PRACTICAL STRATEGIES FOR ACHIEVING HIGH YIELDS

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Introduction

High yields are considered to be any level of yields significantly higher than the maximum county level yields. Producers often use the county level yields as their metric to determine their status among the rest of the producers in the county and to normalize for any potential local weather variation (e.g., lack of rainfall, excess rainfall, hail, high winds, etc.). There is no magic formula for determining how much above the county level yields producers want to be to consider themselves in the high yield club. Another metric that is often used is an evaluation of the production history of the soils they have on their farms. Degraded and eroded soils are not capable of producing the same level of production as a field in which the soil has been maintained and enhanced through management. All producers desire to achieve these levels of yield above the county average; however, they would like to obtain these yields on a consistent basis rather than in a single occurrence.

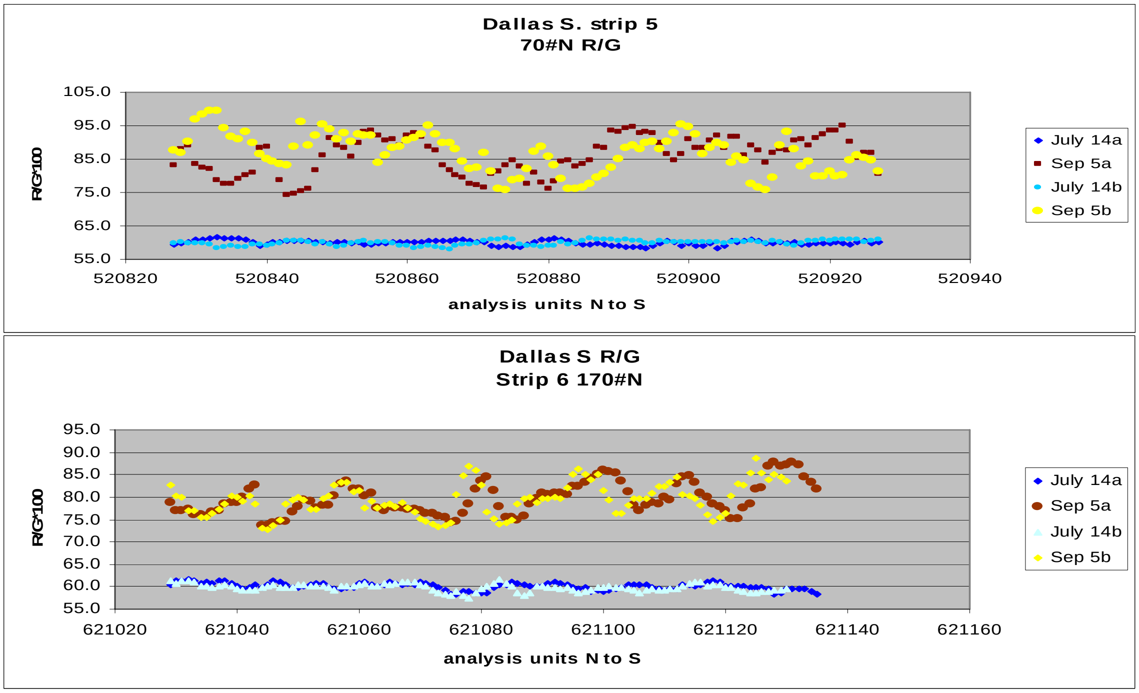
There is no magic formula for producing high yields. Over the past 100 years of agronomic research there has been a continual pursuit of high yields as a measure of being able to properly manage the system. There are no single additives that one can add to the soil or onto the plant that will remove all of the limitations and achieve these high yields. There are, however, strategies that provide a pathway toward being able to more fully understand how to overcome the yield limitations. These approaches represent the integrated efforts from a number of field-scale studies that define how yields respond to various management factors. The approach that has been used in these studies is to dissect the parameters that limit yield and when these effects have occurred during the growing season.

Field-Scale Yield Responses

One of the interesting observations is the sequence in the variations that have been observed across fields throughout the growing season. All fields exhibit a variation in reflectance from the different soils present within the fields. Lighter colored soils reflect more solar radiation and appear brighter to the eye than soils with higher organic matter that appear darker to the eye. In the visible wavelengths there is a large variation among soils within a field. As the crop develops, this variation begins to diminish and, at the maximum vegetative growth near the beginning of the gain-filling period, there is often no variation present in the field. The use of aerial photographs or satellite images confirms there is little variation in the amount of vegetative biomass produced across the field.

An example of this response is shown in Figure 1 for a field in Dallas County, Iowa. Observations made at the time of maximum vegetative growth showed little variation across the field but during the middle of the grain-fill period there was considerable variation in the red/green reflectance vegetative index. This index is a measure of green leaf area of the crop canopy (Weigand and Hatfield, 1988). A similar pattern of increased variation was observed in both the 70 and 170 lbs N/A. This pattern of increased variation during the grain-fill period has been observed in most of the fields and only those areas which maintain the leaf area produce yields that are the highest within the field.

Figure 1. Variation in reflectance index across two nitrogen application rates across a field in mid-July (maximum vegetative growth) and early September (mid-grain fill) for a cornfield in Dallas County, Iowa, 2003.

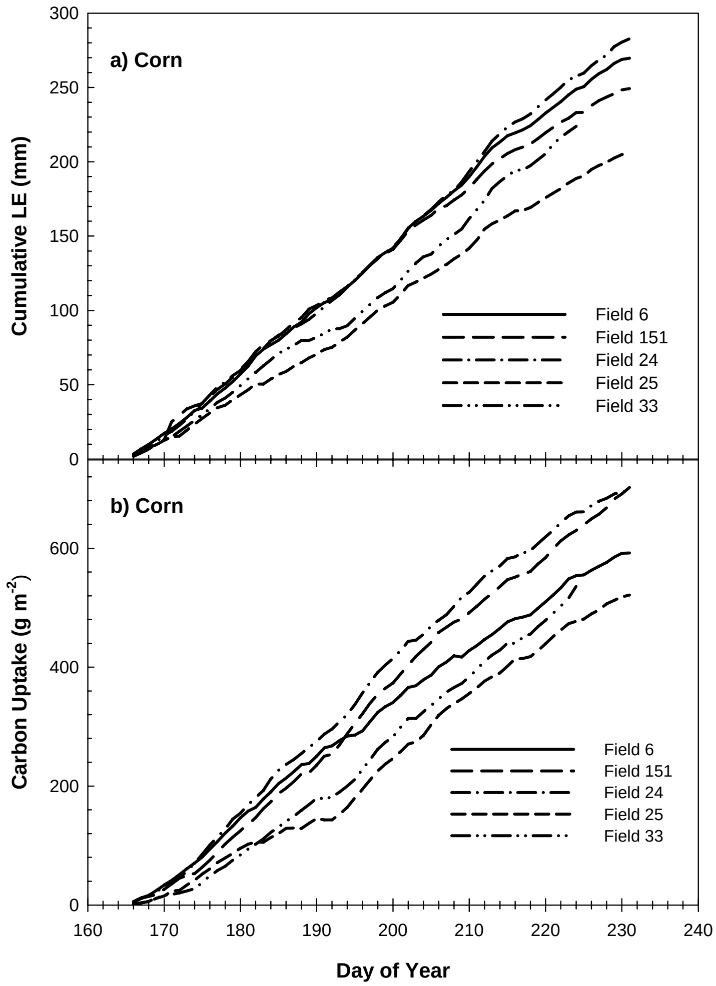


These patterns in reflectance are induced by the patterns in soil water availability across the field. In other studies on the spatial and temporal variation in carbon and water exchanges across a number of production fields in central Iowa, we have found that the major source of variation is due to soil water availability and small differences on an given day can multiply into large differences in biomass or leaf area over the course of the growing season (Hatfield et al., 2006). Recognizing these differences among fields as illustrated by the variation in water use and carbon exchange helps to define why attempts to achieve high yields do not always produce the expected results (Figure 2).

Water Limitations

Water use patterns by crops and water limitations are the primary factors that reduce crop yields. Across the Corn Belt it is often assumed that water is not a major limitation to yield except in dry years; however, we have observed that crop water use patterns vary by a factor of two within a field caused by the variation in soil water holding capacity and the precipitation patterns during the latter part of the growing season (Hatfield and Prueger, 2001). This is best expressed by examining the water use efficiency of the crop. Hatfield et al. (2001) provided an analysis of the value of water use efficiency as a measure of agronomic response to management and the insights this parameter provides to helping compare cropping systems. Efficiency parameters (e.g., water use efficiency) help normalize among cropping systems and management and are not utilized enough to effectively use these in evaluating farming systems. Across a number of different experiments we have observed that there are reductions in water use efficiency induced by the onset of water stress during the grain-filling period. These stresses induce as much as a 30-50% reduction in water use efficiency.

Figure 2. Variation in cumulative latent heat of evaporation (water use) and carbon uptake for five different fields in corn in central Iowa during the 2002 growing season (Hatfield et al., 2006).

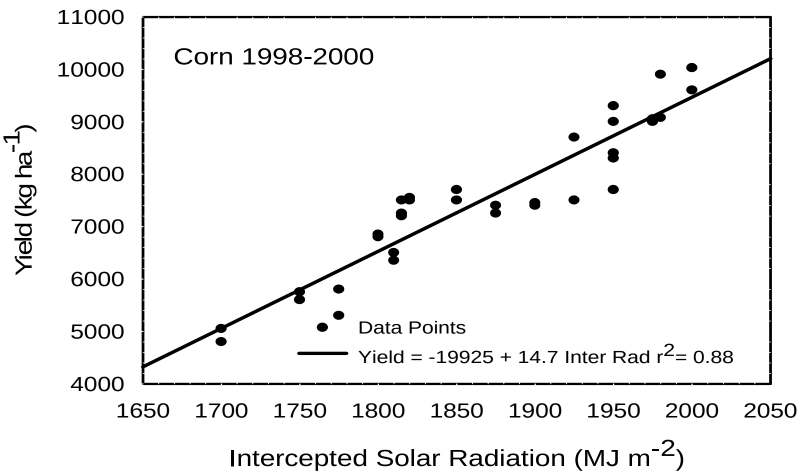


Light Use Efficiency

High yields will only occur when the capture of light is at the optimum level to drive the photosynthetic process. Crop yields are a direct function of the intercepted solar radiation as shown in Figure 3 for corn across three growing seasons. These data represent the cumulative total of intercepted radiation from planting until harvest and there is a linear relationship between corn yield and cumulative light intercepted. However, there are a number of studies when we combined data across fields and years that are displaced below this line in Figure 3. These observations illustrate that crop yield was not commensurate with the amount of light intercepted.

A further examination showed that these relationships are defined by the development of the vegetative biomass that produces a potential yield that is not realized because of the soil water limitations during the grain-filling period. Although there was a canopy present to intercept the solar radiation there was not sufficient soil water to allow the grain filling process to occur without some reductions. The result is that we have light interception but a low crop yield and hence a low light use efficiency. There are situations in which there is leaf area present to intercept solar radiation but the sink to store the fixed carbon in the form of starch for grain-fill is limited. Limited sink size may be due to an early season stress that limits ear size in corn or causes pod abortion in soybean. Understanding the changes in the sink dynamics in response to various stresses during the growing seasons provides us insights into the factors that prevent the crop from achieving high yields.

Figure 3. Cumulative intercepted solar radiation as related to corn yield for three years in central Iowa.

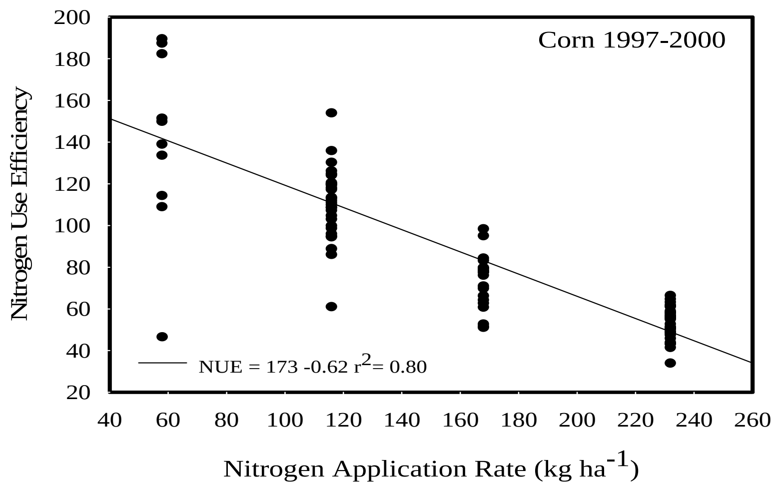


The totals in cumulative solar radiation show a large variation among years. Across the Midwest, years with high precipitation totals during the growing season have more clouds and reduced solar radiation. In rainfed crop production systems there is a balance between adequate soil water and solar radiation to produce high yields.

Nitrogen Use Efficiency

Nitrogen (N) application to corn is considered to be one the primary additions required to achieve high yields. The assumption is that high yields are only possible with high rates of N; however, the return on the N investment must be carefully considered. In order to achieve the high return on N there has to be an adequate supply of soil water throughout the growing season. An illustration of this effect is shown in Figure 4 for a corn crop across a field in four different growing seasons. There is a decline in N use efficiency with increasing N rate. This is typical of the response we have observed across fields that produce average yields. The variation in yield at a given N rate is induced by variation in soil types with the soils that have the higher water holding capacity having the higher N use efficiency (Figure 4). These data illustrate the role that water availability has in producing high yields. The different data sets that have been collected across years illustrate that yields respond to a number of different factors that provide insights into how to produce high yields.

Figure 4. Nitrogen use efficiency as a function of nitrogen application rate for corn grown in central Iowa from 1997-2000.



Strategies for High Yields

Achieving high yields requires a soil that can supply adequate amounts of water during the growing season. If it were this simple then irrigated fields would typically have yields that exceed all other fields. This is not always the case, suggesting that there are other limitations to yield. When it comes to strategies, high yielding crops are produced:

- On soils that have high organic matter content and large water holding capacity.
- On soils that have no compaction layers.
- On soils that have no limitations to crop growth during the early portion of the growing season.
- On soils that have high organic matter content that release CO_2 to the growing crop.
- On soils that supply adequate soil water throughout the growing season but are not waterlogged.
- On soils that supply adequate nutrients to the crop throughout the growing season.
- In environments that do not have extreme temperature events during pollination and that have relatively cool night temperatures during the grain-filling periods.
- In environments that have maximum amounts of solar radiation throughout the growing season.

These factors link the soil and meteorological conditions as the primary factors that produce high yields. The first step to producing high yields is to improve the soil and ensure there are no barriers to root development. The impact of the early season growth has been underestimated as a factor contributing to high yields. The patterns of precipitation and crop water use throughout the growing season are often the two factors that are not easily controlled; however, these are probably the most critical limitations to yields. Increasing soil organic matter content and rooting depth in the soil increases the soil profile available to the crop and the water holding capacity. This helps buffer small variations in precipitation and particularly during the grain-filling period when precipitation events tend to recharge the soil profile at a slower rate than crop water use. This effect is responsible for the yield variation across fields that are often observed by producers.

Conclusions

Achieving high yields is not an art but requires the implementation of an understanding of the principles that affect yield. To achieve high yields requires patience to first improve the soil and then begin to adopt management strategies that increase the efficiency of water, solar radiation, and N use. Evaluation of how these factors respond each season for the crops grown in the field and then compare against the county average will determine if progress is being made toward achieving the higher yields.

References

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