POTATO ROOT DEVELOPMENT AND N UPTAKE

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Introduction

Nitrogen management can alter dry matter partitioning and influence tuber yield and quality of Russet Burbank potato (Ojala et al., 1990; Lauer, 1986). Excessive N applications can overstimulate vine growth, while depressing tuber development (Kleinkopf, 1994). Split applications of N are commonly used to supply ample N for tuber development (Roberts et al., 1991; Ojala et al., 1990), since maximum N uptake rates occur during tuberization and tuber development (Ojala et al., 1990). Knowledge of seasonal root developmental patterns should aid decisions on fertilizer placement and timing.

Our past research that employed destructive root sampling indicated that total root length plateaus or declines after mid-tuber development (Pan et al., 1990), raising questions about whether split N applications would be useful after this growth stage. However, the intensive labor requirements of this root sampling method, and the variation introduced by destructive sampling different plants, limited our ability to characterize the exact nature of seasonal rooting patterns.

Rhizotron system and application

Rhizotrons are underground windows that are useful tools for nondestructively examining root development over time. We have developed a rhizotron system that employs inexpensive, portable scanners as image capture devices. The rhizotron system we have designed is unique, and it has great potential in future root research and for root monitoring in production systems. It is less expensive than commercially available minirhizotron systems, and it provides high quality images of field-grown root systems.

Rhizotron boxes were established in a N x water experiment conducted by Dr. L. K. Hiller and Dr. C. O. Stockle at Othello, Wa. These waterproof boxes featured a clear glass face along which potato roots were allowed to develop in the field. Roots were scanned and images were imported into computer files every 2 weeks with portable hand scanners.

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The recent advent of high resolution, color hand scanning devices has enabled us to create detailed rhizotron images. Seasonal patterns of root development observed in 1992 were verified with a more sophisticated rhizotron system developed for the 1993 growing season, using image analysis algorithms (Pan and Bolton, 1991). Shoot and tuber samples were collected from adjacent plants throughout the growing season.

Root development and N uptake

Early root proliferation indicated roots are a high priority in potato plant development prior to tuber initiation (Figs. 1-3). Root elongation rates were greatest during the first 40-60 days prior to tuber initiation, and prior to the accelerated phase of N uptake. Substantial root development occurred prior to shoot emergence below the seed piece. Root elongation to a 2 ft depth beneath the hill and proliferation into the furrow zone was observed as early as 20-40 days after planting. Shortly after tuber initiation, root elongation rates declined, and net losses in total root length were observed. Root decline during tuber bulking was most noticeable in the hill (Fig. 2). This may reflect a competition between tubers and roots for limited carbohydrates transported from the shoots, and roots may shift from being carbon sinks to carbon sources to help support tuber development.

Two N application strategies were compared: i) applying N according to soil test recommendations in three applications (preplant and 2 in-season splits) vs. ii) weekly N applications during tuber development according to petiole analysis (Fig. 1). Preplant N (50 lb N/A) was supplied uniformly in both N treatments. In the soil test treatment, two additional applications of 100 lb N/A were applied at tuber initiation and two weeks after (designated by solid arrows). In the petiole analysis treatment, N was supplied in 20-50 lb N/A weekly doses over 2 months after tuber initiation (designated by the dotted arrow).

Large applications of N at tuber initiation, prescribed by pre-season soil tests, greatly increased root extension rates in 1992, but decreased tuber dry matter accumulation compared to smaller, more frequent N applications based on petiole analysis (Fig. 1). This raises the question whether excess N supplied at tuber initiation stimulates carbon allocations to the root system at the expense of the developing tuber.

We observed the accelerated N uptake phase corresponded to tuber bulking (Fig. 3). similar to the findings of other researchers (Ojala et al., 1990). Interestingly, this occurred after the phase of rapid root development (Fig. 3). This suggests that early season water and nutrient management is critical for establishing a healthy root system that is capable of absorbing nutrients during tuber development. Shoots accumulated N up to 80 days after planting, after which they became net exporters of N to the tubers. The bulk of shoot and tuber N accumulation occurred between 40 and 100 days after planting, so that it is unlikely that additional N fertilization after 100 days was of great benefit. Roberts et al. (1991) demonstrated with ^{15}N labelling that fertilizer recovery efficiency diminished with late season N applications.

Conclusion

Assuming that the growth of a vigorous root system is necessary for optimum tuber yield and quality, these patterns of root development suggest that preplant soil management is critical in potato production, particularly in systems where irrigation and fertigation is delayed. It is recommended, to promote a prolific and well-distributed root system, that nutrients known to stimulate root growth, such as N and P, be broadcast incorporated to encourage an even distribution of roots throughout the profile. Rapid root development under the furrow is desirable for improving water and nutrient use efficiency from subsequent fertigation. The early proliferation of roots beneath the seed piece suggests that this zone of soil may warrant future management attention for optimal seedling establishment and vigor. The decline in root length and N uptake 100 days after planting implies late season N applications may only have limited benefits.

References

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Figure 1. Nitrogen management effects on tuber, shoot growth and root relative extension rates.

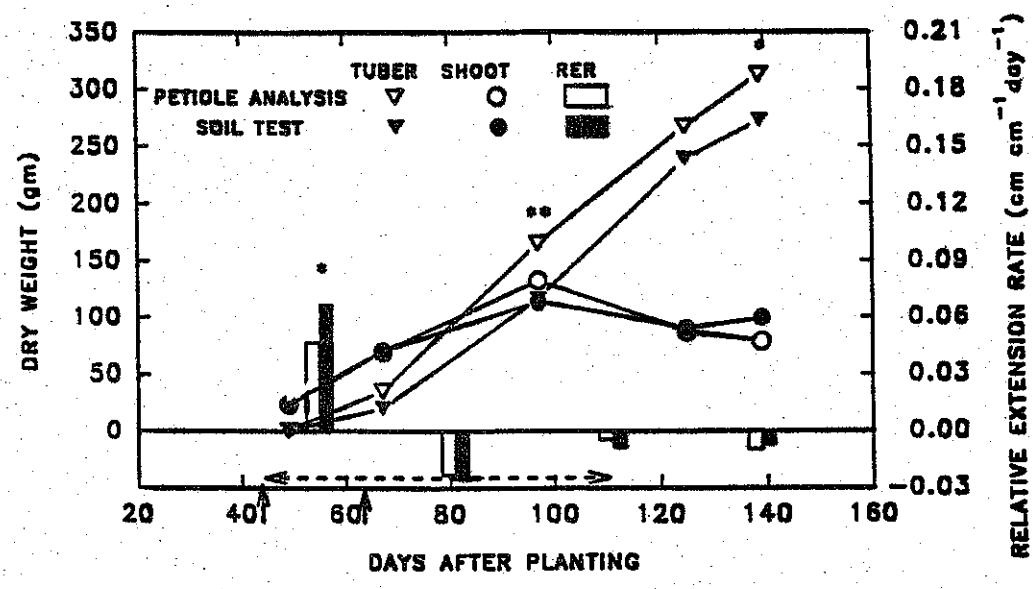

Figure 2. Root length densities observed with the rhizotron in different sections of the soil profile: 1) in the hill to a depth of 6 in. 2) 6 in. to 12 in. below the hill, and 3) 6 in. below the furrow at Othello, Wa. 1992.

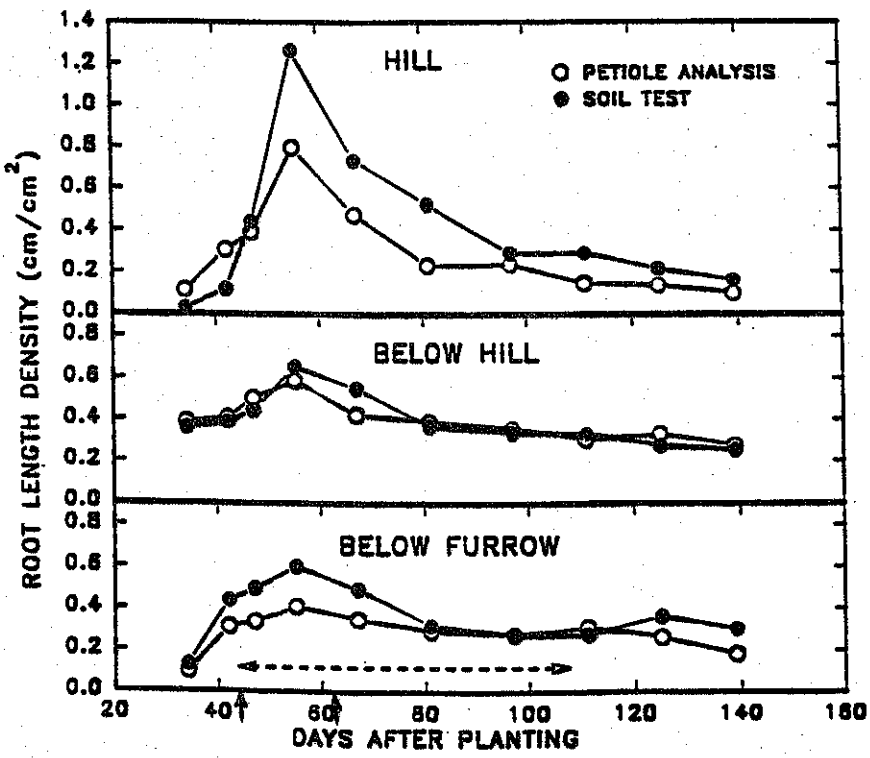

Figure 3. Shoot and tuber dry matter and N accumulation, and root elongation along the rhizotron. Data is averaged over N treatments, which were not significantly different at Othello, Wa. 1993.