NUTRIENT PARTITIONING CHANGES IN THE PAST 30 YEARS OF COTTON PRODUCTION

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ABSTRACT

Modern cotton (*Gossypium hirsutum* L.) cultivars are more compact and efficient due to optimization of genetics and changed management practices in the past 30 years. The most recent work evaluating nutrient uptake by cotton was done in early 1990s, hence a need to re-evaluate the nutrient accumulation and requirements in modern high productivity cultivars. The objective of this study was to compare the resource allocation of modern cotton cultivars (PM HS26, FM 958, and DP 1646) with older ones based on dry matter production, yields, and nutrient uptake and partitioning to different organs. Results showed that the modern cultivars tested in this study partitioned a greater percentage of dry matter and nutrients into the fruit as compared to older cultivars. The nutrient requirements of these modern cultivars differ from 30 years ago especially during boll development. The nutrient uptake per unit of lint produced increased substantially from 1990 to 2018, which highlights the improved efficiency of the modern cultivars. Overall, the results of this study highlight the remarkable improvements in modern cotton cultivars during the past few decades. The results of this study can be a basis for researchers on how nutrient partitioning should be optimized to be more favorable towards reproductive organ development and subsequently, improved yields. This research is important for re-evaluating the optimal nutrient inputs for farmers and producers, especially since new cultivars are released regularly, and environmental conditions change continuously.

INTRODUCTION

Nutrient uptake and partitioning among plant tissues of cotton grown under dryland and irrigated conditions have been documented in several studies prior to 1990s by Fraps (1919), Armstrong and Albert (1931), Olson and Bledsoe (1942), and Bassett et al. (1970). For cotton cultivars grown in southern USA, the most fundamental and recent report on dry matter and nutrient partitioning was provided by Mullins and Burmester (1990). This study reported on the translocation of nitrogen (N), phosphorus (P), and potassium (K) from vegetative to reproductive tissues. The findings of this study have been the basis of the current fertilizer recommendations for majority of the cotton productions in the Southern High Plains of Texas.

After the 1990s, research efforts on genetic improvement and crop management optimization has greatly improved the lint production efficiency of cotton, thus increasing the yield potential. It is possible that the organ nutrient accumulation and the requirement rates of the modern cultivars have also changed, and these played as factors towards the said improvements.

Since the most recent work was done in the late 1980s, a current investigation on patterns of resource partitioning and accumulation is needed.

We hypothesized that the yield improvements are associated with differences in nutrient allocation and the nutrient partitioning, accumulation, and requirements of the modern cotton cultivars will likely be different compared to older cultivars. The objective of this study is to compare the resource allocation of modern cultivars with older ones based on yields, partitioning of N, P, and K to different organs, as well as nutrient uptake per unit of lint produced in irrigated, fertilized cotton.

MATERIALS AND METHODS

Field experiment was conducted in 2018 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 7 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.

Three cotton cultivars (PM HS26, FM 958, DP 1646) were planted on May 21, 2018. Plots were fertilized with an average rate of 100 lb N A^{-1}, 80 lb P A^{-1}, and 27 lb K A^{-1}. The liquid N fertilizer was split-applied as urea-ammonium nitrate (UAN, 32-0-0), using a coulter applicator, on May 19, 2018 (40% pre-plant) and July 11, 2018 (60% side-dressed). 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 (DAP). 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 analyses. Dry matter fractions were submitted to the Texas A&M AgriLife Extension Soil, Water and Forage Testing Laboratory (College Station, TX) for N, P, and K analysis.

Boll distribution was determined using the plant mapping procedure. The number of bolls $plant^{-1}$ at each node was determined by combining the 1st, 2nd, and 3rd position bolls from the corresponding flowering intervals. Mature bolls were harvested within 264 ft^2 area per plot on November 10, 2018. Statistical analysis was performed using the Generalized Linear Mixed Model (GLIMMIX) Procedure in SAS 9.4 (Cary, NC).

RESULTS AND DISCUSSION

At the time period when the maximum crop growth rate was observed, the modern cotton cultivars accumulated more heat units compared to the older ones used in the 1990 study (Table 1). The peak crop growth rate for all the modern cultivars was observed at 800-1100 growing degree days ($GDD_{°C}$), which corresponded to 28-43% of the total dry matter production. In comparison, Mullins and Burmester observed maximum crop growth rate at about 500-800 $GDD_{°C}$, corresponding to 28-38% of the total dry matter production. Growth and development of cotton are temperature-dependent. This difference may be partially explained by the cooler growing environments prior to 1990 compared to recent years. This may have led to greater heat unit accumulation of newer cultivars that in turn may be responsible for optimal biomass production.

In the current study, it can be observed that the partitioning of nutrients varies among developmental stages and different cultivars. For the three modern cotton cultivars, the focus of the plant early in the season is in expansion of vegetative growth. This is reflected in the high nutrient accumulation in leaves and stems. For example, a massive push of N into the leaves and stems was observed (Figure 1). As the plants enter the reproductive stage, there was a decrease in the N content of vegetative parts and a net movement of nutrients to the immature bolls at 90 DAP and then into the seeds at 120 DAP.

Table 1. Comparison of the accumulated heat units, accumulated dry matter at maximum crop growth rate, and seed cotton yields between cultivars developed prior to 1990 and modern cultivars tested in 2018.

Parameters	**1990**	**2018**
Accumulated heat units ($GDD_{°C}$)	500-800	800-1100
Percent of total dry matter	28-38	28-43
Seed cotton yield range (lb A^{-1})	1485 - 2413	3751 - 4058

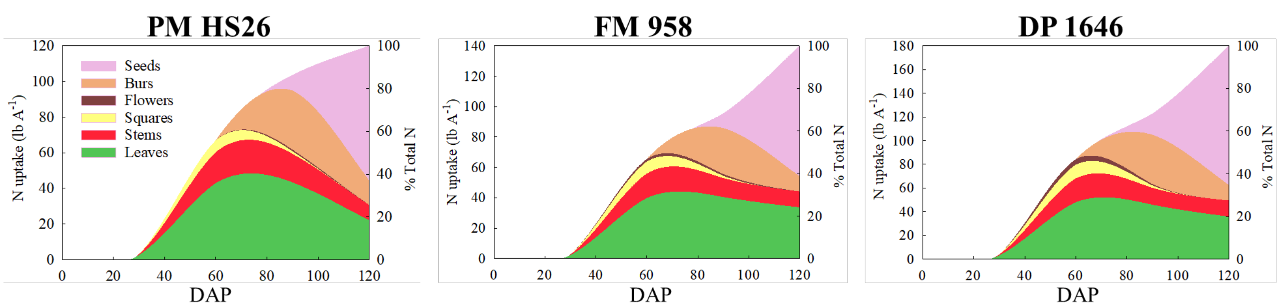

Figure 1. Nitrogen (N) partitioning in the different organs of modern cotton cultivars grown at New Deal, TX in 2018.

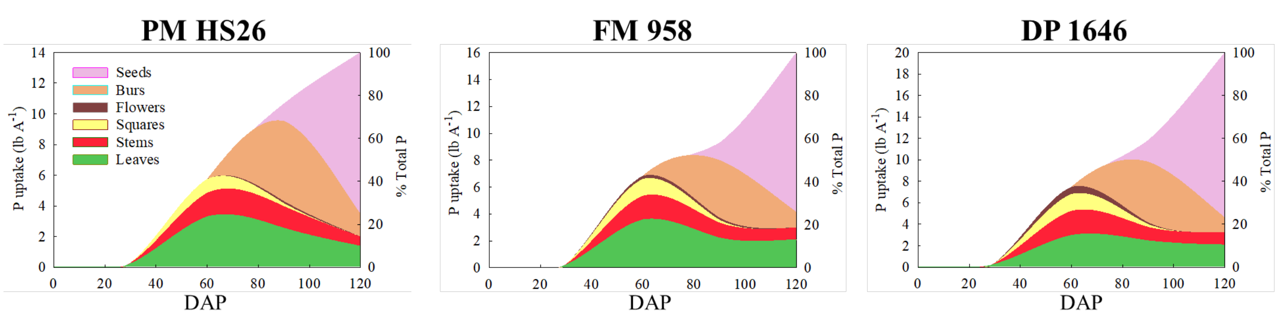

Figure 2. Phosphorus (P) partitioning in the different organs of modern cotton cultivars grown at New Deal, TX in 2018.

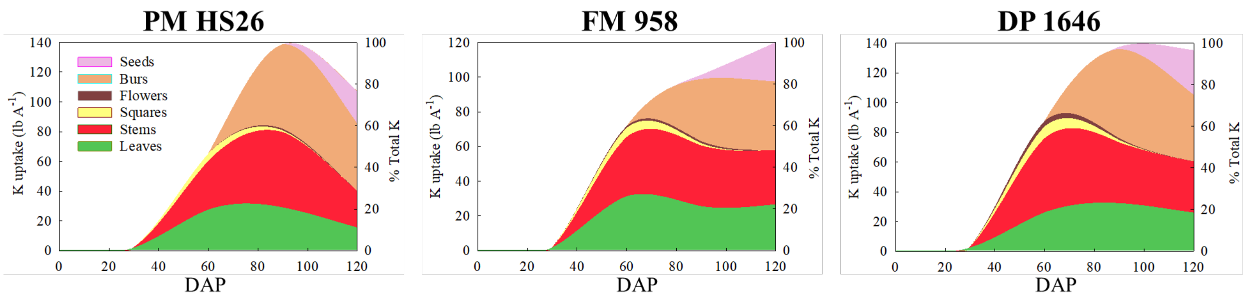

Figure 3. Potassium (K) partitioning in the different organs of modern cotton cultivars grown at New Deal, TX in 2018.

Similar to N, there was a net movement of P into the reproductive parts by the end of growing season (Figure 2). A greater percentage of P was accumulated in the burs at early boll development, which was then later utilized by the developing seed. In young cotton plants, stems and leaves have a high K concentration (Figure 3). As the season progressed, the K content in the stems and leaves decreased or plateaued. Burs, in general, had high K concentration throughout the reproductive stage and had the highest concentration of K among the different tissues at the last sampling date. For all the modern cultivars, the seeds have the lowest K concentration. This was also noted by Mullins and Burmester (1990).

Lint yields of FM 958 and DP 1646 were higher than PM HS26, which is reflected on their higher boll number especially in the middle section of the plants (Figure 4). The improvement of cotton through the years in partitioning its resources towards fruit production can be observed in the trends shown by the three cultivars.

The differences in patterns of accumulation in more modern cultivars reflect the differences in nutrient requirements to produce yield that reaches a cultivar's potential. The noticeable increases in the mean nutrient uptake per unit of lint produced in 2018 compared to 1990 alludes to the enhanced efficiency of modern cultivars in converting nutrient uptake and resource pools to yield production (Table 2).

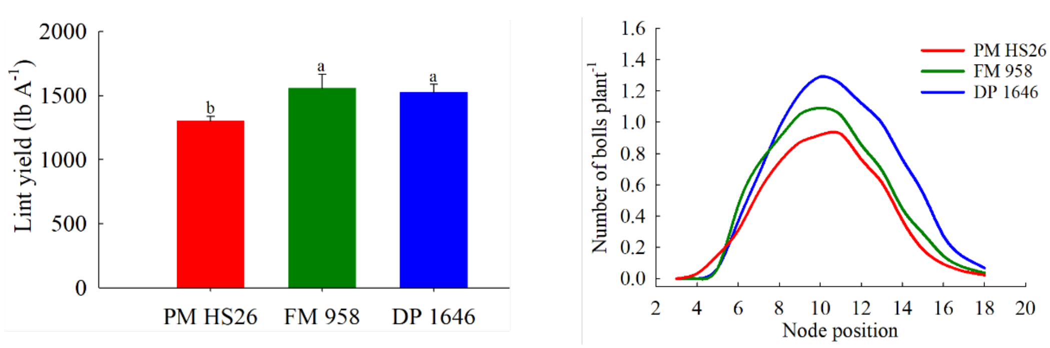

Figure 4. Lint yield and boll distribution of modern cultivars grown at New Deal, TX in 2018. Error bars represent standard error of the mean. Bars annotated by the same letters within the same graph are not different at 0.05 level of significance.

Table 2. Percent increase in the mean uptake of N, P, and K per unit of lint produced of three modern cotton cultivars grown at New Deal, TX in 2018.

Parameter	Increase from 1990-2018, %
Mean N uptake per 220 lb lint	26-47
Mean P uptake per 220 lb lint	4-40
Mean K uptake per 220 lb lint	67-120

CONCLUSIONS

This study provides insights on the remarkable improvements in modern cotton cultivars during the past few decades. Modern cotton cultivars showed a higher accumulation of heat units, increased yields, and significant deviation in nutrient uptake dynamics compared to older cultivars. The last point being the most evident during boll development. Results can provide us with information on how the modernization of cultivars altered their respective nutrient and mineral removal schemes from the soil and how these are distributed to the different organs within a plant. Certain nuances of fertilizer application, such as timing, must be taken into consideration to further increase the uptake efficiency in combination with implementing optimal water and nutrient management strategies to fit any cropping scenario in Southern High Plains of Texas.

REFERENCES

Armstrong, G.M. and W. Albert. 1931. A study of the cotton plant with special reference to its nitrogen content. J. agric. Res 42: 689-703.

Bassett, D., W. Anderson and C. Werkhoven. 1970. Dry Matter Production and Nutrient Uptake in Irrigated Cotton (*Gossypium hirsutum* L.). Agronomy Journal 62: 299-303.

Fraps, G.S. 1919. The Chemical Composition of the Cotton Plant. Texas FARMER Collection.

Mullins, G. and C. Burmester. 1990. Dry matter, nitrogen, phosphorus, and potassium accumulation by four cotton varieties. Agronomy Journal 82: 729-736.

National Cooperative Soil Survey. 2014. National Cooperative Soil Survey Characterization Database http://ncsslabdatamart.sc.egov.usda.gov/Accessed Wednesday, February 27, 2019.

Olson, L.C. and R.P. Bledsoe. 1942. Chemical composition of the cotton plant and the uptake of nutrients at different stages of growth.

SAS Institute. 2013. The SAS system for Windows. Release 9.4. SAS Inst., Cary, NC.