NITROGEN MANAGEMENT WITH DRIP AND SPRINKLER IRRIGATION

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INTRODUCTION: EARLY IRRIGATION PRACTICES

In discussing nitrogen management under drip and sprinkler irrigation, I want to cover recent results from the Treasure Valley of southeastern Oregon and southwestern Idaho. To understand how these nitrogen fertilizer recommendations are different from those of 20 years ago, we need to consider the changes that have occurred in the landscape over the last 150 years and how these changes affect the function and productivity of desert soils. When this area started to be developed in the end of the 19th century, the first rudimentary irrigation systems were built along-side rivers and streams. Push-up dams were placed in the rivers, or water wheels were placed in the river, and lateral ditches were built almost on the contour to carry water down stream and away from the river, increasing the land area below the water. From these lateral ditches, surface flood and furrow irrigation was practiced.

The rudimentary surface irrigation systems evolved into more elaborate gravity feed systems. As dams were built in the hills and mountains above the lower lying valleys, networks of canals and ditches were designed to deliver water by gravity to various fields. A wide variety of crops were grown, and the residues from crop production were incorporated into the soil. Crop rotation was a common practice and animal wastes were incorporated into the soil in production fields. These practices continue to the present.

The soils brought under cultivation by these surface irrigation systems were generally desert soils with low levels of organic carbon and nitrogen. The incorporation of crop residues introduced large amounts of stubble and other organic crop residues organic into these organic-material poor soils.

NITROGEN FERTILIZER APPLICATION FOR SHALLOW ROOTED CROPS USING FURROW IRRIGATION

With the advent of chemical fertilizers, nitrogen fertilization practices became rationalized based on crop nutrient uptake. For example, for every ton of potato (*Solanum tuberosum* L), the corresponding tubers and vines would contain about 8 lb of nitrogen. If the crop were to yield 25 t/acre, then the crop would take up about 200 lb/acre of nitrogen. Since the roots of potato are only somewhat efficient, it was reasoned that the nitrogen requirement would be greater than 200 pounds of nitrogen per acre based on the inefficiency of the root system. So, from an optimistic point of view, if the root systems were able to recover 65 percent of nitrate and ammonium, then 308 lb/acre of nitrogen would be required.

With soil testing the amount of nitrate nitrogen and ammonium nitrogen in the root zone of potato could be determined. If we assume that potato roots make use of the top 2 ft. of soil, then the amount of fertilizer that was required by a 25-t/acre crop could be calculated. Supposing that the soil contained 80 lb of available nitrogen in the top 2 ft at planting, then it was reasoned that 228 lb of nitrogen would be required to satisfy the needs of a 25-t/acre potato crop (Figure 1).

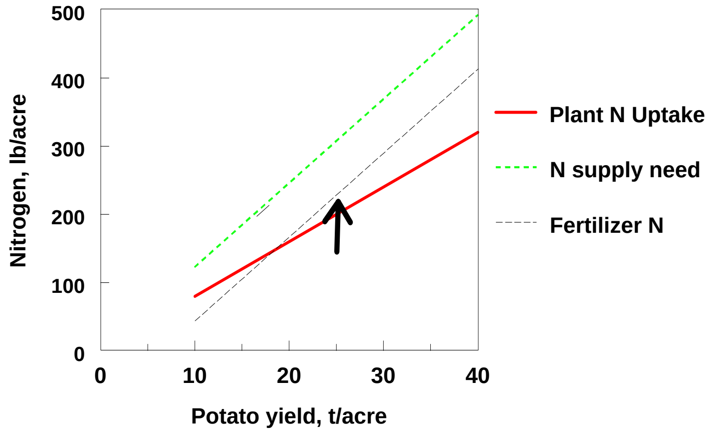

Figure 1. A conventional approach to estimating potato N fertilizer requirements. The total N uptake by potato vines and tubers is related to the yield. Since the roots are inefficient, a larger supply must be present than what will be taken up. For example, if there were 80 lb N/acre available in the soil surface layers at planting, 228 lb/acre of fertilizer N would be required for a 25-t/acre potato crop (arrow).

The assumptions of this exercise are straightforward. The assumptions of this approach are that the amount of nitrogen required by the crop is proportional to the yield, that the inefficiency of the root system requires that more nitrogen be available than what the crop will contain, that the available nitrogen forms will be available for the crop, and that the rest of the nitrogen that the crop needs will have to be applied as fertilizer (Figure 1). The Idaho and Oregon potato fertilizer guides' tables are consistent with this philosophy of making fertilizer recommendations (McDole et al., 1987: Oregon State Univ., 1985).

The same kind of argument was made for other crops. A typical figure for onion (*Allium cepa* L) is that the tops and bulbs require about 3.8 lb of nitrogen per ton. So an onion crop that yielded 40 t/acre would take up approximately 152 lb/acre of nitrogen. A common assumption for onion is that the onion root systems can only obtain 50% of the available nitrogen and are able to explore the top 2 ft of the soil profile; so 304 lb/acre of nitrogen would need to be available for a 40-t/acre crop. If 54 lb/acre of nitrogen were available in the form of nitrate and ammonia from the top 2 ft. of soil at planting, then the onion crop would require 250 lb/acre of fertilizer nitrogen (Figure 2).

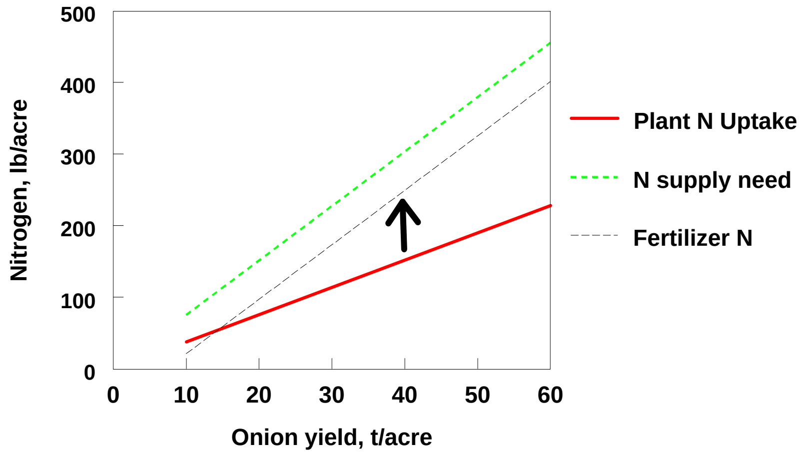

Figure 2. A conventional approach to estimating onion N fertilizer requirements. The total N uptake by onion tops and bulbs is related to the yield. Since the roots are inefficient, a larger supply must be present than what will be taken up. For example, if there were 54 lb N/acre available in the soil surface layers at planting, 250 lb/acre of fertilizer N would be required for a 40-t/acre onion crop (arrow).

The straightforward assumptions work fairly well for nitrogen fertilizer applied to shallow rooted crops under furrow irrigation where no particular care is given to matching crop water needs to water deliveries and nitrogen is applied only once. No particular care is taken to match the irrigation amount to crop water needs because the irrigation system doesn't lend itself to matching water applied to crop needs. A substantial amount of water is inevitably lost due to deep percolation and runoff.

Furthermore, with furrow irrigation, the excess water that moves through the profile can carry nitrate below the root zone of these shallow rooted vegetables. Other nitrogen sources that might be able to contribute to the nitrogen supply may be negated through leaching.

NITROGEN FERTILIZER APPLICATION UNDER SPRINKLER AND DRIP IRRIGATION

With either sprinkler or drip irrigation it is possible to control the amount of water applied to match crop evapotranspiration. It is also much easier to split the nitrogen applied into small doses during the irrigation season. Consequently, the nitrogen use efficiency may be substantially different with sprinkler and drip irrigation systems. To examine the response of potato under sprinkler and onion under drip, we conducted replicated field plot trials for several years.

Four potato varieties were grown with 0, 120, 180, and 240 lb/acre N (Feibert et al., 1998). Sprinkler irrigations were carefully managed so that the crop was always watered at the right moment. The soil water potential of the Owyhee silt loam at 8-in depth in the potato beds was never allowed to become drier than -60 kPa. No more than the accumulated crop evapotranspiration was replaced at each sprinkler irrigation. Available soil N as nitrate and ammonium were 115, 60, and 68 lb/acre in three years following alfalfa, wheat, and wheat respectively. Crop yield responses to N were relatively weak, with the maximum yields occurring at 0, 120, and 120 lb/acre N (0, 135, and 135 kg/ha N, respectively) (Figure 3).

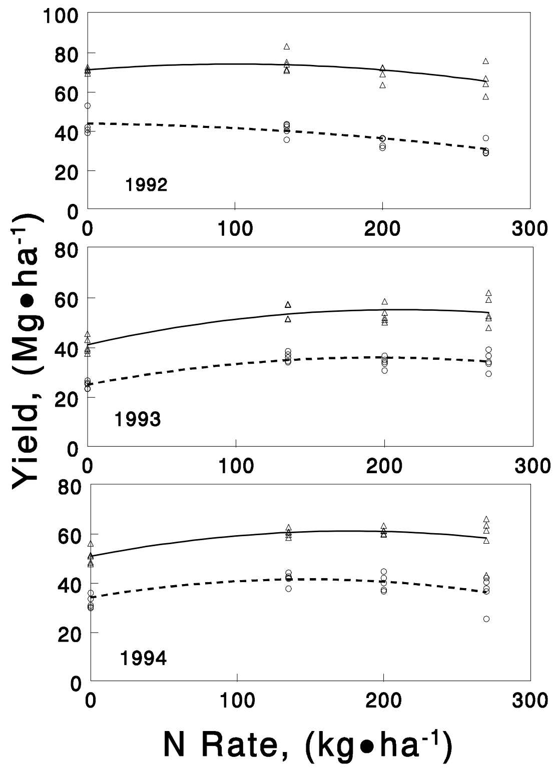

Figure 3. Total yield (solid lines) and US Number 1 (dashed lines) yield of potato responded little to N fertilizer rates (Feibert et al., 1998). 'Russet Burbank', 'Ranger Russet', 'Frontier Russet', and 'Shepody' were grown under sprinkler irrigation on silt loam, following alfalfa in 1992 and following wheat in 1993 and 1994. Malheur Experiment Station, Oregon State University.

On average furrow-irrigated onion yields 31.3 t/acre (70 $Mgha^{-1}$) in the Treasure Valley of eastern Oregon and southwestern Idaho and is supplied with 284 lb/acre (318 kg/ha) N fertilizer. These practices have been implicated in nitrate contamination of groundwater. Drip irrigation, introduced in the early 1990's, has several potential advantages, including reduced leaching losses and several disadvantages including greater cost. Since onion plant populations and N fertilizer rates can sensitively affect economic returns, studies were conducted in 1999, 2000, and 2001 to determine optimum plant populations and N fertilizer rates for subsurface drip-irrigated onion (Shock et al, 2004). Pre-plant soil available nitrate plus ammonium was 79, 121, and 191 lb/acre following winter wheat in successive years. Long day onion (cv. Vision) was subjected to a combination of four plant populations and seven nitrogen fertilization rates of 0 to 300 lb/acre (0 to 336 kg/ha) in 50 lb (56 kg) increments applied between late May and early July

(Figure 4). Onions were grown on silt loam with two conventional double rows on 44-inch beds with a drip tape buried 5 inches deep in the bed center. Soil water potential was maintained nearly constant at -20 kPa by automated irrigations based on soil water potential measurements at 8-in depth. Onion bulbs were evaluated for yield and grade after curing and 70 days of storage. Onion yield and grade were highly responsive to plant population. Onion marketable yield increased, and bulb diameter decreased with increasing plant population. Onion yielded on average 42.4 t/acre (95 Mg/ha) with no applied N fertilizer, averaged over plant populations and years. Onion N uptake did not increase with increasing N fertilizer rate. Onion yield and grade were not responsive to N fertilizer rate. There was no interaction of N fertilizer rate with plant population (Figure 4). Pre-plant available N, N from organic matter mineralization, and N in irrigation water contributed N to the crop.

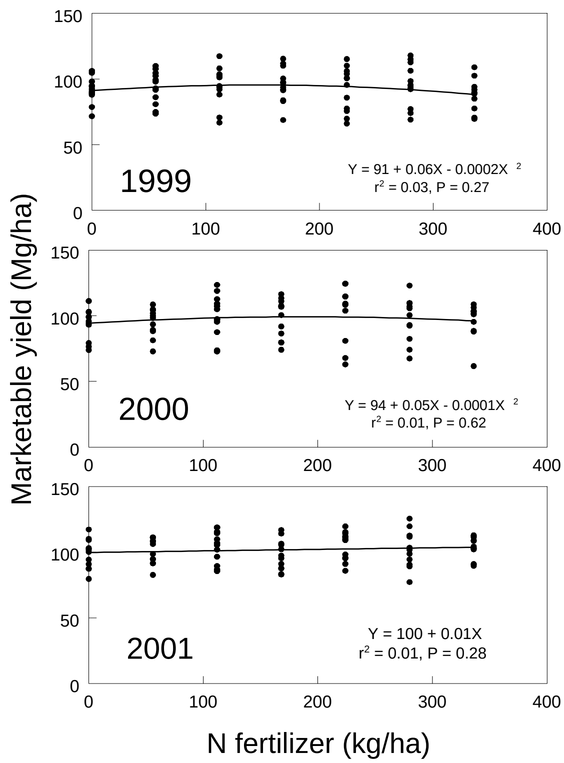

Figure 4. Total marketable yield of ‘Vision’ onion responded little to N fertilizer rates (Shock et al., 2004). Each year onion was grown under drip irrigation on silt loam, following modestly fertilized wheat. Malheur Experiment Station, Oregon State University.

Given the modest response of potato to N fertilizer and the absence of onion response to N, a thorough nitrogen budget approach seems warranted. Sullivan et al. (2001) outlined a comprehensive budget that would include all substantial N sources.

DISCUSSION

Clearly there are large discrepancies between the earlier approach to estimate N fertilizer needs and actual potato and onion responses under carefully managed sprinkler and drip irrigation systems. Our observations show that with the relatively small increments of water added by drip and sprinkler irrigation systems and careful irrigation scheduling, the soil profile is often not becoming saturated at 20-in depth. These irrigation practices apparently allow a larger proportion of all available N sources to remain in the root zone. Residual nitrate and ammonium, a larger part of the fertilizer N, and a larger part of any other N source are less apt to be leached. Our results demonstrate that substantial amounts of N are mineralized from soil organic matter and become available for plant growth (Feibert et al, 1998; Shock, et al. 1996, 2004). While desert soils usually have low organic matter and would be expected to mineralize little N, the incorporation of agricultural residues over the last 60 years or more has apparently built up a large enough labile pool of decomposing organic residue to substantially alter crop N requirements.

Efficient N fertilizer recommendations for sprinkler- and drip-irrigated crops in the Treasure Valley require comprehensive understanding and accounting of all nitrogen sources, including mineralization of recently incorporated residues and soil organic matter. Comprehensive nitrogen accounting is needed, not only to reduce costs, but also to reduce nitrate losses to groundwater.

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