Nutrient Distribution and Requirement of 'Forelle' Pear Trees on Two Rootstocks

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Abstract

Accurate water and fertilizer management are essential in modern high intensity orchard systems to enable the manipulation of both reproductive and vegetative development. Studies have been conducted to establish the annual plant fertilization requirements, of several tree crops but there exists little information regarding the requirements of pear trees on rootstocks of differing vigour. Nine-year-old 'Forelle' pear trees in a commercial orchard on either vigorous, BP1 or dwarfing, Quince A (QA) rootstocks were completely removed from the soil and divided into various tree parts (roots, stems, leaves, shoots and fruit), each part massed, milled and a mineral analysis conducted. Annual requirements of the nine-year-old trees for macro- (N, P, K, Ca and Mg) and micro- elements (Mn, Fe, Cu, Zn, B) were determined by calculating losses and fixation and their requirements expressed in g or mg element/kg yield respectively. 'Forelle' on the more vigorous BP1 shows higher requirements than the more dwarfing QA rootstock mainly because of the higher mass of summer and winter wood removed as prunings as well as a higher mass of young shoots. From these results, and with due consideration given to various production differences, annual minimum and maximum fertilization guidelines based on the yield have been determined.

INTRODUCTION

Most pear orchards in SA are established on the locally bred vigorous BP3 and less vigorous BP1 rootstocks (Du Plooy and Van Huyssteen, 2000) which are more productive than seedling stocks. More dwarfing Quince (*Cydonia oblonga* L.) stocks, that increase precocity and fruit quality especially in the higher intensity modern orchards, are gaining importance (Jacobs et al., 2003). Fertilizer recommendations are routinely based on soil and leaf analysis but are non-specific for cultivar or rootstock (Rease, 1994).

Accurate water and fertilizer management are essential in the highly intensive orchard systems to enable the manipulation of both reproductive and vegetative development, to ensure the possibility of higher quality fruit with longer storage potential and to reduce pollution and costs (Tagliavini and Marangoni, 2000).

Although the important functions fulfilled by macro- and micro- elements are well known (Clarkson and Hanson, 1980; Mengel and Kirby, 1982; Devlin and Witham, 1983; Tisdale, Nelson and Beaton, 1985; Neilsen and Neilsen, 2003), the specific elemental requirements for optimum growth, production and fruit quality per fruit kind and cultivar, especially under high planting densities, need to be determined. A relatively simple method for determining tree nutrient requirement is to base it on whole tree mineral analysis. Various studies have been conducted (Batjer et al., 1952 for apples; Conradie, 1980; 1981 for vines; Haynes and Goh, 1980 for apples; Stassen, 1987 for peach; Stassen et al., 1997a; 1997b for mango's and Stassen et al., 1997c for avocado's. This method takes into account mineral nutrient losses from removal of fruit and pruned wood from the orchard, part of the dropped leaf content and nutrient fixation in the permanent parts of the tree (older wood and roots) relative to tree age (Stassen, 1987 and Stassen et al., 1997a,b,c).

Our objective was to study the macro- and micro-element distribution and estimate the nutritional requirements of ‘Forelle’ pear on two rootstocks and to make recommendations from which annual losses and fixation may be calculated.

MATERIALS AND METHOD

A commercial orchard of nine-year-old ‘Forelle’ pear trees, at 1667 trees/ha, (4mX1.5m), at the Bien Donne research Farm, Western Cape region (34^{o}S, 19^o E) received recommended fertilization and irrigation based on yield, leaf and soil analysis. No growth control measures (scoring, root pruning) other than pruning was conducted.

Three trees on each rootstock were completely removed from the soil just before fruit ripening (mid February) and divided into leaves, one-year-old shoots, main stem, roots and fruit. Each fresh tree portion was massed, then a sample was milled, dried and massed again. Dried samples were subjected to a mineral analysis for Nitrogen, (N), Phosphorous, (P), Potassium (P), Calcium (Ca), Magnesium (Mg), Manganese, (Mn), Iron (Fe), Copper (Cu) and Zinc (Zn) by a commercial laboratory (BemLab, Pty. Ltd, Somerset West, South Africa). Mass of wood pruned during summer and winter (‘prunings’) and their nutrient content was included. Fruit macro-element results were expressed as mg.100g^{-1} dry mass and micro-elements as mg. kg^{-1}dry mass while leaf, root, stem and shoot macro-element results were expressed as percentage and micro-elements as mg. kg^{-1}. This data was then converted to g macro- and mg micro-element content for each tree part using actual part mass.

Statistical analysis was conducted using the SAS system version 6.12. (SAS Inc., 1996).

RESULTS AND DISCUSSION

Average production per tree of the nine-year-old trees averaged 15,7 kg on BP1 and 17,4 kg on QA. Only the dry mass (DM), (P=0.062), P (P=0.059), K (P=0.036), Fe (P=0.059) and B (P=0.037) contents differed between rootstocks in young shoots; the Fe (P=0.071), and B (P=0.075) contents differed in the fruit; and the DM (P=0.019), N (P=0.065), P (P=0.039), K (P=0.012), Ca (P=0.041), Mg (P=0.07), Mn (P=0.079), Fe (P=0.022), Cu (P=0.091), Zn (P=0.095) and B (P=0.014) contents in the prunings differed at the less than10% significance level (Tables 1 and 2).

The DM of one-year-old shoots from trees on the more dwarfing QA averaged 0.58 kg while those from trees on the more vigorous BP1 averaged 1.8 kg. Prunings from trees on BP1 averaged 4.1 kg while those on QA averaged 1.09 kg. There was also a tendency for a lower stem and root mass from trees on QA. A tendency was found for higher levels of N and P in the leaves from trees on QA than BP1 while K, Ca and Mg root content tended to be lower in trees on BP1 than in trees on QA (Fig. 1).

Results shown in tables 1 and 2 were used to calculate losses and fixation (Stassen et al., 1999) as shown in table 3 (macro-elements) and table 4 (micro-elements). N, P and K have been shown to migrate back to the permanent tree parts and this occurs before leaf drop (Terblanche, 1972; Stassen, 1997a) but Ca and Mg do not migrate to any appreciable extent.

Nutrient loss from leaf drop is regarded as temporary as fallen leaves decompose and are mineralized (Stassen, 1987). In high potential soils where mulches are used and where leaves remain on the soil, it is not necessary to compensate for this loss. In low potential soils and/or where fertilizers are distributed by hand, leaf losses must be taken into account to compensate for leaching and inefficiency of placement.

In the latter case, it was assumed that approximately 50% of all elements except Ca and Mg migrated back into the tree before leaf drop (Terblanche, 1972). Prunings were regarded as a loss as these are often removed or decay too slowly to benefit the tree. In these calculations however it was reasoned that mineral content of prunings was already determined as part of the permanent tree parts (old wood) and young shoots and was therefore not used again.

Fixation in the permanent tree parts (roots, stem, older wood) was calculated on an annual basis by using the total over the nine year period divided by the tree age.

Allowance was thus made for losses due to harvesting of fruit, fixation and for the development of one-year-old shoots; this is regarded as the annual minimum mineral requirement expressed on an average per kilogram yield basis.

In less favourable conditions (ie: poor sandy soil, no mulch and hand applied fertilizers), leaf losses must be incorporated (50% of all minerals except Ca and Mg which should be 100%) and this should be regarded as the maximum annual mineral requirement for macro-elements (Tables 3a & 3b) and micro-elements (Tables 4a & 4b). Circumstances that need to be considered when applying the above recommendations are fertilizer applied during soil preparation and results of soil and leaf analysis.

To obtain a fair estimate of annual tree mineral requirements without tree removal, mineral losses due to fruit and wood (summer and winter prunings) removal may be combined and expressed per kg yield. It appears that the nutrient requirements of 'Forelle' trees on BP1 will be higher than on QA if the higher DM of young shoots, stem and prunings are considered (Tables 3 & 4); the former resulting in a DM of 38.9 kg and the latter 28.5 kg. To reduce the vigour imparted by BP1 especially in high density commercial plantings, manipulative methods such as scoring and root pruning may be practiced.

RECOMMENDATIONS

The basic nutrient requirements of pear trees may be calculated using these results and they are especially useful for compiling nutrient mixtures for fertigation and hydroponic systems. Under medium to high potential soil conditions, with organic mulches and irrigation applied fertilizers in the root area, the minimum nutrient requirement may be used. For 'Forelle' trees on BP1, the minimum nutrient requirement (g. kg^{-1} & mg. kg^{-1} yield) for N, P, K, Ca, Mg, Mn, Fe, Cu, Zn and B is respectively 2.29g, 0.47g, 1.83g, 1.75g, 0.49g, 19.9mg, 128.35mg, 7.08mg, 19.19mg and 9.95mg. For 'Forelle' trees on QA, the minimum nutrient requirement (g. kg^{-1} & mg. kg^{-1} yield) is respectively 1.48g, 0.25g, 1.61g, 1.60g, 0.33g, 5.67mg, 79.91mg, 5.83mg, 16.12mg and 5.77mg.

However all the results are given to calculate requirements for other possible scenarios according to circumstances.

As these requirements are expressed per kg yield, they may be used to calculate the nutrient requirements of the real or estimated yield but factors such as mineralization, atmospheric nitrogen contributions and normal fertilization practices will have to be taken into account. Leaf and soil mineral analysis should be used for the fine tuning of the crop requirements.

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Tables

Table 1. Dry mass (DM) (kg) and macro-element content (g) in different parts of nine-year-old 'Forelle' pear trees on two rootstocks.

Tree Parts	DM	N	P	K	Ca	Mg
leaves						
QA	1.68	29.4	2.1	23	24.9	7.8
BP1	1.56	24.9	2.5	20.4	29.1	9.4
young shoots						
QA	0.58	4.5	0.64	1.4	4.4	1.6
BP1	1.8	12.6	2.27	4.7	10.9	3.8
older shoots						
QA	3.9	24.9	2.9	5.2	43.1	7.06
BP1	4.9	31.6	4.13	7.1	54.5	9.92
stem						
QA	6.36	17.6	2.5	8.0	36.5	5.0
BP1	10.4	28	3.5	16.1	34.3	7.36
fruit						
QA	4.16	13.0	2.5	20.9	1.0	1.25
BP1	3.8	10.2	2.73	18.6	0.62	1.12
roots						
QA	10.8	39.3	5.76	43.5	145.4	16.2
BP1	12.28	71.9	16.5	30.28	70.25	10.9
prunings						
QA	1.09	7.4	1.1	2.1	9.7	2.4
BP1	4.1	27.5	6.05	5.1	28.5	13.1

Table 2. Micro-element content (mg) in different parts of nine-year-old 'Forelle' pear trees on two rootstocks.

Tree Parts	Mn	Fe	Cu	Zn	B
leaves					
QA	253	449	10.6	48.7	44.3
BP1	542	754	9.62	68.4	64.6
young shoots					
QA	18.2	56	5.7	12.2	6.7
BP1	100.8	314	13.7	29	22.9
older shoots					
QA	89	290	61.3	93.3	41.3
BP1	219	398	54.8	115.7	51.2
stem					
QA	357.5	1419	538	1004	93.5
BP1	350.4	1145	255	543	129.6
fruit					
QA	15.8	120.29	26.7	147.8	67.96
BP1	14.7	54.5	19.56	99.08	74.39
roots					
QA	199.4	10441	90.67	108	123.3
BP1	213.9	14078	60.56	205.9	125.1
prunings					
QA	49.6	130.7	11.6	23.3	11.9
BP1	393.5	333.7	365	155.3	282.9

Table 3. Mass of macro (g) elements lost and fixed in nine-year-old 'Forelle' pear trees on two rootstocks (based on 15.7 kg. $tree^{-1}$ yield or 26 t. ha^{-1} for BP1 and 17.4 kg. $tree^{-1}$ yield or 29 t. ha^{-1} for QA).

3a. Quince A

Element	**N**	**P**	**K**	**Ca**	**Mg**
A. lost					
1. Fruit	13.07	2.55	20.91	1.00	1.27
2. Leaves	14.7	1.07	11.54	24.87	0.64
3. Prunings	7.45	1.10	2.10	9.72	2.45
B. Fixed					
4. Permanent Parts	8.21	1.12	5.66	22.52	2.84
5. One-year-old shoots	4.54	0.65	1.36	4.40	1.69
Total A+B	47.97	6.49	41.57	62.51	8.89
1+2+4+5	40.52	5.39	39.47	52.79	6.44
1+4+5	25.82	4.32	27.93	23.92	5.8
Max. loss g. kg^{-1}	2.33	0.31	2.27	3.03	0.37
Min. loss g. kg^{-1}	1.48	0.25	1.61	1.60	0.33

3b. BP1

Element	**N**	**P**	**K**	**Ca**	**Mg**
A. lost					
1. Fruit	10.22	2.73	18.62	0.62	1.12
2. Leaves	12.45	1.29	10.34	29.29	4.71
3. Prunings	27.49	6.05	5.11	28.54	13.10
B. Fixed					
4. Permanent Parts	13.15	2.42	5.35	15.92	2.82
5. One-year-old shoots	12.60	2.26	4.76	10.90	3.82
Total A+B	75.91	14.75	44.18	85.27	25.57
1+2+4+5	48.42	8.7	39.07	56.73	12.47
1+4+5	35.97	7.41	28.73	27.44	7.76
Max. loss g. kg^{-1}	3.08	0.55	2.49	3.61	0.79
Min. loss g. kg^{-1}	2.29	0.47	1.83	1.75	0.49

Table 4. Mass of micro (mg) elements removed and fixed in nine-year-old ‘Forelle’ pear trees on two rootstocks (based on 15.7 kg/tree yield for BP and 17.4 kg/tree yield for QA).

4a. Quince A

Element	**Mn**	**Fe**	**Cu**	**Zn**	**B**
A. lost					
1. Fruit	15.83	120.29	26.73	147.83	67.96
2. Leaves	126.0	224.8	5.32	24.36	22.12
3. Prunings	49.68	130.79	11.67	23.35	11.98
B. Fixed					
4. Permanent Parts	64.63	1215.2	69.04	120.6	25.81
5. One-year-old shoots	18.27	55.01	5.70	12.18	6.68
Total A+B	274.41	1746.09	118.46	328.3	134.55
1+2+4+5	224.73	1615.3	106.79	304.97	122.57
1+4+5	98.73	1390.5	101.47	280.61	100.45
Max. loss mg. kg^{-1}	12.91	92.83	6.13	17.52	7.04
Min. loss mg. kg^{-1}	5.67	79.91	5.83	16.12	5.77

4b. BP1

Element	**Mn**	**Fe**	**Cu**	**Zn**	**B**
A. lost					
1. Fruit	14.73	54.52	19.56	99.08	74.39
2. Leaves	271.2	377.28	4.81	34.2	32.3
3. Prunings	393.56	333.78	365.04	155.37	282.9
B. Fixed					
4. Permanent Parts	78.43	1562.3	37.09	86.48	30.60
5. One-year-old shoots	219.88	398.43	54.56	115.73	51.25
Total A+B	977.8	2726.31	481.06	490.86	471.44
1+2+4+5	584.24	2392.53	116.02	335.49	188.54
1+4+5	313.04	2015.25	111.21	301.29	156.24
Max. loss mg. kg^{-1}	37.21	152.3	7.38	21.36	12.0
Min. loss mg. kg^{-1}	19.94	128.35	7.08	19.19	9.95

Figures

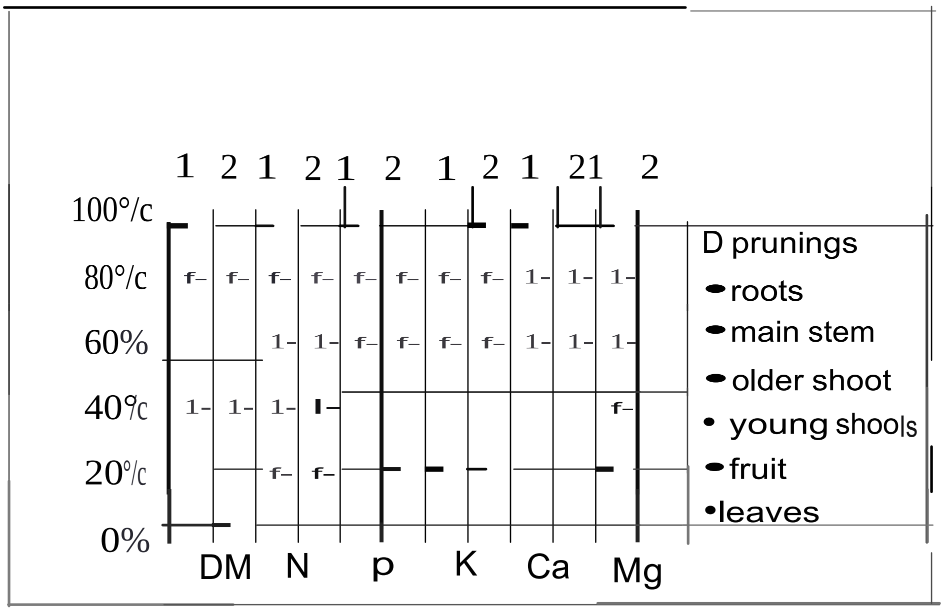

Fig. 1. Percential distribution of dry mass (DM) and macro-elements (N, P, K, Ca and Mg) in nine-year-old 'Forelle' pear trees on QA (1) and BPI (2) rootstocks.