ECONOMIC THRESHOLDS FOR IRRIGATION MANAGEMENT DECISIONS

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Abstract

The field variability of soil moisture can have a direct impact on yield. Computer models have been used to estimate the change in crop yield based on the total amount of applied water and the variability of the available water in a field. Generally, an increase in total water applied will result in greater yields but greater field variability will result in reduced crop yields. The potential change in yield is ultimately realized as profit (or loss) and the amount of profit is dependent on the cost of all inputs. In this example, water is the only input that will be considered when calculating profits.

The variability for two cotton fields in central Arizona were monitored during the 1991 growing season . Data from the actual yields obtained and the variability of available soil moisture were recorded and used to estimate potential yield changes. The field variability from Cooperator A peaked at a high of 72% and Cooperator B at a high of 34%. All other factors remaining constant, it was estimated that Cooperator A could increase yields by as much as 96 #/acre. The potential profit would vary from nothing to as much as $53/acre depending on the cost of water. Cooperator B has the potential to increase yields by as much as 50#/acre but the profit difference would range from a $24/acre loss to a $40/acre profit depending on the cost of water. As the cost of water increases, it is not economically advisable to apply additional water even if an increase in yield were to be expected.

The application of this yield response curve and its derivatives is to calculate the potential increase in yield when additional water is applied. Profit can easily be estimated when the cost of water is known. The key components to these calculations is knowing the field variability of available water. In one season, the field variability can be estimated. Although nothing can change the yield or profit for that season, changes can be made (i.e. in irrigation techniques to apply more water and reduce the variability) to obtain the maximum potential profit for the next season when the cost of water is determined.

Introduction

In Arizona, water is primarily applied to the cotton crop through flood irrigation. Field variability can result in an uneven distribution of irrigation water the length of the field. This variability can affect crop yields. Warrick & Yates (1987) proposed models to estimate change in general crop yield based on field variability of soil moisture and irrigation amounts. In a linear curve model, potential yield will increase as the irrigation amount increases up to the maximum potential yield. Additional water will not increase yield once the maximum has been achieved. As the field variability of soil moisture increases, the relationship between yield and irrigation does not change but the maximum potential yield will decrease. Warrick (1989) further described this relationship between irrigation amounts and maximum yield as the result of the variability of available water and salinity of irrigation water.

A generalized crop yield response curve (Figure 1) can be used to estimate general yield potential based on the variability of available water in the field and the amount of water applied to the crop. Water Applied (W) and Yield (Y) have replaced the *x* and *y* axes. Yield can be estimated by determining the amount of water applied, but the maximum potential yield for any given amount of applied water varies with the variability of available water in the field. In general, highly variable fields will result in lowered maximum potential yields.

As the cost of water increases in the desert southwest, there is considerable interest in conserving water resources thus reducing costs associated with cotton farming. As growers try to reduce costs by cutting back on water applications and amounts, there can be reductions in yields associated with these cutbacks. Also, if water applications are cut back too much then crop stress may result and reduce yields even further. The critical growth stages in cotton production are the flowering periods (Hiler&Howell 1983) and the most important period to avoid water stress is at peak bloom. When water is cheap, there is a trend to apply excessive amounts of water during the season. This additional water could result in yield increases as shown in Figure 1.

The object of this paper is to demonstrate economics associated with an estimated yield production, variable water costs, and variable rates of water applications to calculate the maximum economic return based on these three variables.

Materials and Methods

Field data was obtained from two cotton fields in 1991 (Cooperators A and B) located in Central Arizona in cooperation with the Hydrologic Unit Area Study. Each field was monitored throughout the season for available soil moisture. There were four plots the length of each field and both fields each were a length of 1200' with a slope of .1%.

A neutron probe was used to monitor soil moisture before and after each irrigation after the first irrigation of the season. Data obtained from the neutron probe was used to calculate the variability of available soil moisture in the crop

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root zone. A 4' depth was assumed to be the effective root zone for cotton.

The yield response curve is a modification of the general crop yield response curve from Figure 1. A hypothetical maximum yield was assumed for each variety. The maximum lint yield of any variety is genetically predetermined and modified by environmental pressures, so the maximum yield will differ for any one variety based on the growing season , location, or one of any number of environmental pressures. It is, as a matter of simplicity, assumed here that water is the only variable accounting for lint production and that all other factors remain constant. The evapotranspiration rate from AZSCHED, an irrigation scheduling program, is also used to calculate the yield curve for the different field variabilities.

A maximum lint yield of 1100 lbs/acre was assumed for the variety DP 5816 grown in Cooperator A's field and maximum lint yield of 1300 lbs/acre was assumed for the variety Pima S-7 grown at Cooperator Bs field. Yield responses for each variety at different levels of field variability are based on these maximum yield potentials.

The profit response curve is a modification of the yield response curve for each variety. Profit is calculated simply by multiplying the estimated lint yield by the market prices and subtracting the cost of water. There is no accounting for any other operational costs.

Result and Discussion

Cooperator A

The seasonal variability of plant available soil moisture for Cooperator A can be seen in Figure 2. As the season progressed, the variability of available soil moisture increased steadily and was always greater before irrigation than after irrigation. At the end of the season, the variability peaked at a high of 72% before and 47% after irrigation. At the same time the variability was increasing, the actual amount of available water was decreasing (Figure 3). The greatest amount of available water present in the root zone after irrigation was 6.0 inches. Typically, an irrigation is scheduled when 50% of the available soil moisture is depleted. This should prevent any water stress sustained by the crop. The last five irrigations were scheduled at a time when at least 50% of the moisture was depleted. In addition, the amount of irrigation water applied at these times did not refill the soil profile. Cotton is at peak bloom during this time and water stress will cause the blooms to drop and result in a reduction in yield. Unfortunately, this cooperator was doing just that.

The amount of available water in the field before irrigation is not uniform (Figure 4). There is substantially more available water prior to irrigation at plot 4, the tail end of the field, during the last four irrigations. The amount of available water in the field after irrigation shows a similar pattern (Figure 5). There is consistently more water available at plot 4, the tail end of the field, than at the other three plots. These two graphs indicate that more water is being distributed to the tail end of the field at this time of the season.

Yield and Profit Response Curves 'A'

A yield response curve has been adapted from the original response curve (Figure 6). Lint yield and water applied have replaced the x and y axes. A maximum yield of 1100 #/acre with an evapotranspiration amount of 24" water (ET) were used to produce the response curves for Cooperator A. The actual yield obtained from Cooperator A was 985 #/acre with 41" of applied water. The maximum variability of available soil moisture was 72%. At this theoretical maximum yield and a 72% variability, the actual yield will fit within the response curve quite well. There is a possibility for increased yield. A reduction in variability or an increase in applied water or a combination of both might increase yield for this grower.

The application of additional water could be as simple as allowing an additional 1" of water to be applied at each irrigation. This may also result in a reduction of the variability of available soil moisture by increasing the amount of available water in plots 1, 2, and 3. If this can reduce the variability of available water to just 50%, then the yield may increase as much as 96 #/acre.

An increase in yield may not necessarily result in an increase in profit. The yield response curve has been modified again to reflect a net profit ($Lint profit-$water cost) against the amount of water applied. The cost of water in Central Arizona varies yearly and so do the profit margins (Figure ???).

For a water cost of $25/acre-ft, the profit Cooperator A received was $604/acre (Figure7). By applying an additional 7" of water, the profit would increase by ~$15/acre and this is assuming that the variability of available water remains constant. If the additional water were also to reduce the variation of available water to ~50%, then a potential profit increase of ~$53/acre would be expected. When the water cost increases to $65/acre-ft, the profit is reduced to $467/acre (Figure 8). The application of additional water would not increase profits in itself but only if the result was to reduce the variation in available water and the increase would be about $30/acre.

For these three water costs for Cooperator A, there is still a potential increase in profit when additional water is applied. If the variability of soil moisture is reduced as the amount of applied water increases then profits can be maximized, but when the price of water increases, this potential profit is reduced or even eliminated in some cases.

Cooperator B

In contrast to Cooperator A, the variability of available water remained fairly constant in this field at Cooperator B (Figure 9). There was no definite difference between before and after irrigation soil moisture variabilities and the highest variability reached was only 33%.

The average amount of available moisture in the field remained constant for both amounts before and after each irrigation (Figure 10). The most water available in the root zone after irrigation was 6.5 inches and the least amount of water present in the root zone before irrigation was 3.6 inches. This amount is well above the 50% depletion level, so little or no stress should have occurred.

The amount of available water in the field before irrigation is fairly uniform (Figure 11). There is more available water located at plot 4 at the tail end of the field for most of the season, but the amount of water present at each plot has remained somewhat constant throughout the season with the exception of Plot 3. This plot was located in a high spot in the field and the amount of water present is much lower than the other three plots. The amount of available water in the field after irrigation shows a similar pattern (Figure 12). There is consistently more water available at plot 4 and less available at plot three but the amounts available are fairly consistent throughout the mid to end of season.

Yield and Profit Response Curves ' B'

This yield response curve has also been adapted from the original response curve (Figure 13). A maximum yield of 1300 lbs/acre and an evapotranspiration amount of 30" water (ET) were used to produce the response curves. The actual yield obtained from Cooperator B was 1250 lbs/acre with 46" of applied water. The maximum variability of available soil moisture was 33%. At this theoretical maximum yield and field variability, the actual yield will fit in this response curve quite well, and there is possibility for increased yield but not as great as was possible from Cooperator A because this field is quite a bit less variable.

Again, an application of additional water could be as simple as allowing an additional 1" of water to be applied at each irrigation. This may result in a reduction in the variability of available soil moisture by increasing the amount of available water in plots 1, 2, and 3. And if the variability were reduced to ~25%, the additional 14" water should increase the yield by 50 lbs/acre.

Again, an increase in yield may not necessarily result in an increase in profit and depending on the cost of water may actually result in a loss. The profit response curves for two different water costs for Cooperator B show different possible profits than what was obtained for Cooperator A (Figures 7 &8).

For a water cost of $25/acre-ft, the profit Cooperator B received was $1154/acre (Figure14). By applying an additional 14" of water, the profit would increase by $23/acre and this is assuming that the variability of available water remains constant. If the additional water were also to reduce the variation of available water to ~25%, then a potential profit increase of ~$40/acre would be expected. When the water cost increases to $65/acre-ft, the profit is reduced to $1000/acre (Figure 15), and any additional water would result in a potential loss of up to ~$24/acre.

For these three water costs for Cooperator B, there is only a potential increase in profit when the price of water is low. As the cost of water increases, there is actually an economic loss when additional water is applied even if the yield is increased. For Cooperator B, this can be attributed to the low variability of available soil moisture. There is simply not much to improve upon. The recommendation to a grower regarding additional water depends on the actual water cost.

Although yields will generally increase when more water is applied to a field, there is not always an increase in profit. The high cost of water will reduce or eliminate potential profit that would be gained with an increase in yields. In some cases there would actually be a loss associated with the potential increase in yield. Also, the potential profit increase is so small that it may not be worth the risk to apply the additional water. These are the cases when a field has a low variability of available soil moisture as in Cooperator B. When the field has a large variability then significant increases in yield and profit can occur. This is especially noticeable with a large variability and a low water cost as with Cooperator A. When the water becomes more expensive, there is still a possible increase in profit. The greatest increase in profit would occur when the variability of available water can be reduced.

Summary

The variability of available soil moisture in any particular field will affect yield production and the amount of profit realized by the grower. Fields with a large variabiliy in available soil moisture will result in greater changes in yield as affected by the amount of water applied. These fields will also result in greater profit changes which are less impacted by the cost of water applied to the crop. Essentially, if a field has a large variability of available soil moisture it is profitable to apply extra water to increase yield and profit.

Fields with a low variabiliy in available soil moisture will result in less changes of yield and profit as affected by the amount of water applied. It is profitable to apply extra water in these situations only if the cost of water is minimal. The yield can be increased but when the cost of water increases, any added yield will be offset by the cost of the water.

Now that the field variability has been estimated for both Cooperator's fields, decisions can be made for the management of next season's crop. A recommendation fto Cooperator A would be to apply additional water. The variaibility of the field is large enough that any additional water would result in a yield and profit increase. The recommendation for Cooperator B would be to apply additional water only if it is cheap. Expensive water would eat into the profit marginand could result in a net loss in potential profits.

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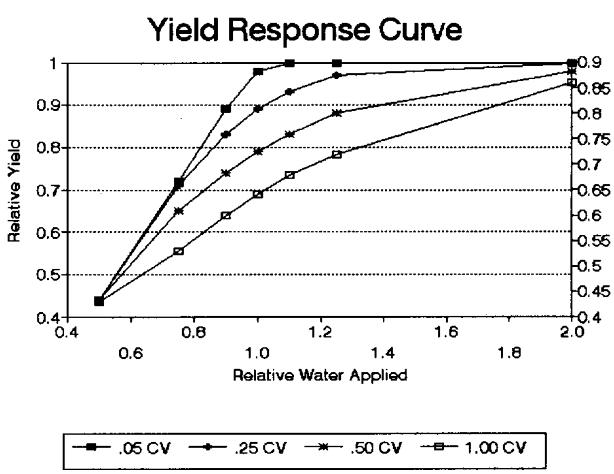

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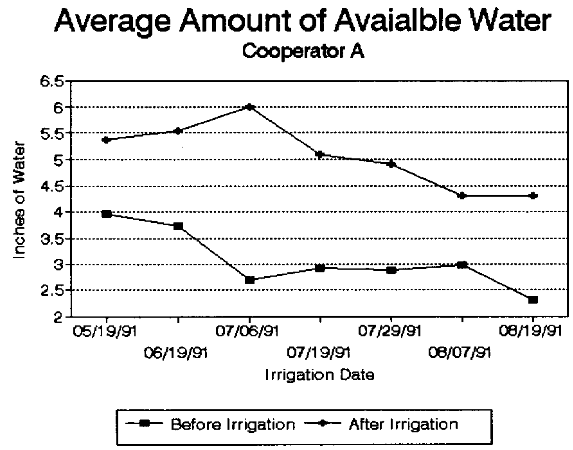

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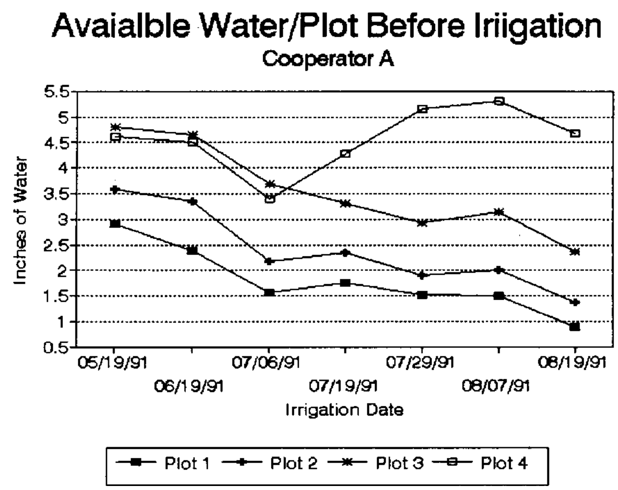

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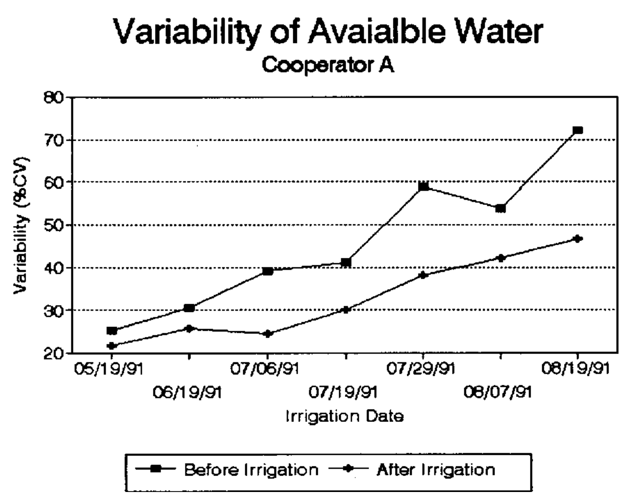

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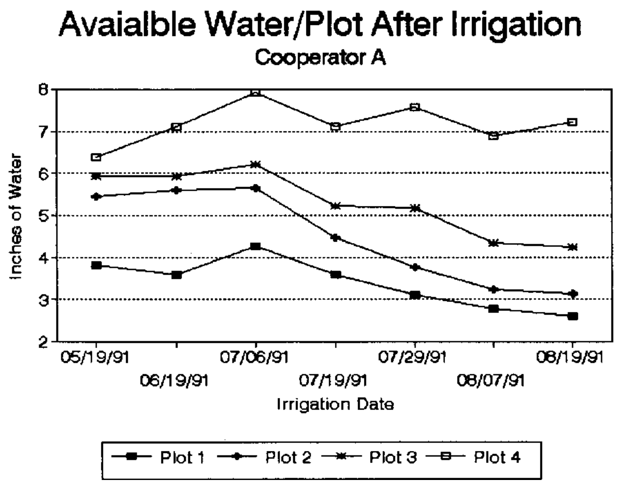

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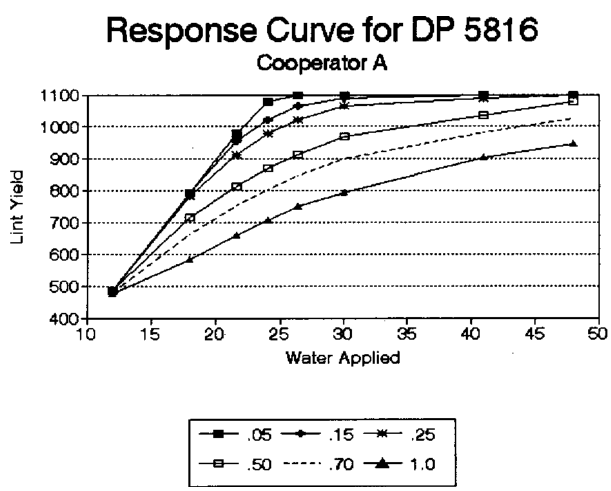

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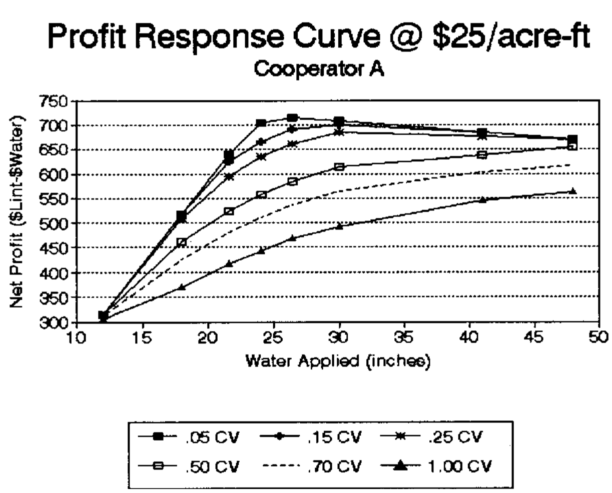

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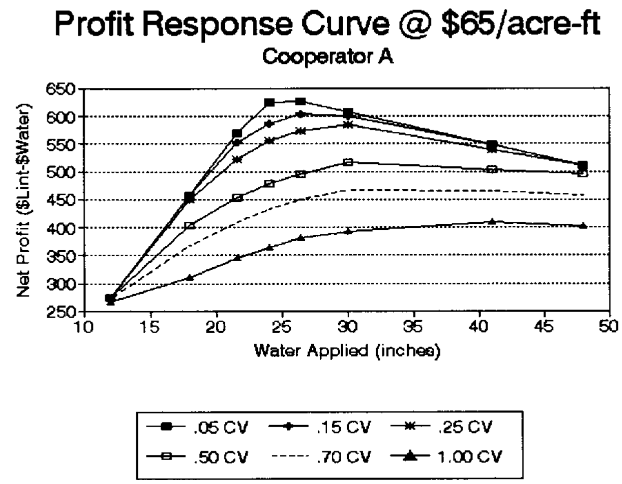

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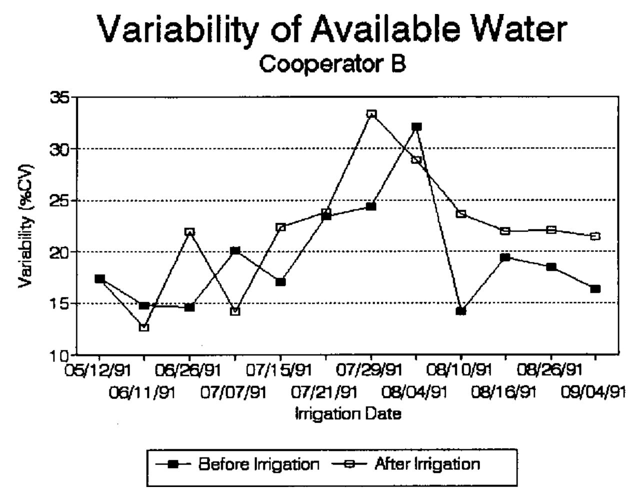

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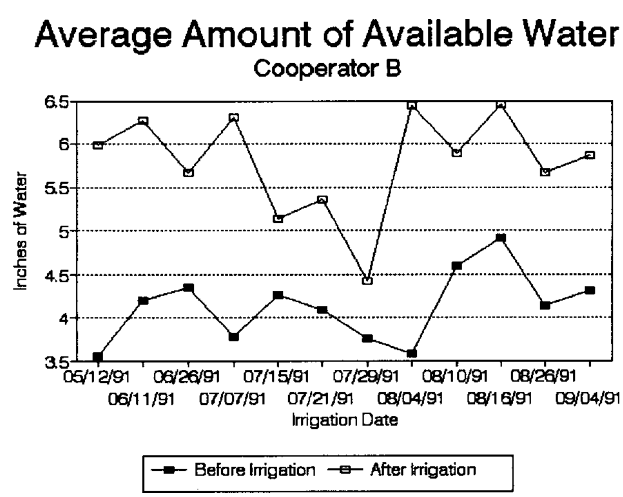

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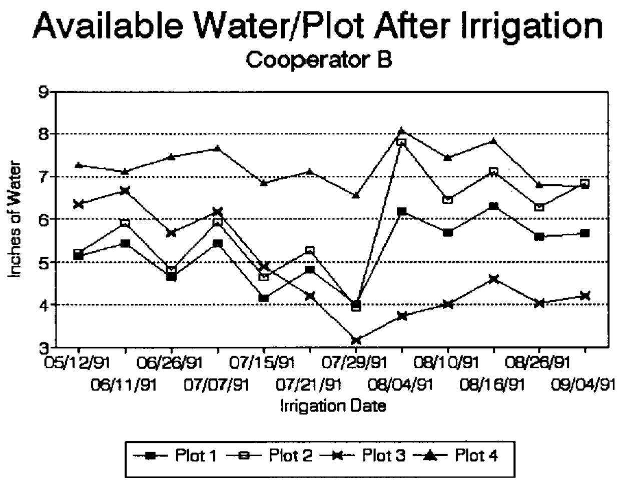

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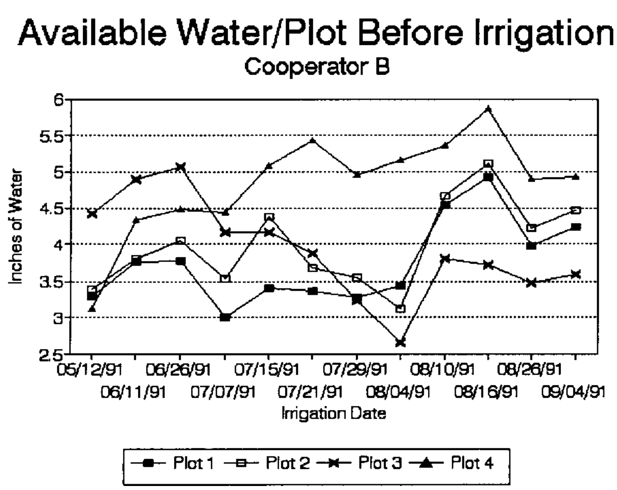

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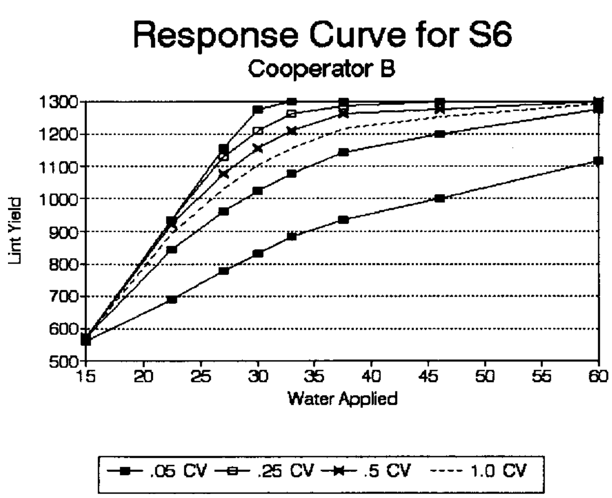

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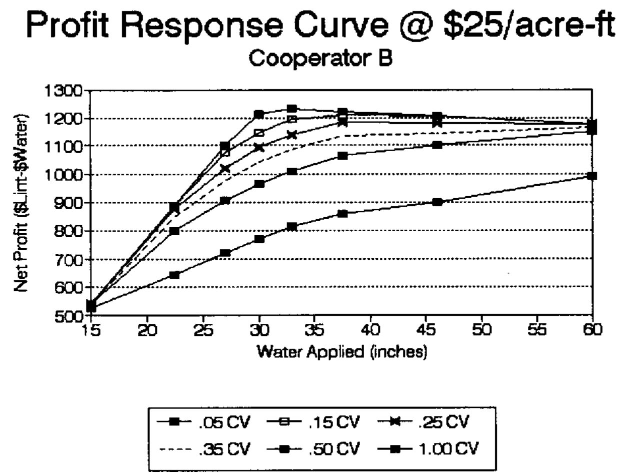

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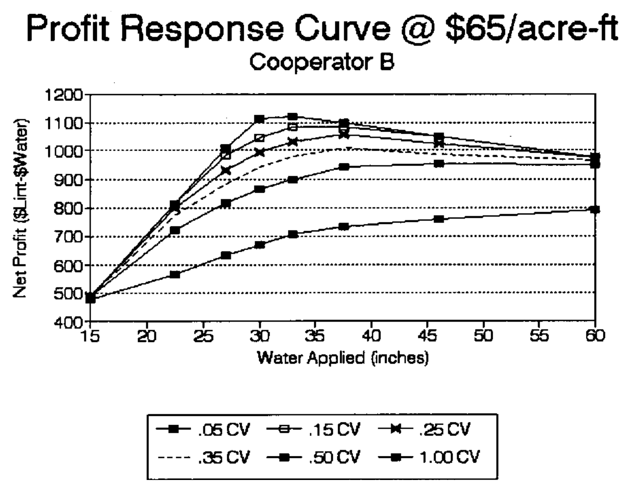

Figure 15.