Yield Response of Old and New Corn Hybrids to Nitrogen

By M. Tollenaar, S.P. Nissanka, I. Rajcan and T.W. Bruulsema

Corn yields in Ontario have increased at about 1.5 bu/A per year during the past four decades. Similar increases in corn yield have been documented in the U.S. and Europe. A significant portion of these increases can be attributed to genetic improvement, which has been associated with increased tolerance to stresses (high plant populations, low soil moisture, and weed competition) and delayed leaf senescence or greater leaf longevity ('stay-green'). We have conducted studies to examine the relationship among 'stay-green', stress tolerance, and soil N in an old and a new corn hybrid grown in Ontario. We gave particular attention to the effects of source and sink balance (supply and demand for assimilates produced by photosynthesis) during the grain-filling period on these factors.

New 'stay-green' corn hybrids take up more nitrogen (N) after silking. Expression of their increased yield potential and nutrient use efficiency advantages depends on adequate nutrient supply in the later part of the growing season.

We postulated that leaves stay green longer in newer hybrids because the source-sink ratio during the grain-filling period is higher than in older hybrids. Although leaf senescence is a genetically controlled process, it can be accelerated or delayed by the source-sink ratio. Field studies were conducted with an old hybrid (Pride 5, released in 1959) and a newer hybrid (Pioneer 3902, released in 1988) grown at two N levels. The high N level was 134 lb/A of N added as ammonium nitrate (NH_4NO_3), while the low N level was no N. However, owing to high levels of organic matter and soil nitrate (NO_3), differences in grain yield due to N levels were only 10 percent.

The source-sink ratio of the hybrids during the grain-filling period was manipulated in three treatments in comparison to a control. For source reduction, 4 to 5 leaves were removed from above the ear. For sink reduction, silks

TABLE 1. Effect of source-sink ratio manipulation on change in stover weight from silking to maturity and percent leaves remaining green at 5 weeks post-silking in two corn hybrids. Means across 3 years (1993-1995) and 2 levels of N.

	Source-sink treatment			
Hybrid	Reduced source	Control	Half sink	No sink
	% change in stover weight			
Old	-36	-24	-3	20
New	-25	-7	20	30
	% of leaves remaining green			
Old	28	41	48	44
New	39	53	51	33

New 'stay-green' corn hybrids take up more nutrients later in the growing season.

were covered for either one day or completely to attain either 50 percent or 100 percent reduction in kernel numbers. The change in stover weight during the grain-filling period was used as an indicator of the source-sink ratio. Stover weight declined by about 30 percent when leaves were removed and increased by about 30 percent in the no-sink treatment (**Table 1**).

The change in stover weight was either less negative or more positive in the new hybrid, indicating that the source-sink ratio was higher than in the old hybrid. Leaf longevity in the control was greater for the new hybrid. Leaves senesce earlier when either the source-sink ratio is low due to assimilate starvation (leaves turn grey) or when the source-sink ratio is high due to assimilate overload (leaves turn red and purplish). Leaves stayed green longest in the control treatment for the new hybrid and in the 50 percent-sink treatment for the old hybrid...that is, in the treatments where the source and sink were in balance. The results confirmed our hypothesis that the higher source-sink ratio in the new hybrid kept leaves green longer.

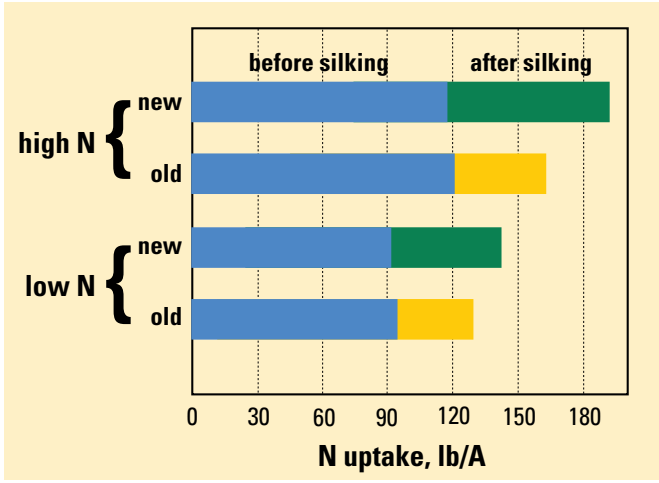

Figure 1. Corn N uptake in a new and an old hybrid in response to high and low soil N availability. Means over 3 years (1993-1995) at Elora, Ontario.

Our second hypothesis was that N uptake after silking would be greater in the new hybrid because of the higher source-sink ratio. Nitrogen uptake is a function of N demand by the plant, N availability, and assimilate availability

TABLE 2. Yield and kernel number per plant of an old and new corn hybrid in response to N level (3-year means, 1992-1994).

Hybrid	N level	Yield, bu/A	Reduction, %	Kernels per plant	Reduction, %
New	High	124		465	
	Low	99	20	412	11
Old	High	101		453	
	Low	80	20	307	32

within the plant because N uptake and metabolism require metabolic energy. In the control treatment of the same field studies, N uptake after silking was clearly much higher in the new hybrid, in particular when the soil N level was high (**Figure 1**).

This result is not surprising, as greater leaf activity would need to be supported by continued uptake of N, not to mention other essential nutrients including phosphorus (P) and potassium (K). The ramifications for nutrient management are important, however. The newer hybrids, bred for higher yields and stress tolerance, take up nutrients over a longer time period than do older hybrids. In the case of N, the 'stay-green' trait has positive implications for the impact of corn production on the environment, since the crop would be more effective in removing and immobilizing NO_3 mineralized from the soil in the later part of the growing season. One could say the new hybrids are in better synchrony with the natural seasonal pattern of soil N mineralization.

In separate field experiments with greater differences in N availability, yield reductions due to low N were similar for the new and the old hybrid (**Table 2**). This was unexpected as previous growth chamber experiments have indicated greater N use efficiency in new hybrids. Also, the decline in kernel number due to the low N treatment was only one-third as large in the new (11 percent) as in the old hybrid (32 percent). Total dry matter accumulation during the grain-filling period, however, was reduced more by low soil N in the new hybrid. This mitigated the effect of harvest index on grain yield. The capacity of the new hybrid to maintain kernel number under low N conditions resulted in marked decline in its source-sink ratio. We speculate that the low source-sink ratio actually reduced the yield performance of the new hybrid under low soil-N conditions.

In conclusion, the 'stay-green' trait of new corn hybrids is associated with a balanced source-sink ratio and better use of N mineralized from the soil. New hybrids are generally more stress tolerant than old hybrids, but the higher stress tolerance of new hybrids may not always result in higher yield.

The capacity to maintain kernel number under N stress reduced the source-sink ratio during the grain-filling period, which reduced the yield of the new hybrid grown under low soil N in our study. This indicates that while new hybrids are more efficient in their use of nutrients, the importance of nutrient supply for the full duration of the growing season is not diminished. BC

Dr. Tollenaar is Professor, Maize Physiology, University of Guelph, Ontario. Dr. Nissanka is former graduate student, now with University of Peradeniya, Sri Lanka. Dr. Rajcan is former graduate student, now with University of Saskatchewan. Dr. Bruulsema is PPI Director, Eastern Canada and Northeastern U.S., Guelph, Ontario.