EC3000

What Does It Take to Produce 80+ bu/ac Soybean?

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The average yield for this producer's field near Atkinson, Neb., was 84 bu/ac in 2015. An adjacent field, managed by the same producer, yielded 92 bu/ac. The photo was taken in early August by Nicolas Cafaro, UNL agronomy and horticulture graduate student.

Yield Potential, Actual Yield, and Yield Gap

Yield potential is defined as the yield of the best adapted crop cultivar when grown with optimal management, non-limiting water and nutrient supplies, and perfect control of weeds, insect pests, and diseases. Weather during the growing season (sunshine, temperature, rain) will determine the yield potential in a given field and in a given year *(left red bar in Figure 1)*. However, actual farm yield is typically below yield potential due to yield limiting factors, including: water, nutrients, non-ideal crop management, soil physical and chemical constraints, insects, weeds, etc. *(right green bar in Figure 1)*. The difference between yield potential and actual yield is called the "yield gap." Producers have an opportunity via their management techniques to narrow the current yield gap and increase the odds of capitalizing on the yield potential in any given year.

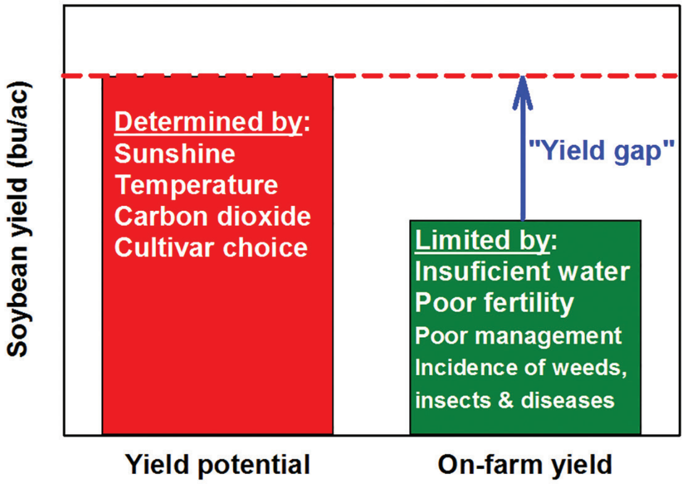

Figure 1. Yield potential (left red bar) and actual farm yield (right green bar). The arrow indicates the yield gap; that is, the difference between yield potential and actual farm yield.

Explaining Soybean Yield Gaps Using Nebraska Producer-Reported Data

We know from previous research that the current soybean yield gap in Nebraska is relatively small. However, depending upon region and year, the size of the yield gap differs across soybean fields. Some producers attain yields very close to the yield potential (i.e., only 5–10 percent below), while others attain yields far less than what might be achievable (30 percent or more below potential). This publication documents the key factors that determine actual yield in irrigated and nonirrigated soybean fields in Nebraska based on yield and management survey data collected from producers' soybean fields during three years.

The ultimate objective of the survey was to identify key factors explaining yield gaps in producer soybean fields in Nebraska and to understand what is needed to produce soybean yields of 80+ bu/ac consistently. We collected data from more than 500 irrigated and nonirrigated soybean fields in Nebraska in 2010, 2011, and in the 2012 drought year. A sample of 500 fields in three years of contrasting weather can provide sufficient data to determine factors impacting most of the state's soybean yields, and also factors that may be affecting only some sub-state regions.

The red symbols in *Figure 2* show the location of the surveyed producer fields. We collected detailed information from each of these 500 fields, including yield, management, and applied inputs. The surveyed fields across the state were well distributed, covering the majority of the Nebraska soybean-producing areas and were representative of the diversity of management practices and soil types statewide.

Water Supply Sets an Upper Limit to Soybean Yield

Figure 3 shows producer-reported on-farm actual soybean yield (vertical axis) for various nonirrigated and irrigated fields *versus* the total amount of seasonal water supply (horizontal axis). Water supply includes available soil water at planting (0–5 foot depth) and in-season rainfall plus irrigation. Blue and yellow symbols correspond to the irrigated and nonirrigated fields, respectively. Each data point corresponds to an individual field in a given year.

Obviously, most irrigated fields (blue) are not typically water-stressed during reproductive development because of well-timed irrigation, and thus have the highest yields in this graph *(Figure 3)*. It is clear that water supply sets an upper limit to soybean yield. About 25 inches of seasonal water supply are needed for maximum yields. Increasing the water supply above the 25-inch level does not benefit soybean yield.

For the majority of years and regions in Nebraska, it is very difficult to achieve 80 (or more) bu/ac without irrigation. The leftmost red line is a best-fit boundary function for the response of soybean yield to water supply, which is estimated to be 3.7 bu/ac per inch of seasonal water supply *(Figure 3)*. Attaining yields (producer symbols) near that red line is equivalent to getting a greater "yield bang per water buck" compared to attaining the same yield but farther to the right of the red line. Nonirrigated and irrigated field data points near that red line reflect the highest yields possible for each inch of water (3.7 bu/ac inch), which in scientific terms is referred to as soybean Water Productivity (WP).

However, along the range of water supplies, most producer fields were well below their attainable water productivity because of (A) "vertical" yield gaps (yields below (↓) their red-line potential); (B) "horizontal" water gaps (yields to the right (→) of the red line), which means a water supply in excess of the minimum crop water requirement; or (C) both. Other Nebraska Extension publications have addressed in detail how it is possible to increase profit by increasing or maintaining soybean yields using less, but more suitably timed applications of irrigation water. See the NebGuides Managing Furrow Irrigation Systems (G1338), Irrigating Soybean (G1367), Predicting the Last Irrigation of the Season (G1871); and the Extension Circulars, Irrigation Scheduling: Checkbook Method (EC709), and Principles and Operational Characteristics of Watermark Granular Matrix Sensor to Measure Soil Water Status and its Practical Applications for Irrigation Management in various Soil Textures (EC783). Also check SoyWater (http://hprcc-agron0.unl.edu/soywater/), a web-decision irrigation tool for soybean producers in Nebraska.

The framework presented in *Figure 3* is very useful in determining what individual producers can do to alter their field-specific soybean management practices to shift their

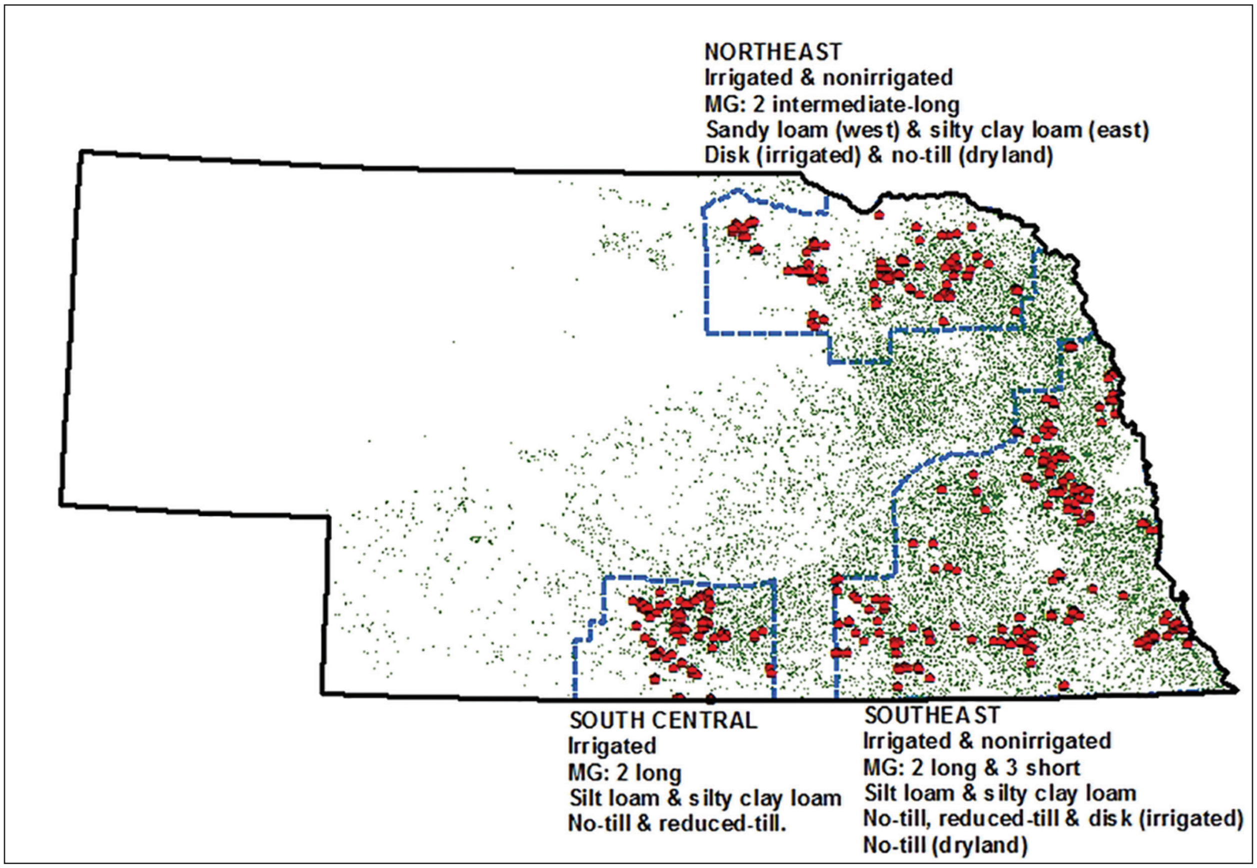

Figure 2. Map showing location of surveyed soybean producer fields in Nebraska. Data were collected during three years of contrasting weather conditions: 2010, 2011, and 2012. Fields were grouped into three regions: south central, southeast, and northeast. Dominant water regime, maturity group (MG), soil texture, and tillage method (by water regime) are indicated for each region. Soybean harvested area is indicated in green.

yields leftward (to get the same yield for less water), and/or to shift their yields upward (to get higher yield for the same amount of water). For example, what symbols in the chart correspond to the yields **you** typically attain on **your** fields? Moving your field yields left and up-ward in the graph will, in net profitability terms, enhance revenue and reduce costs.

Benchmark your soybean yields against the attainable yield based on your seasonal water supply level, using *Figure 3.* You just need soybean yield records from previous years as well as the variables needed to estimate the seasonal water supply (irrigation, in-season rain, and available soil water) at planting. To learn how to estimate stored soil moisture at planting, check the Extension Circular Evaluation of Water Productivity and Irrigation Efficiency in Nebraska Corn Production (EC105). Ultimately, plug your yield and water supply values into the figure and see how close your fields are to the red boundary function. If they are too far, your current crop and/or irrigation management can be further optimized to increase your net profit.

Yield Penalty Associated with Late Soybean Planting

Early planting is also key to reducing the yield gap. Early planting helps build a canopy that "harvests" most of the available sunlight, especially during crop stages that are crucial for yield formation (between early pod setting (R3) and end of seed filling (R7) for soybean). *Figure 4* shows the producer self-reported yields (vertical axis) plotted against self-reported planting dates (horizontal axis) for irrigated (blue) and nonirrigated (yellow) soybean fields in southern Nebraska (left graph) and northeast Nebraska (right graph).

The dashed line ("boundary function") was derived from the observed highest yields across the range of planting dates. This boundary delimits the potential yield for soybean for a given planting date. Reaching—or not reaching—that potential yield will depend on other factors such as seasonal water supply, in-season weather, field-specific soil properties, and other producer- and field-specific management practices besides planting date.

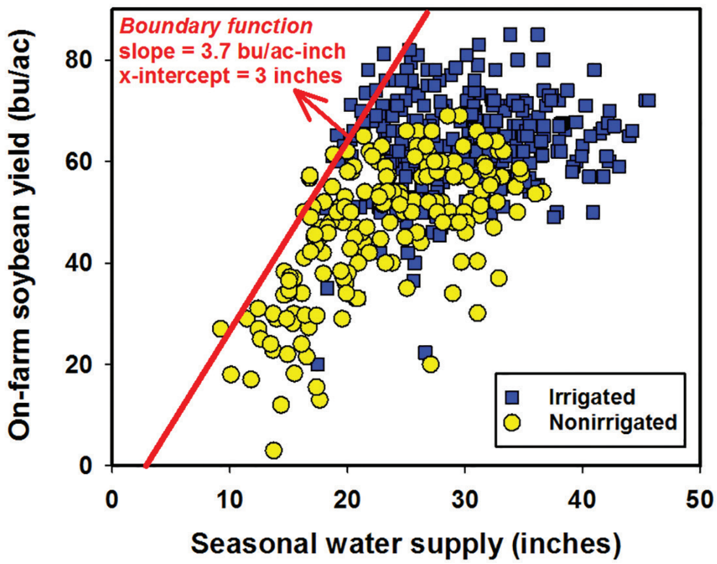

Figure 3. Producer soybean yield *versus* seasonal water supply. Seasonal water supply includes available soil water at planting (0–5 feet) and in-season rainfall plus irrigation. Yellow and blue symbols indicate non-irrigated and irrigated fields, respectively. Each data point represents an individual field-year observation (total: 509). The red line represents the maximum yield response to water supply increase.

Also note that most nonirrigated fields are below the potential yield boundary *(Figure 4)* because in nonirrigated production scenarios, insufficient water supply imposes the main upper limit to soybean yields *(Figure 3)*. There was a yield penalty of ½ bu/ac for southern Nebraska and an even bigger penalty of ¾ bu/ac for northeast Nebraska in potential yield (bu/ac) per day of delay in planting date *(Figure 4)*. These values represent the "opportunity cost" of planting soybeans late. To avoid that cost, you want to plant soybean early to get that soybean field "green to the eye by the 4th of July" (i.e., you want soybean leaves, not the ground, to collect that sunlight by the calendar date around which R3 is reached in most years).

For a given farm, the overall opportunity cost can be estimated by multiplying the daily yield penalty by the number of acres, the current soybean price, and the extent of delay in planting. For example, given an average soybean price of $9/bu, the estimated lost benefit of planting soybeans in a 160-acre field in southern Nebraska on May 8 (seven days after May 1) would be $5,000 (7 x ½ x 160 x 9 = $5,000). That would be a nice net bottom line return to a producer who simply elects to plant that 160-acre field one week earlier. Check your planting date in previous years and use *Figure 4* to estimate your opportunity cost associated with a late soybean planting. To learn more about planting date impact on soybean yield, check the Extension Circular Soybean Planting Date-When and Why (EC145).

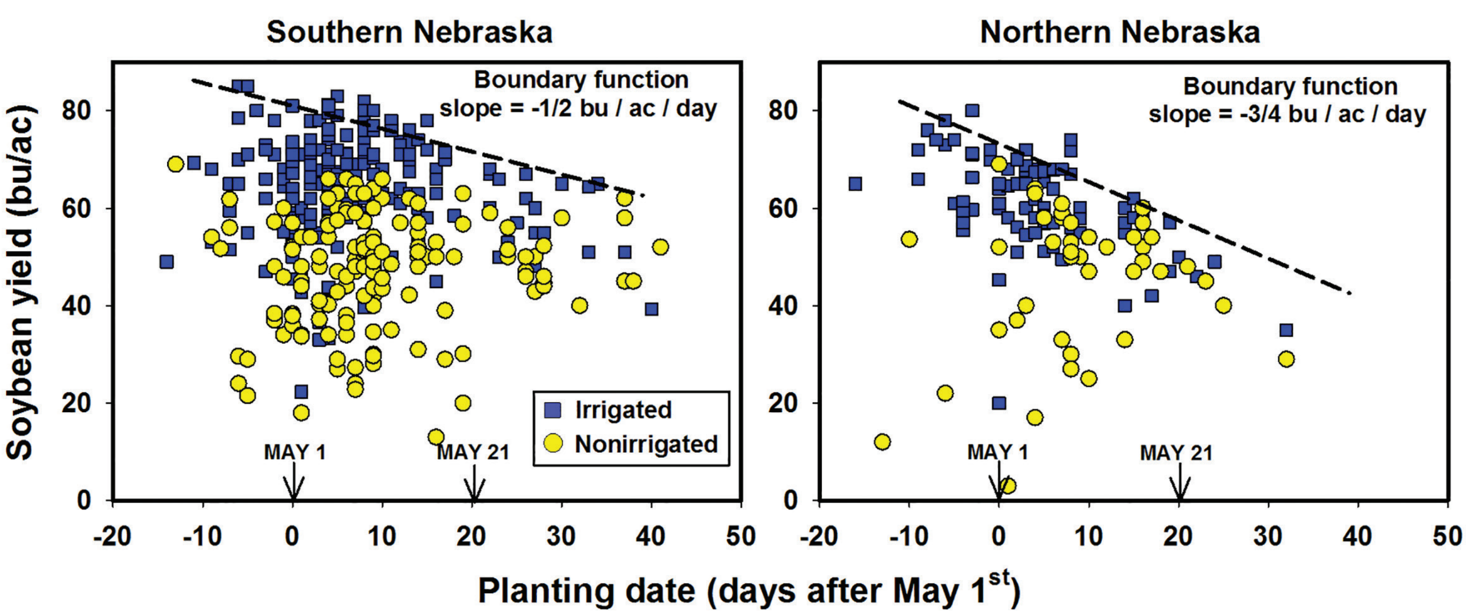

Figure 4. Soybean yield *versus* planting date in southern (left) and northeast (right) Nebraska. Southern Nebraska includes the south central and southeast regions shown in Figure 2 because these two regions exhibited a similar yield response to planting date delay. Planting date range is shown relative to May 1. Each data point represents an individual field-year observation. Yellow and blue symbols indicate nonirrigated and irrigated fields, respectively. The dashed line represents the yield potential response to planting date delay after May 1.

Tillage Method Impacts Irrigated Soybean Yield

Sufficient water supply and early planting are preconditions for high soybean yields in the 80+ bu/ac range. Other factors can also be optimized to further increase soybean yields but an objective cost-benefit analysis is always needed to make sure about their viability.

Figure 5 shows the impact of tillage on soybean irrigated yield in 2010 and 2011 in southern Nebraska. We were not able to perform a similar comparison between tillage methods for nonirrigated fields as we found that >80 percent of them are no-till, suggesting producer recognition of an advantage of no-till in nonirrigated conditions.

Irrigated fields were grouped into two categories: (i) no-till and (ii) reduced-till or disk. Reduced-till included ridge- and strip-till. Each bar in the graph indicates average irrigated yield for regions and years (indicated in the horizontal axis) for which a sufficient number of fields were available for the comparison. The numbers in the boxes are averages for the mean temperature between April 15 and May 15.

The results do not show a yield advantage for no-till when compared with reduced- or disk-till *(Figure 5)*. But there was a yield penalty (2 to 6 bu/ac) in three of the four cases that we analyzed, which corresponded to years with cooler early-season weather. The observed penalty in irrigated fields may have been partly due to later planting in no-till fields, which was three to four days later compared with reduced-till or disk, and delayed emergence due to lower topsoil temperature under the heavy residue from the previous corn crop.

Despite the lower yield associated with no-till in years with cooler spring weather, other factors can counterbalance the no-till yield penalty, such as attaining soil erosion control, better capture of pre- and in-season precipitation leading to lower irrigation water requirements, and lower fossil-fuel use for field operations. The following Nebraska Extension NebGuides provide a comprehensive review on tillage methods: Choosing the Right Tillage System for Row Crop Production (G1516), and Tillage and Crop Residue Affect Irrigation Requirements (G2000).

Are Nutrients Limiting Current Soybean Yields in Nebraska?

Nutrient requirements in a high-yield soybean crop are high. An 80 bu/ac soybean crop will accumulate around 380 lb/ac nitrogen (from fixation and soil) and 40 lb/ac phosphorus (equivalent to 92 lb/ac phosphate) in the aboveground biomass. *Figure 6* shows the impact of fertilizer application on soybean yield in producer fields. Fields were grouped into three categories depending upon producer-reported fertilizer input: (i) no N or P fertilizer applied, (ii) only "starter" fertilizer applied at planting (N or P or both), and (iii) large P application (>15 lb/ac phosphorus, equivalent to >34 lb/ac phosphate), typically applied before planting.

Across the four analyzed region-year cases, we found overall higher yield in fields that received fertilizer, especially with a large P application (2 to 4 bu/ac). This effect was largest in northeast Nebraska, especially with starter fertilizer *(Figure 6)*. This does not mean that all soybean fields are nutrient-deficient. For example, some of the non-fertilized fields may have had adequate N and P levels, and the producer saw no need for fertilizer. What the data say, however, is that nutrients may be limiting soybean yields in many fields. Well-designed and well-conducted on-farm trials are necessary to confirm these preliminary findings. In the meantime, application of starter fertilizer and P should be based on soil tests and expected economic return (see the NebGuides Using Starter Fertilizers for Corn, Grain Sorghum, and Soybeans (G361), G87–859, Fertilizer Recommendations for Soybean, Guidelines for Soil Sampling (G1740), Micronutrient Management in Nebraska (G1830), and the Extension Circular Nutrient Management for Agronomic Crops in Nebraska (EC155). Another source of information about fertilizer response in soybean is the Nebraska On-Farm Research Network website: http://cropwatch.unl.edu/farmresearch.

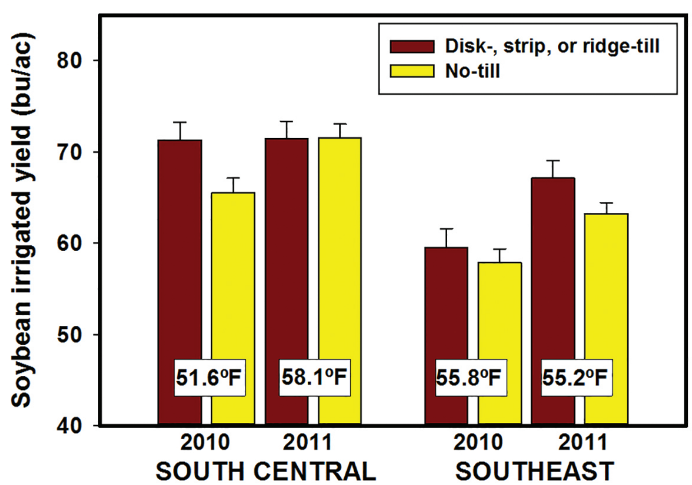

Figure 5. Average soybean irrigated yields in no-tilled fields (yellow bars) and disked, ridge, or strip-tilled fields (dark bars) in two regions of Nebraska and two years. Values inside boxes indicate the average air temperature between April 15 and May 15 in each region-year. Vertical bars indicate the standard error, which gives an idea of the yield variation across fields within the same tillage category, region, and year. Number of fields ranged from 15 to 39 across region-year-tillage combinations. There were not enough field observations in 2012 and the northeast region to perform the comparison between tillage methods.

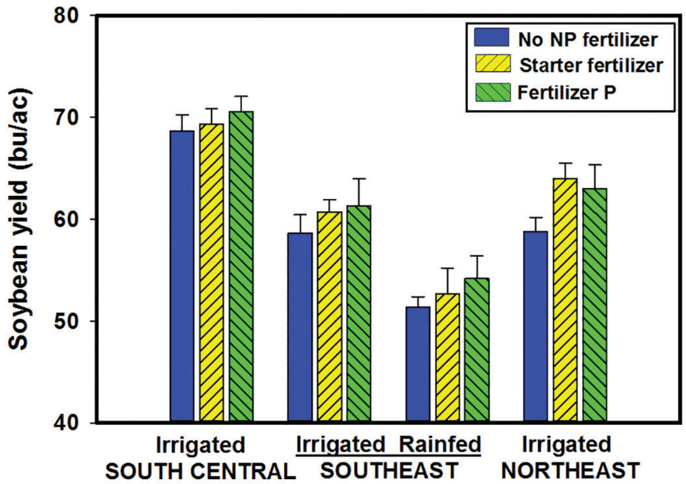

Figure 6. Average soybean yield in fields that did not receive any NP fertilizer input (blue bars); fields that received only a small N and/or P fertilizer application as starter applied at planting (yellow bars); and fields that received a large P fertilizer application (>15 lb/ac phosphorous, equivalent to >34 lb/ac phosphate) before planting (green bars). Vertical bars indicate the standard error, which gives an idea of the yield variation across fields within the same fertilizer input category, region, and year.

Which Other Factors Might (or Might Not) Impact the Soybean Yield Ceiling?

Always remember that water supply and planting date will set the ceiling for your soybean yields. You will not reach 80+bu/ac without sufficient water supply and an early planting date. The above mentioned factors (row width, seed treatment, foliar fungicide, etc.) might play a role at "protecting" your yield potential but, again, none of them will likely bring your soybean field to 80 bu/ac by themselves. More information on the impact of several management practices on soybean yield is available at the Nebraska On-Farm Research Network website: http://cropwatch.unl.edu/farmresearch. Finally, remember to test management practice changes in your field every time you can.

With the modern machinery, you can compare crop practices among replicated field strips. Check this website to learn how to create treatment strips in your own field and join the on-farm research network: http://cropwatch.unl.edu/farm-research-app1.

Cultivar Maturity Group (MG)

Selection of a full season cultivar allows the soybean crop to "harvest" most of the available sunshine during the growing season with a relatively low risk of frost in the fall. Within each region, the reported cultivar MGs spanned a narrow range of about a half unit *(Figure 2).* Most producers know the optimal cultivar MG range for their local area and for their average planting date. In early-planted fields (late April-early May), using cultivars with a slightly later maturity (no more than half MG relative to the MG planted by mid-May) is desirable to take advantage of the longer growing season and to avoid the occurrence of the stages that are crucial for yield formation (from beginning of pod setting to start of seed filling) coinciding with the hottest periods of the growing season (typically, late July and early August). However, cultivar selection based on MG cannot be at the expense of selecting a low-yield cultivar. For now, the safest producer choice is (for any planting date) to simply select the highest-yielding available cultivar amongst the MG range recommended for his/her latitudinal zone.

Our survey data also indicate that producers plant cultivars with a slightly later maturity in nonirrigated fields (relative to the cultivar MGs grown in irrigated fields). Short-season cultivars are more susceptible to a drought-induced hastening of senescence, which can shorten reproductive development in the early-maturing cultivars. This aligns those reproductive phases with the hotter part of the growing season when high temperatures tend to exacerbate the impact of water deficits. It appears that producers are aware of this phenomenon and, therefore, have chosen to grow later maturity cultivars in nonirrigated fields.

Seeding Rate

Our survey data indicate that average seeding rate is around 160,000 seeds per acre in in Nebraska, with a range from 122,000 to 205,000 seed per acre across fields. These rates are well above the required plant density for highest yields and net return (120,000 seeds per acre) as reported by the Nebraska On-Farm Research Network. Such discrepancy between actual *versus* optimal seeding rates may reflect the lower soybean seed cost compared with corn, lack of knowledge and/or trust of reduced seeding rate recommendations, and risk aversion (i.e., high density as "insurance" against any potential causes of stand reduction).

Row Width

Although we did not collect data on row spacing in our survey, most soybean fields in Nebraska (about two thirds) are planted at row widths of about 30 inches. Early-planted soybean fields that do not suffer severe water deficit during May and June will likely look "green to the eye" by the beginning of pod setting (R3 stage in soybean). In these cases, narrow row width will have little yield benefit. In contrast, narrowing row spacing should be considered for production scenarios in which crops will not reach full canopy cover by R3 as is the case of late-planted fields (from mid-May onward), nonirrigated fields that suffer severe water stress in the early growing season (June-early July), and environments with a very short frost-free growing season as those in South Dakota, North Dakota, and Wisconsin.

Seed Treatment

Approximately 70–80 percent of the surveyed fields had seed treatments (i.e., fungicide and often insecticide). Seed fungicide treatments provide protection against germination failure and seedling loss under wet, cold conditions, but might be unnecessary if these conditions are not likely to occur as is the case of late-planted soybean. Given the potential yield reward from early-planted soybeans, but which involves greater probability of the foregoing risks, most producers planting in late April and early May should seriously consider using a fungicide and insecticide seed treatment.

Foliar Fungicide and Insecticide

About 20 percent of the surveyed irrigated fields received an in-season foliar fungicide application (sometimes together with insecticide), typically around the R3 stage (beginning of pod setting). In almost all cases, fungicide/insecticide application was apparently preventive; that is, there was no visual evidence of any disease incidence calling for the application. In specific region-years, we found a small yield advantage in fields that received foliar fungicide/insecticide *versus* those fields that did not receive it. However, the response was not consistent across all regions and years, and we could not find a relationship between the yield response to fungicide/insecticide and weather conditions. Similarly, research conducted at the Soybean Management Field Days sites from 2013 to 2015 also found inconsistent (and often lack of) yield responses to foliar fungicide/insecticide treatments (http://ardc.unl.edu/soydaysresearch).

Number of Previous Corn Crops

Recent research has shown that soybean yield is, on average, about 5 percent greater after two consecutive corn crops than after only one year of corn, but this relative benefit is greater in low-yield soybean fields, compared with high-yield fields.

Key Points

Soybean yield potential is mainly driven by water supply—our analysis indicates an attainable water productivity of 3.7 bu/acre/inch water supply. Most soybean fields have values well below this value, which means that there is room for increasing profit by increasing yield for the same amount of water supply, or by maintaining yield while reducing irrigation amounts, or both.

Planting date imposes another limit to productivity, with a penalty of ½ to ¾ bu/ac in potential yield per day of delay in planting after May 1.

Learn about the current yield gap in your soybean fields. Plug your yield and water supply records from previous years in *Figure 3* and check how close your fields are to the boundary function. If they aren't close, your current crop and/or irrigation management can be further optimized to increase your net profit. Also, use *Figure 4* to benchmark your current planting date decisions and quantify the opportunity cost of planting soybean late.

Sufficient water supply and an early planting date create the preconditions needed for high soybean yields. Other factors that can be further optimized by producers to increase their soybean yields are the tillage method in irrigated fields and N and P fertilizer inputs, but these factors need to be evaluated in a broader context (economic return, irrigation savings, and erosion control with no-till, etc.).

Acknowledgments

This project was supported by the Nebraska Soybean Board. The authors thank Jessica Torrion, assistant professor of crop physiology at Montana State University; Daryl Andersen, water quality specialist at the Little Blue Natural Resources District (NRD); and all of the 23 NRDs for helping collect the data for this study. Haishun Yang and Kenneth Cassman, UNL Department of Agronomy and Horticulture, provided useful comments on an early draft of this publication. We are grateful to the many soybean producers who collaborated in this study.

Further Reading

Grassini P, Torrion JA, Yang HS, Rees J, Andersen D, Cassman KG, Specht, JE. 2015. Soybean yield gaps and water productivity in the western US Corn Belt. Field Crops Research 179, 150–163.

SoySim

A Computer Program That Estimates Yield Potential for Irrigated Soybean Fields

The SoySim model is a computer program developed by UNL researchers that simulates soybean growth on a daily basis from emergence to maturity. This program simulates soybean yield potential and water use plus irrigation requirements under non-limiting conditions, assuming both optimal nutrient supply and no yield losses from abiotic and biotic factors.

SoySim has been validated at irrigated research and field sites in Nebraska, Iowa, and Indiana at which agronomic inputs were optimized to allow a full expression of yield towards yield potential. The results indicated that the model was able to simulate yield with reasonable accuracy, compared with other existing models.

To estimate the yield potential of your specific irrigated soybean field, SoySim requires daily weather data and information on planting date, cultivar maturity group, and seeding rate. More information about the SoySim model is provided at http://soysim.unl.edu/.