by D.R. Krieg

Interaction Between Plant Density And Water Supply Affects Cotton Yield

Texas scientist concludes only way to reduce risk of excessive stress is to match population with expected water supply.

Summary: *Our cotton physiology research program has been addressing the interaction between plant density and water supply on yield performance for several years. Under irrigated conditions, where water supply can be managed to minimize plant stress, narrow row spacings with 3 to 4 plants/foot of planted row resulted in highest yields. Under dryland conditions, where water stress is frequent and often severe, narrow rows still out produce wider rows (40-inch or skip row), but population responses were dependent on stored water at planting and rainfall patterns during the growing season. No consistent pattern was observed, since considerable year to year variation existed in water supply components. Determination of water supply required to produce 5 to 6 mature fruit per plant indicated that a population density of 3,000 plants/A/inch of available water was maximum. Optimum plant densities can be determined at planting by knowing volume of stored water and potential rainfall (and irrigation water) that can be expected in the next 90 days.*

In the Texas High Plains, the question of ideal cotton plant population for maximum yield of highest quality fiber and seed has been debated for many decades. Planting period (late April to mid May) is fairly turbulent due to rapidly changing temperatures and frequent rain and wind storms that damage young seedlings. Low, non-uniform populations produce large, stemmy plants that create harvesting and fiber quality problems from excess stems in the lint and a high percentage of immature fruit resulting from prolonged flowering. Excessive populations delay fruiting onset and increase the risk of intense water stress through varying periods of the growing season. Due to indeterminate growth habit and woody perennial characteristics of cotton, vegetative growth is dominant over reproductive growth under both excessive water and nutrient supplies, as well as deficit conditions of each. Therefore, under water stress conditions, the plant will stop initiating fruiting sites and/or abort existing young fruit, either of which drastically reduces yield potential.

Production conditions on the Texas High Plains range from complete dryland to fully irrigated. About half the planted 3.5 million acres is grown under rainfed conditions where water supply is the single greatest limiting factor. Average annual precipitation is 18.5 inches with about 65 percent occurring during the summer growing season. However, evaporative demand averages between 0.30 to 0.35 inches/day during this period, resulting in a precipitation/evapotranspiration ratio of 0.25 or less. Excessive demand relative to water supply results in considerable plant stress, reducing yield of lint and seed.

The remaining half of the production area has supplemental irrigation. Water supply is highly variable and ranges from 50 to 100 percent replacement capabilities of actual crop water use (ETa). When water supply meets evaporative demand, growing season length becomes the limiting factor. Anything that delays fruiting onset, reduces retention, or prolongs the fruiting period, results in low yields of poor quality fiber and seed. Therefore, ideal or optimum population must be defined for ranges

Table 1. Multiple regression analyses of lint yield and relative contribution of each component across 6 site years (n=120).

Source	Component	Parameter estimate	Partial R^2
Lint yield	Intercept	0.00	---
	Bolls/A	16.77	0.854
	Lint/boll	38.42	0.097
		Total R^2	**0.951**
Boll/A	**Intercept**	**0.00**	**---**
	Bolls/plant	**6.43**	**0.374**
	Plants/A	**1.51**	**0.374**
		Total R^2	**0.748**

of water supplies from rainfed conditions to those replacing ETa.

Our objective in this project (1994-96) was to determine what effect the relationship between plant population and water supply has on lint yield and components of yield, namely fruit number and size. From this relationship, seeding rate guidelines, based upon available water supply, could be developed to minimize risk of yield losses or fiber quality reductions caused by excessive plant water stress.

Search for right match

Field experiments have been conducted for a period of years at two sites reflecting soil texture differences. One has clay loam texture about 4 feet deep, which is typical of the northern half of the southern High Plains cotton growing region. The other has a loamy fine sand about 6 feet deep, which is typical of the southern half of the production area. The two sites are separated by 60 miles, so that the weather components (other than rainfall) are very similar on a day-to-day basis. At each location, sprinkler irrigation capabilities exist such that water supply can be varied from rainfed only to 100 percent replacement of actual crop water use (ETa) at various frequencies. A range of water supplies from dryland to 50, 75, and 100 percent ETa replacement at -weekly frequencies has been the most common water supply variable studied during the course of this experiment.

Several commercial cotton varieties differing in degree of indeterminancy have been used in all experiments. Row spacing and seeding rate have been the major experimental variables used to develop the relationship between water supply and plant density. Row spacing ranged from ultra-narrow (15-inch) to narrow (30-inch) to wide (40-inch) to skip row patterns (2 planted, 1 skip). The dryland system evaluated 30- and 40-inch row spacings planted either solid or in a 2 by I skip row pattern. Seeding rates within the row were also variable and usually consisted of approximately 2, 4, and 6 seeds/foot of plant row, providing a wide range in resultant plant densities.

Final harvestable lint yield was evaluated in terms of yield components, including plant density (plants/A), fruit per acre and per plant, and fruit size (lint and seed weights per fruit). Multiple regression analyses were used to determine the relative contribution of each component to final lint yield/A. Bolls/A were the major yield component accounting for over 80 percent of the yield variation (Table 1) across all treatment variables. Boll size (lint per boll) contributed less than 10 percent to the yield variation, although boll size does differ among varieties, and due to temperature and nutritional variations. Boll number consists of two

Table 2. Correlation analyses of lint yield components of yield as a function of water supply during different parts of the growing season.

Water supply	Yield/A	Bolls/A	Bolls/plant	Lint/boll
Seasonal	0.27	0.33	0.31	-0.01
Planting to SI	-0.53	-0.38	-0.32	-0.56
SI - FF	0.74	0.63	0.54	0.61
FF - PB	0.41	0.61	0.32	0.15
PB - Maturity	-0.35	-0.38	0.11	-0.48

SI = square initiation, FF = first flower, PB = peak bloom

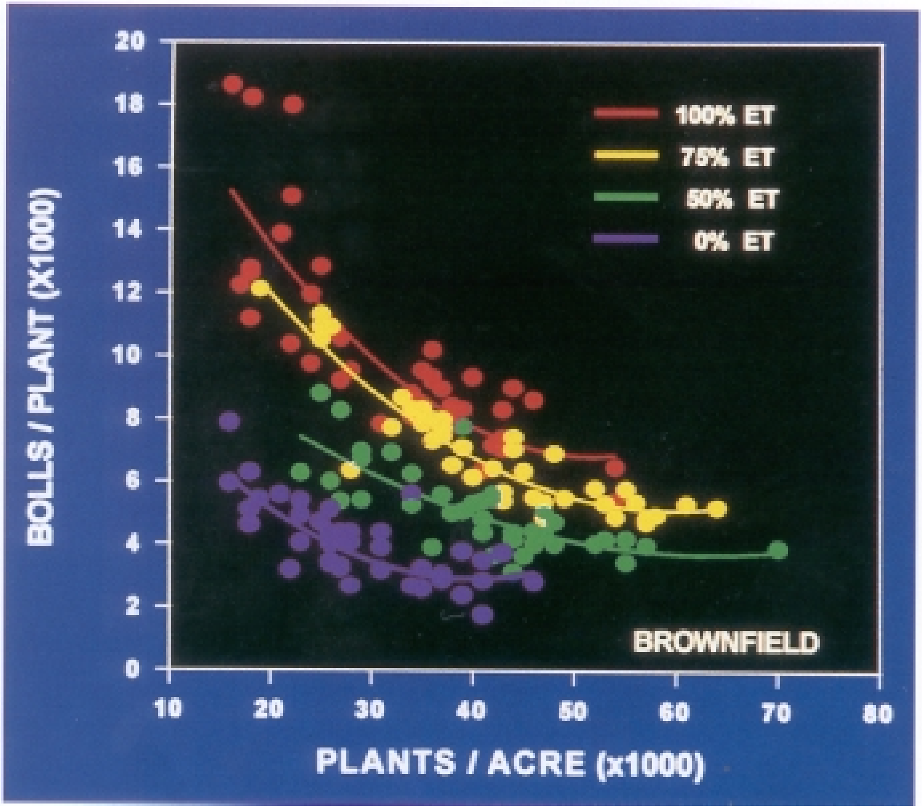

Figure 1. Plant population effects on fruit per plant within varios water supplies, Krieg, Texas Tech University, 1994-1996.

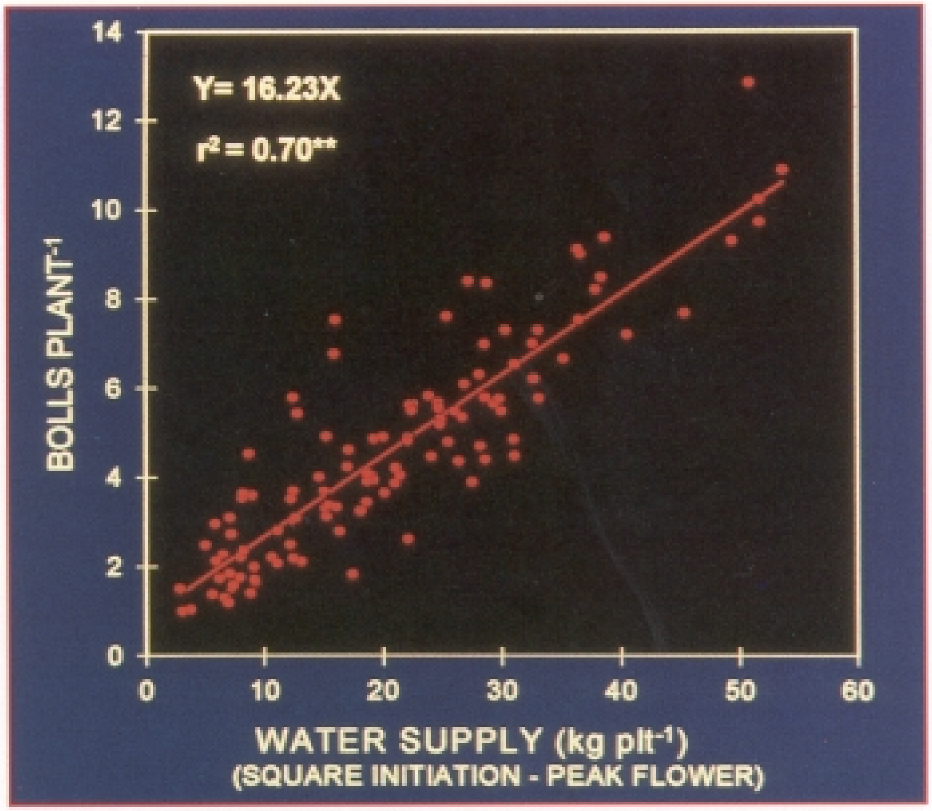

Figure 2. Relationship between fruit plant and water supply/plant during fruiting, Krieg, Texas Tech University, 1994-1996.

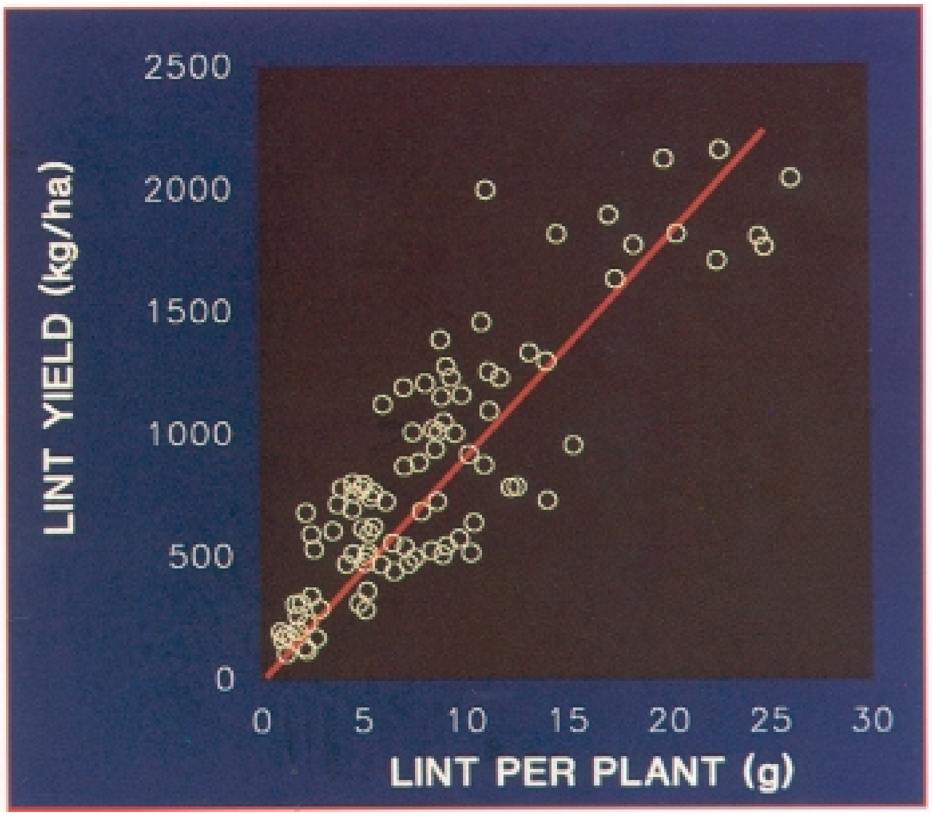

Figure 3. Relationship between individual plant productivity (lint/plant) and lint yield on a land area basis, Krieg, Texas Tech University, 1994-1996.

components that are highly interactive, namely plant population and boils per plant. A strong exponentially declining relationship exists between boils/plant and plant population with the magnitude of the response being strongly affected by water supply (Figure 1). Within each water supply each plant was capable of supporting a certain fruit load determined largely by the temperature regime. As plant density increased within the water and temperature regime, individual plant production declined. Total production of fruit on a land area basis initially increased as population density increased, then plateaued across a range of plant densities, and finally declined as density continued to increase. The population at which lint yield/A plateaued was dependent upon water supply and growing season length.

Analyses of yield components relative to water supply revealed that water supply from floral bud initiation (square initiation) through peak flowering period (peak bloom) was most strongly correlated with yield per acre (Table 2). Boll number and lint per boil were strongly correlated with water supply from square initiation to first flower. During this development period, essentially every floral site is initiated that will ever make it to a harvestable fruit under temperature conditions normally prevailing on the Texas High Plains. Water supply from flower to peak bloom results in a strong correlation with bolls/A, reflecting the effect on boll retention.

It is apparent that water supply from square initiation to first flower affects number and boll size; and water supply from first flower to peak bloom affects fruit retention, therefore boll number. Water supply from peak bloom to maturity has a negative correlation with yield, especially boll size. Increasing water supplies during late season causes the plant to divert more of its daily photosynthate into root growth and storage for overwintering, reflecting the woody, perennial nature of the cotton plant.

Across all water supplies, years, and cultural treatments a strong linear relationship existed between water supply/plant from square initiation to peak flower and fruit/plant (Figure 2). Distribution of the fruit load on the plant was strongly influenced by water supply per plant. First position fruit increased rapidly as water supply per plant increased, reaching a maximum of 6-7 bolls per plant at 10 gallons per plant.

Lint per boll was correlated with water supply from square initiation to first flower. However, magnitude of the change was relatively small and considerable influence due to genetics and temperature during the later part of the fruiting period was more important than water supply. Total plant productivity (lint per plant) was strongly correlated with water supply from square initiation to peak bloom with an r^2 of 0.70. Lint per plant strongly correlated with lint yield/A with an F of 0.76 (Figure 3). These results strongly suggest that plant population should be based on water supply per plant.

Take-home message

To maximize lint production per plant and thus lint yield/A, an individual plant requires approximately 10 gallons of water per plant. An acre-inch of water contains 27,500 gallons so that each inch of available water will support 2,500-2,700 plants/A. If one considers stored water at planting and the potential rainfall and/or irrigation from square initiation to peak bloom, a decision as to appropriate plant density can be made and planting rates adjusted accordingly.

For instance, on the Texas southern High plains, stored water at planting is normally 3 to 4 inches. Approximately 6 to 7 inches of precipitation occurs between square initiation and peak bloom, providing a total water supply of 9 to 11 inches up to peak bloom. If an inch supports 2,500 plants, then dryland systems should target 25,000 to 30,000 plants/A as optimum. For each inch of irrigation water that can be provided during square initiation to peak bloom (approximately 6 to 7 weeks), an additional 2,500 plants/A should be produced.

Typical irrigation water supplies range from 2 to 4 gallons per minute per acre (gpma). Each gpma of irrigation water will support an additional 5,500 to 6,000 plants/A.

The cotton plant has a tremendous compensatory capacity. If one is going to hedge the risk of water stress, it would be better to be on the low rather than the high side from a plant density perspective.

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