FERTIGATION OF FLUID NITROGEN AND PHOSPHATE FERTILIZERS FOR PEARS IN PACIFIC NORTHWEST

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ABSTRACT

Split fertigation of N and P fertilizers and banding application of N and P fertilizers may increase the use efficiency of applied N and P compared with our current N and P management system -- single broadcasting application of dry N and P fertilizers to the soil surface. A field experiment, initiated in 2005, was continued in 2007 on adult green d'Anjou pear near Parkdale, Oregon. Five different treatments: 1) broadcasting application of N and P fertilizers to the soil surface under drip irrigation, 2) banding application of N and P (12 inches deep) under drip irrigation, 3) broadcasting application of N and P to the soil surface under drip irrigation along with soil disturbance caused by banding (no fertilizer was banded), 4) fertigation of N and P under drip irrigation, and 5) fertigation of N and P under micro sprinkler irrigation were compared using a randomized complete block design with four replicates. The 2007 results show that shift from our current N and P management system -- single surface broadcasting application of dry N and P fertilizers to split N and P fertigation produced compatible fruit yield and quality, and had significant beneficial effects on reducing fruit superficial scald and lowering N and P fertilizer consumption on the Parkdale soil.

INTRODUCTION

The Mid-Columbia region in Oregon produces 40% of the "winter" pears and 20% of the Bartlett "summer" pears in the United States. Presently, N fertilizer is mostly broadcast applied on the soil surface once (in March or April) per year at a rate of 80 to 100 lbs N/acre as a dry material followed by an intensive irrigation season. Nitrogen use efficiency is relatively low with this N management system because the tree root system can not take up all the applied N fertilizer of such a high rate in a short time, thus much applied N is leached out of the soil due to rain and irrigation water. Furthermore, the 80 to 100 lbs N/acre of N fertilizer per year is based on the assumption that the present season will produce a normal high pear yield. However, unlike annual crops, pear yields on a specific orchard block vary considerably from year to year due to training, pruning, and weather conditions, and yields below normal have been frequently observed over the seasons. Because lower pear yield requires less N uptake from the soil, more of the applied N fertilizer will be lost to the ground water and atmosphere during those lower yielding seasons compared with the normal yielding years. Overall, inefficient N use with this N management system results in excessive N consumption by orchards, increases production costs, reduces fruit quality, and contaminates water throughout the region. For instance, water quality data collected since 1995 by various entities suggested that Hood River tributaries draining orchard lands have excessive N levels. In 2001, the average concentration of N exceeded the

Oregon Department of Environmental Quality (ODEQ)-recommended N evaluation indicator value (0.3 mg/L NO_3/NO_2) at all 10 sites sampled (Oregon Watershed Assessment Manual pg. VIII-9 Table 2). High N may stimulate algae production, contribute to episodes of high pH harmful to fish including two listed salmonid species, and indirectly reduce the diversity of macroinvertebrate species within affected stream reaches. Nitrate in the Western Hood Basin is listed as an ODEQ Nonpoint Source (NPS) Project Priority, and as a significant NPS concern in Mill Creek in the Eastern Hood Basin based upon ODEQ monitoring. Therefore, there is an urgent need to develop and demonstrate alternate sustainable N management systems and practices for pears in the Mid-Columbia region and the Pacific Northwest.

Similarly, P fertilizer is currently broadcast applied to the soil surface once (in March or April) per year at a rate of 100 to 125 lbs P_2O_5/acre as a dry material in the Mid-Columbia region. Phosphorus use efficiency is relatively low with this P management system because P is highly immobile in the soil, and surface applied P fertilizer does not positionally match up well with pear root system. Thus much applied P is fixed by soil minerals, particularly on the orchards at Parkdale where the soil is derived from volcanic ashes. Overall, inefficient P use with surface application of dry P fertilizer results in excessive P consumption by orchards and increases production costs.

Fertigation of N and P is the practice of applying N and P fertilizers with the irrigation water by injecting fertilizer solutions into the flowing water of an irrigation system. So far, very little research has been done to address the effects of split N and P fertigation on the growth, yield, quality, and storability of pears or other orchard trees in the Pacific Northwest. On the other hand, however, enhanced yields, higher N use efficiency, and improved control of weeds have been reported with N fertigation on some cereal and vegetable crops where N fertilizer application was reduced by over 50% with N fertigation compared with broadcast application of dry N fertilizer to the soil surface (Stiles, 1994). In addition, this study (Stiles, 1994) also shows fertigation could improve crop quality.

We propose a split N and P fertigation system that split the N and P fertilizers into five applications during May to August to match the N and P requirement by pear trees. We hypothesize that the split N and P fertigation system may significantly reduce N fertilizer losses and P fixation and thus increase N and P use efficiencies due to the following reasons: 1) N and P fertilizers are applied much closer to the root system, 2) N and P rates for each application are substantially reduced, 3) over-applications of N and P are avoidable during lower yielding seasons since opportunities are provided for growers to determine whether more N and P application is needed later in the season under split N and P fertigation, compared to the single broadcasting of N and P fertilizers on the soil surface system. In addition, N and P fertigation does not require much labor because it can be operated under an automatic fertigation and irrigation system, and the costs for an N and P fertigation system are relatively low.

The objectives of this study were to: 1) evaluate the effects of fertigation of N and P fertilizers under drip irrigation and fertigation of N and P fertilizers under micro sprinkler as two integrated production systems on pear fruit yield, quality, and storability compared with our current pear production system (broadcast application of dry N and P fertilizers to the soil surface), and 2) compare the costs on installing and maintaining fertigation plus drip irrigation system or fertigation plus micro sprinkler system with the costs on the current production system, and thus to assess grower profitability with the two new fertigation and irrigation systems in Oregon and the Pacific Northwest.

MATERIALS AND METHODS

A field experiment initiated in 2005, was continued in 2007 on adult green d'Anjou pear at Rod Laurance's orchard near Parkdale, Oregon. A randomized complete block experimental design was used with four replicates. The following were the five treatments:

1) Broadcasting application of N and P fertilizers to the soil surface under drip irrigation,

2) Banding application of N and P (12 inches deep) under drip irrigation,

3) Broadcasting application of N and P to the soil surface under drip irrigation along with soil disturbance caused by banding (no fertilizer was banded),

4) Fertigation of N and P under drip irrigation, and

5) Fertigation of N and P under micro sprinkler irrigation.

There were 20 plots in total. Nitrogen fertilizer was applied at 100 lb N acre^{-1} to treatments 1, 2, and 3, while only 80 lb N acre^{-1} of N was applied to treatments 4 and 5. Phosphate fertilizer was applied at 125 lb P_2O_5 acre^{-1} to treatments 1, 2, and 3, while treatments 4 and 5 only received 100 lb P_2O_5 acre^{-1} of phosphate. Both N and P in treatments 1, 2, and 3 were applied once in early April. However, N and P in treatments 4 and 5 were applied in five equal split applications during May to August.

The following samples and measurements were taken on an individual plot basis in 2007: 1) a soil sample was taken at the depth of 12 inches in the fall, about one month after fruit harvest, soil available P, total P, nitrate, ammonium, amino sugar N, and total N in these samples were determined; 2) a leaf sample was collected in the fall, about one month after fruit harvest, N, P, and other nutrients in these tissue samples were determined; 3) tree vigor, fruit yield, and the size, color, firmness, titratable acidity, and sugar of fruit were determined; and 4) fruit storability was evaluated after 3-month cold storage.

Statistical analyses of the data were conducted using the SAS statistical package (SAS Institute, 2007). A randomized complete block design model was used. Analysis of variance was conducted using the ANNOVA procedure. Mean separations were accomplished using the Fisher's protected LSD test (Kuehl, 1994). The probability level less than 0.05 was designated as significant.

RESULTS AND DISCUSSION

Leaf Nutrition after Fruit Harvest

In the 2007 season, fertigation of N and P fertilizers under drip irrigation resulted in similar leaf N concentration as surface broadcasting of N and P fertilizers (Table 1). The two N and P fertigation treatments had equal or significantly higher leaf P concentration than surface broadcasting. The effects of the two N and P fertigation treatments or banding treatment on other leaf nutrient concentrations were statistically insignificant.

Overall, our results agree with those of prior studies that have indicated that split fertigation could supply adequate mineral nutrition to fruit trees, even at a reduced application rate, relative to broadcast application. Worley et al. (1995) found that no reduction in leaf mineral nutrient concentrations of pecans occurred when 112 kg ha^{-1} of N was fertigated compared with 224 kg N ha^{-1} applied via broadcast application under a drip irrigation system in a 10-yr long-term study in Georgia. Smith et al. (1979) reported similar leaf N concentration of several fruit species when the rate of drip-fertigated N was reduced to 50% of the recommended normal rates for broadcast application. Additionally, a similar trend was observed in this study to those of Klein et al. (1989) on N fertigation for apple trees.

Our results show a similar tendency to those of Neilsen et al. (1994) who found P fertigation significantly increased leaf P concentration of apple relative to broadcast application in the first growing season. Enhanced mobility of P in soil under fertigation (O'Neil et al., 1979; Rauschkolb et al., 1976) may be responsible for improved tree P nutrition.

Table 1. Effects of N and P fertilizer application method on leaf nutrient concentrations after harvest.

Trt	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
1	1.872	0.095	1.102	2.655	0.287	0.256	123.85	217.63	53.72	6.075
2	1.822	0.093	1.140	2.410	0.262	0.261	136.73	240.65	54.70	6.425
3	1.755	0.091	1.067	2.595	0.299	0.263	127.83	225.55	56.97	6.400
4	1.852	0.098	1.135	2.655	0.286	0.243	125.15	221.43	59.27	6.150
5	1.942	0.119	1.187	2.667	0.272	0.260	138.58	233.08	60.62	6.500
Sig.	ns	**	ns	ns	ns	ns	ns	ns	ns	ns

** indicates the treatment effect is statistically significant at 1% probability level. Non significant effect is denoted by ns.

Fruit Yield and Quality

The differences in fruit yield were statistically insignificant among the five treatments in 2007 (Table 2). Numerically, pear yield with broadcasting application of N and P fertilizers to the soil surface was 208.5 kg/tree. Banding application of N and P fertilizers had a 1% yield increase over surface broadcasting application. Split fertigation of N and P fertilizers under drip irrigation and split fertigation of N and P under micro sprinkler irrigation increased yield by 3% and 4%, respectively, relative to surface broadcasting application.

Fruit sugar, firmness, or titratable acidity was not statistically different among the five treatments (Table 2). Fruit size or color did not differ among the five treatments (data not presented). On average, the two fertigation treatments reduced both nitrogen and phosphate fertilizer use by 20% compared with broadcasting application of nitrogen and phosphate fertilizer to the soil surface.

Similar to our results, previous research has shown that fertigation can reduce the amount of N applied to orchards while maintaining equal or increased tree fruit productivity relative to broadcast application on other fruit trees. However, the degree of reduction in N application rates via fertigation is site-specific. Sanchez et al. (2003) reported that yield of tart cherry was compatible or even higher, although nitrate leaching dramatically diminished, when N fertilizer was fertigated at a reduced annual rate of 66 kg N ha^{-1} relative to 113 kg N ha^{-1} of surface broadcast N during a six-year field study in Michigan. Worley et al. (1995) found that no reduction in yield or quality of pecan nuts occurred when 112 kg ha^{-1} of N was fertigated compared with 224 kg N ha^{-1} applied via surface broadcasting under a drip irrigation system in a 10-yr long-term study in Georgia. Similar yield of several fruit species was obtained when the amount of drip-applied N was reduced to 50% of the normal recommended N rates under surface broadcasting (Smith et al., 1979). Similarly, Neilsen et al. (1994) reported fertigated P increased apple yield in the first fruiting season in western Canada. Overall, the amount of N fertilizer that can be saved under fertigation is site and management specific. Soil properties, irrigation system, fertigation and irrigation scheduling, and local weather conditions are all key factors.

Table 2. Effects of N and P fertilizer application method on pear fruit yield and quality in 2007.

Trt	Yield (kg/tree)	Sugar (^{o}brix)	Firmness (lbs)	Titratable acid (meg/100 ml)
1	208.5	12.0	13.0	3.9
2	210.3	12.1	10.9	4.0
3	212.7	12.1	11.0	3.9
4	214.8	11.7	12.5	3.8
5	216.9	11.8	13.4	3.7
Sig.	ns	ns	ns	ns

Non significant effect is denoted by ns.

Fruit Storability

Visual evaluation of fruit surface scald was conducted after the fruits had been stored in a cold storage room for three months in 2007. Five categories of excellent, very slightly scalded, slightly scalded, moderately scalded, and severely scalded fruits were used in this evaluation. It was interesting that the two split N and P fertigation treatments reduced the total of slightly scalded, moderately scalded, and severely scalded fruits by 9 to 14% (absolute value) compared with surface broadcasting (Table 3). The increase in marketable fruit, which resulted from the reduction in slight, moderate, and severe scald incidence, could significantly enhance grower profitability. Our results show that reduction in fruit superficial scald during cold storage is another notable benefit with split fertigation.

Table 3. Effects of N and P fertilizer application method on pear fruit surface scald after 3-month cold storage.

Trt	Excellent %	Very slightly scalded %	Slightly scalded %	Moderately scalded %	Severely scalded %
1	13.7	18.2	49.6	14.8	3.7
2	11.4	17.4	31.7	35.4	4.1
3	20.3	15.3	33.2	26.1	5.2
4	16.4	24.8	38.7	18.4	1.7
5	23.8	22.4	39.3	14.6	0.0
Sig.	ns	ns	ns	ns	ns

Non significant effect is denoted by ns.

SUMMARY

The 2007 results show that N and P applications reduced by 20% of current broadcast application rates and fertigated in five equal split applications per season, can supply adult pear trees with adequate N and P nutrition. Shift from the current N and P management practice – single broadcast application on the soil surface to the reduced-rate split fertigation produces compatible fruit yield and quality, and exerts significant beneficial effects on reducing fruit superficial scald and N and P fertilizer consumption. Band placement of N and P has compatible fruit yield and quality when compared with broadcast application with soil disturbance caused by band placement on pear orchards in the Mid-Columbia region of Oregon.

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