EFFECT OF LATE-APPLIED N ON CORN DRY MATTER, N CONTENT, AND YIELD

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Abstract

Nitrogen management of corn (*Zea* mays L.) may be improved by delaying N application until just prior to the rapid growth phase (approximately V6-V8). This timing is commonly referred to as “sidedress”. Some farmers do not sidedress because they are concerned inclement weather may delay N application beyond V8, requiring high clearance equipment to apply N and possibly reducing grain yield. However, few studies have investigated the effects of late-applied N in rain-fed production environments with the use of high-clearance N application equipment to quantify the yield reduction risk. The objective of this research was to compare the effects of a traditional sidedress timing (V7) to a late-applied sidedress timing (V15) on corn plant dry matter (DM), N content (NC), and yield. At each sidedress timing, N rate treatments were 28% urea ammonium nitrate (UAN) band injected at 45, 90, 135, 180, or 225 kg N ha^{-1}. A traditional knife injection tool bar was utilized at V7, whereas a high clearance applicator with a coulter-injection toolbar was used at V15. All treatments, including a starter-only control, received 27 kg N ha^{-1} as starter fertilizer. Whole plant samples were collected throughout the growing season at various growth stages, weighed, and analyzed for N concentration. Total number of ovules at R2, and harvestable kernels at R6, were counted. Both N timing and N rate affected DM, NC, and harvestable kernels, but there was no effect on number of ovules. Agronomic optimum N rate (AONR) for the two sidedress timings were 211 and 199 kg N ha^{-1} with yield levels of 14.9 and 14.1 Mg ha^{-1} for V7 and V15, respectively. The late-applied sidedress application yielded 6.4 Mg ha^{-1} more than the starter-only control.

Keywords: Dry matter; N content; Late-applied N fertilizer.

Introduction

Corn grown without the use of animal manures requires the addition of N fertilizer to maximize yield. The efficient use of N fertilizer has become increasingly important due to economic and environmental concerns. Nitrogen fertilizer use efficiency is generally greater with early sidedress N applications compared to pre-plant or fall N application (Welch et al., 1971; Russelle et al., 1981; Fox et al., 1986; Olson et al., 1986). These positive responses to early sidedress N applications are attributed to the rapid uptake of N by the corn plant during the rapid growth period attaining a maximum uptake rate just prior to silking (Hanway, 1963; Mengel and Barber, 1974; Miller et al., 1975; Russelle et al., 1983; Abendroth et al., 2011).

Nitrogen can be applied later in the growing season with high clearance applicators if N application is delayed beyond the V8 growth stage (8 leaves with visible collars). Nitrogen applications made at V8 and V16 (Russelle et al. 1983) and at the 11 – 12 leaf stage (Olson et al., 1986) resulted in higher grain yields compared to N applied at planting in irrigated production systems. However, sometimes irreversible yield loss may occur when N applications are delayed late enough in corn plant development that N stress reduces yield potential (Jung et al., 1972; Binder et al. 2000; Silva et al., 2005).

Under rain-fed conditions, lack of rain can limit the movement of late-applied N fertilizer into the root zone; thus also limiting crop N uptake and response to late applied N. Dry soil conditions prevented a grain yield increase to late-applied N (Jokela and Randall, 1989). Consequently high amounts of residual NO_3 were present in the soil at the end of the growing season, increasing the potential for NO_3 leaching. In contrast, yield of N stressed corn with adequate rain, was increased by N fertilizer applied at V16 (Jaynes and Colvin, 2006). With rain-fed conditions in Missouri there was no evidence of grain yield loss when N applications were delayed until V11 in 28 N-timing experiments compared to corn which was fertilized at planting or at V6 (Scharf et al., 2002). When N applications were delayed until V12 to V16 there was only a 3% reduction in grain yield. However, when application was delayed until silking yield was reduced 15% compared to at-planting or V6-fertilized corn. Grain yield with N applied at V13 was 1.1 Mg ha^{-1} (9%) less than that applied at V3 in previous work in northwest Indiana (Emmert, 2009).

The objective of this research was to further evaluate the impact of late-applied N fertilizer on corn DM, NC, and grain yield in a rain-fed production system in northwest Indiana.

Materials and Methods

A field experiment was conducted in 2010 at the Pinney Purdue Agricultural Center (PPAC) near Wanatah, IN on a Sebewa loam (*Fine-loamy over sandy-skeletal, mixed, superactive, mesic Typic Argiaquoll*, 0 – 2% slope). Corn (Pioneer P0916XR - relative maturity of 109 d) was seeded approximately 3.8 cm deep on 22 April at 81,500 seeds ha^{-1}. The previous crop was soybean [*Glycine max* (L.) Merr.]. Tillage was fall chisel plow followed by a spring field cultivator pass.

Nitrogen fertilizer treatments were urea ammonium nitrate (UAN) banded between the corn rows at either V7 or V15 growth stages at 45, 90, 135, 180, and 225 kg N ha^{-1} and a control which received no additional N beyond that in the starter fertilizer. Starter fertilizer (140 kg ha^{-1} of 19-17-0) was applied to all treatments at 27 kg N ha^{-1} placed 5 cm beside and 5 cm below the seed.

Individual plots were 9.1 m wide consisting of 12 corn rows spaced 0.76 m apart oriented in a north-south direction and 88 m long. Each replication was an independent field (183 m wide by 98 m long) with all fields being near one another. A randomized complete block design with three replications was used to evaluate 11 treatments.

Whole plant above-ground samples were collected from two or three 1.8 m sections (growth stage dependent) of row per plot at 10 growth stages between V4 and R6. Plants were cut at the soil surface with hand clippers or loppers and dried in a forced air oven at 60 ^{o}C until they reached a constant weight. Dried samples were weighed, ground, and analyzed for N concentration.

At growth stage R2, total number of visible ovules (pollinated or not) were counted. Ovule rows and ovules per row from the base to the tip of each ear made up the total number. At maturity, the number of kernel rows and kernels per row were counted on approximately 24 ears per plot. All ears were shelled and the weight of two 500 kernel samples was determined. Approximately 0.75 L grain was ground and analyzed for N concentration.

Harvest data were collected from the center six rows of each plot with a 6-row Case IH 2166 combine equipped with a calibrated GPS-enabled Ag Leader yield monitor.

Results

Growing conditions were favorable before and after the time of planting resulting in good seed germination and uniform seed emergence and stand establishment. Rainfall was evenly distributed throughout the growing season up until the time of the V15 sidedress application (Fig. 1). However, significant rainfall did not occur until 11 days after the V15 sidedress application. Between V15 and physiological maturity, 218 mm rainfall occurred. Total rainfall throughout the growing season was 512 mm.

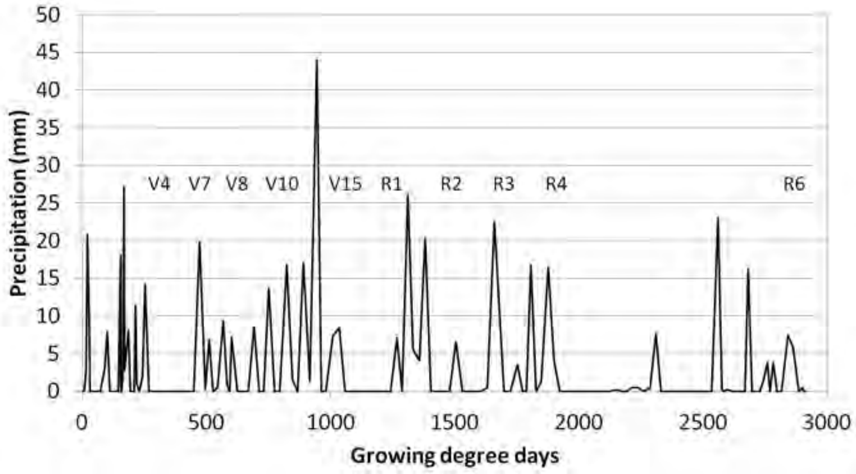

Figure 1. Daily precipitation for the 2010 growing season (April-October) for the PPAC site near Wanatah, IN. Growth stages are noted at the appropriate growing degree day.

Higher DM and NC accumulations were observed with increased N fertilizer rate regardless of application timing (Fig 2 and 3). Dry matter increased throughout the growing season for each sidedress application reaching a maximum DM accumulation at physiological maturity. The starter-only control reached a maximum DM at R4. The V7 sidedress application timing reached a maximum DM accumulation rate between growth stage V15 and R1 at 420 kg DM ha^{-1} day^{-1} and attained a final DM of 25.7 Mg ha^{-1}. The V15 sidedress timing had a total DM accumulation 5% less than the V7 sidedress timing at R6, but 34% greater than the starter-only control at the highest N rate. Dry matter accumulated by the V15 sidedress treatments did not begin to significantly differentiate from the starter-only control until R4. Between R3 and R4 the V15 sidedress timing reached its maximum DM accumulation rate of 354 kg DM ha^{-1} day^{-1} (Fig. 2).

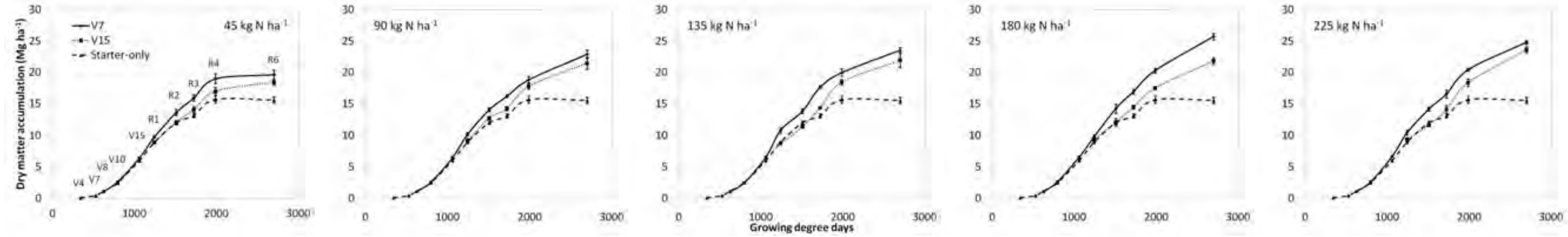

Figure 2. Influence of N rate and timing on dry matter accumulation. Sidedress rates were in addition to 27 kg N ha^{-1} applied as starter fertilizer. Legends pertaining to sidedress timing and growth stages are denoted in the first pane.

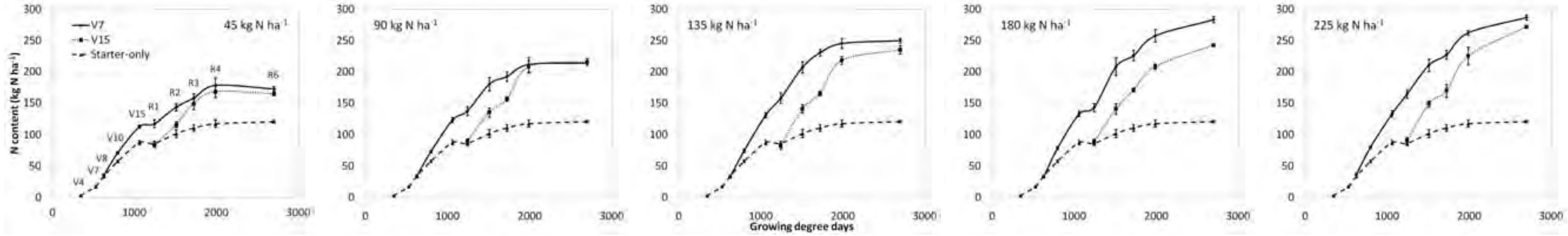

Figure 3. Influence of N rate and timing on N content. Sidedress rates were in addition to 27 kg N ha^{-1} applied as starter fertilizer. Legends pertaining to sidedress timing and growth stages are denoted in the first pane.

All treatments, other than the 45 kg N ha^{-1} applied at V7, reached maximum NC at physiological maturity (Fig. 3). The highest NC achieved was 287 kg N ha^{-1} at 225 kg N ha^{-1}. The highest N accumulation rate was directly following the V7 application between growth stages V8 and V10. The V15 sidedress timing had NC only 5% less than that of the V7 sidedress timing, but accumulated in excess of 150 kg N ha^{-1} more than the starter-only control at maturity at the highest N rate. The four highest N rates sidedressed at V15 began to significantly differentiate from the starter-only control 20 days after the application at growth stage R2. After R2 the highest rate sidedressed at V15 reached its maximum N accumulation rate of 4.7 kg N ha^{-1} day^{-1}. The higher N rates for either sidedress timing exhibited greater N accumulation at maturity when compared to the starter-only control. The lower N rates demonstrated a leveling off near maturity.

Total numbers of ovules were estimated at R2, 46 days after the V7 sidedress application and 20 days after the V15 sidedress application (Fig. 4). The total numbers of ovules were similar among all the rates of the V15 sidedress application and starter-only control. The total numbers of ovules for the V7 sidedress treatments were 3-9% higher than the V15 sidedress application and the starter-only control depending on N rate.

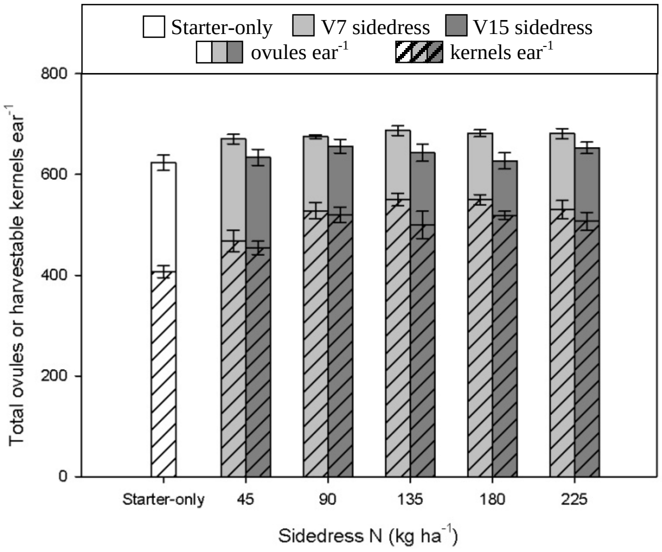

Figure 4. Influence of N rate and timing on ovules ear^{-1} and kernels ear^{-1}. Solid bars are ovules ear^{-1} and striped bars are harvestable kernels ear^{-1}. Sidedress rates were in addition to 27 kg N ha^{-1} applied as starter fertilizer.

Grain yield increased in response to increased rates of N fertilizer (Fig. 5). A quadratic plus plateau response model was fit to the range of N rates for each timing. Plateau yield for the V7 sidedress timing was 14.9 Mg ha^{-1} with an AONR of 211 kg N ha^{-1} while the plateau yield for the V15 sidedress application timing was 5% less at 14.1 Mg ha^{-1} with an AONR of 199 kg N ha^{-1}. Compared to the starter-only control, the V15 sidedress AONR yielded 6.3 Mg ha^{-1} more. The AONR and yield levels for this region of Indiana are consistent with other N rate studies (Camberato et al., 2011).

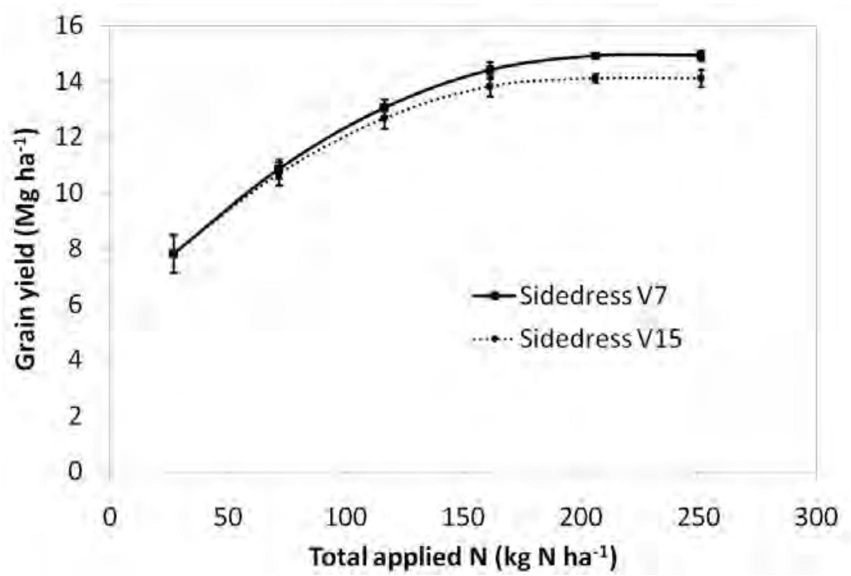

Figure 5. Influence of N rate and timing on grain yield (adjusted to 15.5% moisture). Total applied N includes the 27 kg N ha^{-1} applied as starter fertilizer. Points represent the mean of 3 replications.

At physiological maturity the number of kernel rows ear^{-1} did not differ between sidedress timings or by N rate (data not presented), thus differences in total kernels per ear were the results of differences in kernels per row (data not presented). At the four highest N rates, total kernel number was 2-9% higher for the V7 sidedress timing than the V15 sidedress timing (Fig. 4). The V15 sidedress timing resulted in 20-22% more kernels than the starter-only control (Fig. 4). Kernel weights were the same for the two sidedress timings and both increased with increased N rate to a maximum of 322 mg kernel^{-1} and were 24% greater compared to the starter-only control (Fig. 6).

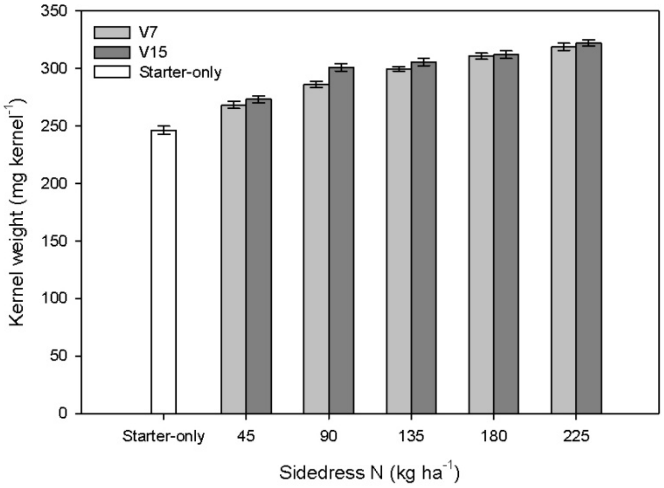

Figure 6. Influence of N rate and timing on kernel weight. Sidedress rates were in addition to 27 kg N ha^{-1} applied as starter fertilizer.

Conclusion

The V15-sidedressed N fertilizer treatments exhibited high DM and N accumulation rates through grainfill and nearly attained equivalent DM and NC as the V-7 sidedressed treatments. Yield differences between the sidedress timings were due to differences in harvestable kernels ear^{-1}. Those differences can be attributed to N stress which occurred during ear size determination (V7 vs. V15 or starter-only) and on kernel survival during grain fill (both sidedress timings vs. starter-only). The results of this study demonstrate that corn can recover from N deficiency stress with applications of sidedress N fertilizer as late as V15. In a year when weather can delay field work, options remain to recover yield with late sidedress N applications.

References

Abendroth, L.J., R.W. Elmore, M.J. Boyer, and S.K. Marlay. 2011. Corn growth and development. PMR 1009. Iowa State University Extension, Ames, Iowa.

Binder, Darren L., Donald H Sander, and Daniel T Walters. 2000. Maize response to time of nitrogen application as affected by level of nitrogen deficiency. Agron. J. 92:1228-1236.

Camberato, Jim, RL (Bob) Nielsen, Eric Miller, and Brad Joern. 2011. Nitrogen management guidelines for Indiana. Purdue University Department of Agronomy Corny News Network Articles. http://www.agry.purdue.edu/ext/corn/news/timeless/CornRespLateSeasonN.html

Emmert, D.J. 2009. Using canopy reflectance to monitor corn response to nitrogen and the effects of delayed nitrogen application. Master’s thesis. Purdue University.

Fox, R.H., J.M. Kern, and W.P. Piekielek. 1986. Nitrogen fertilizer source, and method and time of application on no-till corn yields and nitrogen uptake. Agron. J. 78:741-746.

Hanway, J.J. 1963. Growth stages of corn (*Zea mays*, L.). Agron. J. 55:487-492.

Jaynes, D.B. and T.S. Colvin. 2006. Corn yield and nitrate loss in subsurface drainage from midseason nitrogen fertilizer application. Agron. J. 98:1479-1487.

Jokela, W.E. and G.W. Randall. 1989. Corn yield and residual soil nitrate as affected by time and rate of nitrogen application. Agron. J. 81:720-726.

Jung, P.E., Jr., L.A. Peterson, and L.E. Schrader. 1972. Response of irrigated corn to time, rate, and source of applied N on sandy soils. Agron. J. 64:668-670.

Mengel, D.B. and S.A. Barber. 1974. Rate of nutrient uptake per unit of corn root under field conditions. Agron. J. 66:399-402.

Miller, H.F., John Kavanaugh, and G.W. Thomas. 1975. Time of N application and yields of corn in wet, alluvial soils. Agron. J. 67:401-404.

Olson, R.A., W.R. Raun, Yang Shou Chun, and J. Skopp. 1986. Nitrogen management and interseeding effects on irrigated corn and sorghum and on soil strength. Agron. J. 78:856-862.

Russelle, M.P., E.J. Deibert, R.D. Hauck, M. Stevanovic, and R.A. Olson. 1981. Effects of water and nitrogen management on yield and 15N-depleted fertilizer use efficiency of irrigated corn. Soil Sci. Soc. Am. J. 45: 553-558.

Russelle, M.P., R.D. Hauck, and R.A. Olson. 1983. Nitrogen accumulation rates of irrigated maize. Agron. J. 75:593-598.

Scharf, Peter C., William J. Wiebold, and John A. Lory. 2002. Corn yield response to nitrogen fertilizer timing and deficiency level. Agron. J. 94:435-441.

Silva, P.R.F., M.L. Strieder, R.P. Silva Coser, L. Rambo, L. Sangoi, G. Argenta, E.L. Forsthofer, and A.A. Silva. 2005. Grain yield and kernel crude protein content increases of maize hybrids with late nitrogen side-dressing. Sci. Agric. 62:487-492.

Welch L.F., D.L. Mulvaney, M.G. Oldham, L.V. Boone, and J.W. Pendleton. 1971. Corn yields with fall, spring, and sidedress nitrogen. Agron. J. 63:119-123.

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