European Pear Growth and Cropping: Optimizing Fertilizer Practices Based on Seasonal Demand and Supply with Emphasis on Nitrogen Management, Interpretive Summary

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INTRODUCTION

N fertilization recommendations for California European pear trees have been modified from 1991 -- 75 to 125 lb actual N per acre per year (#N_{act}/A/yr) to 2007 -- 2 lb actual N per ton of crop per acre per year (#N_{act}/t/A/yr). Tissue N critical value is 2.2%, adequate N range is 2.3-2.6% (UC recommendation) measured from non-bearing spur leaves in mid-summer. The 2007 recommendation establishes BMP based on two physiological premises for N management: (1) efficiency of N use in cropping -- a 30 t/A orchard should receive 60 #N_{act}/A/yr; (2) vegetative vigor control– no N if average shoot growth exceeds 12 inches. A 2008 survey of growers found N usage in the main production region of the Sacramento River Delta varied from 40-60 #N_{act}/A/yr (a single organic producer) to a typical rate of120#N_{act}/A/yr. Annual shoot growth is often 3-5 feet. Vigor control is difficult with high water tables and leads to higher fire blight (FB) susceptibility; FB management is the highest production cost. BMP should reflect N partitioning spatially in tissues and temporally during the growth and rest cycles to minimize over-usage, increased vigor, and ground water leaching. There is no 'one size fits all' approach to fertilizer management—some growers take the approach that inputs can be reduced or skipped on an annual basis if no adverse effects result (yield, fruit quality or tree deficiency symptoms) and tissue levels don't indicate inadequacy. Other growers tend to perceive reduction in N as a risk for reduced crop load and fruit size and that CV's established when tonnage was lower and most fruit went to processing (thus fruit size was less important), or fresh fruit were not stored (often stored 2+ months at present), should be re-evaluated. California's Delta trees are 30 to 100+

years old, may retain tissue nitrogen for years without applied N (1997-2000 unpublished study, Ingels), and are intensively farmed in a highly sensitive waterway.

Diagnostic methods for nutrient sampling will be re-examined in this study. Currently, UC recommends testing annually by collecting non-bearing spur leaves in mid-summer (postharvest). Various publications and recommended critical values for European pear elsewhere generally utilize mid-shoot leaves . Analyses after harvest do not allow adjustment for current season yields and quality, and it is possible that leaves collected from fruit-bearing spurs, where demand is likely to be highest, may prove to be a better indicator of nutrient status for cropping. Fruit quality is dependent on N, Ca, K and P (and their 'balance'); optima should reflect current strategy of maximum yield and 'target fruit'. High nitrogen is considered detrimental to fruit quality, as a balance among nitrogen, calcium and potassium, particularly.

OBJECTIVES

1. Determine the relationship between seasonal tissue N partitioning and concentration and tree productivity and growth (i.e. reassess the currently-accepted leaf N critical values, timing of sampling and tissues tested). **Orchards Elliot 1 and McCormack**
2. Compare typical and reduced N to validate recommended N management and the possibility of customizing BMP based on tissue levels, fruit quality and crop load **Orchards Elliot 1 and McCormack**
3. Quantify effects on crop load and fruit quality due to N, K and Ca as influenced by application amount, form and timing **Orchard Elliot 2**
4. Refine current management guidelines for N, K and Ca usage to maintain productivity and fruit quality while reducing potential of over-fertilization **Orchards Elliot 1 and 2 , McCormack**
5. Monitor and quantify growers' irrigation practices in each trial site with the goal of optimum irrigation management to reduce nitrate leaching Cooperate with growers to follow recommended irrigation frequency as outlined by UC recommendations (Pear Production and Handling Manual, UCANR Publication 3483, Mitcham and Elkins (eds), 2007) **Orchards Elliot 1 and 2 , McCormack**

DESCRIPTION

A practical approach has been adopted in which we us three 'Bartlett' orchards with existing conditions that allow manipulation. These orchards represent the majority of Delta 'Bartlett' orchards with a range of yields of (20-32 t/A/yr), tree age, rootstock, soil and growing conditions. All are sampled annually for tissue nutrient levels, and irrigation water and soil N profiles. Orchards '**Elliot1'**and '**Elliot2'** are on Sutter Island. **Elliot1** has had low N beginning in 2007 at about 60 #N_{act}/A/yr, adjusted to 120#Nact/A/yr in 2009-2010 in the orchard outside our test area. We began monitoring **Elliot1** in a preliminary project, funded by the California Pear Advisory Board, in which **Elliot1 (**60 #N_{act}/A/yr) was compared to a 'HighN' orchard (120 #N_{act}/A/yr, uninterrupted) nearby.

The 'LowN' treatment will be annually adjusted to reflect crop load, to approximate UC recommendations. HighN = NH_4SO_4 (60#N_{act}/A) in fall + $Ca(NO_3)_2$ 62 #N_{act}/A via fertigation in spring and LowN = spring fertigation only are the treatments. Yields are typically about 20-25 tons/acre. In 2008, leaf analyses showed 'normal' nutrient levels with the exception of N (3.04%), excessive by UC. Soil pH was 6.33, nitrates 10.9ppm, ammonium 1 ppm, and of other nutrients tested, only Mg exchangeable appeared excessive at 588ppm. 'Low' to 'very low' soil nutrients included: soluble K, Ca, Mg, and boron.

We will test for N:K:Ca effects on fruit quality and cropping in **Elliot2**. Until 2007 the typical fertilizer program in **Elliot 2** was 100 #N_{act}/A/yr immediately after harvest and a fall application of potash (application of K is 'budget dependent'). In 2007 and 2008, no fertilizer was applied. Beginning in 2009, the block was fertigated in spring with KMend (potassium thiosulfate $K_2S_20_3$), soluble potash (K_2O) at 25% and S at 17%, by weight, for a total of 150 lb K/acre. No reduction in vigor and no loss of yield (~25 tons/A) or fruit quality from 2007 onward has been reported by the grower. Urea (1#/100 gallons/acre) is applied in each fireblight spray for 'fruit finish', for a total of 0.7-2.76 #N/acre. This is a typical application practice for 'Bartlett' growers in California. Our project will compare application method and timing of K, critical for fruit quality, as well as any effects of reduced N. The K treatments are either split fertigations of calcium nitrate (total of 60#N each) and KMend or 500# K_2O (muriate of potash) at 150 #Kact/A/yr applied to soil in fall. The spring application allows adjustment of fertilizer quantity based on current season crop load, is applied during the time of greatest demand by growing fruit, and is thought to contribute to better 'fruit finish' and storage longevity.

'McCormack' Orchard will also be used to compare 'optimized' and 'reduced' N to test customizing BMP. McCormack Orchard rows have a N-S orientation with a 'drop' towards the south half, with higher water table and better soil, resulting in increased vigor, earlier harvest, heavier crop load and larger fruit than in the N half. Recent management changes (flood changed to solid set sprinkler irrigation, increased N and better pruning) have increased yields from 20-23 t/A/yr to 30-32 t/A/yr. Both halves of the orchard have received a total of 152#N_{act}/A/yr. The south half will receive 90#N_{act}/A/yr (fertigated in May-June) and the north half will receive 192 #N_{act}/A/yr (fertigation 6-7x May-June = 90 #N_{act}/A/yr from CAN17 + 40#N_{act}/A $Ca(NO_3)_2$ soil-applied twice May-June) + additional N in fall as urea in a custom blend that includes K muriate potash (300 #/A) and micronutrients) to equalize fruit development rate and vegetative vigor between the N and S halves of the orchard.

In **Elliot1** and **McCormack** Orchards the relationship between tissue N partitioning, timing and level of N application with yield, fruit quality and vigor will be addressed. At **Elliot2** tissue partitioning of N will also be tracked, but the emphasis will be on the effects of timing of K application (and method/form of application) on tissue macronutrient levels, fruit quality and yield. We will compare early and late sampling of both vegetative and reproductive leaf tissues with 'standard' sampling (non-bearing spur leaves in late June-July) at all orchards; fruit nutrient levels will be tested at **Elliot2** as well. A collateral study of postharvest and storage fruit quality as affected by treatment will be conducted at UC Davis, funded by the California Pear Advisory Board.

A survey of grower fertilization practices will be conducted in the 'late' pear district (Lake and Mendocino Counties), similar to that previously done in the Delta, funded by the California Pear Advisory Board. Annual reporting to growers in both districts at the CPAB annual research meetings, as well as annual reporting at the FREP conference, will be done.

RESULTS AND DISCUSSION

Elliot1 Nutrient Analyses, 2009-2010

In 2009 no differences of N level were found between **Elliot1** and the 'HighN' orchard in March vegetative and floral buds, but only between bud types (Table 1); spur buds were much higher in N content than shoot buds as reserves were mobilized for flowering and fruiting. N was lower and below the critical value for bearing spur leaves (both orchards) after harvest, while N of shoot and vegetative spur leaves was much higher and adequate. October analyses of both buds and leaves found that buds had much lower levels of N than did leaves (either type) and N levels in all tissues were slightly lower in **Elliot1**. Significant differences between 'high' and 'low' N orchards on October 1 were found for N content. Partitioning into different plant organs (vegetative vs reproductive) was clear and independent of N level treatment, with leaf N values below the critical values set for mid-summer levels, illustrating both movement of N into storage tissues and probably removal of N with cropping. Leaf analyses from April, 2010 show no significant difference between high and low N treatments, within leaf types (Figure 1) and mean values averaged from 2.55%N to 2.99%N (range 2.33-3.29, across leaf types), despite reduced N applications.

McCormack Nutrient Analyses

April values for tissue N levels, among leaf types, ranged from 2.34% to 3.25%. Fruiting spur leaves had N values slightly lower than those of either shoot or vegetative spur leaves, which might be accounted for by higher demand by growing fruit.

Elliot2 Nutrient Analyses

April values for tissue N levels, among leaf types, ranged from 2.74% to 3.14% (figure 3). Fruiting spur leaves had N values slightly lower than those of either shoot or vegetative spur leaves, as did our other two sites. Fruit N was lower still, at ~2.30-2.35%. Conversely, boron was highest in fruit and lowest in fruiting spurs (Figure 4). Additional nutrient distributions are shown in Figures 5-9.

Harvest, 2010:Elliot2

We hand-harvested twice, on 2-3 major scaffolds per 'test' tree (4 trees per treatment/block combination with 4 blocks per K treatment). The first 'pick' was to a minimum size, used by the pear industry for that purpose (2 5/8" Grade #1). The second harvest was a 'strip pick', with all fruit removed from the scaffolds. Thus, we were able to develop baseline data for fruit size, distribution of size grades in the two harvests and in total (Figures 10-14).

Harvest, 2010: Elliot1

Preliminary data from **Elliot1** single harvest establish baseline data (no effect of N level yet) for weight of #1 fruit (~11 oz), count per lb (~2.04), individual #1 fruit weight (11.07 oz), soluble solids (%Brix, 2.05),   Table 2.

Harvest data from **Elliot1** and **McCormack**, as well as July tissue sample analysis, are currently being conducted, and will be reported on at the annual FREP meeting.

Acknowledgements

We wish to acknowledge the support of the California Department of Agriculture's FREP program and the California Pear Advisory Board for their support, as well as the growers and PCAs, without whose inputs and cooperation, this work could not be done.

Table 1Tissue N (% nitrogen) measured in ‘**Elliot1**’ orchard (60#N_{act}/A/yr) vs a ‘HighN’ orchard (120#N_{act}/A/yr) in expanding pear buds and leaves, March 9, July 7 and October 1, 2009. Means separation by Student’s ttest or LS Means, 5% level. ***, **,* = significance at 0.001, 0.01, and 0.05, respectively. Means with the same letters **within rows (a given orchard)** do not significantly differ. Difference between replicate blocks within a single treatment/orchard combination were found to be significantly different in July and October.

March 9	**Shoot terminal bud**	**Spur bud**	**Significance bud type**
60#N	1.60 b	2.50 a	***
120#N	1.62 b	2.42 a	**

July 7	**Shoot leaf**	**Spur leaf**		**Significance**	
		Nonbearing	**Bearing**	**Orchard**	**Leaf type**
60#N	2.75 a	2.48 b	2.09 c		***
120#N	2.64 a[z]	2.41 b	2.15 c		***

October 1	**Shoot leaf**	**Spur leaf**	**Shoot bud**	**Spur bud**	**Significance**		
					Orchard	**Leaf type**	**Bud type**
60#N	2.02 a	1.89 b	0.855 c	0.788 c	***	*	***
120#N	2.17 a	2.13 b	0.886 c	0.806 c	***	*	***

Table 2 Measures of fruit quality in ‘**Elliot1**’ orchard (‘Low N’ 60#N_{act}/A/yr vs a ‘HighN’ treatment (120#N_{act}/A/yr)

Nitrogen level	**Quality**	**Mean**	**Std Error**	**Std Dev**	**Minimum**	**Maximum**
High_N	#1 fruit weight (oz)	11.07	0.38	0.66	10.33	11.59
	Weight for unsorted fruit (oz)	7.30	0.07	0.20	7.10	7.60
	Count/lb of #1 fruit	24.43	0.84	1.46	22.80	25.60
	Soluble solids (Brix)	2.07	0.07	0.12	2.00	2.20
	Percentage of harvest as #1 fruit	79.8	2.12	6.37	65.9	85.9
Low_N	#1 fruit weight (oz)	11.09	0.42	0.73	10.34	11.80
	Weight for unsorted fruit (oz)	6.86	0.10	0.30	6.30	7.30
	Count/lb of #1 fruit	24.47	0.93	1.60	22.80	26.00
	Soluble solids (Brix)	2. 03	0.09	0.15	1.90	2.20
	Percentage of harvest as #1 fruit	70.63	2.86	8.58	59.80	85.90

Figure 1 Distribution of tissue nitrogen in pear leaves, April 2010 at **Elliot1** Orchard. Nitrogen application treatments are: High N (120#N_{act}/A/yr) and Low N (60#N_{act}/A/yr).

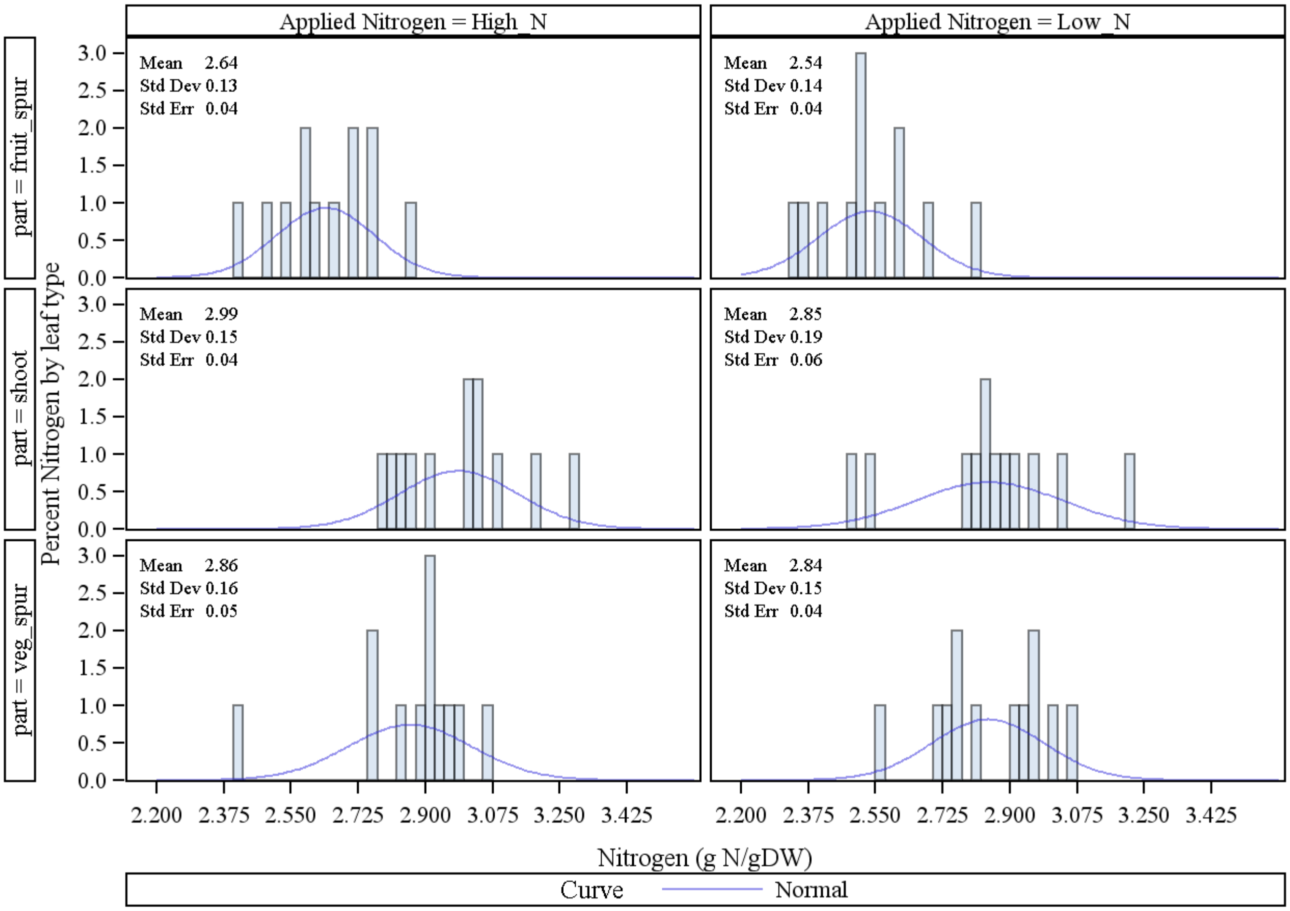


Figure 2 Distribution of tissue nitrogen in pear leaves, April 2010 at **McCormack** Orchard. Nitrogen application treatments are: High N (192#N_{act}/A/yr) and Low N (90#N_{act}/A/yr).

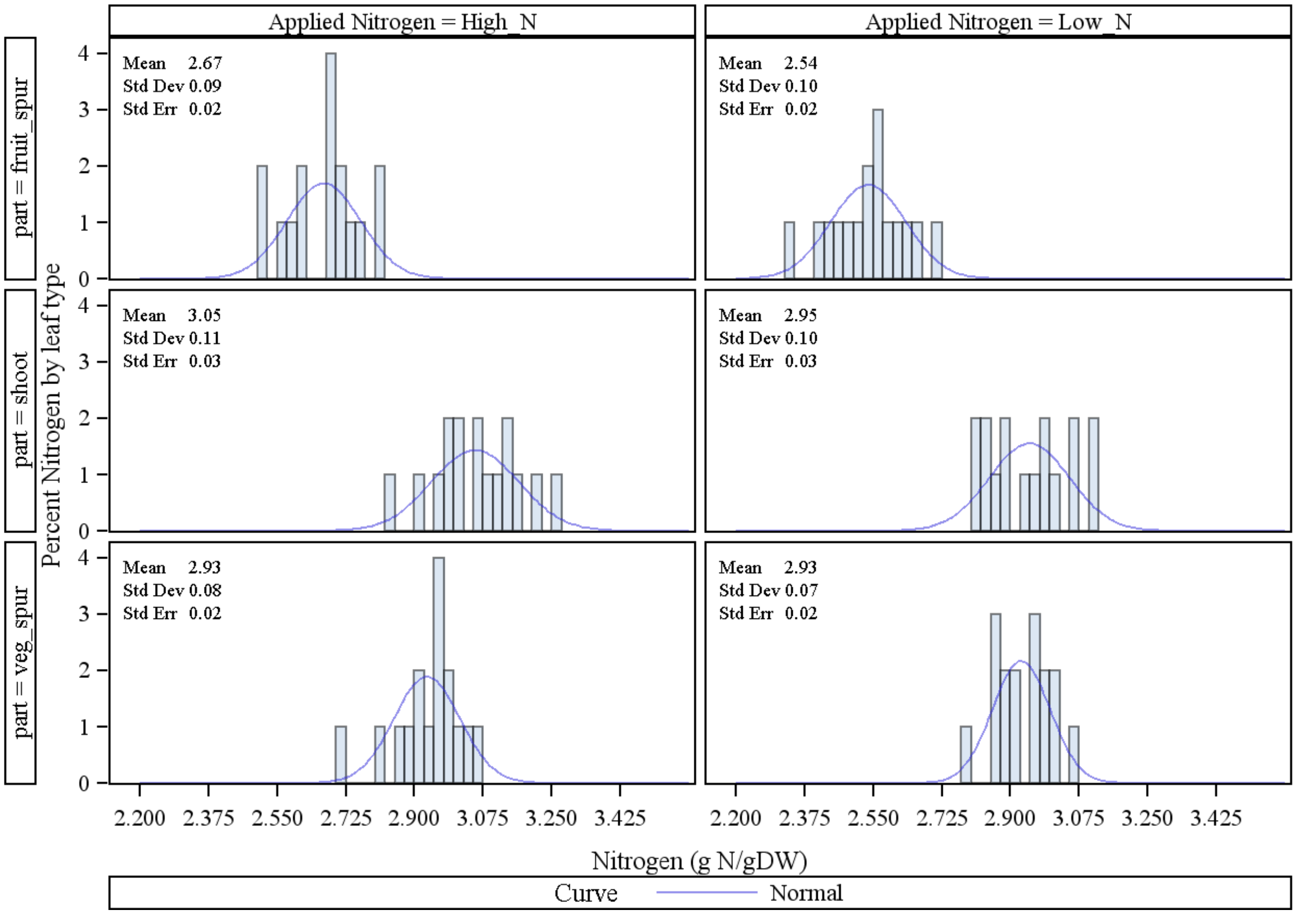


Figure 3 Distribution of tissue nitrogen in pear leaves, April 2010 at **Elliot2** Orchard, test orchard for N:K:Ca effects on fruit quality and cropping.

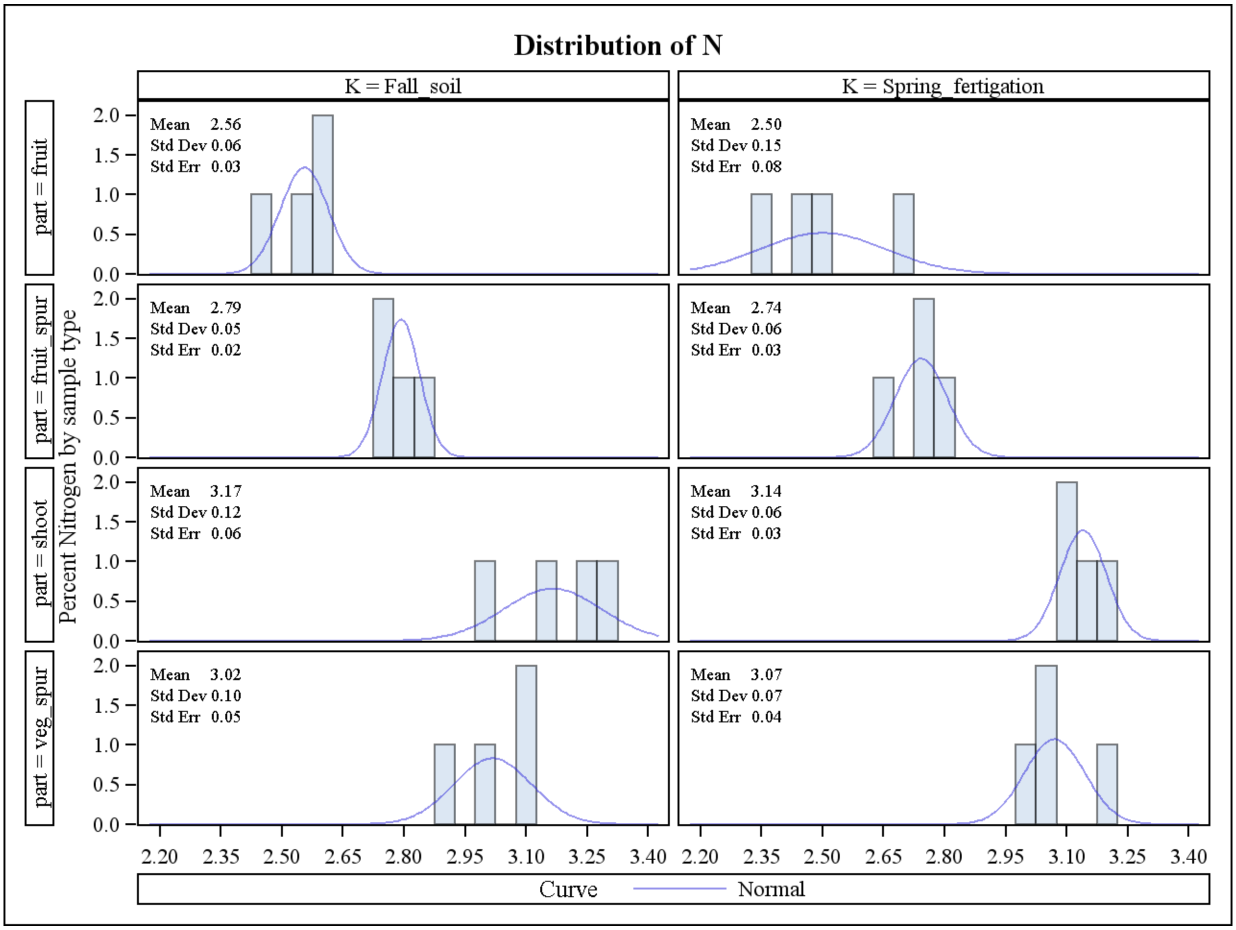


Figure 4 Distribution of boron in fruit and leaf tissues at **Elliot2** orchard, April, 2010.

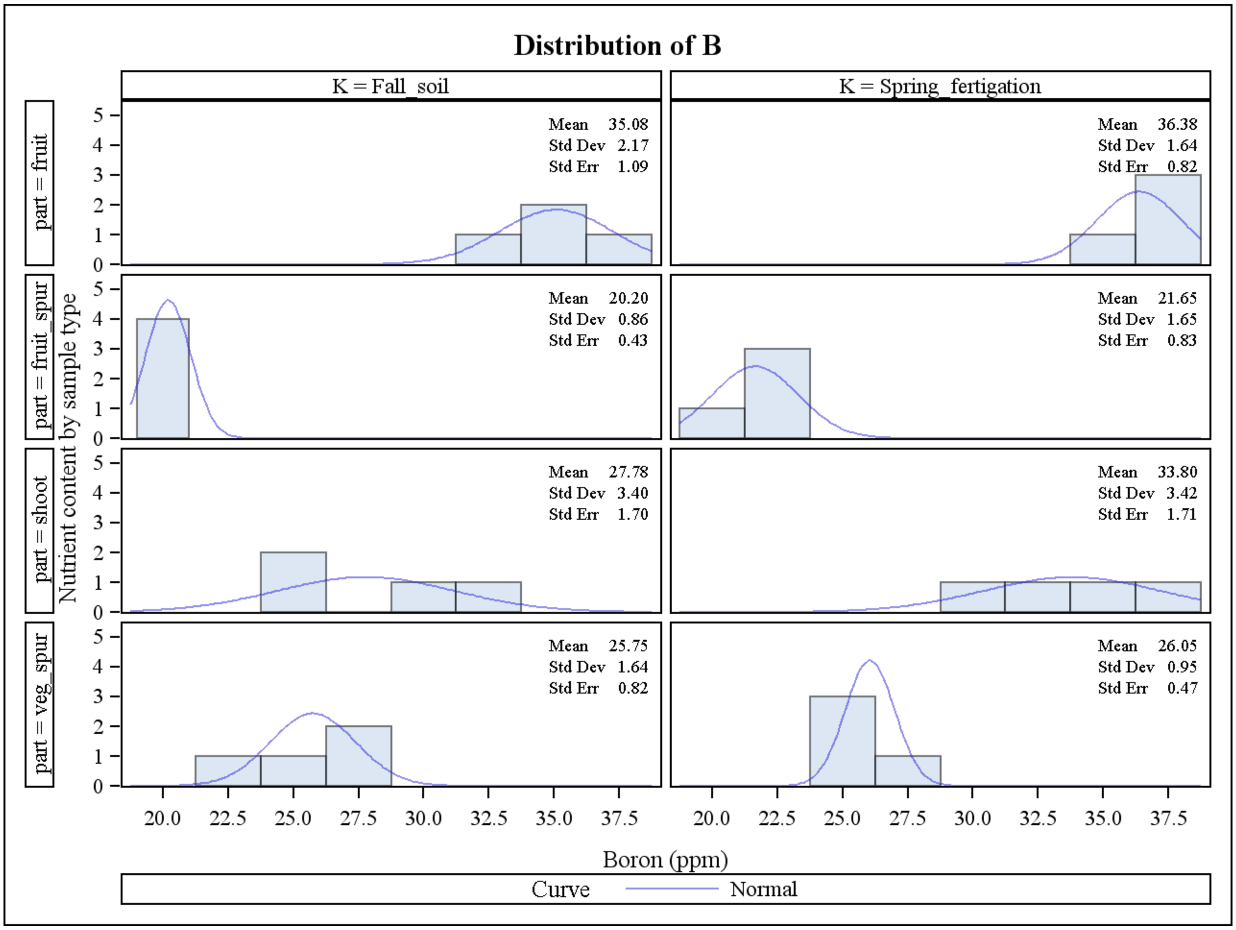


Figure 5 Distribution of phosphorus in fruit and leaf samples from **Elliot2**, April, 2010.

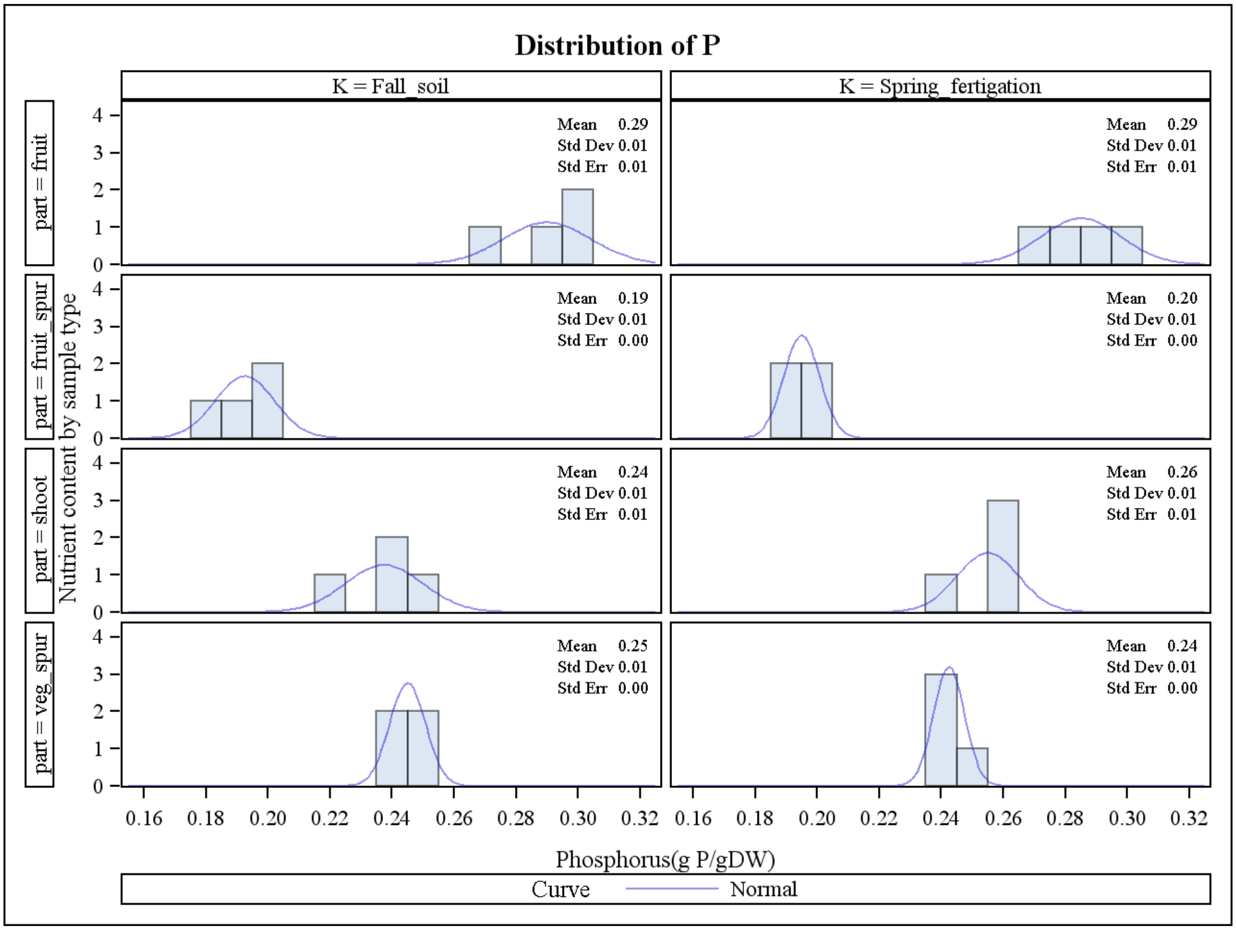


Figure 6 Distribution of zinc in fruit and leaf tissues at **Elliot2,** April, 2010.

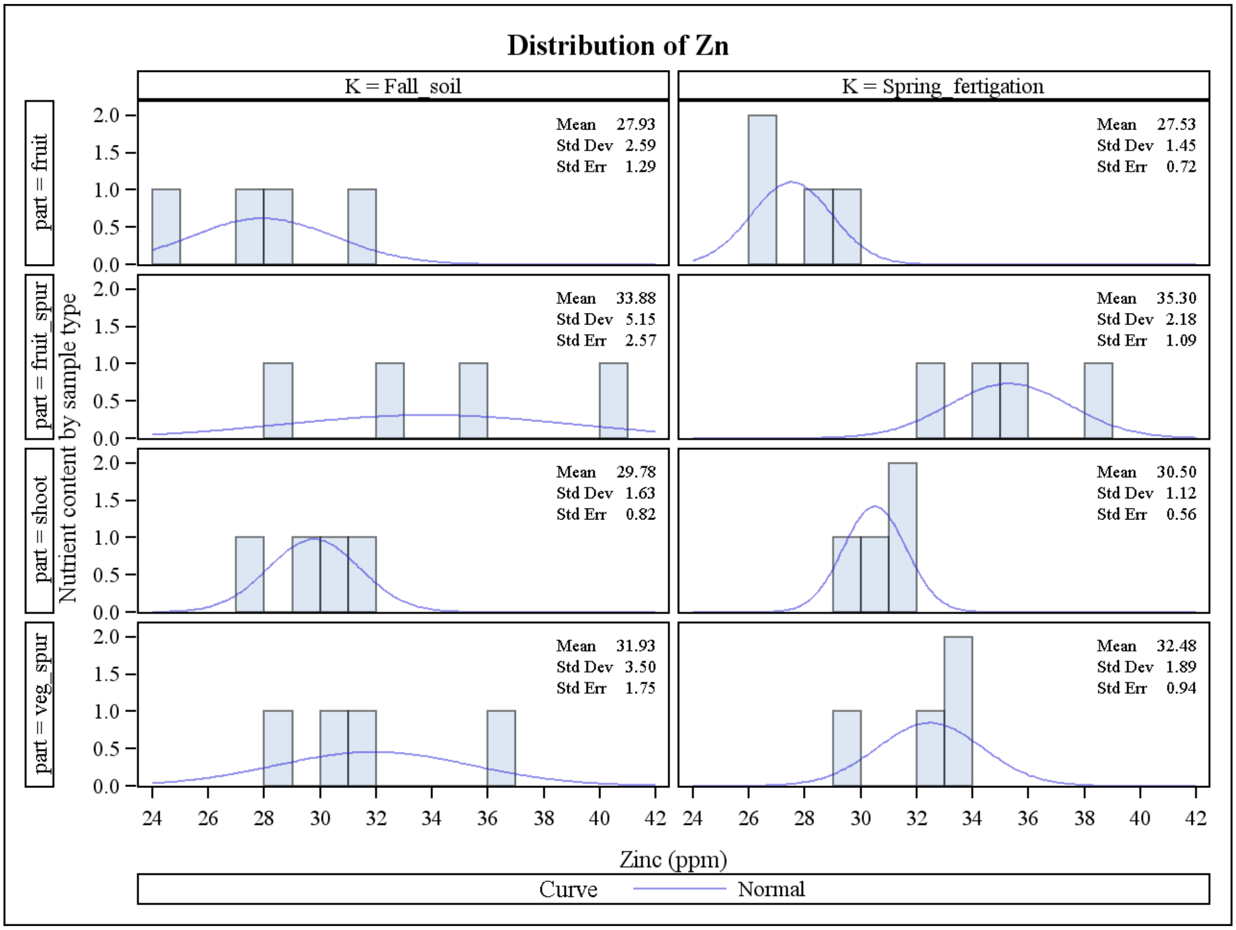


Figure 7 Distribution of potassium in fruit and leaf tissues at **Elliot2**, April, 2010.

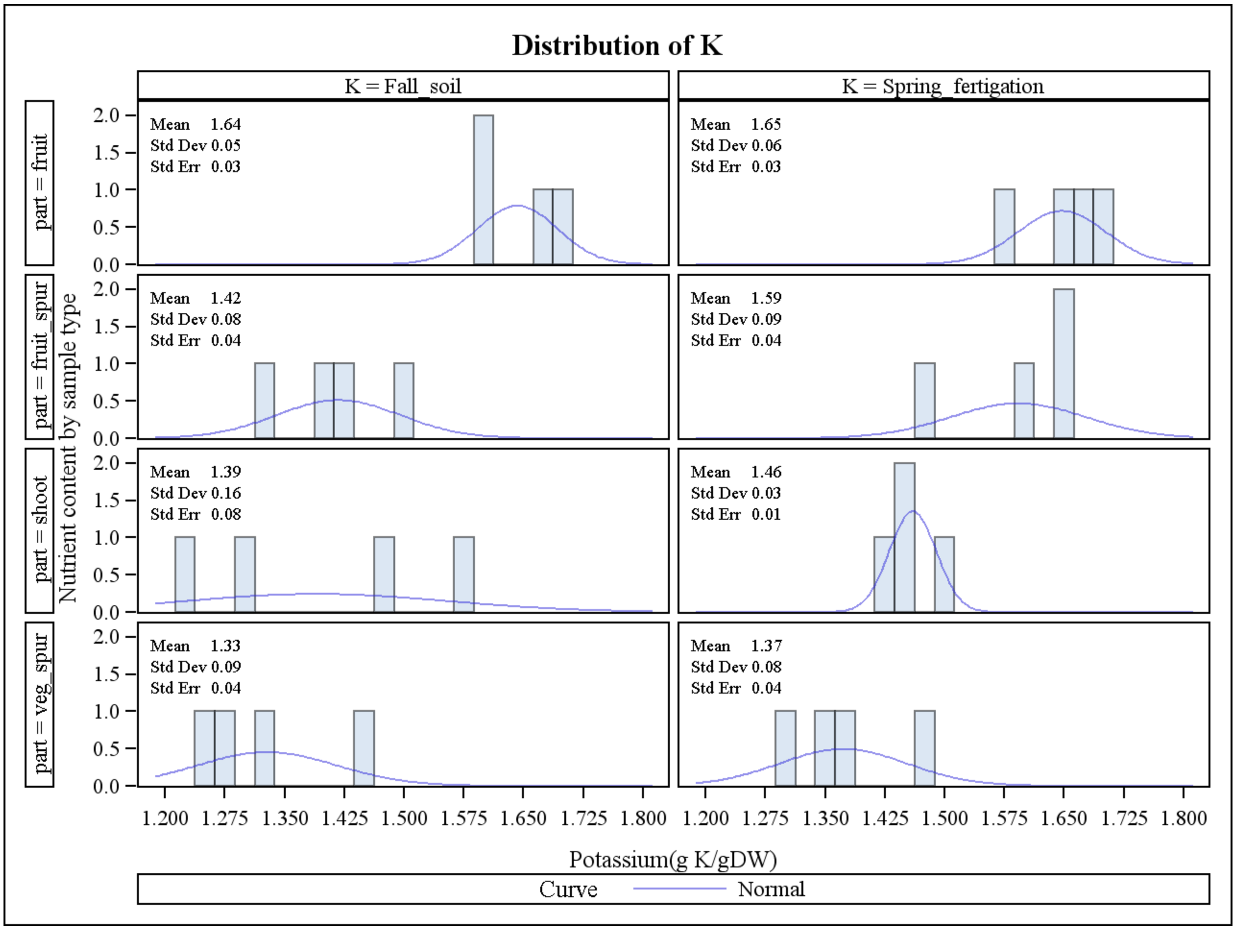
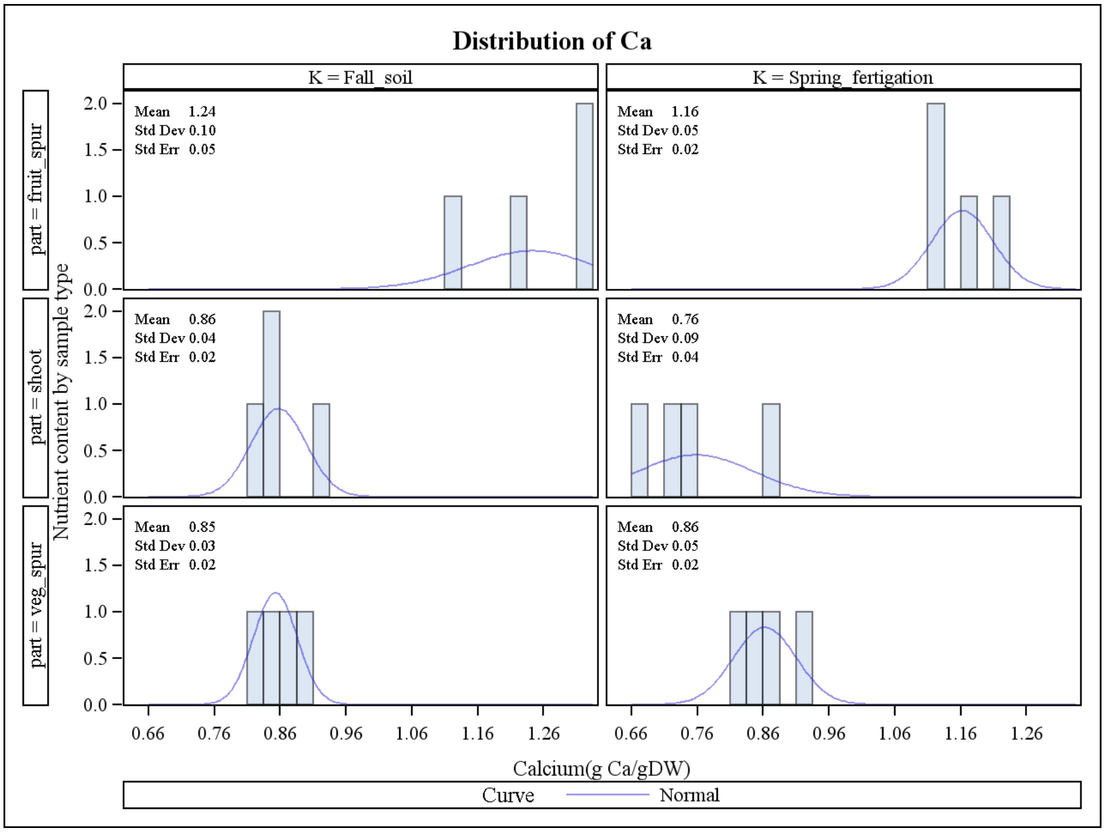


Figure 8 Distribution of calcium in fruit and leaf tissues at **Elliot2**, April, 2010.



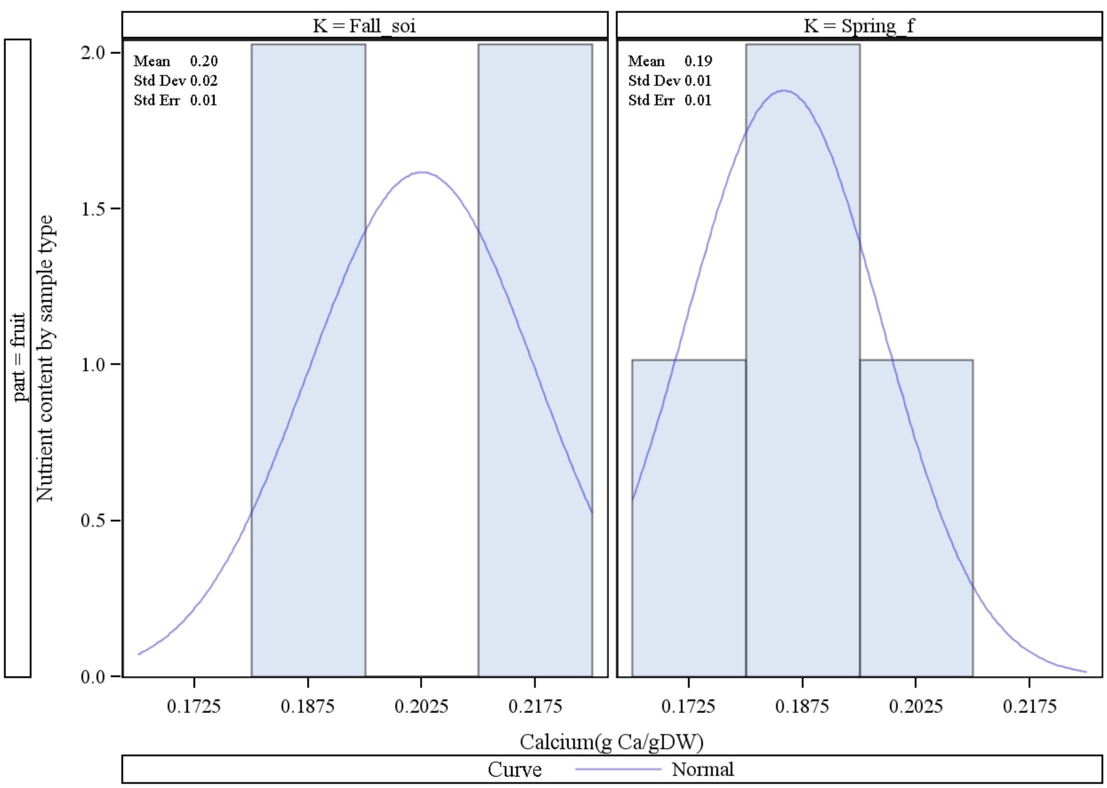


Figure 9 Binary ratio of K_Ca in fruit and leaf tissues at **Elliot2**, April 2010.

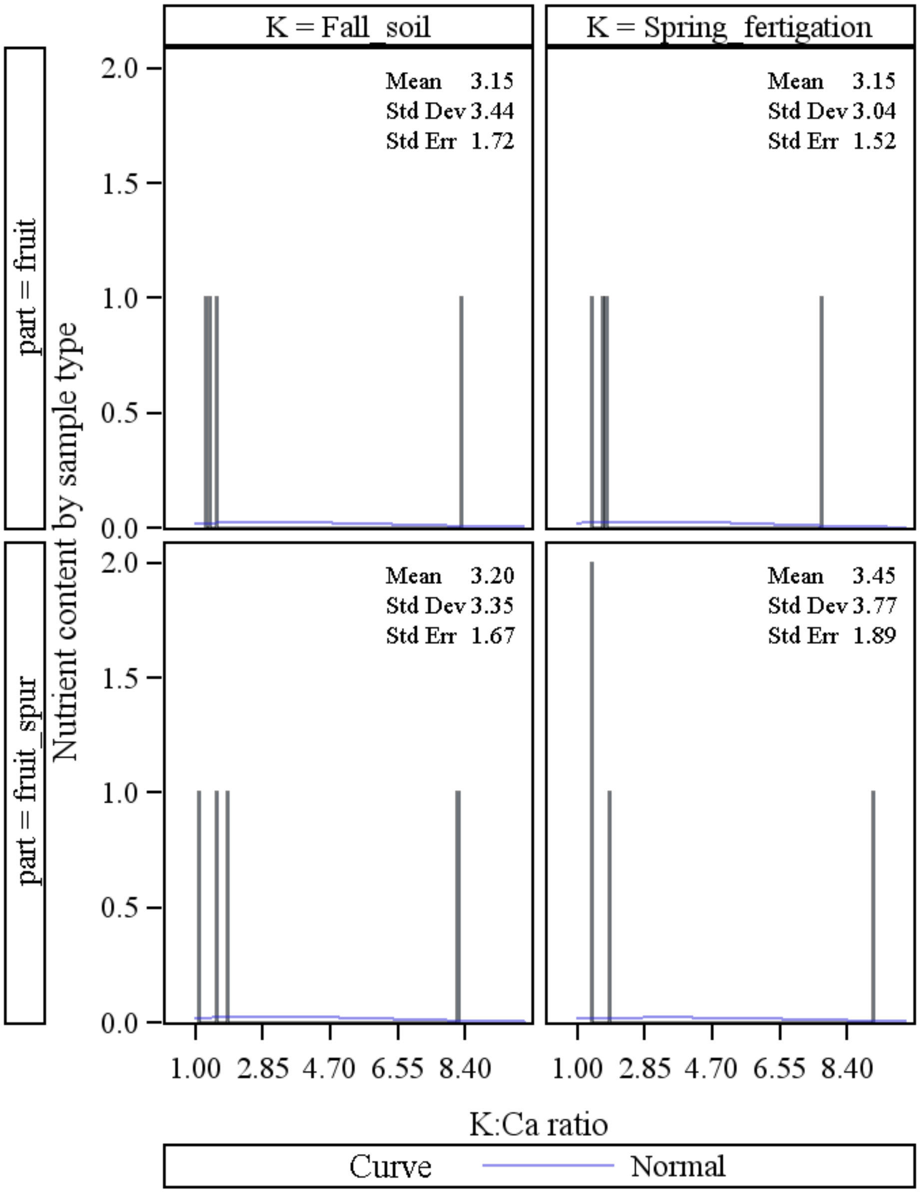


Figure 10 **Elliot2** proportion of #1fruit (#1 fruit ≥ 2 5/8” diameter) harvested in the first ‘pick’, as part of the total harvest in 2010. The first ‘pick’ is entirely size-based.

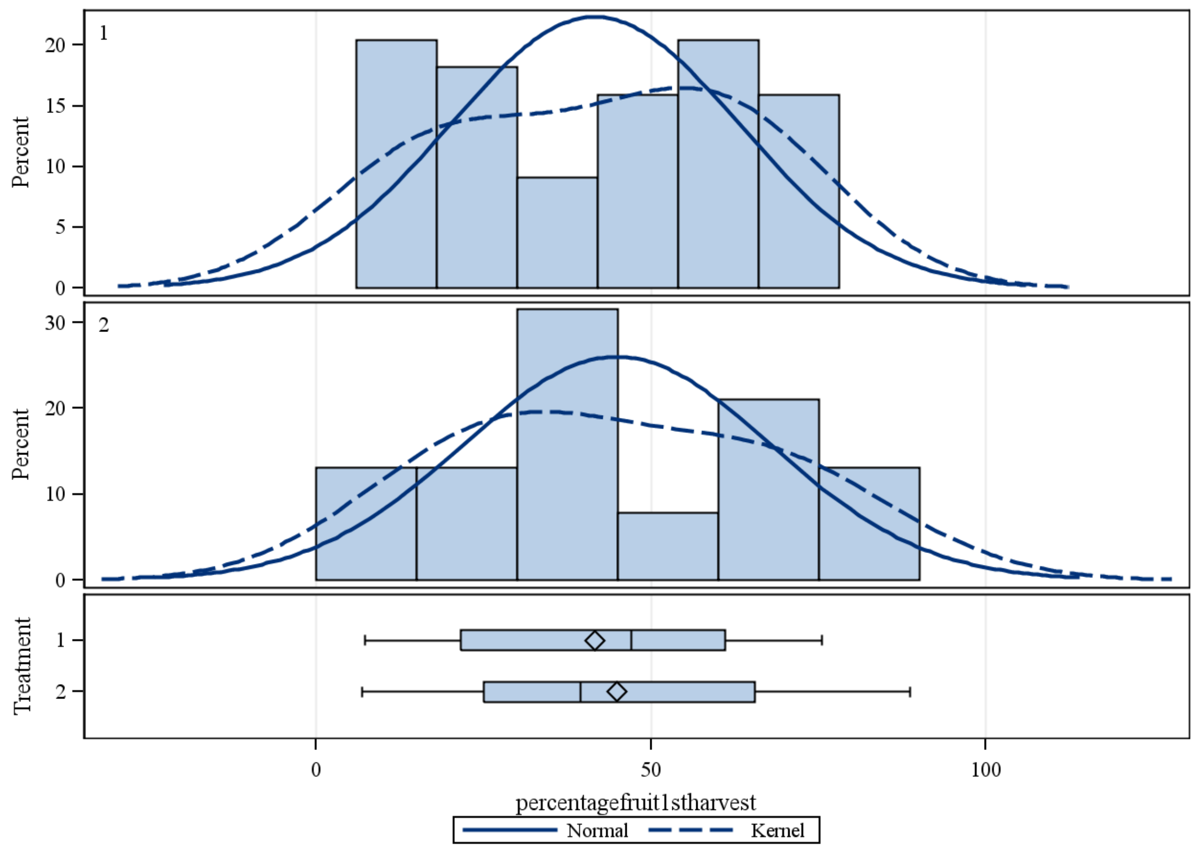


Figure 11 Percentage of #1 fruit (≥ 2 5/8” diameter) in the second ‘pick’ at **Elliot2**, 2010.

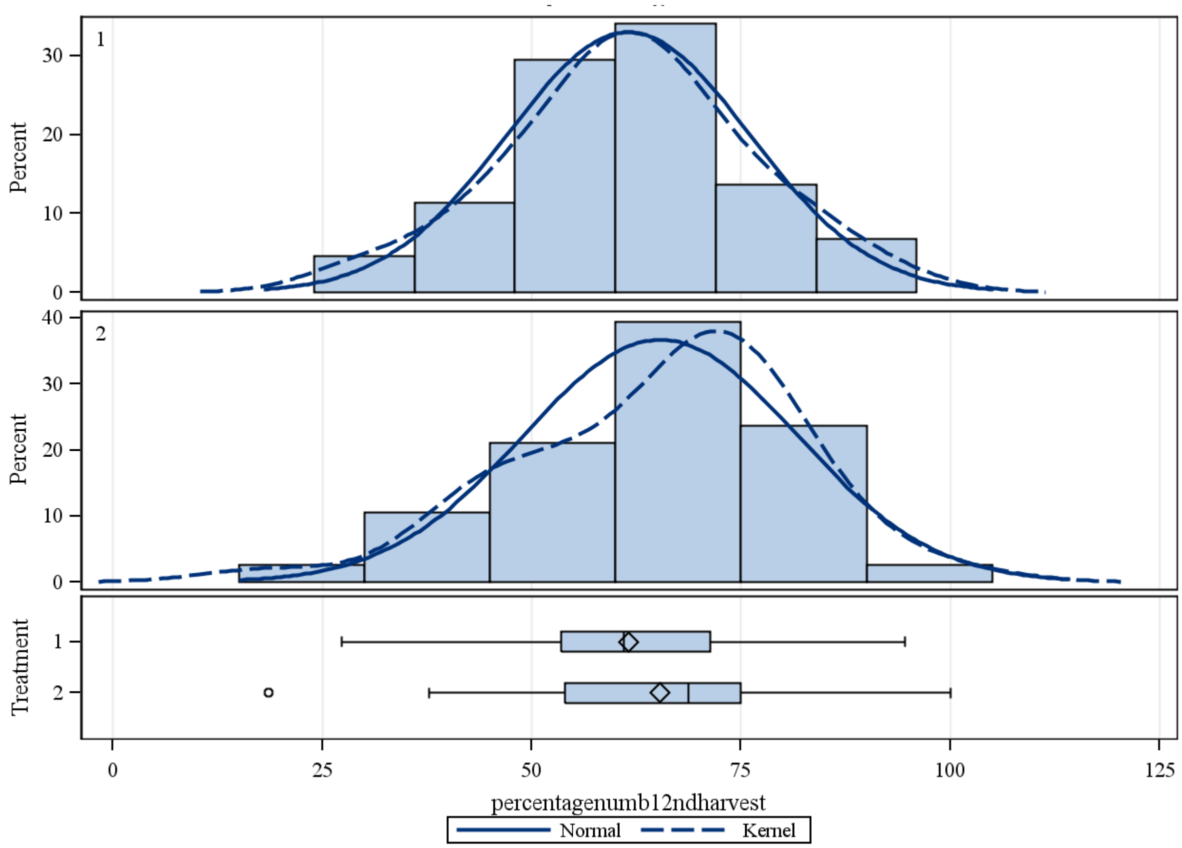


Figure 12 Percentage of the total 2010 crop at **Elliot2** which was #1 fruit (≥ 2 5/8” diameter).

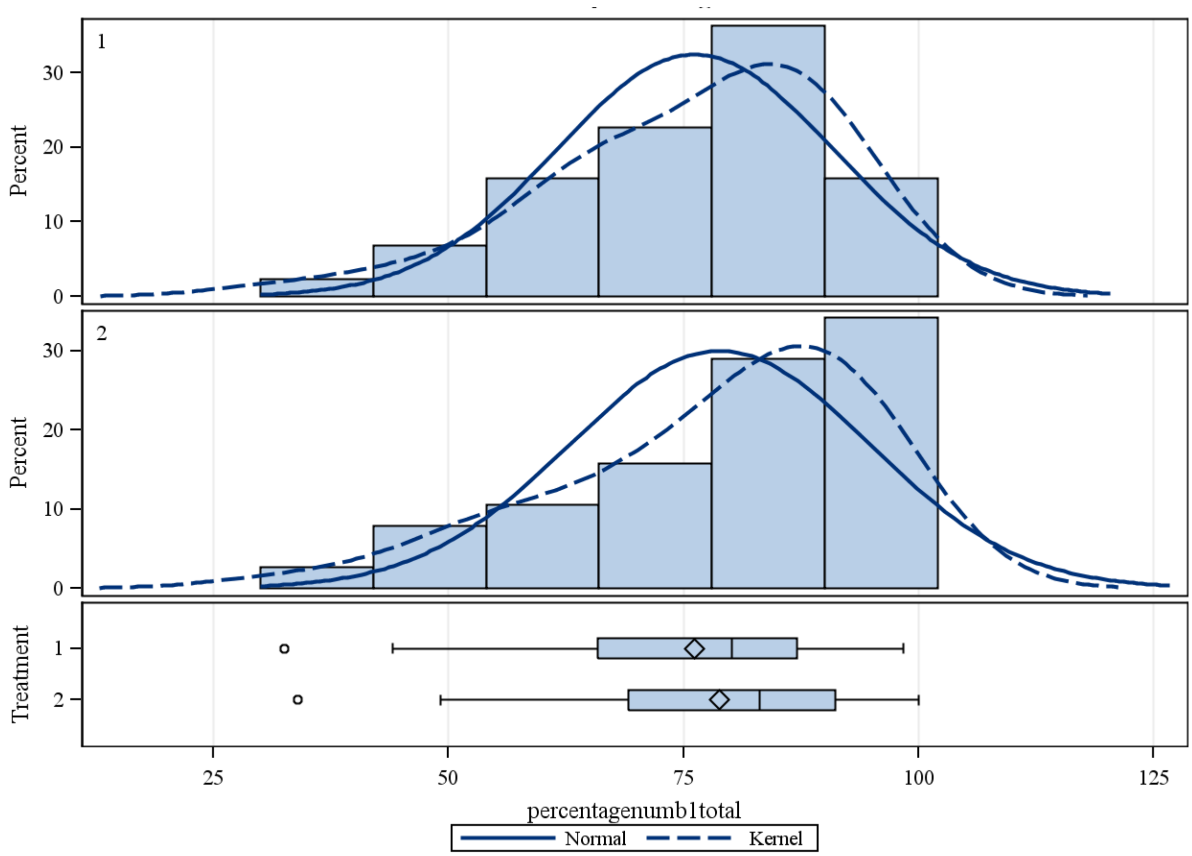


Figure 13 Fruit weight from the second harvest, 2010 at **Elliot2**.

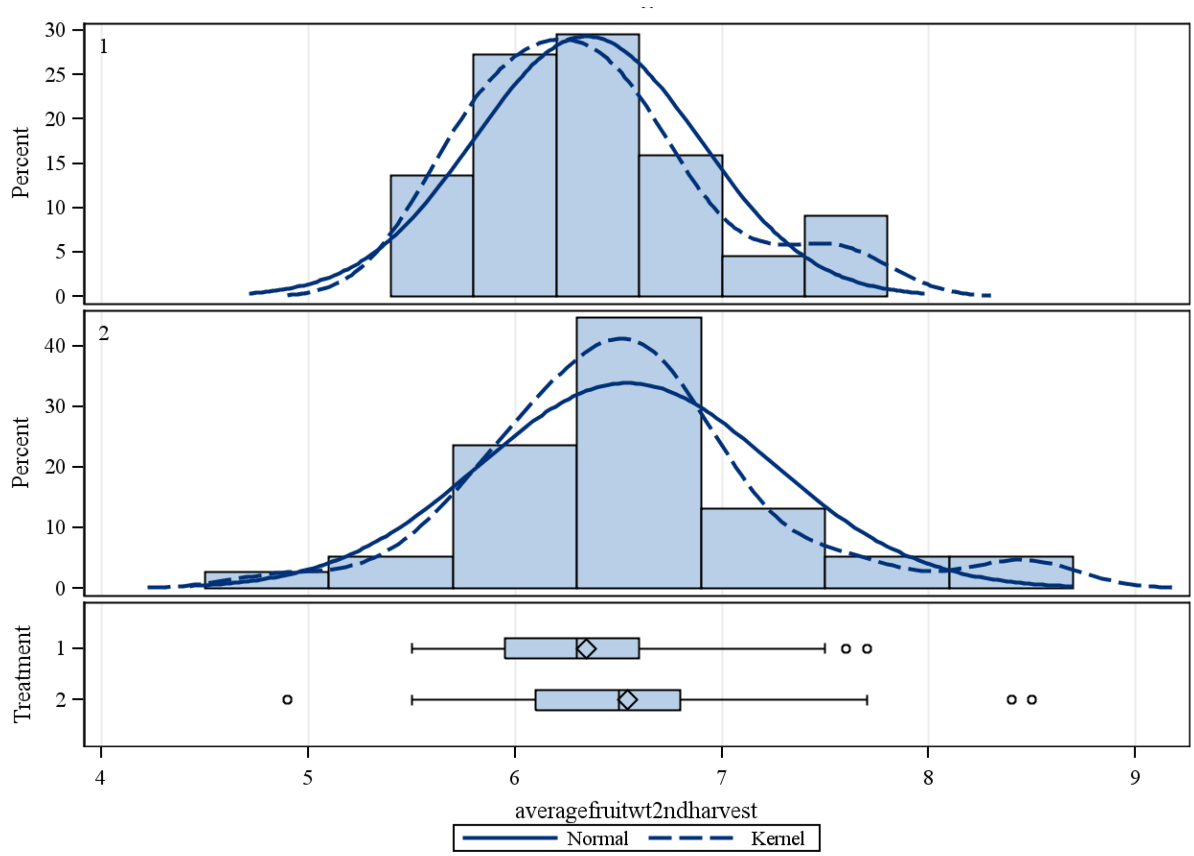


Figure 14 Fruit size, measured as ‘count per pound’, as affected by K treatments at **Elliot2**, 2010.