# GROWTH AND DEVELOPMENT OF POTATO ROOT TYPES: IMPLICATIONS FOR PLACEMENT AND TIMING STRATEGIES IN FERTILITY MANAGEMENT

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The efficient management of plant nutrients in maximizing yields and maintaining tuber quality requires a good working knowledge of potato root developmental patterns in the field. We are completing and summarizing the first phase of our potato root research this year. Our past research has indicated that potato root development, yield and quality are inseparably linked together, and are all influenced by soil management practices.

## Potato root system

Employing bulk root sampling procedures, we have constructed some root developmental patterns as influenced by irrigation management. Four potato root types were categorized by Kratzke and Palta (1985) according to morphological origin. Some of the most significant findings from our research on the development of these root types under field conditions are summarized below.

Stem nodal roots. Stem nodal roots, or basal roots, comprise the bulk of the potato root system, originating from the below ground stem and extending to depths of 60 cm. Development under the furrow is delayed until well after tuber initiation, underscoring the importance of careful water and nutrient management early in the growing season to prevent excessive leaching of nutrients, such as nitrate, under the furrow prior to adequate root development in that region.

Stolons and stolon roots. These roots develop in the tuber zone in the potato hill, and the development of these roots is not extensive under normal cultural practices. Therefore nutrients, such as Ca that rely on these plant structures as conduits for delivery to the tuber, must be made available in this localized region for effective fertility management. This poses a serious problem for Ca management, since available Ca sources may not be able to sustain elevated Ca levels in the soil solution in this soil zone (see leaching experiment below).

Stolon and tuber roots may play an important role in the delivery of Ca to potato tubers. Ca supplied locally in the tuber-forming zone accumulates in the tuber (Kraus and Marschner, 1971; Kratzke and Palta, 1986).

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Furthermore, $^{45}Ca$ applied to the stolon was transported to the tuber, but only during conditions of low relative humidity surrounding the tuber, thus implying xylem flow as an important pathway of Ca delivery to the tuber (Kraus and Marschner, 1971). Baker and Moorby (1969) demonstrated nocturnal inflow of a Ca analog, Sr, into tubers when shoot transpiration rates were low. Dye experiments demonstrated xylem flow from basal roots is largely directed toward above-ground shoots, while there is significant flow from stolon roots into tubers (Kratzke and Palta, 1985).

We used X-ray analysis to show the lack of direct xylem flow from stem nodal roots into stolons during the daytime, preventing Sr movement into the stolon. Xylem-phloem transfer appeared to account for the more immediate transport of mobile nutrients such as Cl into the stolon (Nelson et al., 1990).

Tuber roots. Roots originating from the tuber were occasionally observed in Russet Burbank, but their appearance was transient, and seemed to be somewhat reliant on water stress conditions. Due to their sparse nature, they are thought to only play a minor role in tuber nutrition.

Seasonal patterns. Total root length declined during tuber development, indicating possible competition between roots and tubers for limited growth promoting substances from the shoots, such as carbohydrates and growth hormones. If true, this may limit future efforts to increase potato production and tuber quality under high yielding conditions. More refined tehniques are needed to characterize seasonal and diurnal changes in root growth rates in relation to tuber development, soil management, and environmental stresses.

We have developed a technique for computerized root image analysis that employs desktop scanning technology to measure root dimensions of excavated samples. We also have tested the system for time sequential root growth analysis in a minirhizotron type of system. In contrast to our previous technique of destructive bulk root sampling, washing and analysis, this approach allows for continuous measurement of changes in root growth and development of a single plant. We are currently testing a prototype system in the greenhouse that will be adapted to field use by the upcoming growing season.

Calcium leaching experiment

Laboratory soil column experiments on Warden silt loam and Quincy sand indicated that maintaining elevated Ca levels in the soil solution may be difficult to achieve. Solubility of Ca sources and leaching of soluble Ca need to be addressed to insure that Ca fertilization actually results in increased Ca availability. Predictably, Ca from calcium-ammonium nitrate dissolved and leached quickly through Quincy sand, while with the less soluble sources, calcium carbonate had little effect on soluble Ca, and gypsum had an intermediate effect (Fig. 1). Almost all Ca from either calcium-ammonium nitrate or gypsum was found at a depth below 15 cm at 10 days after application, and below 25 cm at 20 d.

At a watering rate of 10.5 mm/10/min/day, all added Ca was leached out of the 45 cm long column by 30 days after Ca addition. Contrastingly, Ca was retained in the upper 15 cm of the Warden silt loam, 10 days after application with calcium-ammonium nitrate or gypsum, while lime again did not increase Ca solubility (Fig. 2). Calcium-ammonium nitrate maintained higher Ca levels for 20-30 days, and then declined to similar levels as the other treatments, apparently due to leaching. Based on these preliminary findings, split Ca applications with a soluble Ca source are necessary to maintain elevated soluble Ca levels in these soils. Simmons et al. (1988) suggested preplant gympsum was an adequate Ca source in potato production on Wisconsin soils low in Ca.

## Field Experiments

Calcium, nitrogen x irrigation experiments were conducted at Plymouth and Othello, Wa. to test the following hypothesis: Intermittent IBS is related to inhibition of root growth rate and Ca uptake under environmental stress conditions such as water stress or nutrient imbalance.

In a fertility x irrigation experiment (Plymouth, Wa.; 1989) conducted in collaboration with AgriNorthwest, IBS was not a seriously occurring disorder. Yet, some mild IBS symptoms (faint discoloration) did appear with high frequency, particulary in the larger tubers. Split applications of a soluble Ca fertilizer tended to decrease the incidence of IBS in tubers > 10 oz., while not significantly affecting yield (Table 1). Excess or insufficient water did not increase IBS, while the later planting date tended to have slighter higher mild IBS occurrence.

A similar fertility x irrigation experiment was conducted at Othello in 1990 in collaboration with Dr. Larry Hiller. A line-source irrigation design was used to impose varying levels of water availability during tuber development. Calcium was supplied as preplant-incorporated gypsum or midseason applications of calcium-ammonium, nitrate. IBS was not observed. The yield of U.S. No. 1 tubers was not affected by our fertility treatments (Fig. 3); however, there was a significant increase in yield of No. 2 tubers with excessively high N (500 lb N/a), which was reduced with the addition of 112 kg Ca/ha as gypsum. This trend in No. 2's was associated with the increased frequency of pointed ends with high N, and the reduction of pointed ends with the preplant gypsum. Water level during tuber development affected tuber yield and quality (Fig. 4). Both total number and % translucent ends were highest at water levels required to maximize No. 1 yields. No fertility x water interactions were apparent.

## Summary

While Wisconsin researchers indicate a strong relationship between IBS and Ca availability, our results are inconclusive. Over the three years in which we have experimented with soil Ca amendments, severe IBS conditions have not been prevalent. In 1989, when mild IBS occurred at Plymouth, it was most evident in the larger tubers, and in-season Ca fertilization partially reduced the IBS incidence. If Ca availability is indeed associated with this disorder, it must be in association with environmental conditions.

Maintaining elevated soil solution Ca in the stolonroot and tuber forming zone in the hill may be complicated by the solubility of Ca forms available. Gypsum and lime have limited solubility, while calcium nitrate sources may be more immediately available, but on the other hand are more susceptible to leaching. Therefore, Ca fertilization may not always result in increased Ca availability when and where it is needed.

Overall rooting patterns suggest over fertilization and watering during early development will result in losses below the furrow, due to the limited rooting in this zone until after tuber initiation. Declining root lengths during tuber bulking may indicate declining ability to absorb nutrients during this period. Future research will use minirhizotron techniques to address these questions.

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Table 1. Mild IBS occurrence (% of tubers in each wt. class) in potatoes grown at Plymouth, Wa. (1989) as affected by planting date and watering regime. Ca was supplied with calcium-ammonium nitrate at 25 lb Ca/A at each of four intervals on 15, 28 June and 12, 25 July.

| Tuber wt. (oz.) | Ca | Planting date 4/7/89 %water of FC 70% | 4/7/89 90% | 4/24/89 90% | 4/24/89 120% |
|---|---|---|---|---|---|
| 6-10 | + | 8.3 | 7.1 | 15.9 | 14.2 |
| | - | 8.1 | 17.5 | 27.3 | 14.4 |
| 10-14 | + | 10.2 | 19.7 | 18.0 | 11.3 |
| | - | 11.5 | 22.2 | 34.6 | 19.0 |
| >14 | + | 11.9 | 22.7 | 26.4 | 15.0 |
| | - | 13.7 | 24.1 | 35.5 | 24.7 |

Figure 1. Soluble Ca in saturated paste extracts of a Quincy sand as affected by three Ca sources. Columns were analyzed 10, 20, 30, and 40 days after application.

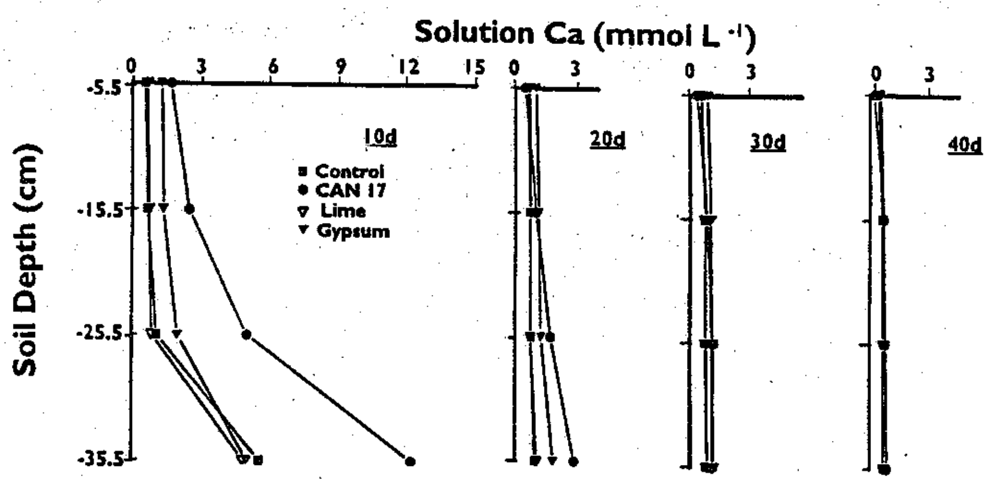



Figure 2. Soluble Ca in saturated paste extracts of a Warden silt loam as affected by three Ca sources. Columns were analyzed 10, 20, 30, and 40 days after application.

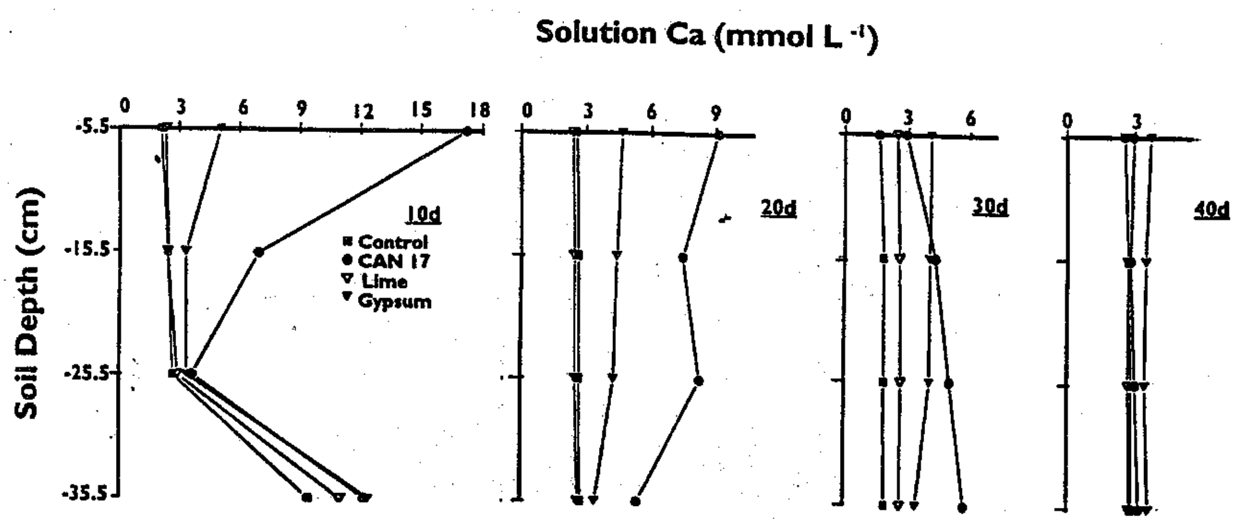
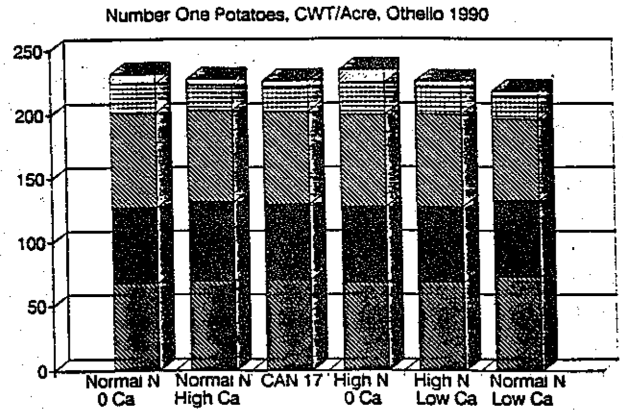
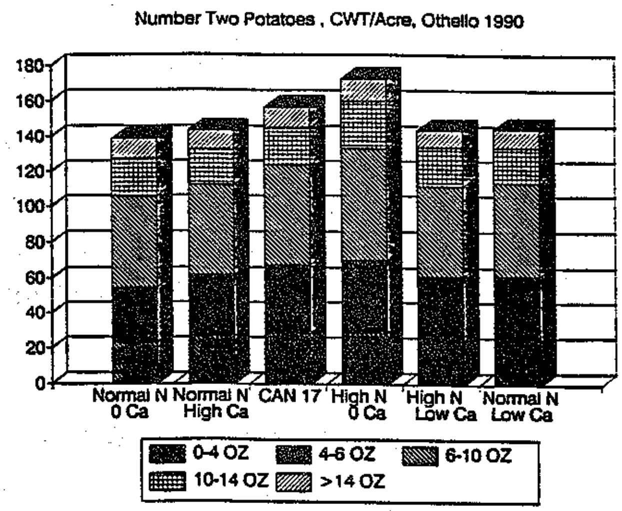


Figure 3. U.S. No. 1, No. 2, and pointed end tubers as affected by N levels and Ca sources.



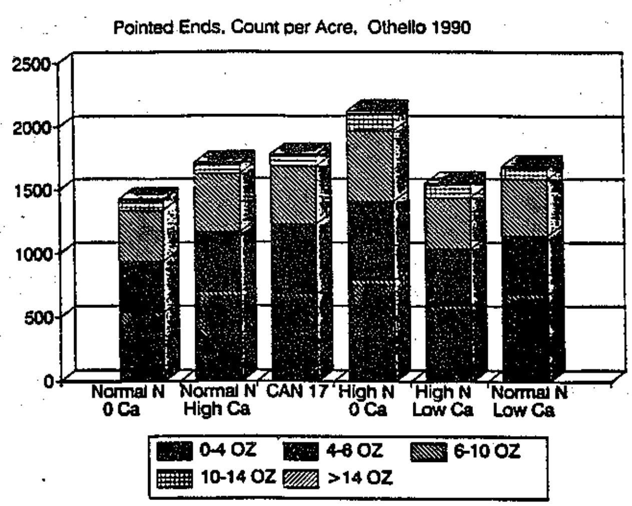



Figure 4. Irrigation effects on tuber yields and pointed ends.