NITROGEN AND PHOSPHORUS FERTIGATION ON PEARS

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ABSTRACT

Avoiding over-application of nitrogen (N) and phosphorus (P) fertilizers and increasing N and P use efficiency on pear orchards have significant benefits on pear productivity and the environment. 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 fertilizers 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 was conducted in 2006 on adult green d'Anjou pear at 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 fertilizers (12 inches deep) under drip irrigation, 3) broadcasting application of N and P fertilizers to the soil surface under drip irrigation along with soil disturbance caused by banding (no fertilizer was banded), 4) fertigation of N and P fertilizers under micro sprinkler irrigation, and 5) fertigation of N and P fertilizers under drip irrigation were compared using a randomized complete block design with four replicates. The 2006 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 show beneficial effects on fruit yield and size and reduction in fruit scald and N and P fertilizer consumption on the Parkdale soil. In addition, banding of N and P fertilizers also has benefits in increasing fruit yield and size and reducing fruit scald compared with our current N and P management system -- surface broadcasting application in the Mid-Columbia region, Oregon.

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 to 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 intensive irrigation schedules. Nitrogen use efficiency is 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. On the other hand, low N use efficiency increases losses of NO and N_2O gases to the atmosphere. These nitrogenous gases are harmful to the ozone, and thus increase the possibilities of human skin cancer occurrence due to the increased atmospheric ultra-violet rays to the earth. 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 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 volcano 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 USA. 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 believe that the split N and P fertigation system will 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 fertilizer rates for each application are substantially reduced, 3) over-applications of N and P fertilizer 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 is operated under an automatic fertigation and irrigation system, and the costs for an N and P fertigation system are relatively low and affordable.

The objectives of this study were to: 1) evaluate the effects of fertigation of N and P fertilizers under micro sprinkler and fertigation of N and P fertilizers under drip irrigation 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 micro sprinkler system or fertigation plus drip irrigation 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 was conducted in 2006 on adult green d'Anjou pear at Rod Laurance's orchard in 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 fertilizers (12 inches deep) under drip irrigation,
3) Broadcasting application of N and P fertilizers to the soil surface under drip irrigation along with soil disturbance caused by banding (no fertilizer was banded),
4) Fertigation of N and P fertilizers under micro sprinkler irrigation, and
5) Fertigation of N and P fertilizers under drip 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 fertilizer 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 fertilizer. Both N and P fertilizers in treatments 1, 2, and 3 were applied once in early April. However, the N and P fertilizers in treatments 4 and 5 were applied in five split applications during May to August.

The following samples and measurements were taken on an individual plot basis in 2006: 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, 2006). 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

Soil Fertility after Fruit Harvest

In 2006, soil total N content, amino sugar N content, or NH_4-N content with the two N and P fertigation treatments was not reduced compared with surface broadcasting although N fertilizer application rate was lowered by 20% for the two fertigation treatments (Table 1). However, soil NO_3-N content under the two fertigation treatments was significant lower than that with the surface broadcasting treatment. The difference in total P or available P content was not statistically significant among the five treatments even though P fertilizer rate was reduced by 20% with the two N and P fertigation treatments relative to the other treatments. Overall, our results suggest that split fertigation of N and P fertilizers may increase the use efficiency of applied N and P fertilizers on pear orchards in the Mid-Columbia region, Oregon.

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

Trt	Total N	Amino sugar N	NH_4-N	NO_3-N	Total-P	Available P
	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
1	0.208c	259.0	1.48	36.6	1310.5	30.3
2	0.261ab	344.4	1.98	59.2	1387.0	43.5
3	0.271a	233.1	1.53	67.6	1256.8	37.0
4	0.234bc	298.2	1.85	8.4	1195.3	36.0
5	0.295a	302.4	1.80	14.4	1255.8	36.8
Sig.	*	ns	ns	*	ns	ns

* indicates the treatment effect is statistically significant at 5% probability level. Non significant effect is denoted by ns.

Leaf Nutrition after Fruit Harvest

In the 2006 season, Fertigation of N and P fertilizers under micro sprinkler irrigation resulted in significantly higher leaf N concentration than surface broadcasting of N and P fertilizers (Table 2). Both fertigation of N and P under drip irrigation and banding application of N and P treatments had insignificant but numerically higher leaf N level than surface broadcasting. It is obvious that the two N and P fertigation treatments had significantly higher leaf P concentration than surface broadcasting. However, the difference in leaf P between the banding application and surface broadcasting treatments was not significant. Similar to leaf P, leaf S concentration was significantly greater under the two N and P fertigation treatments compared with surface broadcasting, and banding application also resulted in higher leaf S 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.

Table 2. Effects of N and P fertilizer application method on leaf nutrient concentrations after harvest.

Trt	N	P	K	Ca	Mg	S	B	Zn	Mn	Cu
	(%)	(%)	(%)	(%)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)
1	1.90bc	0.101b	1.17	2.35	0.28	0.23c	88.9	169.4	67.3	6.3
2	1.99ab	0.106b	1.43	2.19	0.26	0.25ab	98.1	188.7	70.9	7.6
3	1.80c	0.104b	1.18	2.52	0.30	0.24bc	87.2	170.6	74.9	8.0
4	2.07a	0.118a	1.45	2.24	0.28	0.25a	104.5	180.6	66.5	7.7
5	1.99ab	0.127a	1.39	2.33	0.26	0.25ab	98.2	182.0	69.6	8.1
Sig.	*	*	ns	ns	ns	*	ns	ns	ns	ns

* indicates the treatment effect is statistically significant at 5% 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 2006 (Table 3). Numerically, pear yield with broadcasting application of N and P fertilizers to the soil surface was 217.0 lb/tree. Banding application of N and P fertilizers had a 4.6% yield increase over surface broadcasting application of N and P fertilizers. Split fertigation of N and P

fertilizers under micro sprinkler irrigation and split fertigation of N and P under drip irrigation increased yield by 4.2% and 5.7%, respectively, relative to surface broadcasting application.

Fruit firmness was significantly greater with the N and P fertigation treatment under micro sprinkler irrigation relative to surface broadcasting application. Titratable acid was significantly greater with banding application of N and P fertilizers compared with surface broadcasting application. Additionally, fruit size was larger with banding application of N and P fertilizers, split fertigation of N and P fertilizers under micro sprinkler irrigation, and split fertigation of N and P under drip irrigation relative to surface broadcasting application in terms of the nine fruit categories (0-141, 141-158, 158-174, 174-191, 191-211, 211-236, 236-268, 268-309, and 309-999 grams) (data not presented). Fruit color did not differ among the five treatments. On average, the two fertigation treatments reduce both nitrogen and phosphate fertilizer use by 20% compared with broadcasting application of nitrogen and phosphate fertilizer to the soil surface.

Table 3. Effects of N and P fertilizer application method on pear fruit yield and quality.

Trt	Yield (lbs/tree)	Sugar (^{o}brix)	Firmness (lbs)	Titratable acid (meg/100 ml)
1	217.0	13.2a	14.2b	4.6b
2	226.9	13.4a	14.2b	5.1a
3	222.5	12.8ab	14.3b	4.4b
4	226.2	13.0ab	15.3a	4.7ab
5	229.3	12.3b	14.8ab	4.5b
Sig.	ns	*	*	*

* indicates the treatment effect is statistically significant at 5% probability level. 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 2006. 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 and the banding application treatment reduced the total of slightly scalded, moderately scalded, and severely scalded fruits by over 13% (absolute value) compared with surface broadcasting. Reducing surface scald seems to be another benefit with split N and P fertigation and banding application of N and P fertilizers (Table 4).

Table 4. Effects of N and P fertilizer application method on pear fruit surface scald after 3-month cold storage.

Trt	Excellent %	Very slightly %	Slightly %	Moderate %	Severe %
1	25.0	40.0	15.0	15.0	5.0
2	40.0	42.5	17.5	2.5	0.0
3	25.0	27.5	22.5	15.0	10.0
4	37.5	42.5	10.0	10.0	0.0
5	35.0	42.5	12.5	7.5	2.5
Sig.	ns	ns	ns	ns	ns

Non significant effect is denoted by ns.

SUMMARY

Overall, the 2006 results suggest 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 show beneficial effects on fruit yield and size and reduction in fruit scald and N and P fertilizer consumption on the Parkdale soil. In addition, banding application of N and P fertilizers also has benefits on increasing fruit yield and size and reducing fruit scald compared with our current N and P management system -- surface broadcasting application in the Mid-Columbia region, Oregon.

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