Optimizing Control of Insect Pests: Reducing Insecticide Use and Minimizing Economic Injury with JMP

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New Mexico State University

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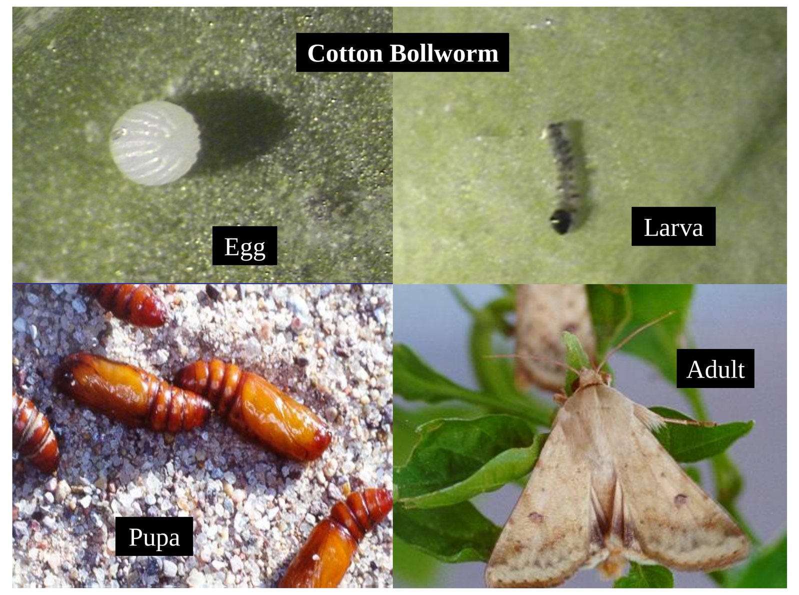
Background

Insect pests cause significant losses in agriculture. Growers frequently turn to insecticides to protect their investment in a crop but the decision to use an insecticide is often difficult and anything but straightforward. Economic thresholds are used to help make these decisions and are often calculated as (loss/insect)/ crop value.

Clearly an understanding of the potential crop value is an essential element in determining return on investment. Unlike some crops cotton produces harvestable yield in the form of bolls containing lint and seed over a relatively long period of time. The flower buds (squares) and bolls are only susceptible for a matter of days and represent only a portion of the total yield. A typical season long yield of 3 bales with 480 lb/bale or 1440 lb/A is not the appropriate measure.

The location of cotton bolls are mapped by node and position so at any point in time growers know which squares and bolls are susceptible to insect damage. In New Mexico, bollworm has historically been one of the key insect pests damaging cotton late season. If late season bolls are only a small portion of overall yield, it might be difficult to justify inputs for protection of these susceptible squares and small bolls. Growers frequently use Bt cotton to avoid bollworm damage but as a late season pest the benefit only applies to late season bolls, also making calculations of value important in justifying the expense of expensive Bt cottons.



Cotton Bollworm Life Cycle

Cotton Bollworm larva feeding on cotton squares (flower buds)

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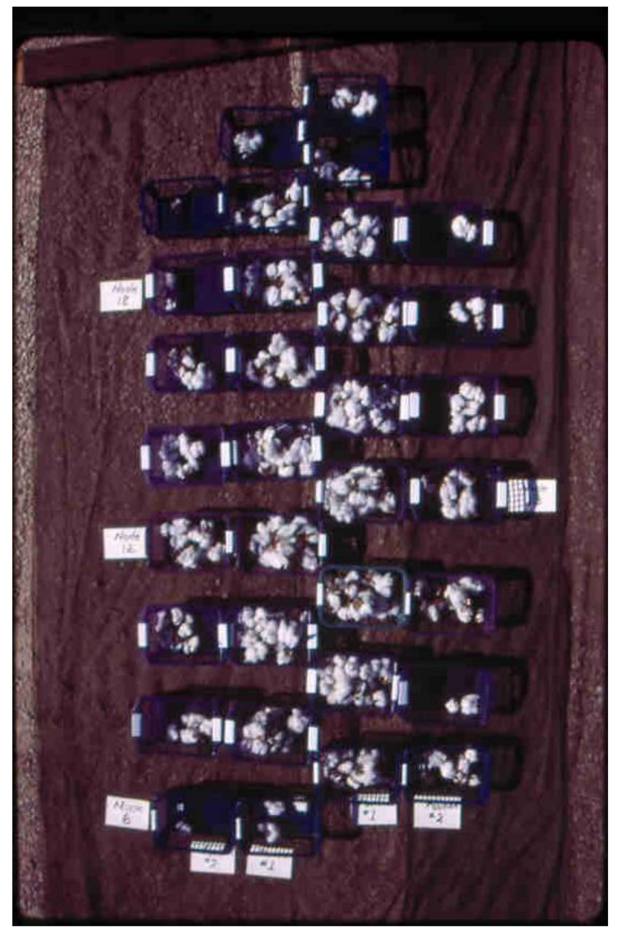
Introduction

Management decisions regarding crop inputs are often difficult. Real and immediate costs for insect control must be weighed against somewhat nebulous estimates of yield losses or crop value. In New Mexico, cotton bollworm is not an early-season pest. Growers generally make insecticide applications for bollworm in August when the value of developing squares on the 15th-22nd node may be questionable. Field trials were initiated to determine the relative value of bolls produced mid to late-season in New Mexico.

Follow-up tests were then conducted to determine if cotton could compensate for mid to late-season losses of squares and bolls. Compensation tests were designed to mimic heavy, late-season losses from bollworm with manual removal of fruiting structures with a locally adapted variety, Acala 1517-99.

Most data on crop value for economic thresholds in cotton assume a worst-case scenario. Boll value is determined from undisturbed plants. The loss is assumed to be equal to the value of that lost boll. However, cotton has a known ability to compensate for insect injury to fruiting structures. Late-season squares are lower value and the late date may allow little time for compensation. Very late season, if squares are unavailable, bollworms will infest small bolls in which the plant has a higher investment. These issues justified field tests to specifically address potential compensation for insect injury to late-season cotton.



Results: Yield Partitioning

Statistical analysis of yield by node and position is more complex than the typical field trials. In those trials yields for whole plots are compared across treatments and simple means separation tests are sufficient. The advantage of using JMP® for these trials is that data visualization drives our interpretation and it is easier to note subtle but important differences late-season. For example when number of bolls or lint weight is regressed on node there is no significant difference across nodes. However a simple scatter plot indicates that there is a relationship and suggests a more complex area where there is no effect of node. (Figure 1)

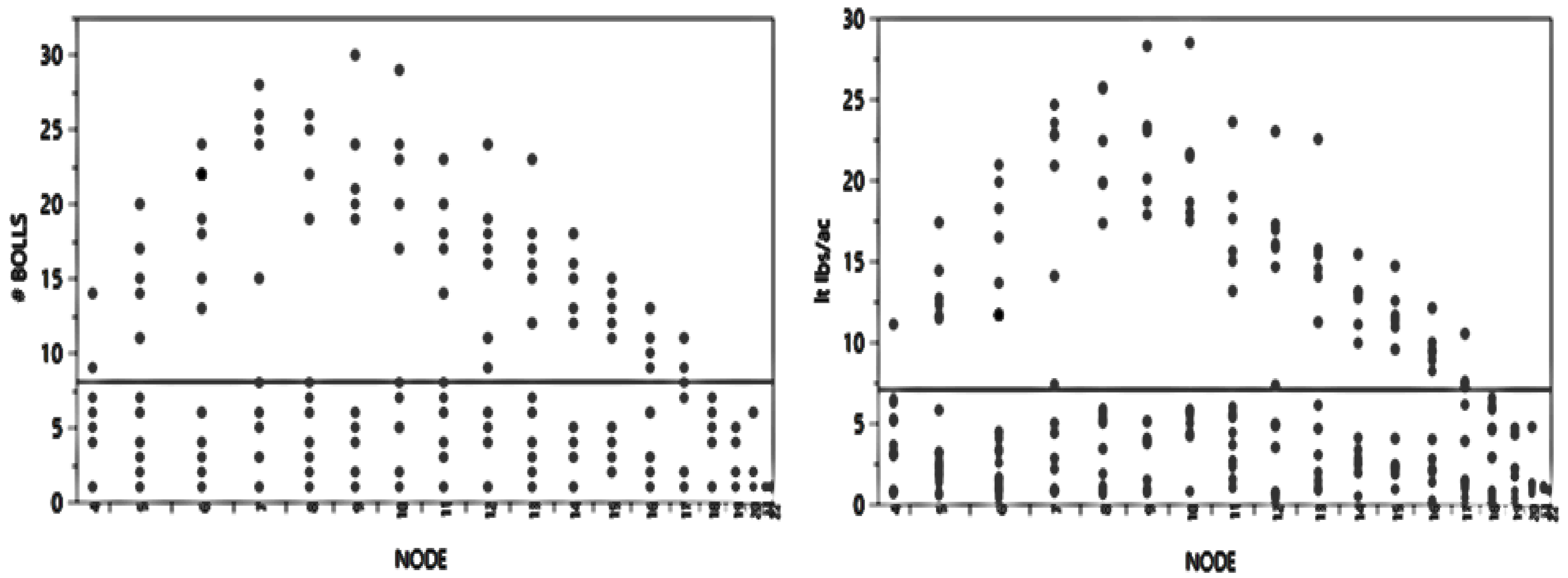


Figure 1.. Influence of node on lint weight and lint weight per boll in 1517-08.

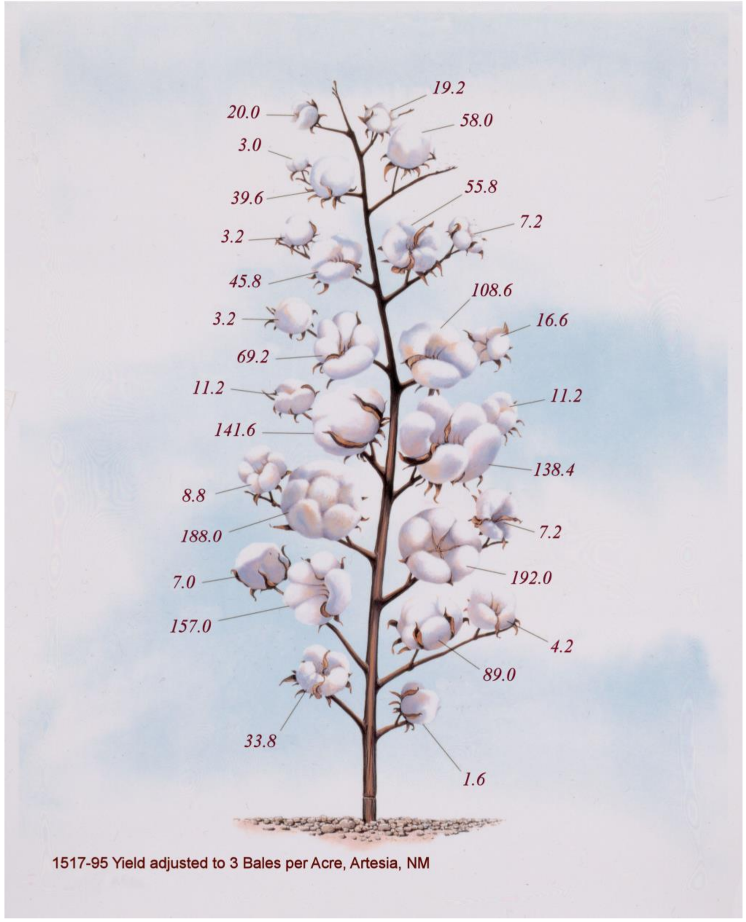


Figure 2. Yield by node and position.

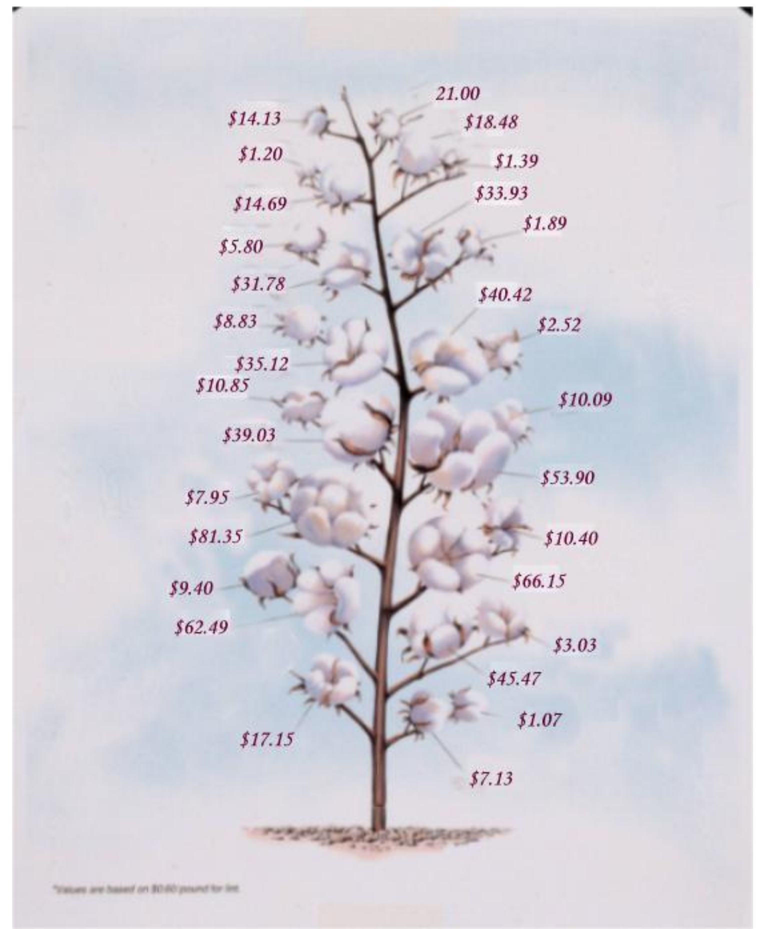


Figure 3. Value of each boll/acre by node and position.

Most growers believe large late season bolls are worth economic inputs. Field observations suggest that inputs are justified particularly when growers observe relatively large bolls. Our data supports this observation and indicates that late season bolls are significantly smaller, but only 25% smaller than mid season bolls. However, differences in overall yield are not due to boll size, but boll number, which is much less apparent.

Scatter plots of node by yield illustrate the tremendous impact of boll number on yield. (Figure 4) Node 10, for example, produced 5 times as many bolls as node 20 with 2.0 and 0.4 bolls/ft respectively. Lint weight per boll on the other hand was only 25% higher on node 10 compared to bolls on node 20 with 2.0 vs. 1.5 g lint respectively, or 20 fold difference in impact.

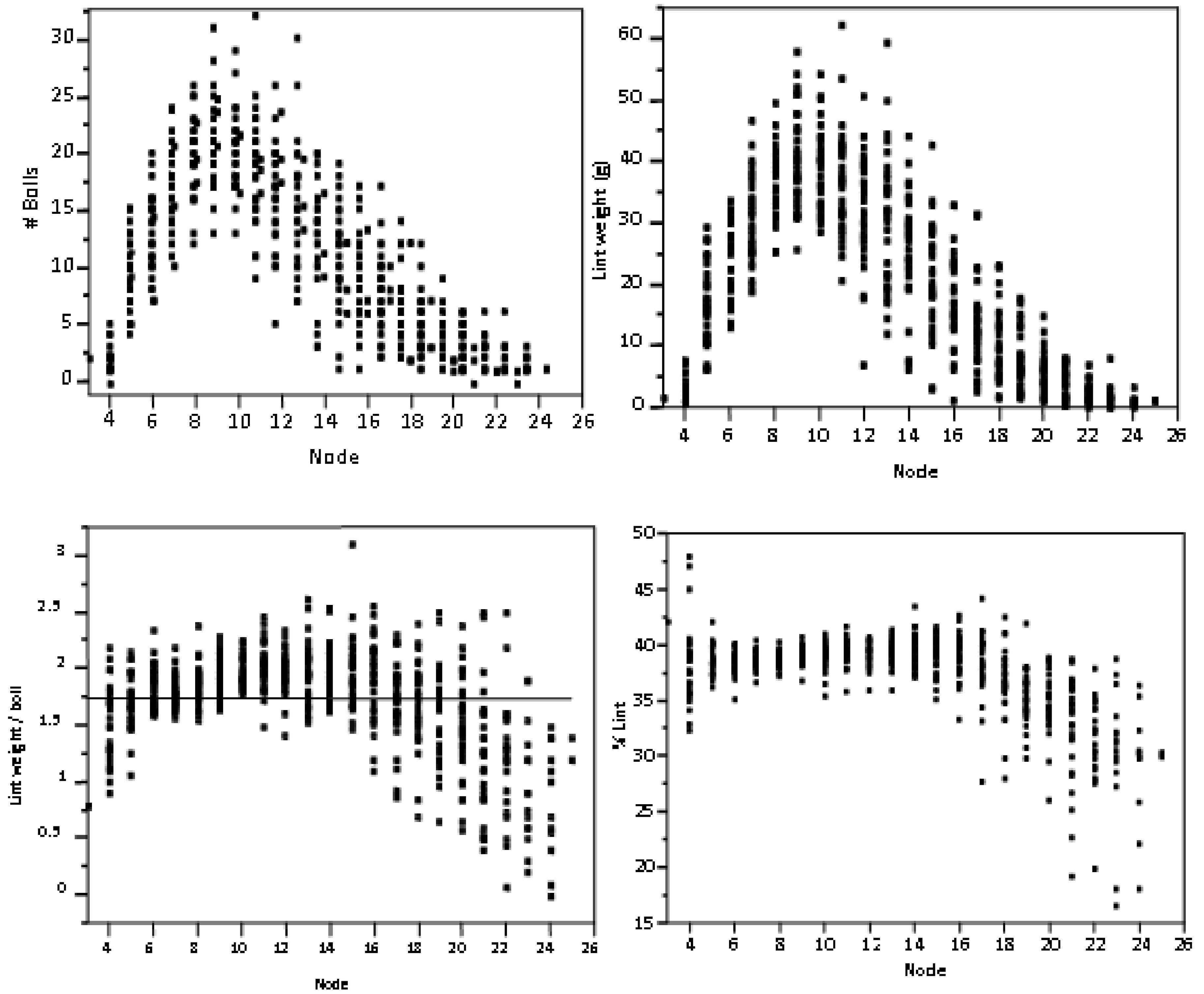


Figure 4. Impact of node on first position bolls number, lint weight and lint to seed ratio.

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Highest yields were in the lower middle portion of the plant, typically nodes 9-14. Nodes 8-18 generally produced over 90% of the total yield. The last three nodes added very little to final yields, typically 1% or less (Figure 5). There is not a high value in very late-season squares. Mid-August in New Mexico squares would typically be produced on the 15-20th nodes.. From that point on, returns on any inputs such as irrigation, fertilizers and insecticide applications to protect squares and bolls diminish very rapidly

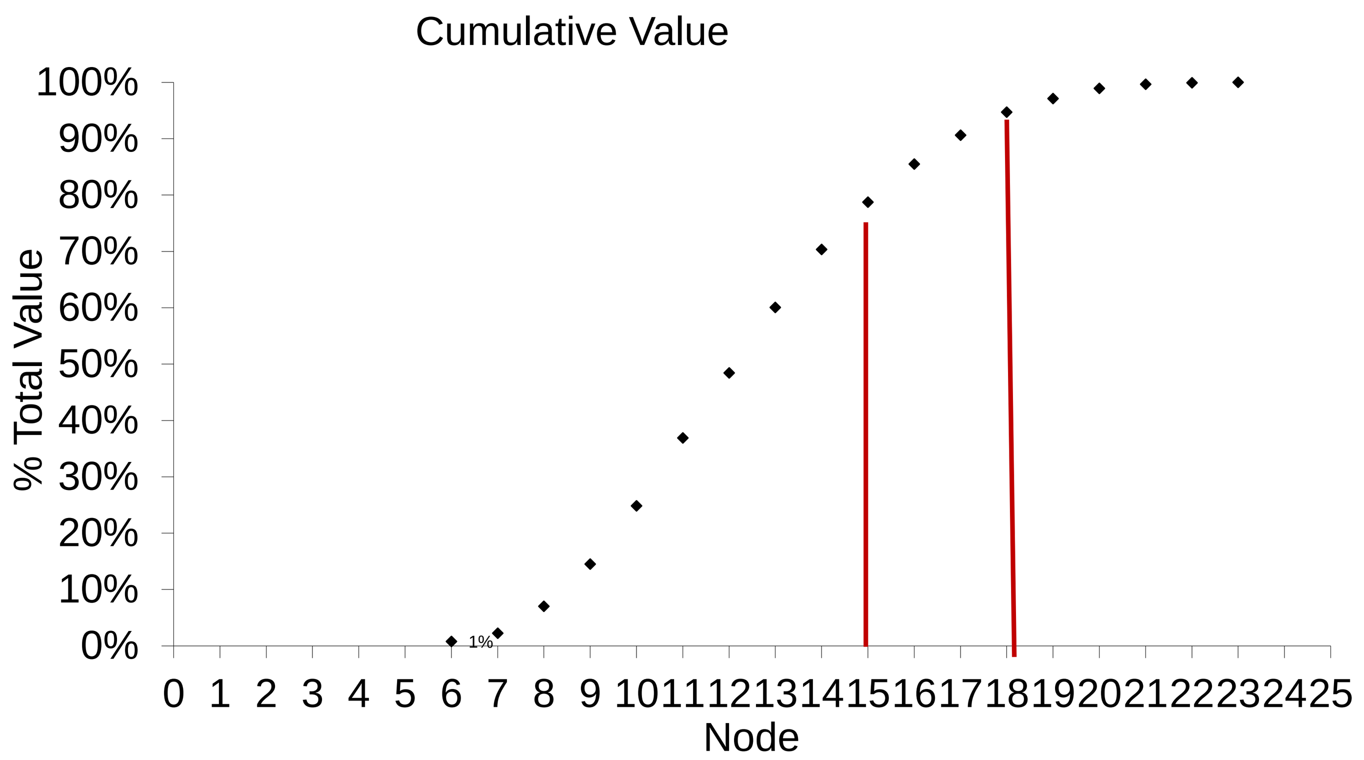

Figure 5. Influence of boll location on yield

Node location has a dramatic impact on number of bolls and yield, for first position bolls but not second or third position bolls. Most cotton bolls 77% were first position bolls while 20% were second position bolls. Only 3% of bolls were in positions 3-5 (Figure 6). In a 2017 trial, the last four nodes including both first and second positions only produced 2.6% of total bolls.

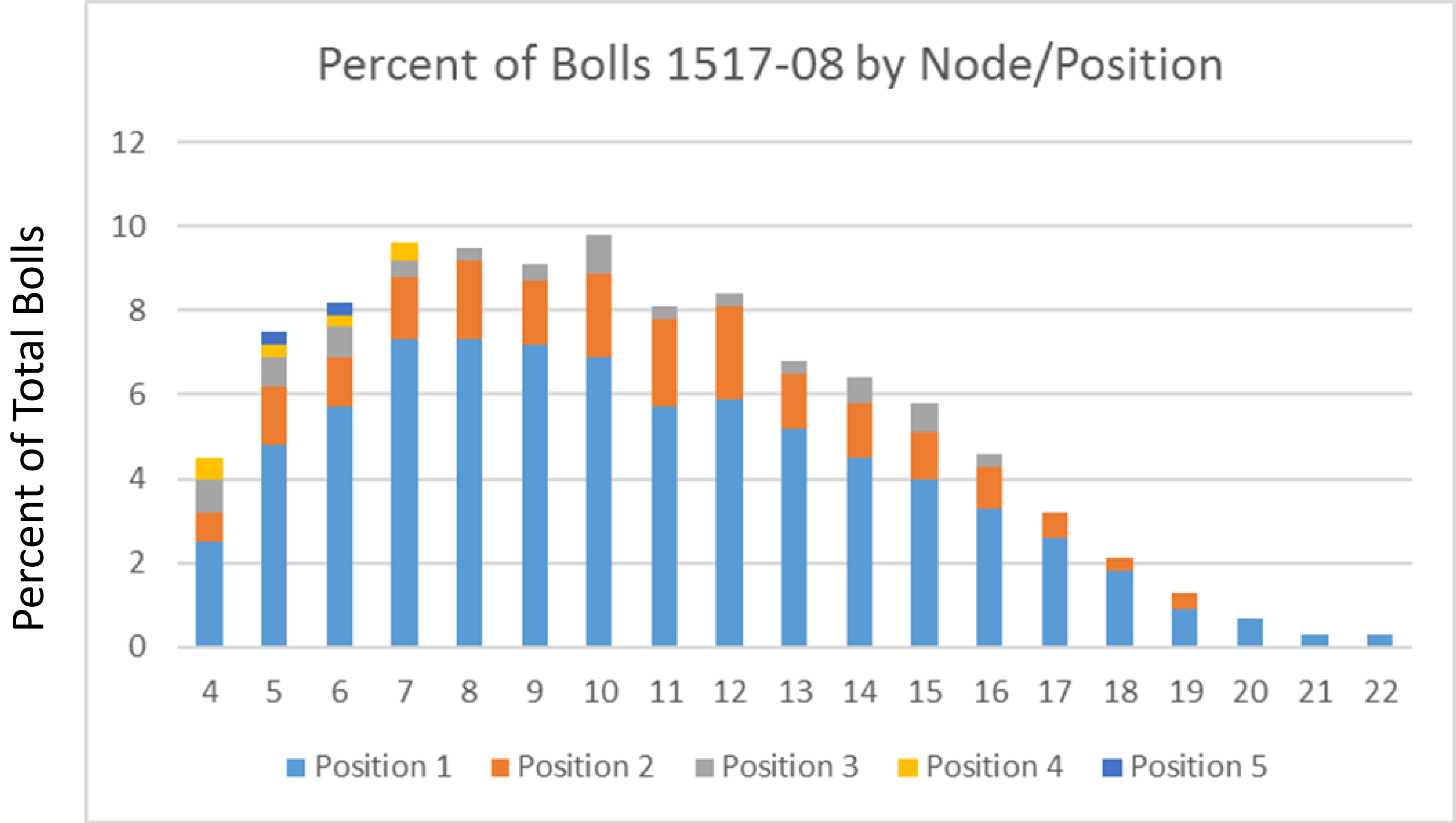

Figure 6. . Production of bolls in 1517-08 by each node and position in Artesia field trial, 2017.

Compensation for Injury

The primary means of compensation for injury by insect pests. was by retaining more squares and bolls, but sometimes also by producing more lint per boll. The highest yield, 1620 lb/A, was from the treatment plots with squares removed 8/15, from the 17-21st nodes. In those same plots mean lint weight per lock and boll was 12% higher than uninjured plants. The difference in boll weight was particularly notable in very late bolls, nodes 19-22 where the injured plants' bolls had 20% more lint than control bolls. (Figure 7 and 8)

Overcompensation was achieved by redistribution of resources adding higher lint weight per lock, to the increased square or boll retention found in most injured plots. Control plots had approximately 0.5 g lint/lock in nodes 10-16, with significantly less lint in nodes 18-20. (Figure 7) Overcompensating plants lint weights per lock in nodes 18-20 were comparable to nodes 10-16.

Cotton bolls produce cotton in locks similar to sections of a tangerine. A better illustration of the cotton plant's allocation of energy to limit production is illustrated by a scatter plot of node to lint/lock. There was a significant correlation between node and lint/lock with reduced lint in bolls in the last few nodes. (Figure 7). Compensation for insect damage on the other hand was evident when plants reallocated resources to the remaining squares increasing the size of the locks to levels similar to or greater than early season nodes (Figure 8).

Cotton boll with 5 locks

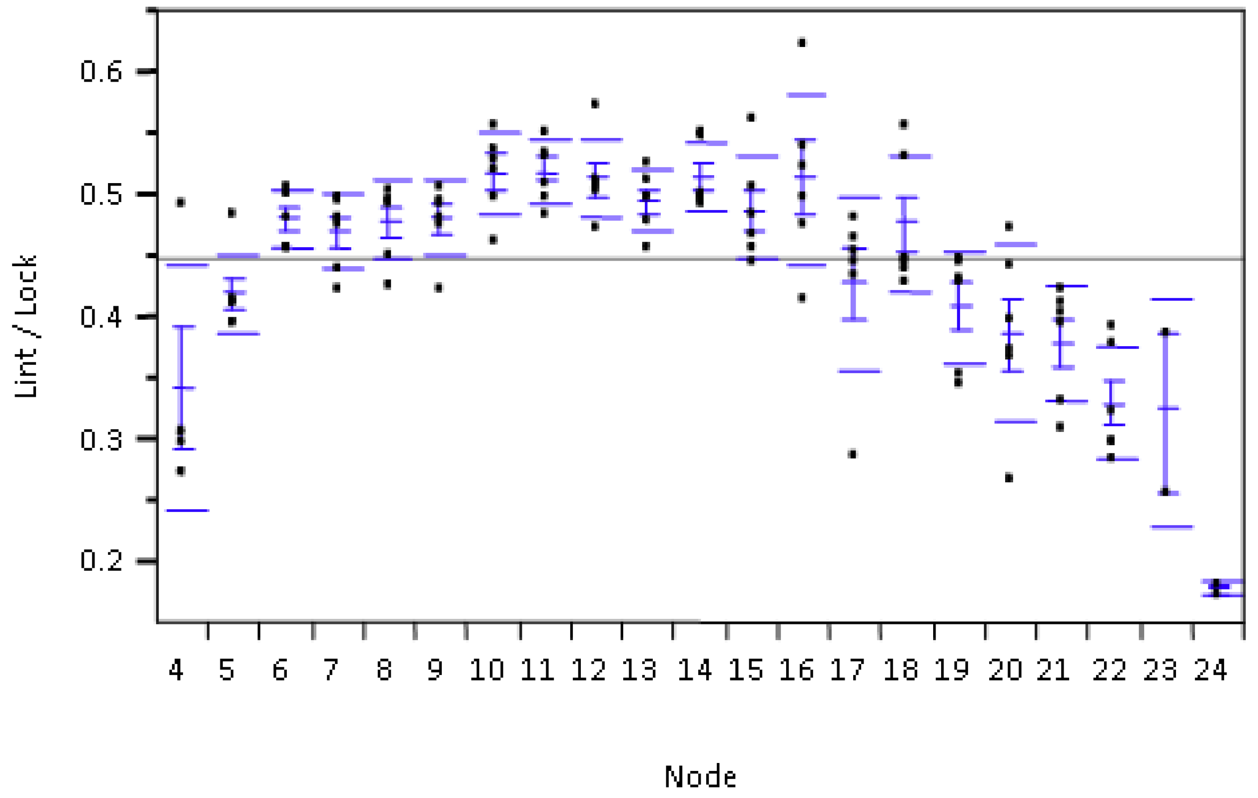

Figure 7. Lint weight per lock by node in undisturbed Acala 1517-99 compensation trial.

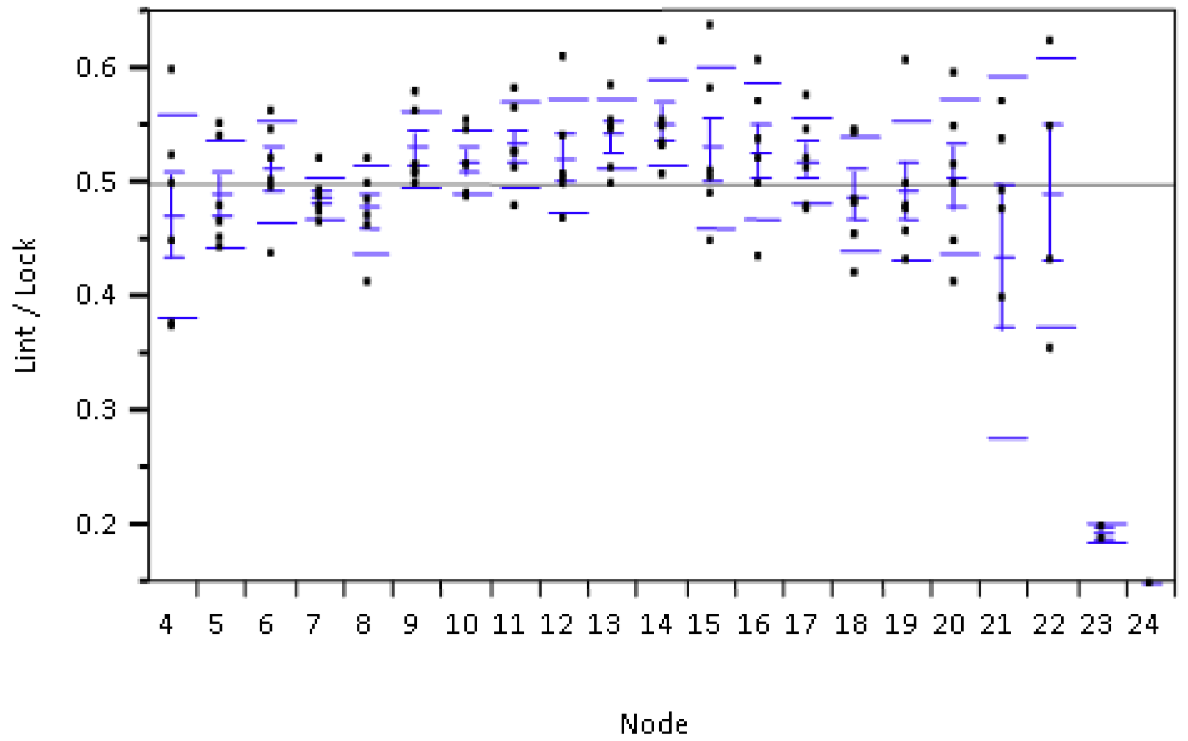

Figure 8. Lint weight per lock by node in plots with four squares removed.

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For comparison to previous data analysis a more straightforward example was a yield compensation field trial with large plots and 4 treatments. Confidence intervals, box plots and other visualization tools are still helpful in illustrating differences. I typically use such data with K-12 and undergraduate students to illustrate the concept of significant differences.

In a large plot compensation trial removal of 4 or 8 squares late season did not result in significantly fewer bolls/A with 31.9 bolls /ft in the check and 28.5 and 26.2 in plots with 4 and 8 squares removed respectively (Table 1). Plots with bolls removed did have significantly fewer bolls at harvest with 24.1 and 20.0 bolls/foot in plots with 4 and 8 bolls removed respectively. Losses from bolls were, not surprisingly much higher than losses from squares with 24-37% loss in boll yield compared to the check

Table 1. Total number of bolls per plot after simulated late season injury.

Treatment	Bolls/ft	s.e.	% loss
check	31.9a	1.3	
4 squares removed	28.5ab	1.8	11
8 squares removed	26.2abc	0.7	18
4 bolls removed	24.1 bc	1.4	24
8 bolls removed	20.0 c	2.3	37

Means followed by similar letters are not significantly different by Tukey's test (SAS-JMP)

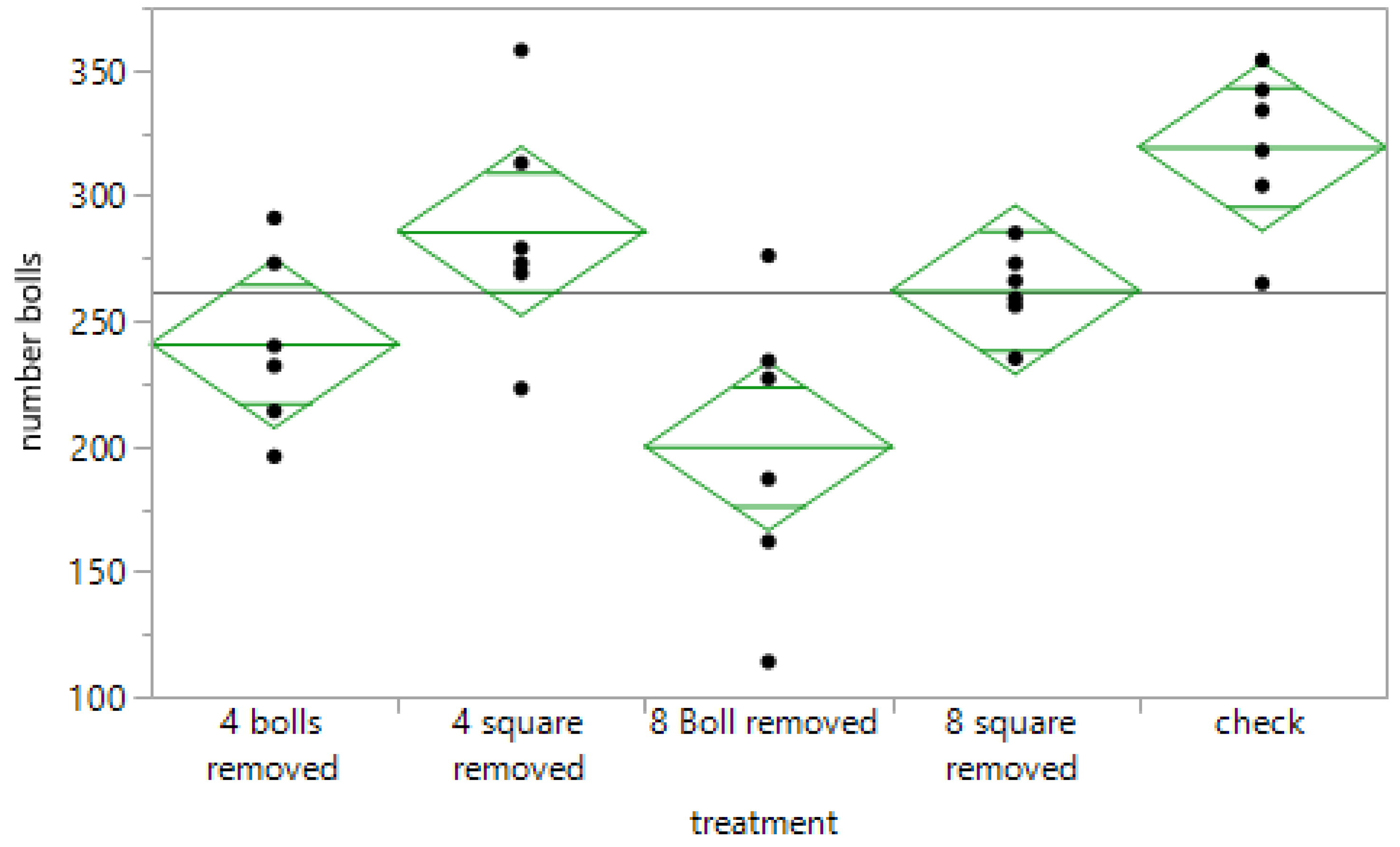


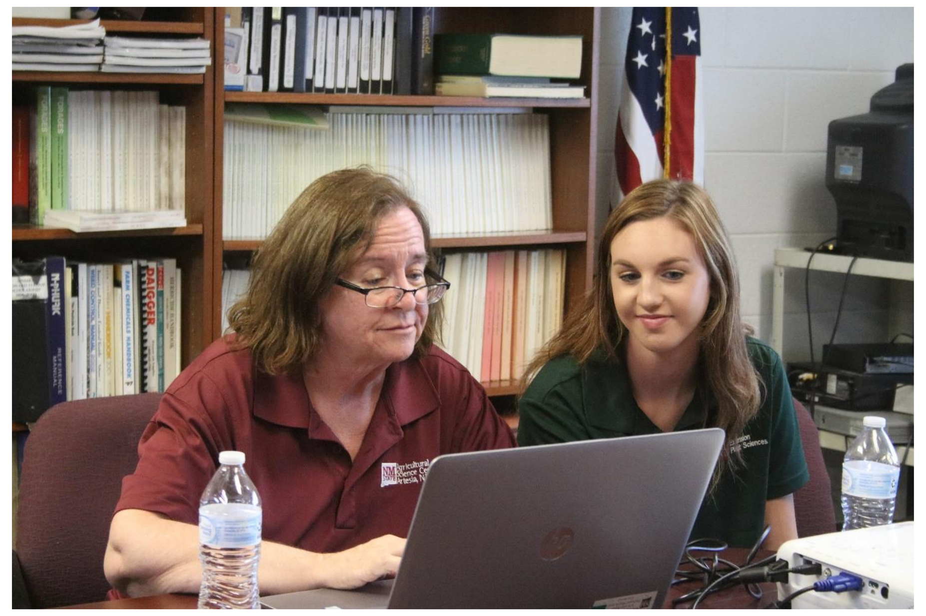
Figure 9. Number of bolls per 10feet after simulated late season injury.

Conclusions

The advantage of using JMP® for yield partitioning and compensation data is that there would be a greater likelihood that subtle but important differences would be missed. Such differences are very apparent when using JMP®. The plot of node vs bolls and yield made it very apparent that we needed to look for interactions which prompted us to segregate data by boll position. It prompted us to ultimately look at yield by lock to understand the plants ability to compensate for damage not only by retaining squares it would otherwise shed but also by reallocating carbohydrates to late season bolls that would have been smaller if there had been no injury.

These field trials suggest that inputs including insecticide treatments to protect squares may not be profitable mid-season, and is unlikely to be profitable late-season. Injury to squares from cotton bollworm is unlikely to be worth the cost of insecticides late season particularly since cotton can compensate for injury by retaining squares and reallocating resources. Injury from bollworm to bolls is a different issue and is more likely to produce losses that should be prevented. While rare, late season losses to boll can be severe. Very late season bollworm losses to squares resulted in 40% yield losses in 1998 in our field plots so close monitoring is still necessary.

Other considerations are the use of Bt cottons and biological control. Biological control rates particularly from predation are generally high in New Mexico. Field trials typically have 60-85% predation of bollworm eggs. Plant resistance is typically the first line of defense from insect pests however transgenic crops unlike conventional plant resistance is expensive. Since bollworm is a late season pest in New Mexico this data suggests that the use of Bt cottons for the control of lepidopterous pests may not be cost effective.



Acknowledgements

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