LINKING ROOT ARCHITECTURE AND FERTILIZER PLACEMENT TO IMPROVE NUTRIENT USE IN CORN HYBRIDS

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ABSTRACT

Hybrid selection has largely relied on above-ground traits, while roots receive less attention because they are difficult to measure. However, modern corn hybrids differ in root size and structure, which influence their access to soil nutrients. The objective of this research was to evaluate four corn hybrids, previously classified by root architecture (vertical or horizontal), in response to banded versus broadcast fertilizer at planting. Field trials were conducted at ACRE in West Lafayette, IN (2024 - 2026) and at PPAC in Wanatah, IN (2025) as a randomized complete block design with a two-factor factorial arrangement. Hybrids included two with vertical (6414, 6280) and two with horizontal root systems (6184, 6152), which received surface-banded or broadcast SuperU + MicroEssentials SZ at 200 lb N/ac at planting. Data included grain yield, root angle, root surface area, and N uptake. A significant root architecture x fertilizer placement interaction ($P < 0.10$) was observed for grain yield at both locations. At ACRE, horizontal hybrids yielded 18 bu/ac more under broadcast than under banded application, whereas vertical hybrids yielded similarly under both strategies. At PPAC, horizontal hybrids out-yielded vertical hybrids by 24 bu/ac under broadcast. At R1, vertical hybrids had steeper root angles than horizontal hybrids (46° vs. 42°), regardless of placement. Under broadcast application, N uptake at V8 increased with root surface area only in horizontal hybrids. These results suggest that farmers using a broadcast strategy should consider hybrids with horizontal root systems, and, if banding, hybrids with vertical root systems to increase yield stability.

INTRODUCTION

Modern corn hybrids achieve greater yield potential primarily through genetic improvements in crowding-stress tolerance (Hammer et al., 2009). One important phenotypic trait linked to a hybrid's ability to tolerate crowding stress is root system size and architecture (Hammer et al., 2009; Hopkins & Hansen, 2019; Stutter et al., 2012), which strongly influences the plant's capacity to access both water and immobile nutrients such as phosphorus (P) and potassium (K) (Gordon & Pierzynski, 2006).

Root architectural traits also contribute to nutrient acquisition under variable fertility conditions. For example, Schneider et al. (2022) demonstrated that variation in maize root angle can enhance deep nitrogen capture under suboptimal fertility, supporting the concept that breeders can target specific root traits to optimize hybrid performance under region-specific nutrient environments.

As farmers continue to adopt new practices, such as tillage and fertilizer placement, along with innovations in fertilizer source, rate, and timing, hybrid performance can vary

substantially across these management systems (Potratz et al., 2020; Tesch, 2025). Indeed, hybrid productivity depends not only on genetic potential but also on environmental conditions and on how the surrounding cropping system is managed. Research shows that corn hybrids differ in root architecture, which can directly influence nutrient uptake depending on fertilizer placement; for example, smaller-rooted hybrids have achieved higher yields when P and K were banded directly within the root zone (Foxhoven, 2022).

Therefore, understanding these hybrid x management interactions may help farmers, advisors, and breeders better position hybrids according to the practices employed, thereby improving nutrient-use efficiency and enhancing yield stability across diverse corn production operations. Importantly, this type of research may also reshape how corn hybrids are selected and managed in the U.S. Midwest, where fertilizer placement strategies vary widely across farms and environments. Selecting hybrids with contrasting root system architectures based on a producer's fertility program (e.g., banded versus broadcast nutrient placement) may represent an additional agronomic management tool that complements traditional decisions such as hybrid selection, plant density, and nitrogen rate. Thus, the objective of this research was to evaluate four corn hybrids, previously classified by genetic background and root architecture (vertical or horizontal), in response to banded versus broadcast fertility at planting.

MATERIALS AND METHODS

Research location

Field trials were conducted at the Purdue Agronomy Center for Research and Education (ACRE) in West Lafayette, Tippecanoe County, IN in 2024, 2025 and 2026, and at the Pinney Purdue Agricultural Center (PPAC) in Wanatah, LaPorte County, IN in 2025, for a total of three site-years (ACRE 25, ACRE 26, and PPAC 25). Soils at ACRE were Raub-Brenton silt loam–silty clay loam (0–1% slope) and Drummer silty clay loam (0–2% slope). Soil at PPAC was a Tracy sandy loam (0–2% slope).

Experimental Design and Plot Layout

The experiment was conducted as a randomized complete block design with a two-factor factorial arrangement of treatments and four replications in each site-year. The first factor was hybrid root architecture, with two levels: vertical and horizontal. Each level was represented by two corn hybrids (Beck's Hybrids, Atlanta, IN): Beck's 6414V2P and 6280TCV2P (vertical) and Beck's 6184V2P and 6152D1 (horizontal). The second factor was fertilizer placement, with two levels: surface-banded and broadcast. A nontreated control (no fertilizer) was included for each hybrid in every replication for reference but was excluded from the statistical analysis. Plots were 15 ft wide (six rows spaced 30 inches apart) and 40 ft long in all site-years.

Agronomic field management

In all site-years, the previous crop was soybean [*Glycine max* (L.) Merr.] and trials were rainfed. ACRE received spring vertical tillage, and PPAC was no-till. Corn was planted at 32,000 seeds/ac on 3 May 2024, 8 May 2025, and 11 May 2026 at ACRE, and on 19 May 2025 at PPAC. At planting, fertilized plots received 200 lb N/ac and 20 lb S/ac as SuperU

(NBPT + DCD; 46-0-0; Koch Agronomic Services) plus 200 lb/ac of MicroEssentials SZ (12-40-0-10S-1Zn; The Mosaic Company), either surface-banded 4 to 6 inches from the seed row or broadcast. Weed and disease control followed Purdue University Extension recommendations (Loux et al., 2025). The center two rows were harvested on 9 Oct. 2024, 30 Sept. 2025, and 7 Oct. 2026 at ACRE, and on 27 Oct. 2025 at PPAC, with a Wintersteiger plot combine and yield adjusted to 15.5% moisture.

Data Collection

At ACRE, three plants from each of rows 2 and 5 were sampled per plot at V8 (2025–2026) and R1 (2024–2026). Shoots were dried, weighed, and analyzed for N concentration, and N uptake per plant was calculated as dry weight multiplied by N concentration. Root crowns were excavated (10–12 inches in diameter and depth), washed, and imaged with the Corn Root Observation Platform (Fatemi et al., 2025). Root angle was calculated following Grift et al. (2011), with greater values indicating a steeper root system, and root surface area was estimated from the root pixel area of each image (0.202 mm/pixel).

Statistical Analysis

Data were analyzed with linear mixed-effects models in R v4.5.0 (lme4; Bates et al., 2015), with root architecture, fertilizer placement, and their interaction as fixed effects. Model assumptions were checked with the Shapiro–Wilk and Levene's tests. Because ACRE and PPAC differ in soil and tillage, and site-year × treatment interactions were significant, data were analyzed by location. ACRE years were combined, with year and replication within year as random effects, and year x treatment interactions are reported where significant. The relationship between N uptake and root surface area at V8 was tested by including root surface area as a covariate in the model. Means were separated with Šidák-adjusted comparisons (emmeans; Lenth, 2025) at $\alpha = 0.10$ (Quinn et al., 2021).

RESULTS AND DISCUSSION

Grain Yield

Grain yield responded to the root architecture x fertilizer placement interaction at ACRE ($P < 0.001$) and PPAC ($P = 0.016$), and this response was consistent across years at ACRE ($P = 0.629$) (Fig. 1). At ACRE, horizontal hybrids yielded 18 bu/ac more under broadcast than under banding (287 vs. 269 bu/ac), whereas vertical hybrids yielded similarly under both placements (284 and 279 bu/ac). At PPAC, horizontal hybrids under broadcast had the greatest yield (252 bu/ac), out-yielding vertical hybrids under broadcast by 24 bu/ac (228 bu/ac). Although PPAC yields were about 40 bu/ac lower, likely because of its sandy loam soil, horizontal hybrids performed best under broadcast at both locations, while vertical hybrids did not benefit from broadcast.

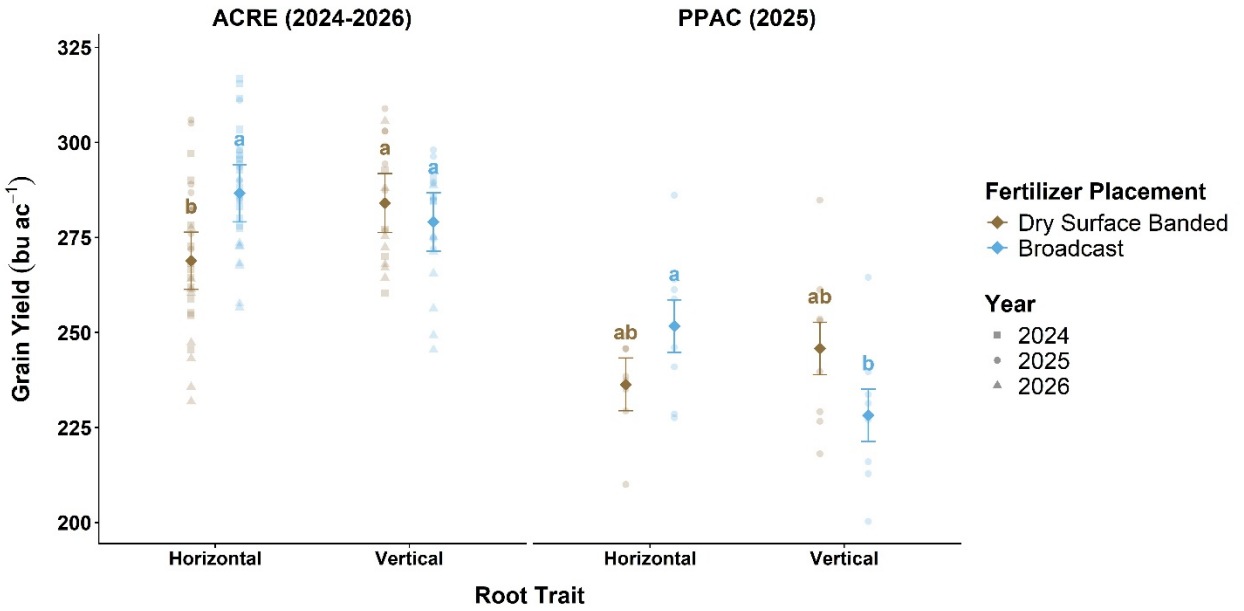


Figure 1. Corn grain yield as affected by hybrid root architecture and fertilizer placement at ACRE (2024–2026) and PPAC (2025), Indiana. Diamonds are means ± SE, and points are individual plots. Means with the same letter within a location are not different (α = 0.10).

Root angle and Root Surface Area

Vertical hybrids had steeper root angles than horizontal hybrids at V8 (51.9° vs. 50.2°; P = 0.085) and R1 (45.9° vs. 41.8°; P < 0.001), regardless of fertilizer placement (P ≥ 0.247) (Fig. 2), confirming the root architecture classification under field conditions. At R1, this difference was consistent in 2025 and 2026 (P < 0.001) but not in 2024 (P = 0.503). Root surface area did not differ at V8 (P ≥ 0.292). At R1, broadcast increased root surface area by 1.7 in² compared with banding (24.5 vs. 22.8 in²; P = 0.005), regardless of root architecture, although this effect occurred only in 2024 (year × placement, P = 0.017).

N uptake in Relation to Root Surface Area

At V8, the relationship between N uptake and root surface area depended on fertilizer placement (P = 0.027) (Fig. 3). Under broadcast, N uptake by horizontal hybrids increased by 86 mg N/plant per additional in² of root surface area (P = 0.002), whereas the slope for vertical hybrids was not significant (P = 0.167). Under banding, N uptake was unrelated to root surface area for both root types (P ≥ 0.322). Broadcast fertilizer is spread across the soil surface and requires greater soil exploration, which favors laterally spreading roots, whereas banded fertilizer is concentrated near the row and can be reached without a large root system. This explains why vertical hybrids yielded similarly under both placements, whereas horizontal hybrids lost 16 to 18 bu/ac when fertilizer was banded, consistent with Foxhoven (2022).

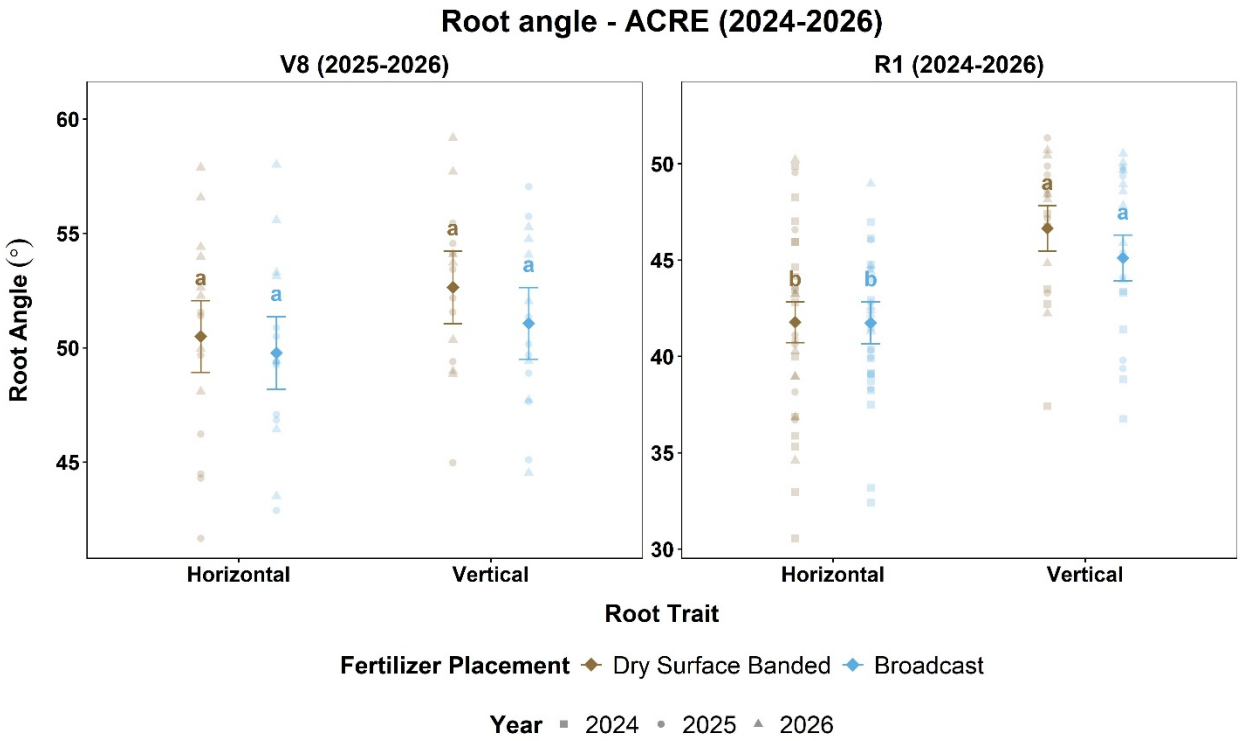


Figure 2. Root angle as affected by hybrid root architecture and fertilizer placement at V8 (2025–2026) and R1 (2024–2026) at ACRE, Indiana. Greater angles indicate a steeper root system. Diamonds are means ± SE, and points are individual plots. Means with the same letter within a growth stage are not different (α = 0.10).

CONCLUSIONS

Hybrid root architecture affected corn yield response to fertilizer placement. Horizontal hybrids yielded 18 bu/ac more under broadcast than under banding at ACRE, and they out-yielded vertical hybrids under broadcast by 24 bu/ac at PPAC. Under broadcast application, N uptake increased with root surface area only in horizontal hybrids. Vertical hybrids maintained steeper root angles regardless of placement and yielded similarly under both strategies. Farmers using a broadcast strategy should consider hybrids with horizontal root systems, and farmers who band fertilizer should consider hybrids with vertical root systems to improve yield stability.

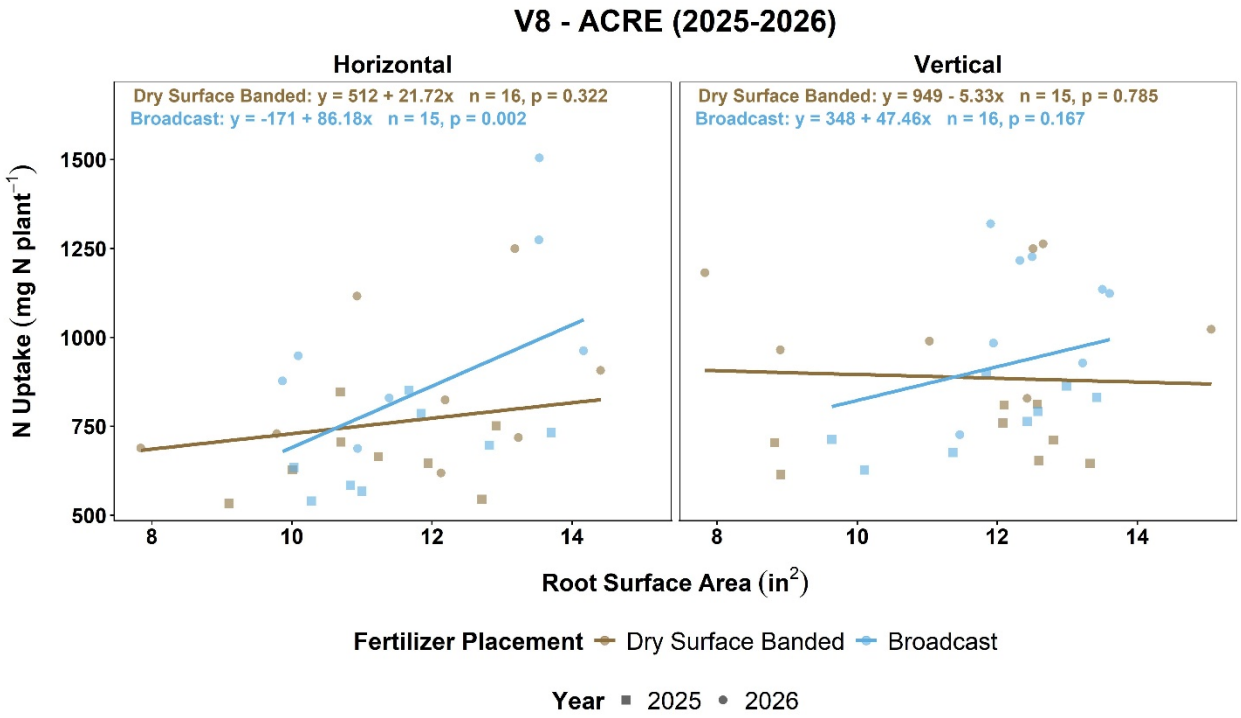


Figure 3. Relationship between whole-plant N uptake and root surface area at V8 for horizontal and vertical hybrids under banded and broadcast fertilizer placement at ACRE (2025–2026), Indiana. P values test whether each slope differs from zero.

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