represents a 2−hour period average. The convention used for wind direction is 0 and 360 represent North.

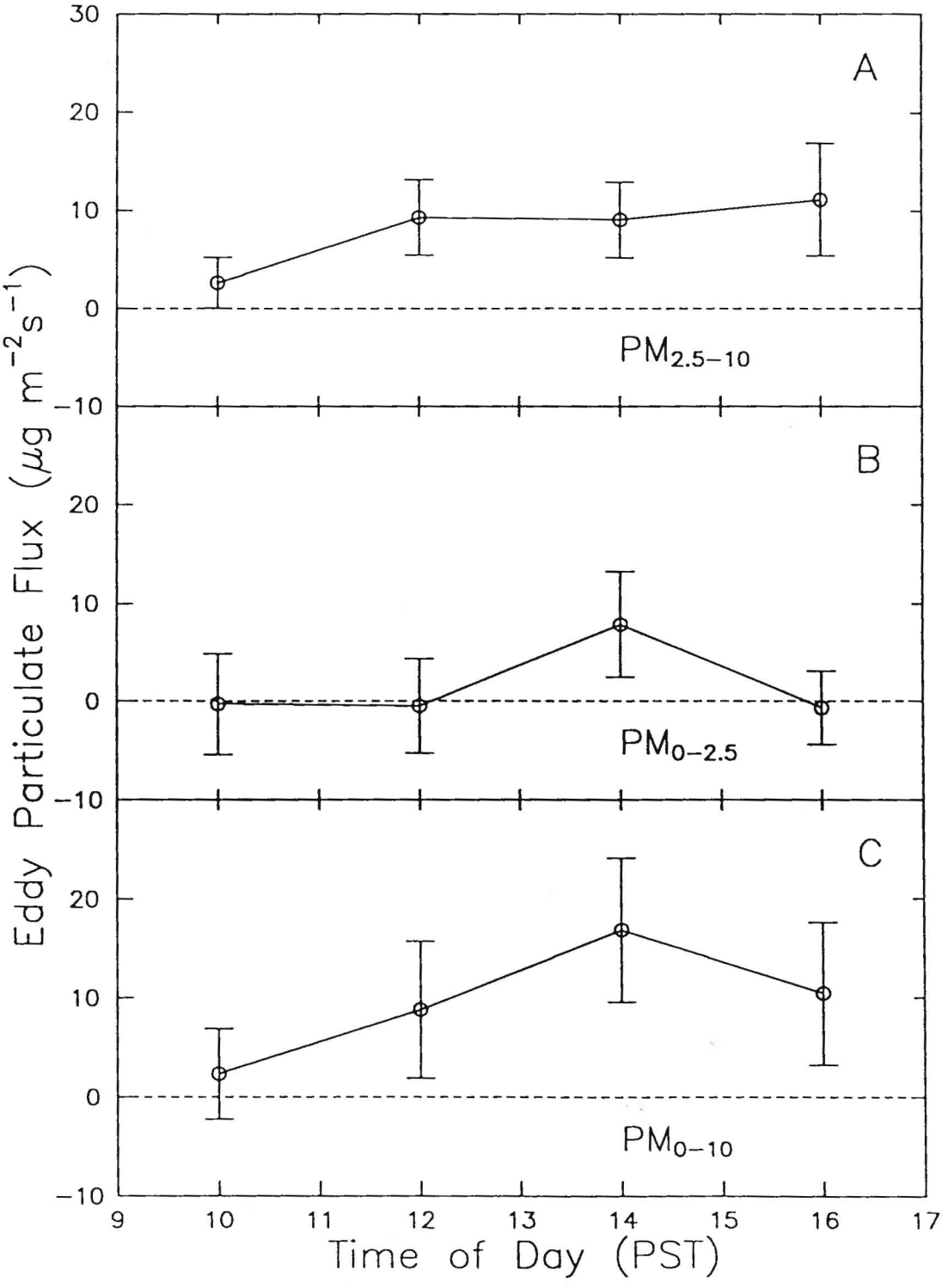

Figure 11. Daytime pattern of the average and standard error of eddy particulate flux for each 2−hour period.

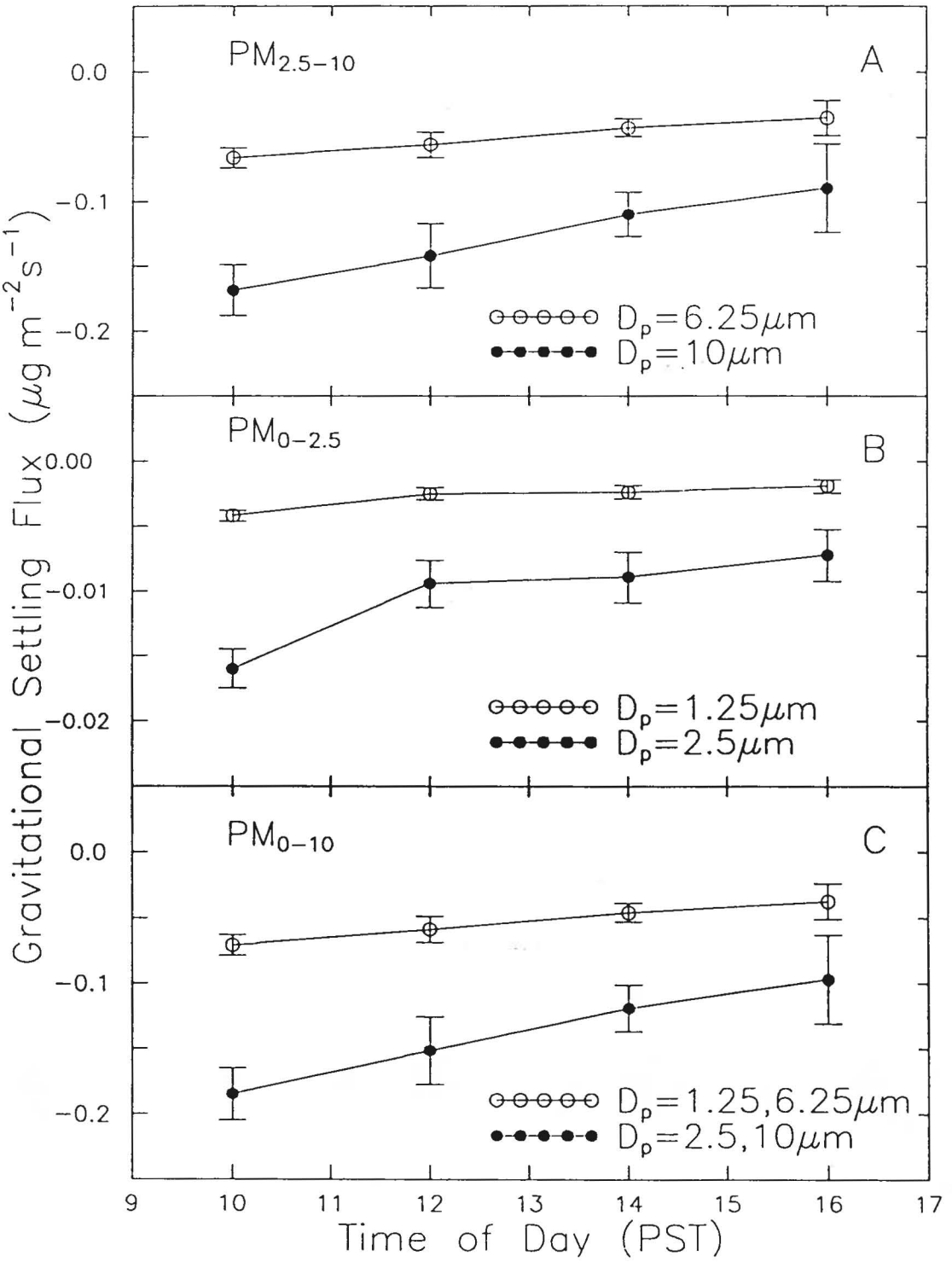

Figure 12. Daytime pattern of the average and standard error of particulate gravitational settling flux for each 2−hour period. Here, circles and dots represent the fluxes calculated using the arithmetically averaged particulate diameters and maximum size particulate diameters for corresponding size ranges, respectively.

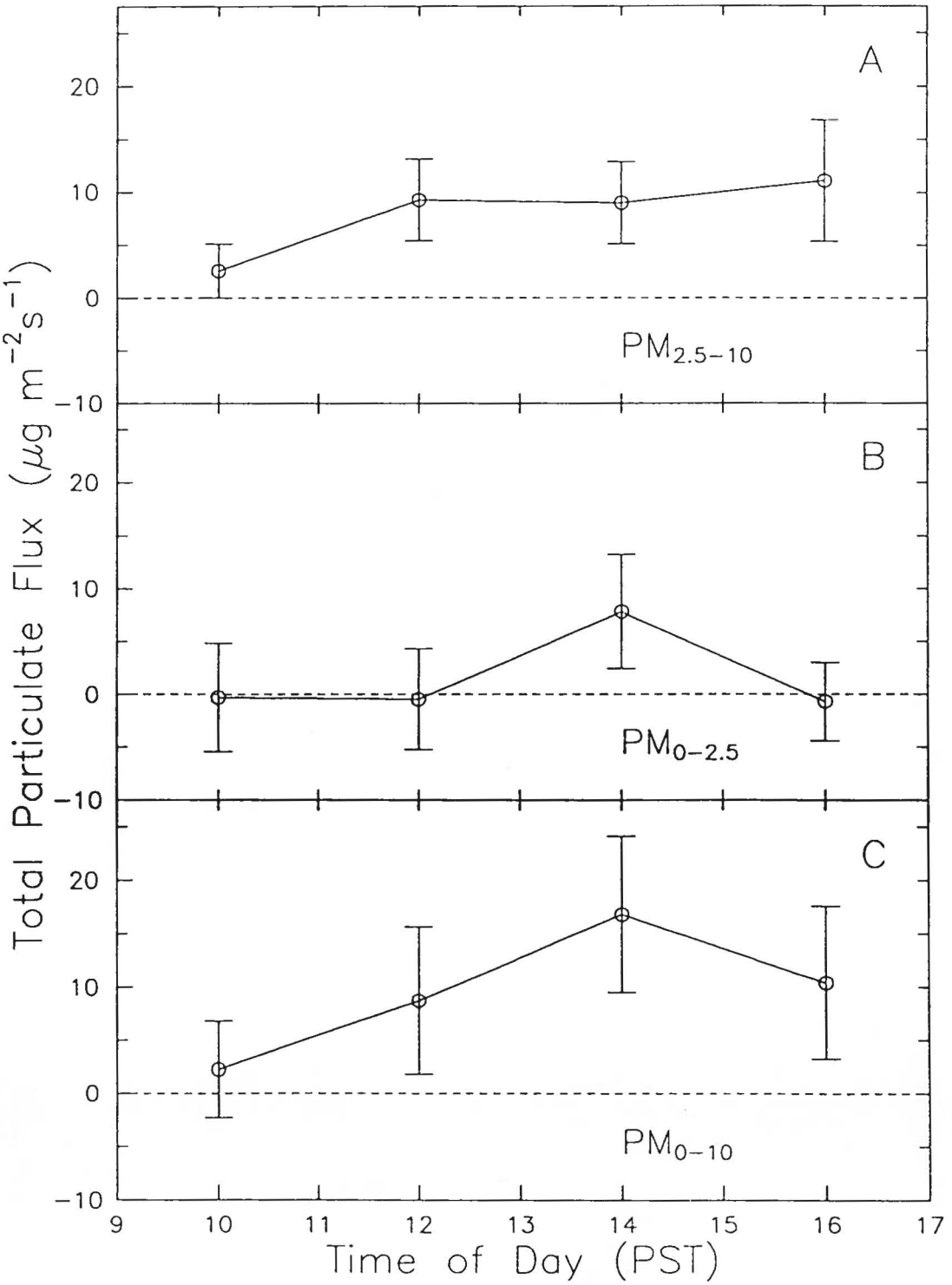

Figure 13. Daytime pattern of the average and standard error of total particulate fluxes, including both eddy and gravitational settling fluxes, for each 2-hour period.

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December 21, 1992

Susan McCloud
California Almond Board
P.O. Box 15920
Sacramento, CA 95852

Dear Susan:

This year I do not even know what the deadline is for submitting the annual report on our projects, so I don't know how early or late I am. I hope I'm early so I can make up a bit for past tardinesses. Anyway, on behalf of Themis and all our cooperators I want to thank you and the almond industry for your support of this work. Even though it is exasperating at times, most of it is fun and interesting.

As we discussed at the almond meeting at KAC, here are my best judgments of the time frame for completion of the subprojects within our proposal:

1. Hull rot -- 3 years. In fact, I expect to have good information in two years, and hope to use the third year to tie together whatever surprises the first two years hold.

2. Ceratocystis canker control -- 3 years. The initial screening should be accomplished within a year but testing against established cankers both at KAC and in grower orchards will take time.

3. Bloom disease control -- this could be a more or less ongoing project that can be altered, adjusted, reduced, expanded, dropped on an annual basis. The experiment in Kern County will be completed in 1993 as the last of a five year project. The scab trial will require two more years (1993 and 1994).

4. Shot hole on fruit -- 1993 should be the last year.

Best wishes for a wonderful holiday season. See you in 1993.

Sincerely,

Beth

Beth L. Teviotdale
Extension Plant Pathologist

BLT:dlb