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CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)

Annual Report

Project Title:

Using High Rates of Foliar Urea to Replace Soil Applied Fertilizer in Early Maturing Peaches

Project Leaders:

R. Scott Johnson, Extension Pomologist, UC Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648. Phone 209/891-2500, FAX 209/891-2593.

Richard Rosecrance, College of Agriculture, California State University-Chico, Chico, CA 95929-0310.

Cooperators:

Harry Andris, Fresno County Farm Advisor, 1720 S. Maple Avenue, Fresno, CA 93702. Phone 209/456-7285, FAX 209/456-7575.

Patrick Brown, Pomologist, Pomology Department, University of California, Davis, CA 95616. Phone 916/752-0929, FAX 916/752-8502.

Steven Weinbaum, Pomologist, Pomology Department, University of California, Davis, CA 95616. Phone 916/752-0255, FAX 916/752-8502.

Project Objectives:

Objective 1. To determine the optimum timing and concentration of 1 or 2 foliar urea sprays in the fall on early season peach trees.

Objective 2. To study the effects of foliar urea sprays over several years on tree productivity, fruit quality and vegetative growth.

Objective 3. To study the distribution within the tree of N from foliar urea sprays using ^{15}N as a tracer.

Objective 4. To disseminate information to growers about foliar urea using newsletters, meetings, radio and popular journals.

Executive Summary

1997 was the final year of this project. Results have continued to show the effectiveness of foliar urea as a method of supplying nitrogen to peach trees. Our emphasis in the last year of the study has been on determining the optimum time of fall applications, the distribution of N throughout the tree from such applications and the effects of this practice on long-term tree productivity and vegetative growth.

To address objectives 1 and 3, mature O'Henry peach trees were sprayed with a 10% ^{15}N urea solution on Sept. 20, Oct. 11, or Nov. 1, 1996 (Experiment 1). Leaves were collected as they fell and the trees were then excavated in January, 1997, so that ^{15}N contents and distribution could be determined.

Peach leaves rapidly absorbed urea-N irrespective of timing of application, and much of it was translocated to perennial tree parts within 4-7 days after application. Between 48 and 58% of the urea-N applied was recovered in abscised leaves or perennial tree parts. Leaves exported $\geq$ 60% of the urea-N when applied prior to leaf senescence (September 20 or October 11), but < 50% when applied shortly before leaf fall (November 1). Of the urea-N translocated, most of it was recovered in roots ($\geq$ 38%) following application in September or October, however, in November urea-N primarily remained in the current year wood ($\approx$ 45%). Thus, leaf senescence processes affected foliar urea-N translocation and distribution rather than absorption. Foliar application of urea in September and October supplied the equivalent of about 20% of crop nitrogen content, but only 15% (i.e. $\approx$ 30% lower) when applied shortly before leaf senescence in November.

We have conducted a couple of experiments to address objective 2. Our first experiment suggested there may be a problem of reduced fruit size when foliar urea alone is used to fertilize peach trees. We subsequently initiated an experiment on Early Maycrest peach to evaluate the idea of supplementing soil fertilization with a single foliar urea spray in the fall of about 50 lbs N/acre (experiment 2). Results over the past 2 years have been very promising, particularly with a treatment receiving 50 lbs N to the soil in September and 50 lbs N to the leaves in October. Compared to the soil fertilized control, this treatment had equal yields and fruit size. It also had higher stored N levels in roots and shoots during the dormant season which contributed to strong fruit and shoot growth early in the season. However, by mid summer leaf N values were slightly lower than the control leading to an overall reduction in vegetative growth. This resulted in a significant decrease in summer pruning weights which is a desirable benefit in early maturing varieties.

Experiment 1

Foliar uptake of ^{15}N-urea applied to peach leaves at different times during the post-harvest season and the subsequent distribution of ^{15}N throughout the tree.

Objective

This experiment was conducted to evaluate the best timing for applying foliar urea in the fall by studying uptake, translocation and distribution of ^{15}N throughout the tree.

Materials and Methods

Sixteen, eight-year old peach trees (*Prunus persica* [L.] Batsch) cv. 'O'Henry' on 'Lovell' rootstock were selected from the Wolfskill Experimental Orchard in Winters, CA. Tree selection was based on similarities in July leaf N concentrations, and trunk cross-sectional areas. Trees were spaced 2 m within the row and 5.5 m between rows (969 trees ha^{-1}), and their canopies trained to the "KAC-V". The soil is classified as a Yolo clay loam (fine, mixed, non-acid, thermic Mollic Xerfluvent). Trees were irrigated weekly by micro-jet sprinklers and fertilized during the spring with 112 kg N ha^{-1}.

Four trees were sprayed on September 20, October 11, and November 1, 1996 with an urea solution (10%, w:v) enriched with 4.62 atom% ^{15}N and 0.1% Triton X-100. A mechanical cherry picking machine (tree squirrel) was used to ensure uniform and complete canopy coverage, and a tarp was placed underneath the trees to collect the urea solution that dripped from the trees. Urea collected on the tarp was then removed from the orchard. A volume-retention equation for the peach leaves was developed by weighing leaves before and after dipping in a 10% urea solution. This equation was used to quantify the amount of urea-N intercepted by the canopy of each tree. Abscised leaves were collected from underneath the trees weekly, weighed, and subsamples were taken to get leaf areas and wet-to-dry weight ratios. This allowed us to determine the total tree leaf areas and weights of abscised leaves of the treated trees.

The kinetics of foliar urea uptake were determined from samples of 10 leaves taken at 8, 24, 48, and 168 hours after urea application, as well as from abscised leaves. Eight mesh bags were used to enclose branches around the periphery of each tree soon after urea application to collect the abscised leaves.

Leaf samples were shaken for 2-3 min in 20 ml of water to wash off and recover residual urea remaining on leaf surfaces. After rinsing the leaves, leaf areas were determined using a Delta T leaf area meter (Decagon, Pullman, WA). The urea washed off leaf surfaces was analyzed colorimetrically by the modified diacetyl method (LeMar and Bootzin, 1957; Polacco, 1976). Leaves were then dried at 60 °C, pulverized to a fine powder in a ball mill, and sent to Isotope Services, Los Alamos, NM for ^{15}N analyses. Recovery of foliar-applied ^{15}N was calculated using the following equation (Hauck and Bremner, 1976):

Recovery ^{15}N (%) =

$$\frac{100p(c-b)}{f(a-b)}$$

where p = the leaf N content, f = the N applied to the leaf (g $leaf^{-1}$), a = the atom % ^{15}N in fertilizer, b = the atom % of the unlabeled leaf fraction, and c = the atom % of the labeled leaf fraction.

On January 14, 1997, the twelve trees that had previously received foliar-applied urea were excavated with a backhoe and separated into the following 5 fractions: roots, rootstock, trunk, canopy branches, and current year wood. The various tree factions were weighed with a load cell and mechanically chipped. About 3 kg subsamples were weighed fresh, dried at 60 °C, reweighed, and processed similarly to the leaf samples. The ^{15}N enrichment in treated trees was calculated by subtracting the natural ^{15}N abundance measured in untreated control trees. Foliar N absorption was calculated as the amount of labeled ^{15}N found in the harvested trees, plus that

recovered in the abscised leaves. The amount of N derived from applied urea was calculated by multiplying the amount of ^{15}N excess in the tissues by 21.6 (the ratio between the 100% total N to the 4.62% ^{15}N excess of the enriched urea).

The experiment was set up as a completely randomized design, with three applications times and four replicates per application. The effects of urea-N application time on foliar N uptake and export were assessed by a one-way analysis of variance and mean separation by Duncan's Multiple Range test.

Results and Discussion

The time course of leaf fall and leaf N contents are presented in Figure 1. Leaf fall occurred primarily between late October and Mid-November (Fig. 1A). The urea application in September caused < 20% of the leaves to abscise early (Fig. 1A), and most of these leaves were located in the tree interior (personal observation). Leaf N remobilization occurred just prior to leaf fall in control trees (compare Figs. 1A and B). Peach trees remobilized 45% of their leaf N, and most of this occurred between late October and mid-November (calculated from Fig. 1B). The urea-N application in November occurred as leaves were beginning to abscise and nitrogen was being mobilized out of the leaves.

The pattern of ^{15}N-urea rinsed off leaf surfaces and recovered inside the leaves is presented in Figure 2. Within 48 hours following application < 35% of the foliar-applied ^{15}N-urea was recoverable in the leaf rinsate. The recovery of urea in the wash solution was not influenced by application time (Fig. 2A). Concomitant with urea disappearance from the leaf surfaces, the percentage recovery of ^{15}N in leaves increased, peaked 48 hours after urea application, and then declined (Fig. 2B). The decline in the ^{15}N recovery percentages primarily occurred between 4 and 7 days following applications (Fig. 2B). Foliar ^{15}N-urea application in November resulted in greater ^{15}N retention in the leaves compared with the earlier application dates.

Between 48 and 58% of the urea applied to the tree canopies was recovered either in abscised leaves or in perennial tree parts (Table 1). The time of application did not affect the percentage recovered, but did change the partitioning of urea-N. Significantly more urea-N was recovered in perennial tree parts and less in the abscised leaves following application in September and October compared with November. Perennial tree parts contained 60, 64, and 48% of the total urea-N recovered in September-, October-, and November-treated trees, respectively.

Tree dry weights and N contents did not vary with the date of foliar application, and therefore, the data were combined (Table 2). The canopy branches and roots (including rootstock) comprised 47 and 31% of the total tree dry weight and 27 and 46% of the total tree nitrogen, respectively. Thus, roots were the major organ for N accumulation in mature peach trees. Roots were also the primary sink for N following application of ^{15}N-urea in September or October, containing 38 and 45% of the total 15 N recovered in perennial tissues, respectively. The November application resulted in only 28% recovery of ^{15}N-urea in roots. As a result, roots contained almost double the amount of ^{15}N when applied in September or October compared with November.

Table 1. Amounts of foliar urea-N (g N $tree^{-1}$) applied onto the tree canopy, recovered in perennial tree tissues, and removed in the abscised leaves. Each value is a mean of four replicates; mean separation was conducted by Duncan's Multiple Range test.

Date of urea application	Foliar N applied to leaf canpy	Foliar N in perennial tree parts	Foliar N removed in abscised leaves	Percentage N recovery in the tree
20 Sept.	35.2	10.7 a	7.4 ab	51.3
11 Oct.	32.1 ns	10.0 a	5.6 b	48.4 ns
1 Nov.	28.1	7.9 b	8.5 a	58.4

Table 2. Tree dry weight (kg $tree^{-1}$), N content (g $tree^{-1}$), and the effect of urea application date on the distribution of ^{15}N (mg $tree^{-1}$) in different organs in January. Numbers in parentheses are percentages of the total in perennial tissues. Values are the mean of 12 replicates for dry weight and N content and 4 replicates for ^{15}N content. Mean separation was conducted using Duncan's Multiple Range test.[1]

	Tree Part						
	Roots	**Rootstock**	**Trunk**	**Canopy branches**	**Current year wood**	**Total in perennial tissues**	**Abscised leaves**
Dry Weight (kg $tree^{-1}$)	4.3 (16)	4.3 (16)	2.5 (9)	12.8 (47)	3.1 (11)	27	2.4
N Content (g $tree^{-1}$)	31 (30)	16 (16)	5 (5)	28 (27)	22 (22)	102	50
^{15}N Content (mg $tree^{-1}$)							
20 Sept.	139 a (28)	51 a (10)	18 (4)	108 (22)	180 a (36)	496 a	341 ab
11 Oct.	144 a (31)	64 a (14)	13 ns (3)	112 ns (24)	182 b (28)	461 a	259 b
1 Nov.	68 b (19)	34 b (9)	12 (3)	83 (23)	168 ab (46)	365 b	395 a

[1] Tree dry weights and total N contents did not vary with the foliar urea application date, and therefore, the data were combined.

Nectarine and peach leaves rapidly absorbed foliar-applied urea-N, irrespective of application date. The rate of absorption was similar to that reported for many other fruit tree species (Swietlik and Faust, 1984). The translocation of urea-N out of the leaves was also rapid, with much of it occurring within 4 to 7 days of application (Fig. 2B). Our data are consistent with those of Dilley and Walker (1961) who found that urea-N was readily hydrolyzed and assimilated into amino acids within 20 hours of delivery to the leaves through the petiole. A number of previous studies, however, reported that foliar urea applications to peach leaves were ineffective (El-Banna et al., 1981; Norton and Childers, 1954; Proebstring, 1951; Weinberger et al., 1949). The resolution obtainable in these foliar uptake experiments, however, may have been compromised by low urea concentrations (<1.5%) and delayed leaf sampling after urea application (>5 days). The rapid absorption and export of urea-N out of peach leaves probably misled researchers into thinking that foliar urea-N was not absorbed by peach leaves.

Nitrogen movement out of the leaf was restricted when urea was applied in November. In November leaves were yellowing and in a more advanced stage of leaf senescence than in September or October. As leaves senesce, membranes breakdown, enzymes are catabolized, and vascular connections are broken (Feller and Fischer, 1994), and these processes probably reduced N export from leaves. Therefore, to maximize N utilization by the tree, foliar urea sprays need to be applied before leaf senescence and N remobilization processes are under way. It appears not to matter if the application is made well ahead of leaf senescence since the September and October treatments did not differ substantially in N partitioning (Tables 1 and 2). However, it is interesting to note the large differences in ^{15}N recovery 2 days after treatment (Fig. 2B). The 11 October application occurred just prior to the rapid remobilization of N out of leaves (Fig. 1B). Ammonium assimilating enzymes such as glutamine synthetase may increase just prior to leaf senescence (Streit and Feller, 1983), which may have increased the rate of ^{15}N-urea export out of the leaves at this time.

Experiment 2

Using Foliar Urea to Supplement Soil-Applied Fertilizer in Early Maturing Peach Trees

Objectives

This experiment was set up to test the effect of different combinations of soil and foliar fertilizations on peach tree growth and productivity.

Materials and Methods

In a block of Early Maycrest peach trees at the Kearney Agricultural Center, we set up an experiment comparing different combination of soil and foliar fertilizations. The four treatments are as follows:

1. Unfertilized control
2. Soil N only – 50#N/acre in April, foliar – 50#N/acre in September
3. Soil – 50#N/acre in April, Foliar – 50#N/acre in October
4. Soil – 50#N/acre in September, Foliar – 50#N/acre in October

Each plot consists of 2 trees and is replicated 5 times per treatment. The experiment was initiated in the spring of 1995.

Results and Discussion

In January 1996 and 1997 treatments 2-4 had all received 100#N/acre although at different times and by different methods. Sampling of dormant shoots and roots indicated the treatment which had received all its N in the late summer and fall (trt 4) had the highest level of stored nitrogen (Table 3). Therefore, this approach of splitting nitrogen fertilization between soil and foliar applications appears to be a very effective method of supplying nitrogen to the tree.

Table 2. The effect of low biuret foliar urea sprays on Early Maycrest peaches.

	Treatments			
	Unfertilized Control	**Soil Fertilized Control**	**Split April – Soil Oct. - Foliar**	**Split Sept. – Soil Oct. - Foliar**
	1	**2**	**3**	**4**
Root N (%)				
1/96	.70 c	1.33 b	.97 c	1.59 a
1/97	1.02 c	1.29 b	1.37 b	1.62 a
Yield (kg/tree)				
5/96	8.4 b	12.8 a	10.7 ab	12.6 a
5/97	10.7 b	15.0 a	15.1 a	15.1 a
Fruit Weight (g)				
5/96	97.7 b	114.8 a	110.3 a	113.5 a
5/97	90.9 b	110.8 a	103.1 a	110.9 a
Leaf N (%)				
7/96	2.45 b	2.76 a	2.79 a	2.60 ab
7/97	2.56 b	2.72 ab	2.92 a	2.63 b
Summer Pruning (kg/tree)				
7/96	2.4 b	5.9 a	5.0 a	3.5 b
8/97	3.2 c	9.0 a	6.6 b	6.2 b

Treatment 4 was also effective at maintaining yields and fruit weights comparable to the soil fertilized control (trt 2) in both 1996 and 1997 (Table 3). No doubt the high level of stored nitrogen in this treatment promoted rapid early fruit growth since there is a good correlation between stored N and fruit weight at thinning time (data not shown).

Treatment 4 had the further advantage of reducing vegetative growth which can be quite excessive in an early maturing peach variety. Summer pruning weights taken in mid summer of both 1996 and 1997 were significantly reduced compared to the soil fertilized control (Table3). At this same time leaf N values tended to be lower in treatment 4 which could explain the reduced vegetative growth.

In contrast, the other split application treatment (trt 3), which received foliar urea in the fall but a spring application of soil N, did not perform as well in any of the parameters mentioned above. In general, this treatment had lower stored N, yields and fruit weight and higher vegetative growth and summer leaf N than treatment 4. Therefore, the timing of the split application appears to be important in determining the effectiveness of the treatment.

In conclusion, foliar urea in the fall can be used effectively to supplement soil applied fertilizer. By combining a September soil fertilization with an October foliar spray, stored N can be maximized and fruit productivity can be maintained. In addition, excessive vegetative growth can be reduced and the potential for ground water contamination by nitrates can be minimized.

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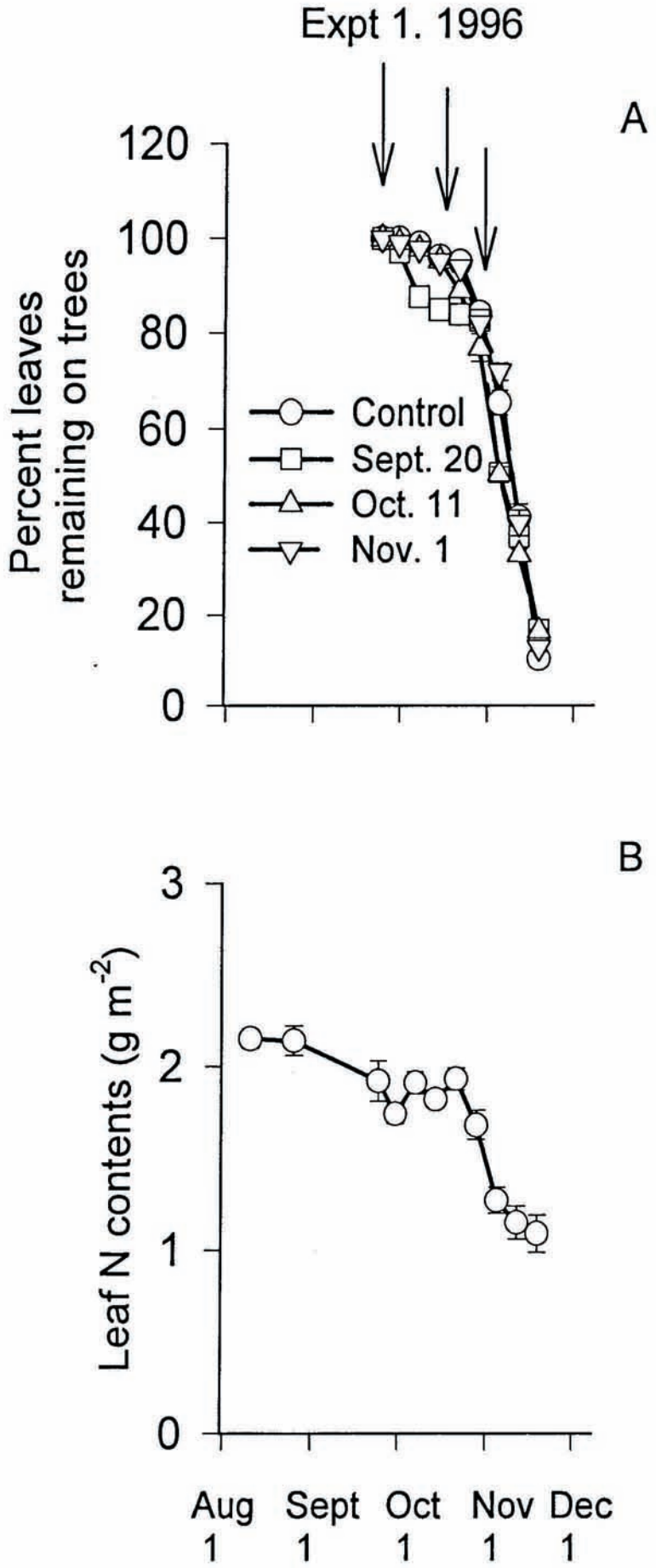

Figure 1. Seasonal patterns of leaf fall (A) and leaf N per unit leaf area (B). The arrows indicate times of foliar urea applications on 20 Sept., 11 Oct., and 1 Nov. 1996. The vertical bars indicate ± SE; n = 4.

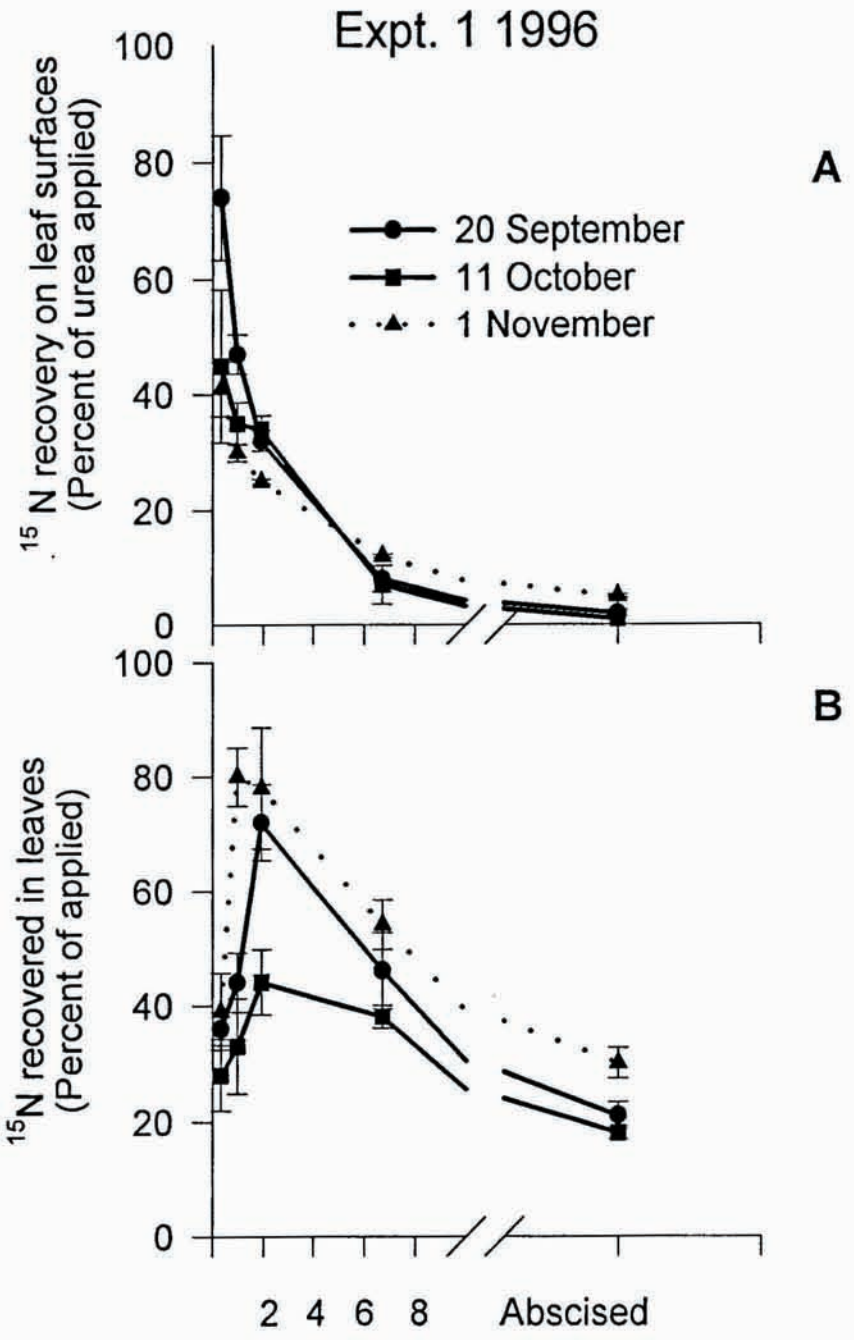

Figure 2. Kinetics of urea disappearance from leaf surfaces (A) and ^{15}N recovery in leaves (B) following foliar application of labeled urea. Leaves were sampled 8, 24, 48 and 168 hours after the spray application and also when they naturally abscised. The vertical bars indicate ± SE; n = 4.