Site-Specific Nutrient Management in Mandarin Orchards

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Site-specific nutrient management (SSNM) can help tailor fertilizer applications for individual orchards and begin to address a more complex problem of wide variation in fruit yield within orchards.

India has 320,000 ha of mandarin orchards producing 2.07 million metric tons (M t) of fruit annually. Although orchard productivity is highly variable within space and time, the average productivity per planted area of about 6 t/ha is obviously low if compared to the international average of 30 to 35 t/ha. A major constraint is inadequate and imbalanced nutrient use. The objective of this research is to narrow the gap in productivity by adopting principles of SSNM.

The study included two distinct yet representative soil types. Site 1 had a relatively shallow soil profile classified as a Typic Ustorthent (Entisol), while Site 2 was a Vertisol with a deeper soil profile classified as a Typic Haplustert (**Table 1**). These soil types are both derived from basaltic parent material with typical soil profiles predominantly rich in expanding-type, 2:1 montmorillonitic clay minerals characteristic of the sub-humid tropical climate of central India. The Vertisol at Site 2 had intersecting slickensides strongly expressed within the 52 cm to 1.48 m depth, an indication of significant shrink and swell activity.

Established orchards were 12-years old at Site 1 and 8-years old at Site 2. Plant to plant and row to row distances were 6 m. Both orchards used a scion of Nagpur mandarin (*Citrus reticulata Blanco*) budded on rough lemon rootstock (*Citrus jambhiri Lush*). A total of 16 treatments were applied based on soil analysis and the principles of SSNM (**Table 2**).

Two levels of input intensity were incorporated in the design based on a high and low nitrogen (N) rate. These treatments were replicated four times in a randomized block design. Timing of fertilizer applications were kept the same at both sites. Nitrogen was applied in the months of April, August, and October; phosphorus (P) and potassium (K) were applied in August and October. Two seasons of data collection included measurements of tree canopy growth, fruit yield and quality, leaf nutrient concentrations, and a cost:benefit analysis. Only the effective treatments and the current recommendation (CR) are discussed in this article.

Significant changes in leaf nutrient

Table 1. Soil physiochemical characteristics and fertility for soil surface horizons.

	Site 1 Entisol	Site 2 Vertisol
pH	7.3	7.6
E.C., d/Sm	0.21	0.18
$CaCO_3$, g/kg	21.2	20.2
Texture, g/kg		
Sand	384.0	296.6
Silt	203.8	222.4
Clay	412.2	482.0
Available nutrients, mg/kg		
N	88.2	96.2
P	7.6	11.4
K	132.6	162.8
Fe	6.1	8.2
Mn	8.0	7.6
Cu	0.9	1.2
Zn	0.7	0.8

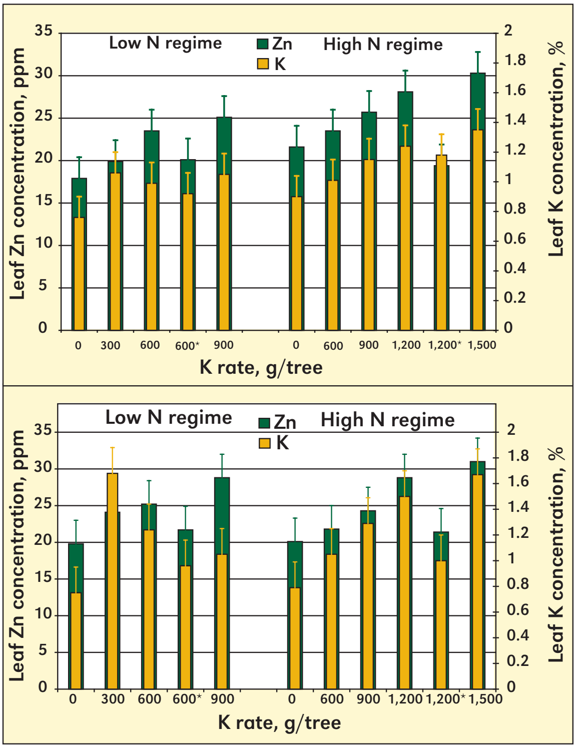

Figure 1. Influence of K rate and micronutrient input on leaf K and Zn concentration under two nutrient input regimes. Asterisk (*) indicates no micronutrient input.

concentrations, expressed as parts per million (ppm), occurred in response to fertilization. Micronutrient inputs particularly affected zinc (Zn) concentrations of leaves and in some cases elevated leaf N, P, and K concentrations. Application of K increased leaf Zn concentrations irrespective of soil-type or whether any micronutrient was included in the treatment (**Figure 1**). However, the effect of K was greatest when co-applied with the micronutrients, and the effect increased as K supply increased. Hence, K application improved the efficacy of soil Zn and applied Zn, a result of similar metabolic pathways during the course of Zn absorption.

Canopy and fruit growth response differed between sites. The more mature trees at Site 1 responded more favorably to the more input intensive regimes. Differences between high and low N regimes were much less apparent at Site 2. Thus, at Site 1, T_9 and T_{10} registered the highest increases in canopy volume over initial measurements and T_{11} produced a comparable result (**Table 3**).

These treatments provided the highest levels of N, P, micronutrient, and secondary nutrient fertility plus either 600, 900, or 1,200 g K_2O/ha. Significant yield responses to fertilization followed responses observed in leaf nutrient concentrations. Fruit yield response to micronutrients was highly evident at both sites under either the high or low input regimes. Yield failed to respond to K application beyond 600 g K_2O/tree under the high input at both sites. However, a differential response to K was noted between sites under the set of low N input treatments, as Site 1 responded up to 900 g K_2O/tree while yield at Site 2 reached a plateau at 300 g K_2O/tree. Highest fruit yields of 14.7 t/ha (52.7 kg/tree) and 19.0 t/ha (68.3 kg/tree) were obtained with T_9 (Site 1) and T_6 (Site 2), respectively.

A cost/benefit analysis of T_9 at Site 1 produced a net return of Rs.58,569/ha (US$1,325/ha) or Rs.2.12 per rupee invested in fertilizers and other inputs. At Site 2, T_6 produced a net return of Rs.46,260/ha (US$1,045/ha) or Rs.1.68 per rupee invested.

Table 2. Range of fertilizer treatments applied to both orchards.

	N	P_2O_5	K_2O	M_1[1]	S_1[2]
Current	----- Rate, g/tree -----				
Rec.	600	200	100	✘	✘
Low N					
T_1	600	400	600	✓	✓
T_2	600	200	600	✓	✓
T_3	600	0	600	✓	✓
T_4	600	600	600	✓	✓
T_5	600	400	0	✓	✓
T_6	600	400	300	✓	✓
T_7	600	400	600	✘	✘
T_8	600	400	900	✓	✓
High N					
T_9	1,200	600	600	✓	✓
T_{10}	1,200	600	900	✓	✓
T_{11}	1,200	600	1,200	✓	✓
T_{12}	1,200	600	1,500	✓	✓
T_{13}	1,200	600	0	✓	✓
T_{14}	1,200	600	1,200	✘	✓
T_{15}	1,200	600	1,200	✘	✘

[1]M_1 = 300 g each of $ZnSO_4$, $FeSO_4$, $MnSO_4$, and 100 g borax/tree;
[2]S_1 = 400 g $MgSO_4$/tree and 100 g elemental S/tree.

Table 3. Canopy volume and fruit yield response to fertilization (mean of 2 years).

Treatments	Site 1 Canopy[1] volume, m^3	Site 1 Fruit yield, kg/tree	Site 1 Fruit yield, t/ha	Site 2 Canopy[1] volume, m^3	Site 2 Fruit yield, kg/tree	Site 2 Fruit yield, t/ha
Current Rec.	3.5	31.5	8.7	3.0	53.75	14.9
Low N						
T_1	3.9	37.4	10.4	3.5	58.90	16.4
T_2	3.7	30.6	8.5	2.7	57.25	15.9
T_3	3.4	27.9	7.7	3.1	57.15	15.9
T_4	4.6	39.2	10.9	2.9	58.00	16.2
T_5	4.2	33.4	9.3	2.4	55.30	15.4
T_6	4.7	33.9	9.7	5.4	68.30	19.0
T_7	3.8	25.1	7.0	2.6	39.25	10.9
T_8	5.7	49.9	13.9	4.3	48.70	13.5
High N						
T_9	6.6	52.7	14.7	3.7	60.95	16.9
T_{10}	6.6	41.8	11.6	3.3	50.40	14.0
T_{11}	5.8	39.3	10.9	3.9	56.10	15.6
T_{12}	4.6	36.3	10.1	4.3	56.35	15.7
T_{13}	3.8	33.3	9.3	3.3	46.55	12.9
T_{14}	4.5	33.9	9.4	2.9	46.35	12.9
T_{15}	3.9	30.0	8.3	2.9	45.50	12.6
LSD (p=0.05)	1.2	8.0	2.2	1.0	8.10	2.2

[1] Expressed as increase over initial values

Table 4. Fruit quality response to fertilization (mean of 2 years).

Treatments	Site 1 Juice, %	Site 1 TSS, %	Site 1 Acidity, %	Site 2 Juice, %	Site 2 TSS, %	Site 2 Acidity, %
Current Rec.	44.0	8.6	0.57	43.1	8.5	0.68
Low N						
T_1	45.7	8.2	0.56	45.5	8.1	0.77
T_2	44.5	8.5	0.64	41.6	7.6	0.68
T_3	44.1	9.1	0.60	42.4	8.4	0.75
T_4	44.7	8.8	0.63	43.7	7.9	0.68
T_5	41.9	9.6	0.56	42.4	8.7	0.64
T_6	44.9	9.3	0.58	49.8	8.6	0.67
T_7	45.2	8.6	0.62	46.5	7.8	0.81
T_8	48.3	8.2	0.75	48.2	7.9	0.82
High N						
T_9	45.4	8.9	0.55	42.7	8.8	0.62
T_{10}	42.6	8.6	0.59	43.6	8.2	0.71
T_{11}	44.9	8.5	0.63	44.8	8.1	0.76
T_{12}	48.4	8.2	0.80	46.3	7.6	0.86
T_{13}	41.6	8.2	0.51	42.5	9.1	0.66
T_{14}	43.2	9.5	0.64	43.7	8.5	0.77
T_{15}	44.6	9.6	0.63	43.8	8.2	0.74
LSD (p=0.05)	3.1	0.5	0.09	3.2	0.6	0.08

Across sites, micronutrient and secondary nutrient application had little impact on juice content, total soluble solids (TSS), or fruit acidity (**Table 4**). However, both sites and input regimes demonstrated significant quality responses to K. Maximum fruit juice contents corresponded with conditions of high K fertility, as did fruit acidity. This latter observation suggests that K fertilization will play a role in influencing the time to fruit maturity since fruits with higher juice acidity take more time to attain the color break stage.

Total soluble solids showed a negative response to increased K application. Significant response to improved fertilization strategies over currently recommended doses of fertilizers warrants addressing nutrient requirements on a site-specific basis. BC

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