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Research Letter

Is Static Nitrogen Management in Northwestern US Sugarbeet Production Appropriate?

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Core Ideas

- With increased yields, a yield goal N management approach can lead to oversupply of N.
- Oversupply of N can increase sugarbeet impurities and decrease profit.
- N supply needed for max. yield was 179–204 kg N ha^{-1} for Idaho studies in 1977, 1997, and 2011.
- Research is needed to evaluate a static N management approach in sugarbeet production.

Abstract: Nitrogen (N) management is important in sugarbeet (*Beta vulgaris* L.) production. This paper presents data to support additional research to evaluate a new N management approach in the northwestern United States. Evaluation of historic data suggests that static N management (fixed N supply independent of yields) may have advantages compared with yield goal-based N management in the northwestern United States. From the early 1970s to 2011, the amount of N supply needed to maximize yields in research studies was within a narrow N supply range of 179 to 204 kg N ha^{-1}. Recommended N supplies (179–204 kg N ha^{-1}) have not increased as yields have increased. Evidence suggests that following the past recommendations under current yield levels will likely oversupply N. On the basis of this analysis, a regionwide project has begun to determine if a static N management approach is appropriate.

Nitrogen (N) supply is an important management factor for sugarbeet (*Beta vulgaris* L.) production because both under- and oversupplying N relative to plant needs can result in decreased profits (Stout, 1960). Undersupplying N reduces root and sucrose yields, whereas oversupplying N results in decreased root sucrose content and increased root impurities, which decreases sucrose extraction efficiency (Carter and Traveller, 1981; James et al., 1971). In addition, oversupplying N can lead to increased N losses to the environment. Because of this unique relationship between N and sugarbeet quality/quantity, periodic research studies have been conducted in the northwestern US sugarbeet growing area to determine sugarbeet N needs.

History of Sugarbeet N Supply Recommendations in the Northwestern United States

Historically, a yield goal N management approach has been used for sugarbeet. The basis of yield goal N management was to determine the total available N supply (soil NO_3–N and NH_4–N to a depth of 0.6 m + fertilizer N) needed to optimize yield and quality (root NO_3–N, root electrical conductivity). To determine the recommended N supplies, field-specific realistic sugarbeet root yields were multiplied by the research-derived N requirement (Nr) factors. The Nr factors represent the kilograms of N needed to grow a Megagram of sugarbeet roots (kg N Mg^{-1} roots). Past Nr factors were 4 kg N Mg^{-1} roots (1977), 3.7 kg N Mg^{-1} roots (1997), and 2.5 kg N Mg^{-1} roots (2011) (Table 1). The difference between N supply and soil available N (soil NO_3–N and NH_4–N to a depth of 0.6 m) was the rate of commercial fertilizer N applied. A by-product of the yield goal-based N management approach is that recommended N supply increases linearly as sugarbeet root yields increase and N applications quickly surpass research-based N supply limits.

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Table 1. Yield goal-based N requirement (Nr) values (kg N Mg^{-1} roots), developed from the time of research (italicized) and in subsequent years, average area sugarbeet root yields, and yield goal N rate recommendations (Nr × root yield).

Year	Source(s)	Nr	Root yield†	N supply recommendations‡
		kg N Mg^{-1} roots	Mg ha^{-1}	kg N ha^{-1}
1977§	*Univ. of Idaho and Amalgamated Sugar Co.*	*4*	*45*	*179*
1980	Univ. of Idaho and Amalgamated Sugar Co.	4	49	197
1985	Univ. of Idaho and Amalgamated Sugar Co.	4	52	206
1990	Univ. of Idaho and Amalgamated Sugar Co.	4	54	215
1995	Univ. of Idaho and Amalgamated Sugar Co.	4	56	224
1997	*Univ. of Idaho and Amalgamated Sugar Co.*	*3.7*	*56*	*205*
2000	Univ. of Idaho and Amalgamated Sugar Co.	3.7	60	221
2005	Univ. of Idaho and Amalgamated Sugar Co.	3.7	63	228
2010	Univ. of Idaho and Amalgamated Sugar Co.	3.7	72	262
2011	*USDA–ARS and Amalgamated Sugar Co.*	*2.5*	*74*	*204*
2015	USDA–ARS and Amalgamated Sugar Co.	2.5	83	228
2016	USDA–ARS and Amalgamated Sugar Co.	2.5	87	241

† Yields are the Amalgamated Sugar Co. growing area 3-yr average (the year listed and the two previous years).

‡ N supply recommendation (soil NO_3-N and NH_4-N to a depth of 0.9 m [3 ft] + fertilizer N) = Nr × average annual root yield.

§ Italicized rows represent years with revised Nr based on recently concluded research trials.

The North Dakota–Minnesota growing area switched from a yield goal-based approach to a static N management approach in 2001 based on research from the growing area (Lamb et al., 2001). Figure 1 shows root yields are increasing over time with a nearly consistent average N supply. These data indicate that N is not limiting root yield increases over time. The growth time frame in which sugarbeet needs adequate access to N is shorter than other crops because sugarbeet sucrose yields are increased when availability to N later in the growing season (6 wk before harvest) is reduced (Kaiser et al., 2011).

Procedures

To evaluate the potential use of static N management, we gathered the following information:

- Average sugarbeet root yields from 1970 to 2016 across the northwestern United States obtained from the USDA National Agricultural Statistics Service (www.nass.usda.gov).
- Research-based sugarbeet Nr factors obtained from published recommendations and research data from Amalgamated Sugar Co., University of Idaho, and USDA–ARS (Amalgamated Sugar Company, 1977; Stark et al., 1997; Tarkalson et al., 2016).

To evaluate the relationships between N supply and optimizing sugarbeet root yield in the Northwest U.S., the following analysis was performed. The research-based Nr factors were multiplied by the average root yields during the time the research was conducted to determine the time-specific optimum N supplies. These time-specific optimum N supplies were compared with scenarios in which Nr was not adjusted over time as root yields increased.

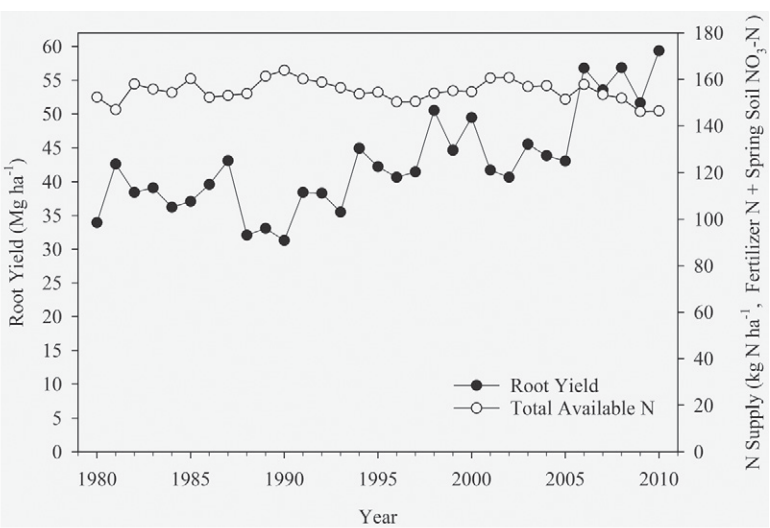

Fig. 1. Average sugarbeet root yields and total N supply (fertilizer N + soil available NO_3-N) over time in the North Dakota and Minnesota growing area.

Results and Discussion

Average sugarbeet yields in the northwestern United States have continually increased over time (Fig. 2) and will likely continue to increase in the future. The rate of yield increase over time is a result of improved genetics and management practices (Panella et al., 2014). Since the introduction of glyphosate-resistant cultivars, the rate of yield increase has increased from 0.5 Mg ha^{-1} yr^{-1} (1970–2004) to 2.1 Mg ha^{-1} yr^{-1} (2005–2016). When following a yield-based recommendation approach, recommended N supplies increase as yields increase. The yield goal management approach was valid for the typical yields during the time the research was conducted (Table 1). The italicized rows in Table 1 represent the years for which Nr factors were updated due to current research. However, when using a set Nr factor over time, absent new research, the recommended N supply exceeds the amount needed to maximize yields. For example, when the new research-based Nr factor of 4 kg Mg^{-1} was used in years after 1977, where average yields continue to increase (Fig. 2), the recommended N supply increases. However, the 1977 Nr factor was based on research conducted in the mid-1970s at yield levels lower than yields during those subsequent years. By 1995, the 1977 Nr factor was still recommended in published recommendations because no other research had been conducted. Table 1 shows a scenario where research-based Nr factors from 1977, 1997, and 2011 were used over time before new research Nr factor adjustments. Table 1 also shows the N supply from research-updated Nr factors over time. The average N supply to reach maximum root yields for each time period with updated Nr factors was within a narrow range of 179 to 205 kg ha^{-1}.

When the 1977-derived Nr factor was used up to 1995 (2 yr before a new published Nr factor), the recommended N supply was 19 kg N ha^{-1} greater than in 1977 (205–224 kg ha^{-1}). When the 1997-derived Nr factor was used up to 2010 (1 yr before new published Nr factor), the recommended N supply was 58 kg N ha^{-1} greater than in 1977 (204–262 kg ha^{-1}). On the basis of this evidence and assuming the N supply needed to maximize yields in 2016 was the same as the past, the 2011-derived Nr factor resulted in 37 kg N ha^{-1} greater than needed (204–241 kg ha^{-1}).

In the northwestern United States, the N supply to reach maximum yield from the three research periods (1977, 1997, and 2011) follows a similar pattern, although with a less-dense data set, as in the North Dakota–Minnesota growing area (Fig. 1): a narrow 26 kg N ha^{-1} range of N supply, compared with continued use of past research-based Nr values at current yield levels, to maximize yield, independent of root yield data from the North Dakota–Minnesota and northwestern US growing areas shows that sugarbeet need a relatively narrow range of N supply to produce maximum yields across a range of yield levels. The net result of these relationships was greater N use efficiency and thus, increased economic return and reduced losses of N to the environment.

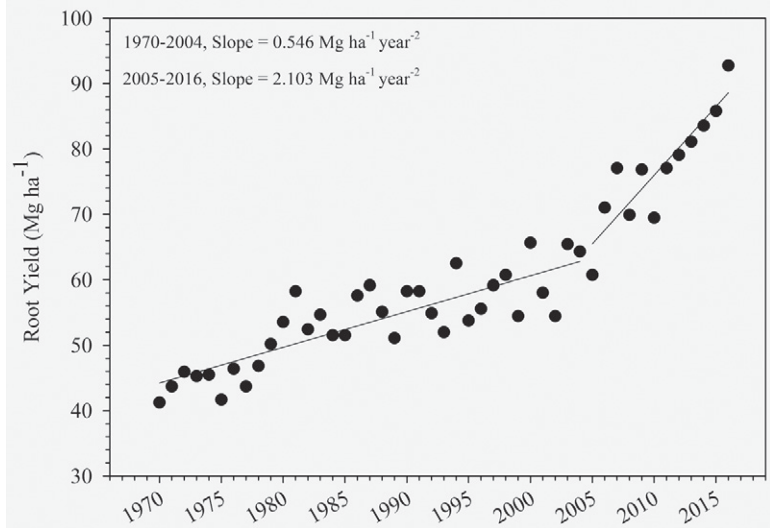

Fig. 2. Average sugarbeet root yields over time in the northwestern US growing area.

Conclusions

Historic data suggest that as yields increase, a yield goal N management approach can lead to oversupply of N, and sugarbeet crops only need total N supply within a narrow range compared with continued use of past research-based Nr values at current yield levels. We provide evidence here that continued research is needed to evaluate whether a static N approach is valid in the northwestern United States.

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