

# Nitrate Compensation Points of Several Plum Clones and Relationship to Nitrate Uptake Effectiveness<sup>1</sup>

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**Abstract.** The Nitrate Compensation Points (NCP) of 4 plum clones, Marianna 2624 (*Prunus cerasifera* Ehrh. × *P. munsoniana* Wight & Hedr.?), M-17 (*P. cerasifera* × *P. munsoniana*?), Myrobalan 3-J (*P. cerasifera*) and Myrobalan B. (*P. cerasifera*) were determined following NO<sub>3</sub><sup>-</sup> depletion from aerated nutrient solutions. Differences among NCP's were statistically significant; however, since the NCP's were low (ca. 5 μM NO<sub>3</sub><sup>-</sup>) relative to the [NO<sub>3</sub><sup>-</sup>] of typical agricultural soils, the relevance to NO<sub>3</sub><sup>-</sup> uptake effectiveness under field conditions remains unresolved. Maximum NO<sub>3</sub><sup>-</sup> influx took place above 20 μM NO<sub>3</sub><sup>-</sup>, but 15 hour exposures to higher ambient [NO<sub>3</sub><sup>-</sup>] resulted in higher NCP's. Both decreased influx and increased efflux of NO<sub>3</sub><sup>-</sup> may have contributed to higher NCP.

Uptake of nutrients may be limited by their rates of diffusion through the soil or by the absorptive capacity of the root (15). At sufficiently high soil nutrient concentrations transport through the soil will clearly not be limiting. However, at lower concentrations the root may reduce the concentration at its surface to a very low level. Rate of uptake is then determined by the rate of transport to the root surface and the effectiveness of uptake from dilute solutions. A characterization of NO<sub>3</sub><sup>-</sup> uptake effectiveness should, at least hypothetically, include the "Nitrate Compensation Point" (NCP), i.e., the minimum [NO<sub>3</sub><sup>-</sup>] below which net NO<sub>3</sub><sup>-</sup> influx ceases (5, 6, 17). Since NO<sub>3</sub><sup>-</sup> remains in the soil solution even when plants exhibit N deficiency symptoms, not all NO<sub>3</sub><sup>-</sup> in solution is available (12). Selection of rootstocks with low NCP may increase NO<sub>3</sub><sup>-</sup> availability at low concentrations and minimize the level of NO<sub>3</sub><sup>-</sup> remaining in the soil following cropping. Ingestad (8) found that the ability of roots to absorb ions under extreme nutrient conditions varied among species, and these differences might be important in ecological adaptation. Warncke and Barber (17) found that plant species differed in the efficiency with which their roots removed nitrate from nutrient solution and reported the following NCP's: forage sorghum, 1.7 μM; grain sorghum, 2.7 μM; soybean, 2.4 μM; and bromegrass, 1.4 μM NO<sub>3</sub><sup>-</sup>.

The objectives of this study were to determine the NCP's of several plum clones and to assess the biological significance of this parameter when extrapolated to the field situation. To our knowledge the NCP's of deciduous fruit tree species have never been published.

## Materials and Methods

Six individual plants of each clone, each plant in a separate 2-liter container, were pretreated for 12 days in aerated nutrient solutions lacking nitrogen to enhance subsequent rates of N influx. The relationship between the ambient [NO<sub>3</sub><sup>-</sup>] of the aerated nutrient solution and the rate of NO<sub>3</sub><sup>-</sup> depletion (net NO<sub>3</sub><sup>-</sup> influx) was determined by the disappearance of NO<sub>3</sub><sup>-</sup> from the ambient solution. NO<sub>3</sub><sup>-</sup> was determined colorimetrically according to Cataldo (3), by sampling 1-5 ml aliquots of nutrient solution over the course of the experiment. Since solution volumes were maintained by periodic addition of distilled, deionized water the decrease in NO<sub>3</sub><sup>-</sup> concentration of

the solution was indicative of the net NO<sub>3</sub><sup>-</sup> absorption. Nutrient solutions contained 2 mM CaSO<sub>4</sub>·2H<sub>2</sub>O, 5 mM phosphate buffer pH 6, micronutrients (minus iron) as in full strength Hoagland's solution (7), 12 μg/ml chloramphenicol, and KNO<sub>3</sub> (initial concentration 100, 250, or 500 μM NO<sub>3</sub><sup>-</sup>). Nitrate concentration in the nutrient solutions reached a minimum within 15 hours. The experiment was conducted during the light period in a growth chamber maintained at day/night temperatures of 25°/20°C. The light intensity was 27 klx over a 16 hr day length. NO<sub>3</sub><sup>-</sup> depletion curves were plotted using rate equations based on a least square fitting of a fourth degree polynomial.

## Results and Discussion

Nitrate depletion patterns of 4 plum clones, M-17, Myro 3-J, Myro B, and Mar 2624 were obtained (Fig. 1). Because of differences in root weights and volumes, the times required to reach the NCP's varied among replicates. Therefore, the curves presented are depletion patterns of individual plants characteristic of each clone.

Only Myro B (Fig. 1) exhibited a conspicuous (2-4 hr) lag period prior to NO<sub>3</sub><sup>-</sup> depletion. Since plants were pretreated 12 days in the absence of NO<sub>3</sub><sup>-</sup>, the lag phase presumably represents the time required to reinduce the NO<sub>3</sub><sup>-</sup> uptake system. The physiological basis for the difference between Myro B and the others is unknown. A 2 phase pattern of NO<sub>3</sub><sup>-</sup> uptake characterized by a lag phase followed by a linear rapid absorption phase is well documented for several species including barley (4, 16), corn (9), perennial rye grass (1, 13), and wheat (2).

The decrease (in μ moles) of NO<sub>3</sub><sup>-</sup> from the ambient solution is referred to as net NO<sub>3</sub><sup>-</sup> influx and represents the difference between NO<sub>3</sub><sup>-</sup> influx and NO<sub>3</sub><sup>-</sup> efflux. Net NO<sub>3</sub><sup>-</sup> influx was linear with time until some NO<sub>3</sub><sup>-</sup> concentration (C<sub>m</sub>) was reached below which the rate of influx decreased (Fig. 1). The fact that NO<sub>3</sub><sup>-</sup> influx remained linear implies that its rate was neither NO<sub>3</sub><sup>-</sup> limited nor affected by the presumed accumulation of NO<sub>3</sub><sup>-</sup> or reduced nitrogenous constituents in the root tissue during this phase of NO<sub>3</sub><sup>-</sup> depletion. Salt saturation was not responsible for the inability of the plants to further deplete the NO<sub>3</sub><sup>-</sup> level of the external solution, for NO<sub>3</sub><sup>-</sup> absorption continued if plants were transferred to solutions containing higher NO<sub>3</sub><sup>-</sup> levels (data not presented).

The NCP's varied among the plum clones tested and were affected by the initial ambient [NO<sub>3</sub><sup>-</sup>] (Table 1). Myro 3-J exhibited a lower NCP, i.e., depleted solution NO<sub>3</sub><sup>-</sup> to statistically lower levels, than Myro B, M-17 and Mar 2624 (Table 1). The NCP of ungrafted Mar 2624 plants was significantly different from that of the French prune/Mar 2624 combination (Table 1). This appears to be the first report of scion modification of the compensation point. French prune, ('Agen'), in-

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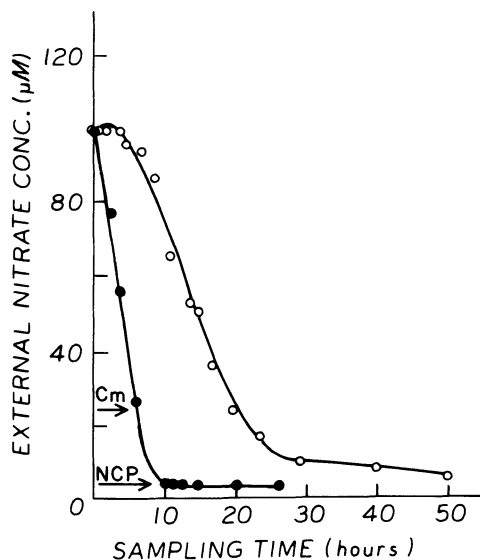


Fig. 1. Depletion of  $\text{NO}_3^-$  from 2 liters of nutrient solution by representative plants of 2 plum clones. The M-17 depletion pattern (closed circles) was also characteristic of Myro 3-J and Mar 2624 plants. In contrast, Myro B plants (open circles) exhibited a 2-4 hr lag prior to  $\text{NO}_3^-$  uptake.

creased the NCP (Table 1) and so reduced the  $\text{NO}_3^-$  depletion capacity of Mar 2624 in the grafted plant.

Exposure of plum clones (particularly M-17 Table 1) to higher ambient  $[\text{NO}_3^-]$  resulted in both higher  $C_m$  values and higher NCP. The influence of higher  $[\text{NO}_3^-]$  may have been mediated by reduced influx and/or increased  $\text{NO}_3^-$  efflux (10, 14). The relationship between nutrient status and uptake is well documented (10); however, the relationship between ambient  $[\text{NO}_3^-]$ ,  $C_m$  and the NCP has not generally been appreciated. In our system the effect of ambient  $[\text{NO}_3^-]$  on NCP was expressed within 15 hr of exposure to differential  $[\text{NO}_3^-]$ , i.e., the time course of the experiment. The effect of ambient  $[\text{NO}_3^-]$  on the NCP may be interpreted in several ways. The restriction of net  $\text{NO}_3^-$  uptake may be associated with progressive increases in root  $\text{NO}_3^-$  concentrations (10), with differential permeability of root  $\text{NO}_3^-$  such that total concentrations did not accurately reflect the concentration available for passive leakage (efflux) into the medium. Kuiper and Kuiper (11) reported an alteration in the lipid composition of *Plantago* roots upon exposure to low salt conditions and suggested that the maintenance of free ster-

Table 1. The effects of clone and initial ambient nitrate concentration on  $C_m$  and NCP and scion modification of these values.  $C_m$  is the ambient nitrate concentration below which nitrate uptake is reduced; NCP is the nitrate concentration at which net N influx = 0.

Clone or combination	Initial ambient $[\text{NO}_3^-]$ ( $\mu\text{M}$ )	NCP ( $\mu\text{M}$ )	$C_m$ ( $\mu\text{M}$ )
Myro 3-J	100	1.74 a <sup>z</sup>	20.00
	250	1.90 a	—
M-17	100	3.78 b	22.20
	250	6.97 c	40.74
	500	11.56 <sup>y</sup>	108.00
Myro B	100	6.68 c	16.00
	250	—	24.50
Mar 2624	100	—	24.50
	250	3.85 b	—
French prune/Mar 2624	250	5.87 c	64.00

<sup>z</sup>Each value is an average of 6 replications. Means with the same letter do not differ statistically at  $P = 1\%$ .

<sup>y</sup>Not included in statistical analysis.

ols in the roots and the more saturated condition of root lipids might reduce nutrient leakage. The magnitude of  $\text{NO}_3^-$  efflux would be dependent upon (a) the size of the cytoplasmic  $\text{NO}_3^-$  pool relative to that of the ambient  $\text{NO}_3^-$ , (b) the permeability of the plasmalemma to  $\text{NO}_3^-$ , (c) the activity of the active absorption mechanism on the external surfaces of the plasmalemma, (d) energy charge, and/or (e) the extent to which the absorption sites are dominated by the ambient  $\text{NO}_3^-$  (10).

The  $C_m$  was between 16 and 22  $\mu\text{M}$   $\text{NO}_3^-$  in 100  $\mu\text{M}$  (initial)  $\text{NO}_3^-$  (Table 1), which agreed closely with values presented for corn (5). A comparison of  $C_m$  values with their respective NCP indicates a broad concentration range (i.e.,  $C_m$  is between 2.4 and 12 times higher than the NCP).

The efficiency of fertilizer use for crop production may be improved by minimizing the amount of N lost by leaching in percolating water. Maintenance of low soil solution N levels when leaching is likely to occur may reduce this loss. Also, an increased capacity of plants to utilize  $\text{NO}_3^-$  from dilute soil solution should minimize the amount of  $\text{NO}_3^-$  in the soil which is inaccessible to the plant and, hence, vulnerable to loss. In this study we found that maximal rates of  $\text{NO}_3^-$  influx were maintained at several orders of magnitude lower ambient  $[\text{NO}_3^-]$ , i.e., 20  $\mu\text{M}$   $\text{NO}_3^-$ , than the  $\text{NO}_3^-$  levels reported (0.36-3.6 mM) to occur in agricultural soils (James Quick, Cooperative Extension Soils Specialist, Davis, personal communication). These values, however, presumably represent the  $[\text{NO}_3^-]$  of bulk soil samples rather than the  $[\text{NO}_3^-]$  in the immediate vicinity of the root surface. Thus, although NCP's differ mathematically among clones, it is not clear whether these differences are agriculturally meaningful or relevant. The NCP's for corn, sorghum, soybean, and bromegrass were reportedly much lower than the  $[\text{NO}_3^-]$  of bulk soil samples from field where N deficiency was prevalent in the crop (17). This indicates that the movement of nitrate through the soil to the root is an important factor in determining the minimum nitrate level in soil-plant system. In the experiment reported here, the NCP were the mean  $[\text{NO}_3^-]$  at the root surface, for the solution was stirred. In plant-soil systems, concentration gradients around the roots occur so that the nitrate level at the root surface may be much lower than the average level in the soil (17).

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## Chemical Stimulation of Branching in Deciduous Tree Fruit Nursery Stock with Ethyl 5-(4-chlorophenyl)-2H-tetrazole-2-acetate<sup>1</sup>

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**Abstract.** Ethyl 5-(4-chlorophenyl)-2H-tetrazole-2-acetate (PP528) applied in early summer to apple (*Malus domestica* Borkh.) and pear (*Pyrus communis* L.) trees stimulated lateral branching the first year in the nursery. Concentrations of 25 to 50 ppm were effective, while 100 ppm or more sometimes killed shoot terminals and stopped or retarded further vertical growth for the season. Branch angles were not measured, but when terminal meristems were not killed, branch angles were wide. If terminal meristems were killed, the uppermost branch angles were narrow. Double applications 2 weeks apart of 25 or 50 ppm were sometimes more effective than single applications. Timing, uniformity of growth, and application during active growth were important to produce maximum branching effect and branching in suitable locations. PP528 caused more branching in 2 non-spurred 'Delicious' apple cultivars (up to 9 times control values) than in 'Oregon Spur Delicious' (up to 3 times the control). Treatments with up to 200 ppm were largely ineffective on sweet cherry (*Prunus avium* L.). Use of 100 or 250 ppm GA was of little benefit in overcoming the stunting effect of high concentrations of PP528.

In today's intensively managed orchards, early yields are highly desirable. One reported method to secure early production is the use of well-feathered (branched) maiden trees which not only provide a sound framework of branches but also flower and fruit sooner than unfeathered trees (11, 17).

Nursery trees vary in natural branching tendency. Many produce few or no branches, while others produce well-branched trees the first year in the nursery. Branching varies with species, cultivar, rootstock, climate, cultural practices, and propagation techniques (1). Chip-budded trees branch more than T-budded trees (5). Peaches and apricots usually branch readily, while many apple cultivars do not. Conditions that produce vigorous growth promote branching.

Some branching can be stimulated by manual removal of the shoot tips during the growing season; however, this usually stimulates formation of only 2 to 3 narrow-angled branches near the point of decapitation (Fig. 1a).

Chemical pruning agents offer a potentially less expensive and more effective alternative to hand pruning for the production of branched nursery trees. Cytokinins overcome apical dominance (14, 15) and other chemicals specifically stimulate lateral bud growth (2, 6, 8, 10, 18). A few chemicals stimulate

branching of fruit trees in the nursery and in the early years in the orchard (1, 3, 4, 7, 9, 12, 13, 16, 18).

This paper reports the results of the use of an experimental chemical, PP528, for stimulating branching of apple, pear, and sweet cherry trees during the first year in the nursery.

### Materials and Methods

In 1976 and 1977, the top 25 to 30 cm of the scion shoots of first-year apple, pear and cherry trees growing on seedling roots in commercial nurseries in Yakima and Wenatchee, Washington were sprayed to runoff when the scions were 45 to 60 cm high; some plots were resprayed 2 weeks later. X-77 (principal functional agents: alkylaryl polyethylene glycols, free fatty acids, isopropanol) at 0.1% was used as a surfactant. Treatment dates were June 24 and July 7, 1976 and June 15 and 30, 1977. On the last treatment date in 1977, some plots were also sprayed with 100 or 250 ppm GA<sub>3</sub> to see if GA would reduce the stunting noted from some levels of PP528 in 1976. PP528 was used between 50 and 200 ppm in 1976. These concentrations appeared excessive and were lowered to 25, 50, or 100 ppm in 1977. Plots included 3 to 5 trees with 3 replications of each treatment. Just before digging in November, the trees were measured and lateral branches 3 cm or longer were counted. Trees with normal nursery growth were planted in commercial orchards and developed normally. Those stunted in the nursery were discarded.

### Results and Discussions

For brevity, only data from 1977 are included (Table 1). In 1976, 'Anjou' and 'Bartlett' pear and 'Wellsur Delicious,' 'Oregon Spur Delicious,' and 'Winter Banana' apple trees

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