DYNAMIC CROPPING SYSTEMS: IMPLICATIONS FOR LONG-TERM RESEARCH

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ABSTRACT

Long-term cropping systems research provides critical information to producers regarding the sustainability of management practices. Fixed cropping sequences in long-term cropping systems research, while useful from the standpoint of understanding specific crop rotation effects on agronomic and environmental attributes, run the risk of losing relevance with producers over time due to changes in cropping practices brought about by market forces and technological innovations. A dynamic cropping systems concept – defined as a long-term strategy of annual crop sequencing that optimizes crop and soil use options to attain production, economic, and resource conservation goals – is proposed as an approach to long-term cropping systems research to better maintain relevance with producers over time. Two basic design options are considered for evaluating dynamic cropping systems over the long-term: 1) compare a dynamic cropping system to other crop sequencing approaches, or 2) compare different approaches to managing dynamic cropping systems. Comparisons between a dynamic cropping system and other crop sequencing options allow for a direct evaluation of crop sequencing decision processes on cropping system performance. Comparisons between different management approaches within dynamic cropping systems allow for evaluations of whole production systems. If treatments within each design option are carefully selected, they have the potential to maintain relevance with producers over time. However, application of experimental treatments may be challenging, owing mainly to difficulties associated with objectively selecting crops on an annual basis within dynamic cropping systems.

INTRODUCTION

Long-term cropping systems research has been instrumental in determining the relative sustainability of agricultural management systems for more than 150 years. Evaluations conducted over the long-term (>20 yr) have been key to the success of cropping systems experiments, as treatment effects often take many years before consistent and measurable changes in soils and crops are detectable (Rasmussen et al., 1998; Richter and Markewitz, 2001). This is especially true for dryland cropping systems in semiarid regions, where low production levels contribute to a slow rate of change in soil properties (Liebig et al., 2006). Furthermore, expression of treatment effects on agronomic and environmental attributes can change over time (Six et al., 2004), thereby affecting cropping system performance and overall system sustainability.

While the value of long-term cropping systems research is readily apparent, there are certain attributes of cropping systems experiments that may limit their value to agricultural producers as well as researchers. In particular, experiments with fixed rotations (i.e., crops are sequenced over time in a consistent, unchanging pattern) run the risk of becoming irrelevant in regions where new crops and/or management innovations are incorporated into established cropping systems by agricultural producers. Such a scenario leaves researchers with two options to regain relevancy with their clientele: 1) alter the treatments of an existing cropping systems experiment such that new crops and/or management innovations are incorporated, or 2) discontinue the experiment and start a new experiment with updated treatments. It is important to note, however, that if the experimental design in the second option does not allow for potential adoption of future changes to the treatments, the cycle will eventually repeat itself.

Cropping systems experiments have evolved to incorporate treatments with increasing flexibility in annual crop sequencing. Experiments with opportunity/flex-cropping treatments represent an excellent example of an approach that allows researchers to adjust cropping system intensity and/or diversity based on externalities, such as soil water status at planting (Farahani et al., 1998; Sadras and Roget, 2004). Another approach to increase flexibility in annual crop sequencing is through the application of a dynamic cropping systems concept (Tanaka et al., 2002), where crop sequencing decisions are made annually based on externalities as well as management goals. The fact that crop sequencing decisions are not predetermined makes the adoption of a dynamic cropping systems approach in a long-term experiment complicated. How treatments are defined and applied represent critical issues that need to be addressed prior to embarking on an evaluation of dynamic cropping systems. The objective of this paper is to briefly discuss these and other issues by reviewing different design options for evaluating dynamic cropping systems in long-term experiments.

DYNAMIC CROPPING SYSTEMS

Description

A dynamic cropping system represents a long-term strategy of annual crop sequencing that optimizes crop and soil use options to attain production, economic, and resource conservation goals by using sound ecological management principles (Tanaka et al., 2002). Dynamic cropping systems are region-specific, differing in their crop portfolios (i.e., adaptable crop species) from one region to another. Successful implementation of dynamic cropping systems within a region is contingent upon a thorough understanding of short-term crop sequencing effects on relevant agronomic and environmental attributes. Crop by crop-residue matrix experiments have been especially useful in investigating crop sequence 'synergisms' and 'antagonisms' in the short-term (2 to 4 yr) for the northern Great Plains (Krupinsky et al., 2006), thereby providing the necessary foundation for developing strategies to sequence crops over a longer period of time.

Potential Design Options for Long-Term Research

Potential design options for evaluating dynamic cropping systems in long-term experiments may be structured two ways, depending on the goals of the researcher. Designs may be structured to 1) compare dynamic cropping systems to other crop sequencing approaches, or 2) compare different approaches to managing dynamic cropping systems. Attributes of both design options are presented in Table 1 and are discussed separately below. Please note that the attributes are far from comprehensive nor are they original, but are presented simply to encourage further discussion.

Table 1. Attributes of different design options for evaluating dynamic cropping systems in long-term experiments.

Possible treatment comparisons	Management considerations	Benefits	Drawbacks
Research goal: ***Compare dynamic cropping systems to other crop sequencing approaches***			
Dynamic cropping system vs. o Fixed rotation with opportunity/ flex-cropping option. o Fixed rotation without opportunity/flex-cropping option. o Conventional benchmark (e.g., Spring wheat – fallow). o Other.	o Need consistency across treatments regarding the application of management variables not linked to crop sequencing (e.g., tillage, fertility recommendations, etc.). o Relative diversity of crop portfolio must be decided *a priori* for non-DCS[†] treatments.	o Research goal provides a direct comparison of DCS to other crop sequencing approaches. o Application of non-DCS treatments is relatively straightforward.	o 'Optimization' scheme used for selection of crops in DCS treatment is value-laden. o Non-DCS treatments may eventually become irrelevant.
Research goal: ***Compare different approaches to managing dynamic cropping systems***			
Possible treatment comparisons	Management considerations	Benefits	Drawbacks
System diversity comparison: o Full crop portfolio with forages/cover crops. o Full crop portfolio without forages/cover crops. o Partial crop portfolio (e.g., cereals, oilseeds, legumes). o Limited crop portfolio (e.g., small grains, oilseeds).	o Need consistency across all treatments regarding the application of management variables not linked to crop sequencing (e.g., tillage, fertility recommendations, etc.).	o Good comparison of cropping system diversity in a DCS context.	o Expression of treatment effects may take longer than other types of comparisons.
'Optimization scheme' comparison: o Profit-centered scheme. o Resource conservation scheme. o 'Middle of the road' scheme. o Other.	o Objective application of 'optimization' schemes may be difficult for a single investigator.	o Comparisons explicitly test value-laden aspect of crop sequencing.	o Relevance of optimization schemes may decrease with changes in government programs, attitudes toward conservation, etc.
Management paradigm comparison: o No-till, full crop portfolio. o Reduced tillage, partial crop portfolio. o Certified organic system. o Other.	o Objective application of management paradigms may be difficult for a single investigator.	o Treatments could be patterned after management systems predominant in region, thereby increasing relevance with producers.	o Management paradigms change over time, thereby affecting the relevance of selected treatments.

[†] DCS = Dynamic cropping system.

Compare dynamic cropping systems to other crop sequencing approaches

Designs for this type of long-term experiment would provide a direct evaluation of the dynamic cropping systems concept as it relates to other crop sequencing approaches. Possible treatment comparisons in such an evaluation could include fixed rotations (with or without an opportunity/flex-cropping option), fixed rotations with different levels of cropping system diversity, and a conventional benchmark (e.g., spring wheat – fallow). To increase the validity of treatment comparisons, this design option would require management consistency across treatments for variables not directly linked to crop sequencing (e.g., consistent tillage type and fertility recommendations).

Though the application of the non-dynamic cropping system treatments is straightforward from a management perspective, they run the risk of becoming irrelevant over time because the crop sequences would be fixed. A more significant drawback with this design option relates to the approach used for selecting crops each year for the dynamic cropping systems treatment. Even with the most current knowledge and information on crop sequencing, the selection of the 'most optimal crop' from year-to-year is value-laden, and therefore may differ from one investigator to the next. One option to increase the objectivity of crop selection in dynamic cropping systems experiments is to have interdisciplinary research teams make cropping decisions by consensus, possibly with input from a producer panel. Using such an approach, while certainly inclusive, would require a significant time investment for the individuals involved. A somewhat less cumbersome option would be to establish crop sequences for dynamic cropping systems treatments on a periodic basis, such as every two, three, or four years. Crop sequences within the chosen timeframe would be fixed, and then revised at the end of the cropping period. This option provides the opportunity to retain greater relevance in a study over the long-term, while adhering to a more clearly defined set of treatments in the short-term.

Compare different approaches to managing dynamic cropping systems

Treatments within this design option closely represent whole production systems (Ulrich et al., 2001), and are accordingly much more complex than the treatments outlined above. Treatment comparisons can generally be grouped within a 'management theme', with themes based on the research goal(s) of the investigator (e.g., system diversity, energy use, management paradigms, etc.).

The primary benefit from evaluating different approaches to managing dynamic cropping systems stems from the fact that the treatments represent whole production systems. Long-term evaluation of whole production systems is essential to understand the interaction of system components on economic and environmental attributes contributing to agroecosystem sustainability (Ulrich et al., 2001). An associated benefit relates to producer interest and acceptance of the experimental design. Assuming the 'management theme' and related treatments are relevant, this flexible design option should maintain the interest of agricultural producers over time.

Major drawbacks of this design option relate to challenges in objectively applying treatments. Because each treatment within this design option represents a dynamic cropping system, crop sequencing decisions must be made every year or at least periodically (i.e., 2-4 yr) if a fixed short-term cropping timeframe is used. Either way, crop sequencing decisions increase the management burden on the investigator. Furthermore, a single investigator may not objectively apply each management treatment, choosing instead to most effectively manage the treatment they have the greatest understanding of or preference for. This particular concern underscores the value of making cropping decisions with additional input from a research team and/or producer panel.

SUMMARY

Evaluating dynamic cropping systems in long-term experiments provides the opportunity to determine the performance and sustainability of this novel crop sequencing approach relative to traditional fixed-rotation cropping systems. While the inherent flexibility of dynamic cropping systems increases the potential that related treatments will maintain the interest of producers over time, there are considerable challenges with their inclusion in long-term experiments. Most notably is the challenge associated with the selection of crops on an annual basis, which is inherently value-laden.

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