COMPARATIVE ANALYSIS OF RESOURCE PARTITIONING AND NUTRIENT UPTAKE EFFICIENCIES IN MODERN COTTON CULTIVARS

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ABSTRACT

Understanding the complex process of resource partitioning within the plant provides prospects to develop new crop improvement strategies for varying environmental factors and agronomic practices. In upland cotton, the partitioning of dry matter is as crucially important as that of macronutrients and micronutrients in improving productivity. This presentation highlights research works pertaining to the changes in macronutrient and micronutrient uptake and partitioning alongside the remarkable improvements in modern cotton cultivars during the past few decades. Results demonstrated that the newer cultivars were more efficient in partitioning and remobilizing nitrogen, phosphorus, potassium, sulfur, zinc, and copper into the developing boll and this increased efficiency translates to greater lint yield production for every unit of nutrient taken up compared to the earlier report in the 1990s. These improvements in nutrient uptake capacity in combination with the availability of high levels of residual soil nitrogen were able to sustain plant growth and maintain yield even under reduced nitrogen application. However, even with improved nutrient uptake efficiencies, growth and development could easily be hindered by slight differences in the availability of possible toxic elements such as sodium in the soil and irrigation sources. The changes in the patterns of assimilation and partitioning of nutrients within the cotton plant influences different aspects of crop adaptation, productivity, and survival. Therefore, it is important to have an utmost understanding of the mechanisms underlying these changes and how these mechanisms contribute to the interactions among genetics, environment, and management in order to maximize the potential of newer and soon-to-be developed cotton cultivars.

INTRODUCTION

Several studies conducted before the 1990s, such as those by Fraps (1919), Armstrong and Albert (1931), Olson and Bledsoe (1942), and Bassett et al. (1970), have documented the nutrient uptake and distribution among different plant tissues of cotton grown under dryland and irrigated conditions. For cotton cultivars grown in the southern USA, the most fundamental and recent report on dry matter and nutrient partitioning was provided by Mullins and Burmester (1990, 1993). This study reported on the patterns of translocation of macronutrients and micronutrients from vegetative to reproductive tissues. The findings of this study have been the basis of the current fertilizer recommendations for the majority of the cotton productions in the Texas High Plains.

After the 1990s, advancements in genetic enhancement and optimal crop management have significantly improved the efficiency of lint production in cotton, consequently boosting its yield potential. There is a likelihood that the nutrient accumulation in plant organs and the required rates for modern cultivars have undergone changes, contributing to these improvements. Since the most recent work was done in the 1990s, a current investigation on patterns of resource partitioning and accumulation is needed. The objective of this study is to compare the resource allocation of modern cultivars with older ones based on the nutrient partitioning to different organs across the growing season and the nutrient uptake per unit of lint produced in irrigated, fertilized cotton.

MATERIALS AND METHODS

Field experiments were conducted in 2018 and 2019 at Texas Tech University Research Farm, New Deal, TX, USA (33° 44' 13.76" N, 101° 43' 58.04" W, 994 m above sea level). The study location is in a semi-arid climate with an average annual precipitation of 19 in for the last seven years. The soil is a Pullman clay loam (fine, mixed, superactive, thermic, Torrertic Paleustolls) (National Cooperative Soil Survey, 2014). The measured soil pH ranged from 7.9 to 8.1 across 0-24 in soil depth.

For each season, three cotton cultivars (Paymaster PM HS26, FiberMax FM 958, Deltapine DP 1646) were planted on the third week of May. Plots were fertilized with an average rate of 100 lb N per acre, 80 lb P per acre, and 27 lb K per acre. The liquid N fertilizer was split-applied as urea-ammonium nitrate (UAN, 32-0-0), using a coulter applicator (40% pre-plant, 60% side-dressed mid-season). Both P and K were applied 100% at pre-plant. The total in-season irrigation applied was 14 in (through subsurface drip irrigation system) and the total seasonal rainfall received was 8 in.

Destructive plant sampling was conducted at 30, 60, 90, and 120 days after planting. Biomass samples were separated into leaves, stems, burs (squares, flowers, immature bolls), and mature bolls. The plant tissues were dried, weighed, and ground prior to analysis. Dry matter samples were submitted to the Texas A&M AgriLife Extension Soil, Water and Forage Testing Laboratory (College Station, TX) for nutrient analysis.

RESULTS AND DISCUSSION

The findings of this study showed a notable improvement in the efficiency of newer cultivars when it comes to the partitioning and remobilization of essential nutrients, including nitrogen, phosphorus, potassium, sulfur, zinc, and copper, towards the development of the cotton boll (Figures 1 and 2). This increased efficiency has significant implications, particularly in the context of lint yield production (Pabuayon, Lewis, and Ritchie, 2020). The findings suggest that, in comparison to the earlier report from the 1990s, modern cultivars have an improved ability to convert each unit of absorbed nutrient into a greater yield of lint. The advancements in cultivar characteristics and nutrient uptake contribute to an overall improvement in yield production.

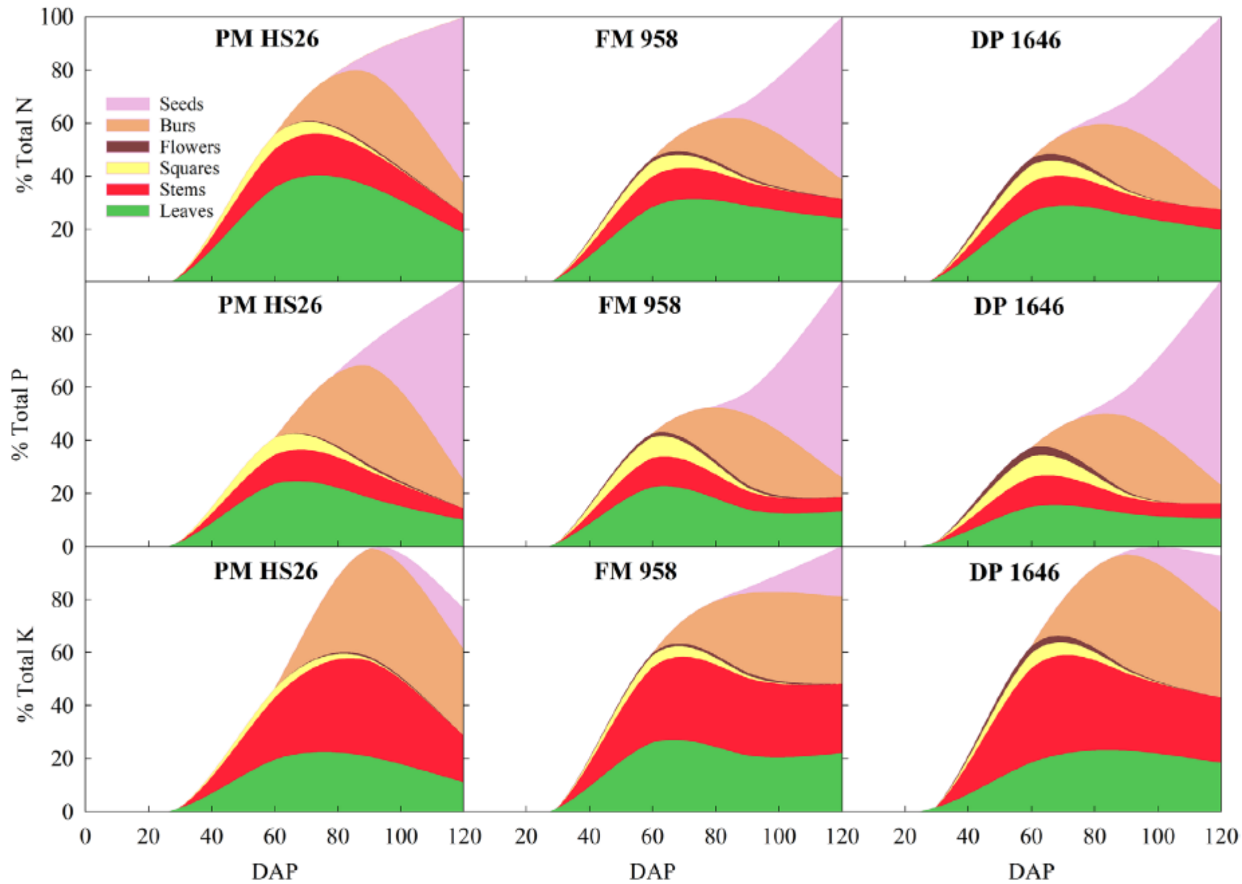

Figure 1. Comparison of the primary macronutrient partitioning between old and new cotton cultivars. DAP means days after planting. This data represents the results from 2018 and has already been published. The results for the 2019 study, including the partitioning patterns for secondary macronutrients can be accessed in the following publication: Pabuayon, I. L. B., Lewis, K. L., & Ritchie, G. L. (2020). Dry matter and nutrient partitioning changes for the past 30 years of cotton production. *Agronomy Journal*, 112(5), 4373-4385.

Aside from the improvements in nutrient uptake efficiencies observed in modern cultivars, our study showed that modern cultivars have the capacity to reallocate potentially toxic elements, such as sodium, to non-photosynthetic tissues. The accumulation of sodium in non-photosynthetic tissues of cotton is thought to be a response to enhance salt tolerance. In situations where there is an excess availability of sodium beyond what is necessary for normal plant growth, a phenomenon occurs where sodium is redistributed and accumulates specifically in the transpiring leaves (Pabuayon, Lewis, and Ritchie, 2021). This suggests an abundance of sodium can lead to its relocation and concentration in the leaves involved in the process of transpiration. This dual response underscores the intricate ways in which plants manage sodium in different tissues as a strategy to cope with varying environmental conditions, particularly in contexts where salt stress is a prevalent concern.

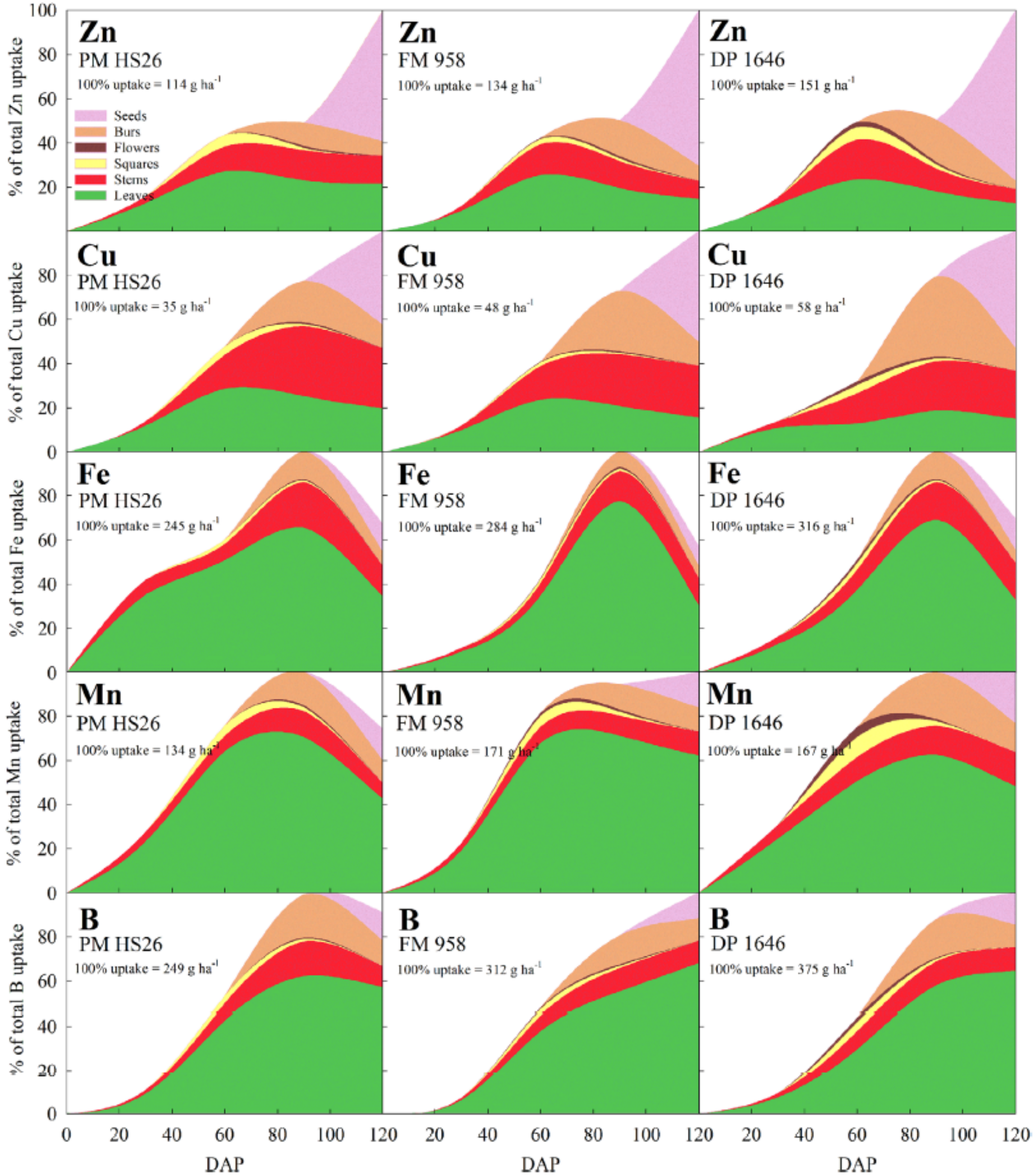

Figure 2. Comparison of the micronutrient partitioning between old and new cotton cultivars. DAP means days after planting. This data represents the results from 2018 and has already been published. The results for the 2019 study can be accessed in the following publication: Pabuayon, I. L. B., Lewis, K. L., & Ritchie, G. L. (2021). Hidden fractions: Another look at micronutrient and sodium partitioning in modern cotton cultivars. *Crop Science*, 61(5), 3623-3636.

CONCLUSIONS

Overall, our research provides insights on the shifts in nutrient uptake and partitioning alongside the remarkable improvements in yields of modern cotton cultivars during the past few decades. Results showed the newer cultivars have an enhanced capacity to accumulate and remobilize nutrients to organs associated with reproductive development. The results from this study can be valuable for researchers and producers, offering guidance in making informed decisions about fertilizer management, especially when precise nutrient requirements at specific growth stages are known.

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