Interstems reveal scion variety potential to transport nutrients

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Abstract

An experiment aimed at understanding the genotypic potential of certain widely planted scion cultivars to transport nutrients in their vascular systems (stems) was set up by raising apple trees that featured interstems of different scion cultivars. We produced four interstem tree replicates for each cultivar using the vigorous rootstock 'B.118' as both root system and scion with a 15cm long interstem made with cultivars 'Empire', 'Golden Delicious', 'Honeycrisp', 'Ida Red', 'Jonagold', 'Liberty', 'Mutsu' and 'Red Delicious' for a total of 32 trees. We collected 10 fully expanded leaves from the top 1/3 of each nursery tree and processed for nutrient analysis which yielded concentration values of N, P, K, Ca, Mg, S, and other micronutrients. Finished trees were planted in an orchard in Geneva, NY, in June 2018. In November 2019, an XRF instrument was used to monitor the relative concentration of P, K, Ca, S, and some micronutrients like Fe, Mn, and Cu in one and two-year-old stems. We noticed some general trends for each of the nutrients when comparing genotypic means to the overall mean for each nutrient. From the leaf analysis data, we found that leaf calcium concentration means ranged from 0.8% to 1.1%, with values for 'Red Delicious', 'Liberty', 'Honeycrisp' and 'Empire' interstems were below the overall mean (0.99%) while the values for the rest of the cultivars were above the mean. Honeycrisp displayed the highest values (1.8%) for leaf potassium whereas 'Empire' and 'Liberty' had the lowest values (1.3%). Leaf sulfur and leaf nitrogen were highly correlated variables, and among cultivars, 'Honeycrisp' had the highest means (1.88% N and 0.13% S), and 'Liberty' had the lowest means (1.61% N and 0.11% S). Vascular transport of nutrients may be an intrinsic genetic property of scion cultivars. This work has implications for the practice of top-working older orchards or using interstems.

Keywords: nutrient, rootstock, breeding, yield components, fruit quality.

INTRODUCTION

Fruit disorders related to nutrient content are known to cause significant losses of marketable apples, where certain apple scions seem sensitive to nutrient-related disorders while others are not. Different genotypes of apple rootstocks have been shown to influence dry matter nutrient content of grafted scions (Kruczynska et al., 1990; Fazio et al., 2020;). This may be due to differences in molecular components of absorption and transport systems that are genetically controlled. While scions cannot display absorption differences (no roots), they may display genotypic differences in the transport systems (passive and active) that move the ionome from the rootstock to different sinks in the plant (fruit, leaves, meristems), where some genotypes may be more or less efficient than others in transporting nutrients like calcium, copper, boron, etc. Grafting allows the joining of two or more genotypes into a composite finished tree. Interstems or interstocks are segments of stem from a unique genotype that unite or bridge a rootstock to a scion (Carlson and Oh, 1975; Domoto, 1982).

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While interstems have been leveraged to introduce dwarfing or bridge compatibility barriers in grafted trees, they represent an opportunity to study their function as filters and transporters of nutrients, metabolites, and water (Lord, 1983; Perry and Dilley, 1984). In this specific research, we sandwiched different interstem genotypes taken from common scion varieties between the same rootstock genotype. All roots were the same, all scions were the same, and only the interstems changed. This experimental setup was done to learn more about the transport properties of scion stems – are they all the same, or do they differ? Knowledge of these scion-specific tendencies may help pair rootstocks and make fertilizer improved fertilizer recommendations.

MATERIALS AND METHODS

Four rootstock replicates of the vigorous rootstock 'B.118' were bench grafted with scion varieties 'Empire', 'Golden Delicious', 'Honeycrisp', 'Ida Red', 'Jonagold', 'Liberty', 'Mutsu' and 'Red Delicious' in March of 2016 and planted in a nursery (Figure 1).
Grafts were trained to a single shoot chip budded with 'B.118' buds 15 cm above the graft union in August 2016 to generate consistent interstems of the various cultivars 15 cm long.

Healed dormant buds were forced by topping the trees 2 cm above the chip bud in May 2017, and the 'B.118' shoot was trained to a single stem.

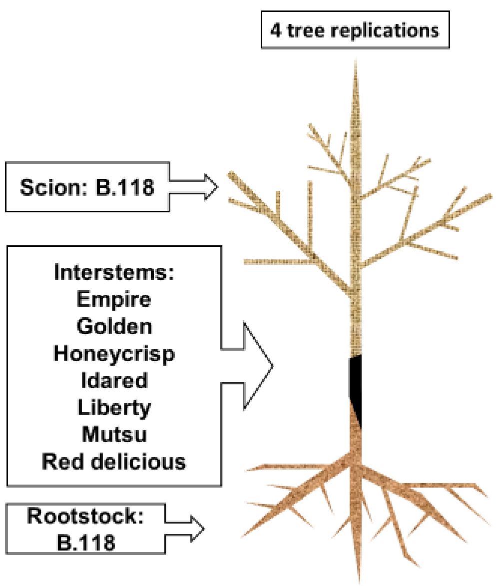

Figure 1. Experimental setup of the interstem trial. Four tree replicates for each interstem.

Fully expanded leaves from the top 1/3 of the nursery tree were harvested in September 2017 and processed for nutrient analysis which yielded concentration values of N, P, K Ca, Mg, S, and other micronutrients. Finished trees were planted in an orchard in Geneva, NY, in June 2018. In November 2019, an XRF instrument (Bruker Tracer 5) was used to monitor the relative concentration of P, K, Ca, S, and some micronutrients like Fe, Mn, and Cu in one and two-year-old stems, where five to 10 shoots were measured for each tree replicate. Statistical analyses (ANOVA, Pearson Correlations) and graphs were obtained with SAS JMP15-Pro software (Cary, NC 27513-2414, USA).

RESULTS AND DISCUSSION

2017 ICP and 2019 XRF data were highly correlated for Ca, P, N, S, and K. Ca content was the lowest in 'Liberty' and 'Honeycrisp' interstem. (K+N)/Ca was highest in 'Honeycrisp' (Figure 2). This experiment was a proof of concept where we wanted to see if interstem genotype (from different scion varieties) can modulate the content of nutrients in a common scion. Given the data developed in this experiment, we can surmise that the genotype of vascular system of each scion cultivar can display a differential capacity to transport some nutrients. This is different than the observations by Chun et al. (2002), who monitored mineral nutrient changes using interstems derived from conventional apple rootstocks (Chun et al., 2002; Fallahi and Chun, 2002) and found no significant differences among interstems. Alternatively, Ebel et al. (2000) found that 'M.9' and 'M.26' interstems increased leaf concentration of calcium of 'Golden Delicious' scion (Ebel et al., 2000) and displayed other significant effects on mineral nutrition. We saw a similar tendency in calcium content data when we compared 'Fuji' and 'Honeycrisp' scions grew on a series of different rootstocks (Fazio et al., 2015), where the median content and distributions were overlapping for copper and other nutrients but for calcium, they were significantly lower in 'Honeycrisp'. Shoot growth was similar for all trees. The use of just the interstem eliminates influences caused by leaf morphology and evapotranspiration that are unique for each scion. The intention of this work was to learn about vascular conductivity specific to scions which could be obtained by measuring leaves and shoots. At the time of data collection there was no fruit on the 'B.118' scion therefore we did not conduct analyses on the fruit, but we can surmise from studies comparing leaves and fruit nutrients that the patterns could be different according to each nutrient (Fazio et al., 2020). In addition to describing scion capacity to transport nutrients, this type of experiment can be used to study genotype-specific transport of phytohormones, etc. From the practical standpoint, this work has implications for the practice of top-working older orchards with new scion varieties where the new scion might be affected rootstock's ability to absorb and transport and the interstem effects to transport nutrients.

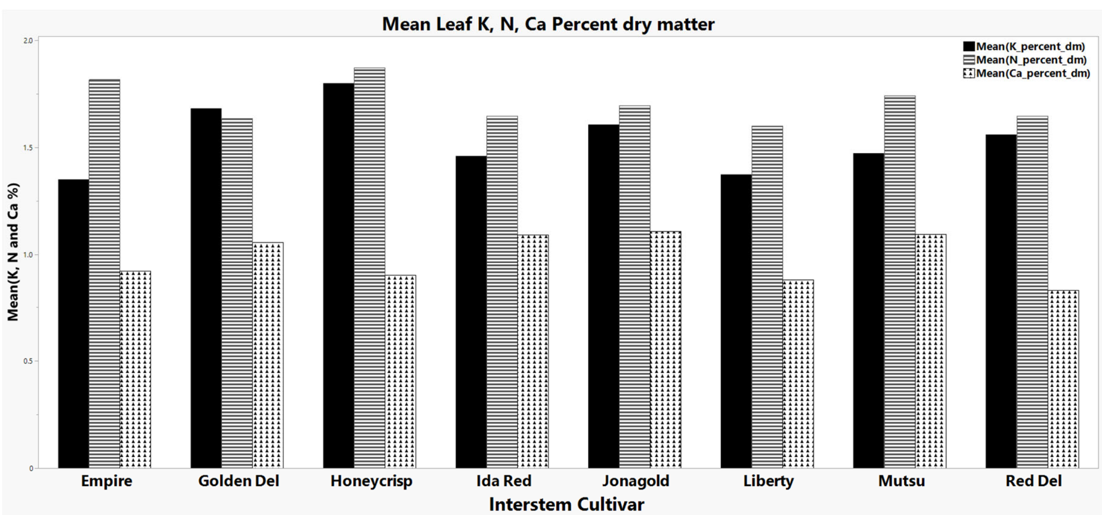

Figure 2. Relative differences in leaf content of N, P, K (ICP data 2017) of nursery trees having different scion cultivar interstems. LS means of 4 tree replicates for each cultivar.

The first set of this data was collected with inductively coupled plasma mass spectrometry, whereas the second set used X-Ray Fluorescence to determine content (Kalcsits, 2016; Zuniga et al., 2017). For Ca, K, P, and S, it is remarkable that the genotypic means for the interstems displayed correlations as high as 0.9 (Table 1, Figure 3). The XRF instruments, while they cannot read Mg, B very well, seems well adapted to derive K/Ca ratio, which is important to determine fruit sensitivity to bitter pit. XRF can also measure S very well, which has been shown in this experiment and others to be highly correlated to N content and could be substituted for N after proper transformation. We are performing expanded similar experiments to further study nutrient transport in apple stems.

Table 1. Correlation coefficients among data collected in 2018 (leaves, ICP generated) and 2019 (stems, XRF generated).

Correlation	Ca % dm	K % dm	N % dm	P % dm	S % dm	Ca XRF ppm	K XRF ppm	P XRF ppm	S XRF ppm
Ca % dm	1.00	-0.29	0.20	0.45	0.57	0.96	-0.61	0.28	-0.12
K % dm	-0.29	1.00	-0.20	-0.14	-0.25	-0.35	0.84	-0.15	-0.24
N % dm	0.20	-0.20	1.00	-0.32	0.86	0.27	-0.08	-0.41	0.63
P % dm	0.45	-0.14	-0.32	1.00	-0.01	0.37	-0.42	0.93	-0.06
S % dm	0.57	-0.25	0.86	-0.01	1.00	0.60	-0.31	-0.13	0.57
Ca XRF ppm	0.96	-0.35	0.27	0.37	0.60	1.00	-0.58	0.24	-0.12
K XRF ppm	-0.61	0.84	-0.08	-0.42	-0.31	-0.58	1.00	-0.29	-0.08
P XRF ppm	0.28	-0.15	-0.41	0.93	-0.13	0.24	-0.29	1.00	0.01
S XRF ppm	-0.12	-0.24	0.63	-0.06	0.57	-0.12	-0.08	0.01	1.00

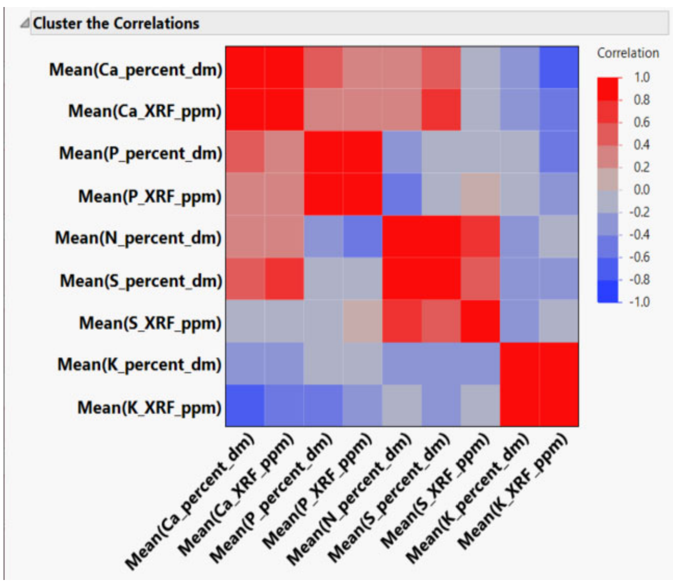

Figure 3 Clustered correlations of nutrient content data collected in 2017 (ICP) and 2019 (XRF) showing good correspondence between instrument types and years.

CONCLUSIONS

Interstems were used to understand the intrinsic capacity of scion cultivars to transport mineral nutrients. This research may be extended to hormones and other metabolic substances and perhaps include gene expression changes caused by the presence of a different genotype in the stem. We already know that dwarfing rootstock interstems will cause a tree to be dwarfed and early bearing. Experiments that leverage interstems will enable learning more about such traits' mechanisms.

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