



CLIMATE, WEATHER AND SWEET CORN



IOWA STATE UNIVERSITY



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Climate, Weather and Sweet Corn

This document may be cited as:

Morton, Lois Wright, Ajay Nair and Mark Gleason. 2017. Climate, Weather and Sweet Corn. Sociology Technical Report 1048. Department of Sociology, Iowa State University, Ames, Iowa. 14 pp.

This weather-based uncertainty and specialty crop production series presents conceptual maps of growers' views and priorities on apples (technical report 1046), wine grapes (technical report 1043), hops (technical report 1045), strawberries (technical report 1047) and sweet corn (technical report 1048). Department of Sociology, College of Agriculture and Life Sciences, Iowa State University, Ames Iowa. www.soc.iastate.edu/research/specialtycrops/

Report design and format by Renea Miller, Department of Sociology, Iowa State University, Ames, Iowa. March 2017. USDA Census of Agriculture data tables and figures by Anna Johnson.



This research, North Central Fruit, Vegetable and Wine Growers' Assessment of Soil and Water Vulnerability Under Changing Climate Conditions and Extreme Weather Events funded by USDA-Agricultural Research Service (ARS) Midwest Climate Hub.

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Sweet corn production and a changing climate: growers' views and priorities to manage uncertainty in production systems

Lois Wright Morton, Ajay Nair, and Mark L. Gleason

Sweet corn production, weather and climate risks

Sweet corn is one of 25 major annual vegetable crops produced in the United States (U.S.). It is an important commercial cash crop valued over \$1.2 billion in 2012, and is grown in all fifty states. Almost 70% is produced for fresh markets and the balance for frozen and canned markets. Processing sweet corn in terms of production totaled 2.9 million tons valued at \$73.1 million in 2012; and was surpassed only by processed tomatoes (Huntrods, 2013). Sweet corn for processing is concentrated in the upper Midwest and Pacific Northwest; and fresh market production is dominated by California, Florida and Georgia.

Sweet corn requires sunny, well-drained soil, and an abundant water supply. Although there are many local variations in sweetness, color, and maturity, sweet corn has a 65-90 day window from planting to harvest. Both soil and air temperature are major environmental challenges for the production of sweet corn. Periods of high heat and minimum and maximum daily temperatures affect soil temperature for seeding, tasseling, pollination and harvest dates (Walthall et al., 2012). First seeding requires soil temperatures reach 50°F and a frost-free period thereafter; and subsequent seeding occurs 10-14 days between plantings for a sequential harvest period until frost (Fritz et al., 2010). However, supersweet and improved supersweet cultivars are highly sensitive to cool soil conditions and do best when soil temperatures run between 60°F and 70°F to increase germination rates. Like field corn, one of sweet corn's most vulnerable periods is during pollination when extreme temperatures can reduce full kernel development and ear quality. Further, heat units affect uniform germination and growth stages. Sweet corn water use is dependent on evapotranspiration (ET), which is influenced by stage of growth, air temperatures, and solar radiation (Fritz et al., 2010). Yield and ear quality will be reduced if moisture stress occurs

during tasseling, silking and kernel fill. Irrigation scheduling requires regular soil and water monitoring, with the highest water use occurring from tassel to harvest.

Walthall et al. (2012) suggest that climate is an additional risk joining production, finance and marketing risks already managed by growers. They note that climate risk will add complexity to U.S. specialty crop systems and increase uncertainty in agricultural decision environments. Changes in climate interact with other environmental and societal factors in ways that can either moderate or intensify its impacts on sweet corn production systems. In conjunction with changes in the timing and distribution of precipitation, warmer growing season temperatures result in greater crop water requirements, with potential to affect yield and profits as a result (Melillo et al., 2012). Precipitation and temperature patterns as well as other weather and climate variables are specific to individual regions, sub-regions, and localities; thus, their impacts are localized also.

As climate and weather become more variable, sweet corn growers face increased uncertainty in making decisions about their crop. One interpretation of this uncertainty is that growers may not have quite enough information to adequately evaluate their management options in the context of climate risk. Uncertainty can stem from social, economic, relational and/or biophysical factors that constrain or limit knowledge needed to make timely, good decisions. **What is not well understood is how sweet corn growers perceive climate-weather risks to their production systems and what kind of adaptations have potential to reduce uncertainties associated with their management decisions.** This technical report is a preliminary effort to summarize information gathered from Iowa sweet corn growers to better understand what they are thinking and how they view uncertainty and their production challenges. First, a brief overview of U.S. and Iowa sweet corn production

is presented, followed by the methodology used to gather and analyze grower information. Then, conceptual maps of Iowa sweet corn growers' views and priorities associated with managing their production systems under increasing uncertainties are shown and discussed. Supporting data are found in Appendices I and II.

Sweet corn production for fresh markets in the United States

U.S. sweet corn consumption is about 24 pounds per person (2011) after peaking at 29 pounds per person in 1996 (Huntrods, 2013). Most sweet corn is consumed frozen (9.5 pound per capita) followed closely by fresh sweet corn consumption at 8.7 pounds per person. Although sweet corn is available almost year around, climate plays a big role in where and when sweet corn is grown. According to the U.S. Census of Agriculture, there are 28,000 farms harvesting sweet corn across the U.S. with about 229,000 acres harvested for fresh market in 2015 (figure 1) . This is a drop from a high of 245,730 acres harvested for fresh market in 2002. The U.S. produced almost 28 million cwt of sweet corn for fresh markets, valued at nearly \$788 million in 2015 (Figure 2).

Iowa sweet corn

Based on acreage, sweet corn is the number one vegetable crop grown in Iowa (USDA-NASS, 2012). According to 2012 USDA agriculture census, Iowa growers harvested 3,393 acres of sweet corn. This number does not include the growing number of acreages that are now being utilized for contract farming. In last five years, in addition to growing for local markets, Iowa sweet corn growers have expanded to cater to processors such as Birds Eye Inc., Waseca, MN. In 2016, Birds Eye contracted close to 2,500 acres with sweet corn growers in Iowa. Given the growing demand, sweet corn growers strive to produce an early high quality sweet corn crop by carefully choosing appropriate cultivars and planting dates. The entire crop cycle from seeding to harvest is significantly influenced by weather. Soil temperature, moisture, and fertility, pest management, labor, and marketing are all key factors that are affected by weather. Growers experience multiple challenges when it comes to weather: 1) accurate real-time weather estimates, 2) interpretation of weather forecast data, and 3) utilizing the weather data in planning optimal planting and harvest dates. In addition, growers need research-based information on sweet

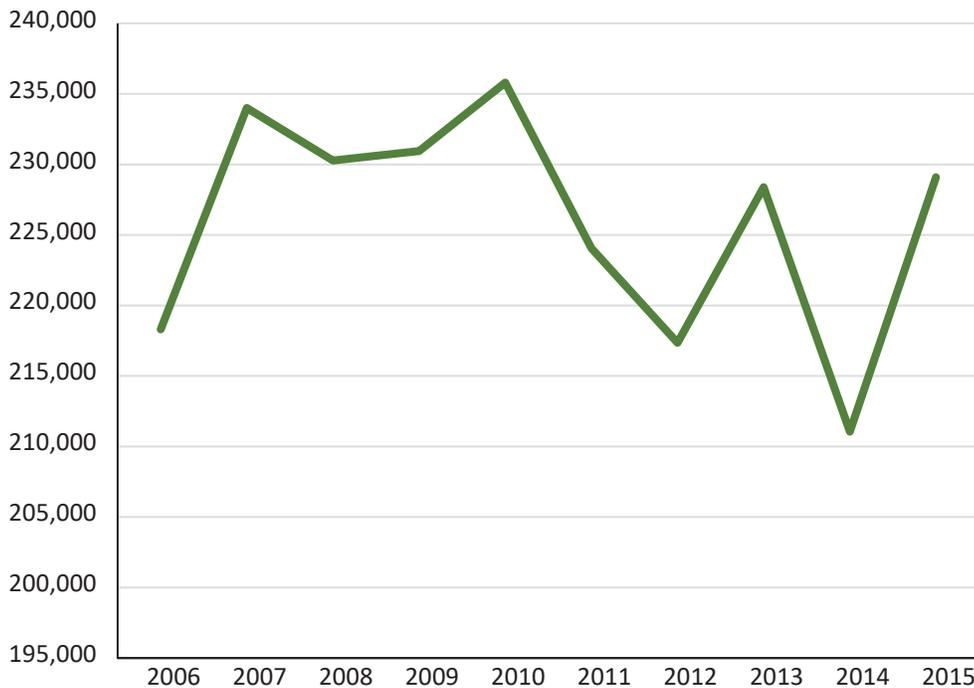


Figure 1. U.S. sweet corn fresh market acres harvested 2006-2015. Total sweet corn, fresh market acres harvested in 2015, 229,090 acres. USDA National Agricultural Statistics Service (NASS) 2015.

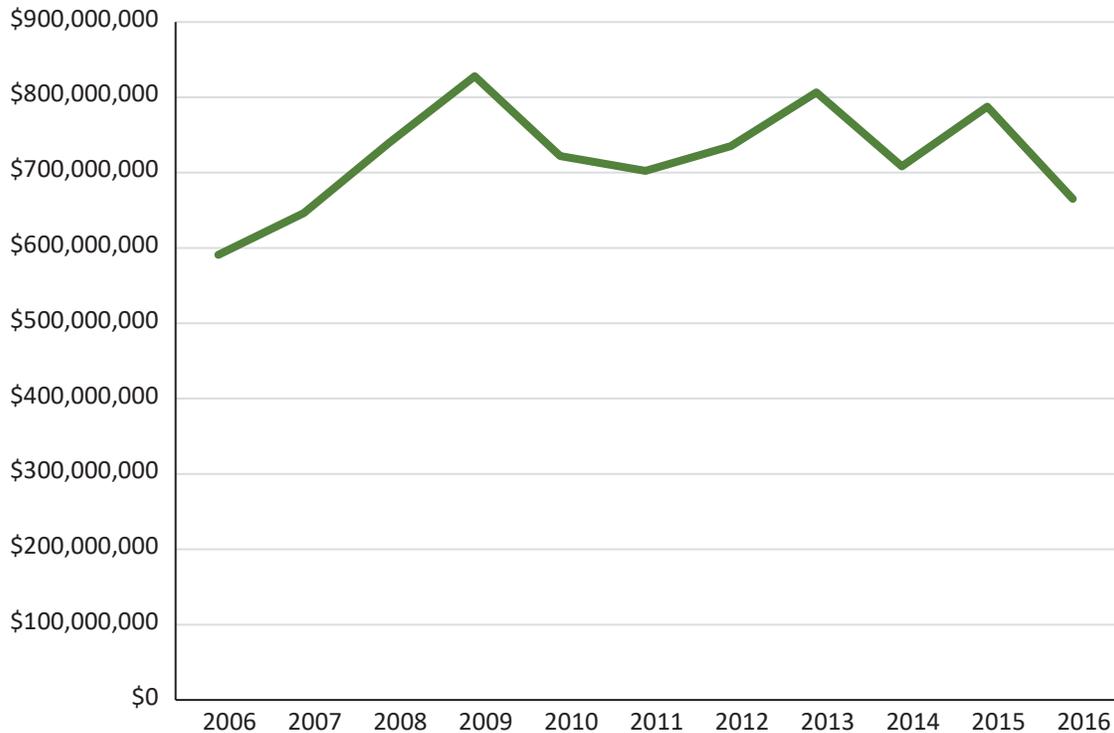


Figure 2. Total value of U.S. sweet corn fresh market production from 2006-2016. Total value of 2016 U.S. fresh market crop \$665,301,000; 2015 fresh market crop \$787,581,000. National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

corn type (se, sh2/synergistic), cultivar, interaction of type/cultivar with soil temperature, soil fertility and pest management. With sweet corn, as with many other processing crops, planting and timing of harvest is critical because seed germination, crop growth and the quality of the end product change rapidly both before and after harvesting. Weather interacts with soil temperature, moisture, insects, and diseases to determine appropriate planting and harvest dates of sweet corn. Current practice for sweet corn planting and scheduling is to base the expected harvest dates on accumulated experience from preceding seasons (Bussell et al., 1979). Another challenge growers face is insect management, especially corn ear worm. Growers use traps to monitor insect populations and follow a strict spray schedule to protect their crop from corn earworm. Use of Bt-sweet corn is also gaining popularity and acceptance among growers.

Concept mapping views and priorities

Sweet corn growers are seeking strategies to better assess the risks and vulnerabilities, and reduce

uncertainty in their production systems under changing short- and long-term weather conditions and improve their decision-making capacities. Nine sweet corn growers and crop advisors were identified in Fall, 2016 as key leaders in their industry and were invited to meet in Altoona, Iowa at the Iowa State University Extension, Polk County office to discuss impacts of temperature, precipitation, and other weather-related issues on their production systems. The focus was on critical production and marketing decision points throughout the year for the sweet corn crop. Scientists from Iowa State University met with the growers to identify and prioritize production concerns and uncertainties in their systems that they have difficulty managing. A concept mapping process was used to capture individual growers' challenges as well as areas of common concern among the group. Of interest to the science team was to gather information to guide future research and extension-outreach programming that would reduce uncertainty in different aspects of production decisions.

The concept mapping methodology is a participatory planning process that spatially maps the thoughts and knowledge of a particular group of people and enables the creation of a common framework for planning and evaluation of issues that matter to that group (Kane and Trochim, 2007). The process begins with the group brainstorming key ideas together, then individually rating each of the idea statements by how critical or important it is to them, followed by individual conceptual sorting of the statements into groups of similar concepts.

On November 4, 2016, sweet corn growers first brainstormed by completing the statement: “One uncertainty in my production system I have difficulty managing is...” The brainstormed statements were recorded on a large screen where the entire group could read them and discuss as the list was made. Fifty-seven statements were generated (see Appendix II for the list of 57 statements). Then, the nine participants individually rated each statement using a 1-5 Likert scale based on how critical they thought it was to reduce uncertainty in their production system related to this statement (1 = not critical;

2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical). Lastly, participants individually sorted the 57 statements into separate piles or groups based on perceptions of statement similarities and gave them labels. Some participants lumped statements together, whereas others split the statements into many groupings. The smallest number of groups created by a participant was four; the largest contained twelve groupings.

Conceptual maps were computed using multi-dimensional scaling analysis that locates each statement as a separate point on a map based on how the participants sorted the 57 statements. A similarity matrix from the sorts was constructed from statements based on how they were grouped together by the participants. Statements that were conceptually viewed as similar are located closer to each other on the point map and those that were grouped together less frequently, have more distance separating them on the map (Figure 3). Hierarchical cluster analysis was used to partition the statements on the map into clusters representing conceptual groupings. Then the average ratings

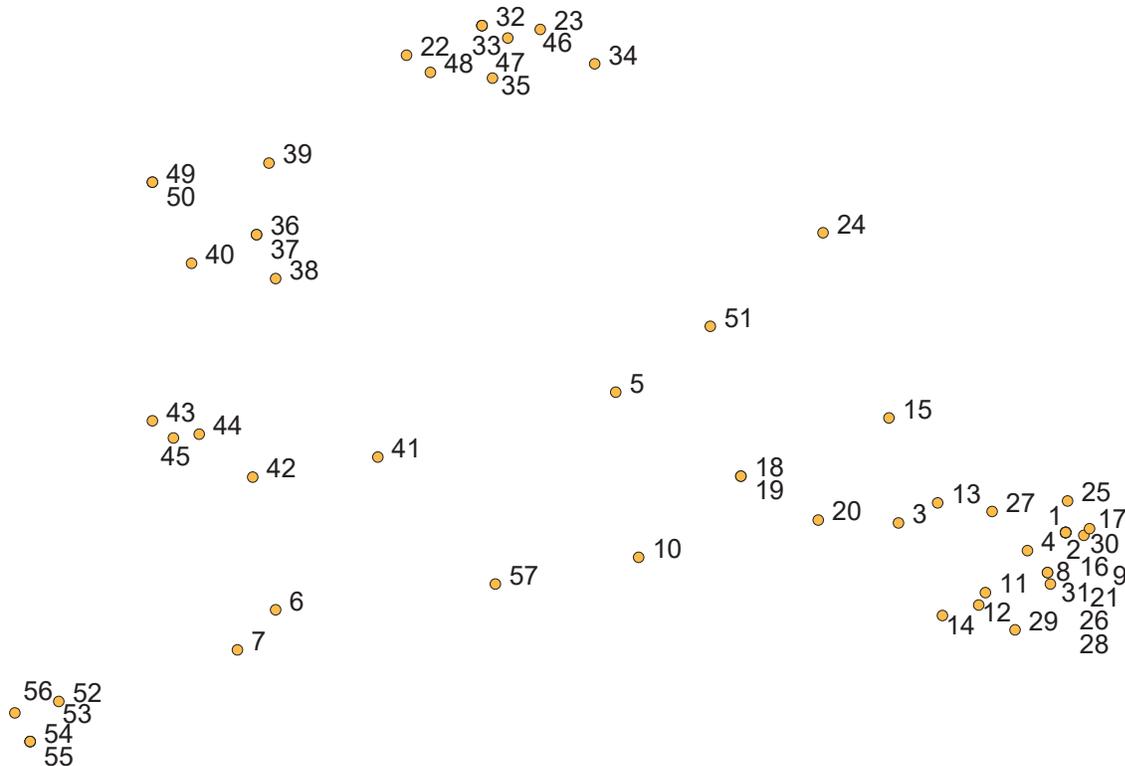


Figure 3. Point map of Iowa sweet corn growers’ sort of 57 statements, “One uncertainty in my production system I have difficulty managing is...”

for each statement and each cluster, based on how critical it is to reduce uncertainty, were computed and overlaid on the spatial map.

Iowa sweet corn growers' conceptual maps and priority ratings

The point map (Figure 3) and cluster maps represented by the polygons in Figures 4 and 5 offer a visual way to understand the conceptual thinking of the sweet corn grower participants. The maps along with the cluster lists (Table 1; Appendix I) and statement ratings list (Table 2; Appendix II) provide data that help interpret what growers view as critical uncertainties in their production systems and which uncertainties are more difficult for them to manage. These three maps—the point map and two different cluster maps—are different ways of portraying the conceptual structure of the data. However, the maps are inter-related and reflect different ways to assess what sweet corn growers

are thinking. The point map (Figure 3) represents an integration of where all participants located each statement in relationship to other statements—i.e. the way statements were categorized as similar or different. Each of the 57 different statements growers brainstormed are uniquely located on the point map. Note some numbers group together and other numbers are quite distant from other numbers. Thus, even without drawing polygons around the grouped numbers, it is apparent that the statement numbers group into two or more distinct clusters.

Iowa sweet corn growers' cluster maps and priority ratings

The two-cluster (Figure 4) and six-cluster (Figure 5) rating maps show how the statements can be grouped with average cluster ratings overlaid. The cluster names were chosen subjectively by the researchers using a combination of the labels given by growers and the items within

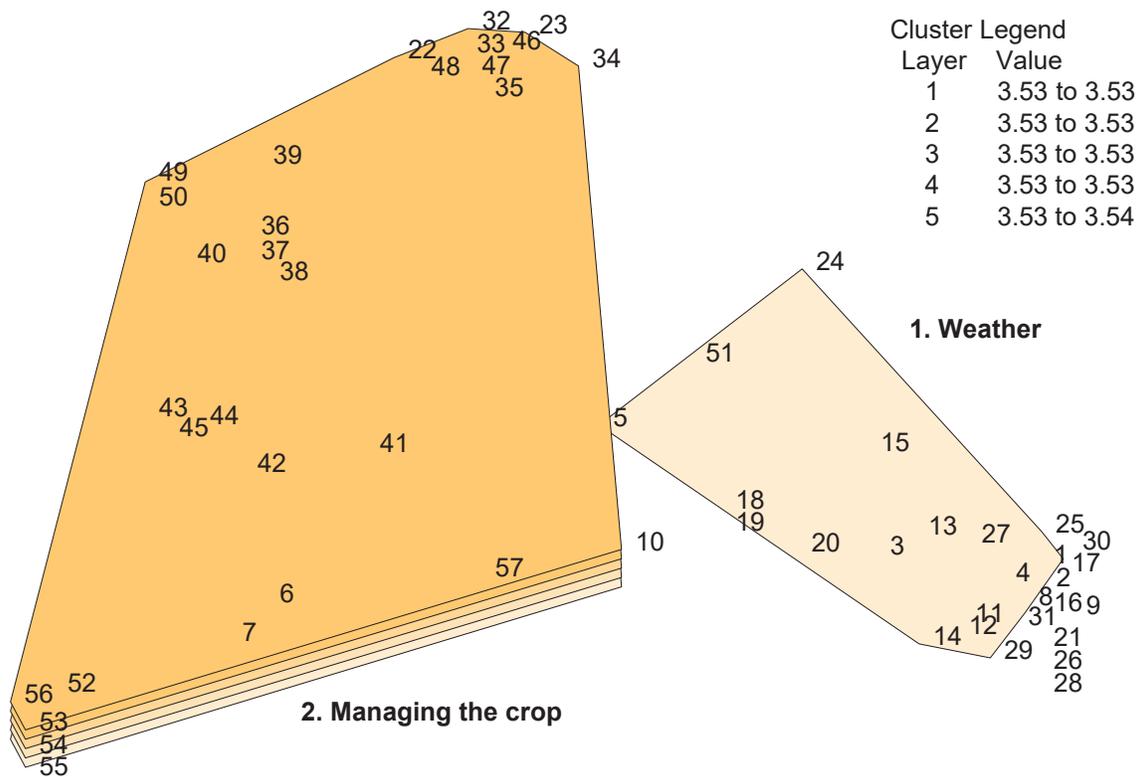


Figure 4. Two-cluster Iowa sweet corn growers' conceptual map derived from the prompt, "One uncertainty in my production system I have difficulty managing is..." and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

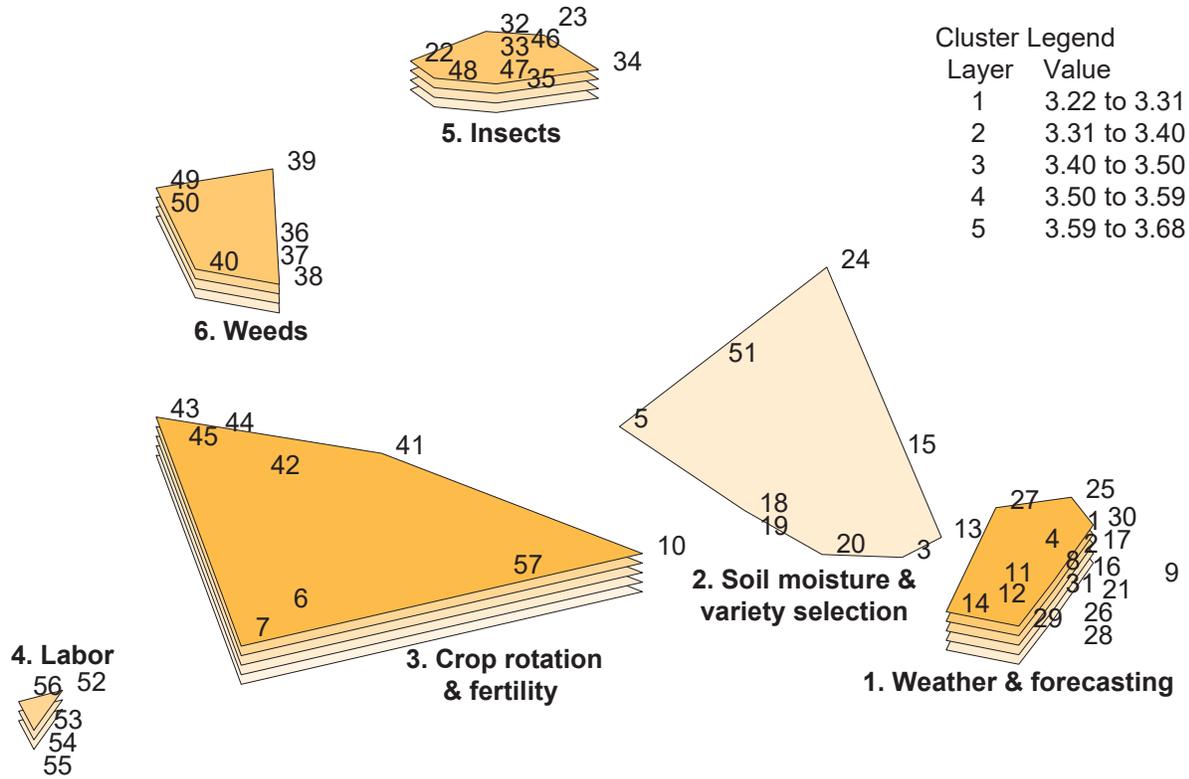


Figure 5. Six-cluster Iowa sweet corn growers' conceptual map derived from the prompt, "One uncertainty in my production system I have difficulty managing is..." and rated based on, "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

each cluster. Multi-layered polygons represent the relative importance of the different clusters. The two-cluster rating map in Figure 4 shows two major conceptual areas of uncertainty identified by the sweet corn growers: *managing the crop* and *weather*. Although the *managing the crop* polygon shows a higher priority weighting (3.53-3.54) compared to *weather* (3.53) as critical to reduce uncertainty, the value range for both of these clusters is essentially the same, representing an average assessment between moderately and very critical. This is not unexpected; growers were asked to identify areas of uncertainty and all items brainstormed by the group are substantive challenges they are facing. This two-cluster map reflects that uncertainties associated with sweet corn production are both social and biophysical in nature.

One value of the conceptual maps is that they identify and prioritize general and specific areas where research and programming would most

benefit growers and guide where to invest resources. Further analysis of the point map reveals that the *managing the crop* and *weather* uncertainties clusters can be more finely divided into smaller, more focused sub-areas for improved targeting. Figure 5 shows a six-cluster map that breaks the *managing the crop* polygon from Figure 4 into four sub-areas of uncertainty: 1) *crop rotations & fertility*, 2) *weeds*, 3) *insects*, and 4) *labor*. The weather polygon breaks into two sub-groupings: 1) *soil moisture & variety selection* and 2) *weather & forecasting*. Table 1 provides summary data on these six clusters, their grand means and the top-ranked statements in each cluster. Note that the six clusters have grand means that range from 3.68 (very critical) to 3.22 slightly above moderately critical (3.0) to reduce levels of uncertainty.

A look at the statements within each of the six clusters (Figure 5; Table 1) offers a deeper

Table 1. Iowa sweet corn growers' priority ratings of uncertainties in their production systems. "One uncertainty in my production system I have difficulty managing is..."

Cluster Name	Grand Mean	# Statements	Top-ranked Statement(s)	Statement Rating
Weather & forecasting	3.68	18	1. Weather forecasting	4.78
Crop rotation & fertility	3.60	9	41. Soil fertility, rate & timing	4.44
			6. Matching supply to demand	4.44
Insects	3.56	9	32. Earworm control. Grocery stores expect perfection; need to spray 2-3 days to avoid earworm	4.44
Weeds	3.51	7	36. Weed management	4.44
Labor	3.42	5	52. Labor	3.89
Soil moisture & variety selection	3.22	9	5. Factors that affect yield	4.33
			51. Variety selection	4.33

understanding of what each cluster conceptually represents (Appendix I).

Weather & forecasting, consisting of 18 statements, is the highest ranked cluster (3.68), with growers giving it an overall value of slightly below very critical (4.0) but considerably above moderately critical (3.0) to reduce uncertainty. The top ranked statement in this cluster, weather forecasting with a mean of 4.78 is considered very-to-extremely critical to reduce uncertainty. The next two highest rated statements are heat units (Growing Degree Days) at 4.33 and forecasting heat units three months earlier at 4.22, slightly above very critical (see Appendix I). Four other statements rated at 4.11, above very critical are: early spring freezes, spring frost is unpredictable, degree days model tools are needed to assist with succession planting, and the historical and forecast Growing Degree Day tools on the Useful to Usable (U2U) webpage are helpful in reducing uncertainty. Two statements identify heat and temperature concerns as very critical at 3.89: heat spells in July and August affect planting and harvest time; and varieties are needed that can withstand severe weather (high heat) close to harvest. Other effects growers thought were very critical to address to reduce uncertainty are cool weather increases germination time (3.78); temperature affects corn maturity (3.78), and precipitation at the time of planting (3.56). Two statements fall slightly above moderately critical at 3.44: early in the year temperatures and spring soil

moisture. Growers expressed a moderately critical (3.00) need to have more certainty about the time between planting and harvest: when we plant in April and May we never know what the weather will be in July, and when will June planting be ready to harvest? The statement, forecast on fall freeze to guide last planting or extend your planting, was rated 2.56, between somewhat and moderately critical to reduce uncertainty. The last statement in this cluster, fall freezes can affect sweet corn harvest (2.11) echoes the weather-harvest relationship of earlier statements.

Crop rotation & fertility, the second highest ranked cluster, consists of 9 statements ranging from a high of 4.44 (very critical to reduce uncertainty) to 2.11 (moderately critical to reduce uncertainty). The grand mean for this cluster at 3.60 has a rating slightly below weather & forecasting and can be interpreted as very critical to reduce uncertainty. The two top ranked statements for this cluster, soil fertility, rate & timing (of fertilization) and matching supply to demand are rated very critical at 4.44 (Appendix I). The next highly rated statements in this cluster are spacing of planting schedules and unpredictability in supply and demand at 3.89, very critical. The cost of nitrogen (3.56) and decision making and information delivery (3.44) are both mid-way between very critical (4.00) and moderately critical (3.00). Crop rotations were considered slightly above moderately critical at 3.33: sweet corn followed by

field corn is not a good rotation; and crop rotations are important. The last statement in this cluster is about cover crops, recognizing that annual rye can cause issues with soil drying in the spring (2.11) considered somewhat critical.

Insects, the third highest ranked cluster (3.56) has nine statements with the highest ranked statement, earworm control; grocery stores expect perfection and we need to spray 2-3 days to avoid earworm problems at 4.44 (very critical to reduce uncertainty). The second highest rated statement in this cluster is concerned about the resistance to corn earworm insecticides (4.33) (Appendix I). The global statement forecasting for insects is also highly rated at 4.22, very critical to reduce uncertainty. High heat will accelerate reproduction of corn earworm egg and larval growth (3.89) is rated very critical; followed by frequent spraying (3.56) and alternating Warrior II and Hero is working ok, but now we are seeing some resistance in later planted sweet corn (3.56). Slightly below moderately critical (3.00) is the statement one needs to spray more the Se type sweet corn (2.89); and two other statements, corigen is expensive (2.56) and Bt vs non-Bt (2.56).

Weeds, is the fourth highest ranked cluster with a grand mean of 3.51, mid-way between moderately critical (3.00) and very critical (4.00) with seven statements. Weed management, a global statement about weeds, is the highest rated in this group at 4.44, very critical (Appendix I). Raccoons, birds, deer, and black birds were the second most highly ranked statement in this cluster at 4.11, very critical. Just slightly below very critical, at 3.89 is the statement weeds are not responding to herbicide sprays. Wildlife issues were rated 3.56, late planting of sweet corn is difficult with respect to weeds (3.22), and site selection for weed management (3.22) were all considered above moderately critical to reduce uncertainty. The last statement in this grouping is smut contamination (2.11) rated somewhat critical.

Labor, the fifth highest ranked cluster with a grand mean of 3.42 (above moderately critical) has five statements with the generalized term, labor (3.89), given the highest rating in the group of very critical. The next highly rated statements in this group are politics affect labor (3.56); timing

of labor (3.33); and not many people available at the time of harvest (3.33), all above moderately critical. The last statement, E-verify regulations, received a moderately critical rating (3.00).

Soil moisture & variety selection, although the lowest ranked of the six clusters with a grand mean of 3.22 has an overall rating of moderately critical, only slightly below the top ranked cluster with a grand mean of 3.68. Comprised of nine statements, the two top ranked statements at very critical (4.33) are factors that affect yield and variety selection. The next two statements are just below the very critical (4.00) rating with spring ground temperature (ground starts warming; see how early you can plant; ground works up nicely early March) at 3.89 and the relationship between precipitation and timing of spray at 3.78. Two moderately critical statements are varietal selection based on weather and temperature (3.44) and when will March 20th planting be ready in July? (3.22). Three statements were rated somewhat critical: one cannot only depend on rain, might also need to irrigate (2.22); irrigation is important, depending on soil type (2.00); and southwest Iowa might need irrigation; as well as southeast (1.78).

Top quartile statements. Another way to examine the findings is to list all 57 statements arranged by highest to lowest rating (Appendix II). The top quartile (25%) of sweet corn growers' statement rankings based on ratings is shown in Table 2. These top 16 statements range from 4.78, extremely critical to 4.11, very critical that levels of uncertainty be reduced in sweet corn production systems to make timely, good decisions. These highest rated statements focus on weather forecasting, heat units (GDD), weed and insect management, variety selection, factors that affect yield, and matching supply to demand.

Observations

In recent years, the specialty crop segment of U.S. agriculture has seen tremendous growth. An increasing number of growers are interested in diversifying their farm operations, especially in the Midwest, to grow specialty crops such as sweet corn, other vegetables and fruit. The specialty crop industry in Iowa, by value of sales, generated close to \$123 million in 2012 (USDA-NASS, 2012). The

Table 2. Top quartile (25%) Iowa sweet corn growers' ranked statements. "How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical)."

Statement Number		Average Rating
1	Weather forecasting	4.78
6	Matching supply to demand	4.44
41	Soil fertility rate and timing	4.44
32	Earworm control. Grocery stores expect perfection; need to spray 2-3 days to avoid earworm problem	4.44
36	Weed management	4.44
25	Heat units (Growing Degree Days)	4.33
5	Factors that affect yield	4.33
51	Variety selection	4.33
46	Resistance to insecticides being used for corn earworm	4.33
26	Forecasting heat units three months earlier	4.22
35	Forecasting for insects	4.22
21	Early spring freezes	4.11
16	Spring frost is unpredictable	4.11
27	Degree day model tool that will assist with succession planting	4.11
28	U2U Useful to Usable webpage (historical and forecast Growing Degree Day)	4.11
50	Raccoons, birds, deer, black birds	4.11

United States Department of Agriculture (USDA) has taken concerted efforts to increase and expand production of specialty crops throughout the country. Interest in supporting local food systems by the federal and state policymakers has led to the development and implementation of programs such as *Know Your Farmer Know Your Food*, *Farm to School*, and *Buy Fresh Buy Local* to connect farmers and consumers, strengthen local and regional food production, increase the use of sustainable agricultural practices, and promote consumption of fresh, local food (Martinez, et al., 2010).

One of the threats that can derail the momentum of specialty crop production is the changes in the geographic distribution and seasonality of temperature and precipitation. Global land and ocean temperatures have been on the rise primarily due to rising greenhouse gas concentrations (IPCC, 2007). Warming of our planet directly impacts agro-ecosystems and future production of crops for human consumption and other basic

needs. There is a growing concern that increased temperatures will benefit pest populations by increasing prevalence of specific insect pests in mid- to high-latitude regions of the world (Bale et al., 2002; Patterson et al., 1999). Not only insects, but weeds and pathogen mediated plant diseases will be significantly influenced by changing climate (Patterson et al., 1999).

Grower operations now and in the future are affected by an increasingly variable climate, suggesting a need for research, decision support tools and information that help address risk and uncertainty and inform adjustments to management. This preliminary report offers a snapshot of Iowa sweet corn growers' observations, thoughts, concerns, and priorities for their crop. The concept mapping process identified weather and forecasting, insects, weeds and crop management as top concerns.

Sweet corn is highly sensitive to temperature (frost, soil temperature, and excessive heat), prolonged

periods of wetness or drought, high winds, hail, and long-term shifts in climate. The increasing uncertainty about weather impacts on pest and crop management is one of specialty crop growers' largest challenges.

References

Bale, J.S. et al. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores *Global Change Biol.* 8 1–16 [11].

Bussell, W.T., R.E. Lill, R.E., Burgmans, and B.T. Rogers. 1979. Programming the production and harvesting of process crops. *Proceedings of the Agronomy Society of New Zealand* 9: 89-91.

Fritz, V.A., C.B. Tong, C.J. Rosen, and J.A. Wright. 2010. Sweet corn (vegetable crop management) University of Minnesota Extension. <http://www.extension.umn.edu/garden/fruit-vegetable/sweet-corn/>

Huntrods, D. 2013. Sweet corn profile. AgMRC Agricultural Marketing Resource Center. Iowa State University.

IPCC WGI 2007 Climate Change. 2007. The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Kane, M and W.M.K. Trochim. 2007. *Concept Mapping for Planning and Evaluation*. Thousand Oaks, CA: Sage Publication.

Martinez, S., M. Hand, M. Da Pra, S. Pollack, K. Ralston, T. Smith, S. Vogel, S. Clark, L. Lohr, S. Low, and C. Newman. 2010. Local Food Systems: Concepts, Impacts, and Issues. Economic Research Report Number 97, 80 pp.

Melillo, J. M., T.C. Richmond, and G. W. Yohe, Eds. 2012. Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program. Washington.

Patterson D T, Westbrook J K, Joyce R J V, Lingren P D and Rogasik J 1999 Weeds, insects and diseases. *Climate Change* 43 711–27.

USDA-NASS. 2012. Census of Agriculture. <https://www.agcensus.usda.gov/Publications/2012/>

USDA-NASS (National Agricultural Statistics Service). 2015. US Census of Agriculture. USDA. https://www.agcensus.usda.gov/Publications/Census_of_Horticulture_Specialties/

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M. Rivington, E. Roskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stöckle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright Morton, L.H. Ziska. 2012. *Climate Change and Agriculture in the United States: Effects and Adaptation*. USDA Technical Bulletin No. 1935. Washington, DC. 186 pp.

Appendix I. Iowa sweet corn growers' six-cluster rankings

Iowa sweet corn grower statements sorted by cluster derived from the prompt, “One uncertainty in my production system I have difficulty managing is...” and rated based on, “How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical).”

One uncertainty in my production system I have difficulty managing is...

		Average Rating
1. Weather & forecasting		3.68
1	Weather forecasting	4.78
25	Heat units (Growing Degree Days)	4.33
26	Forecasting heat units three months earlier	4.22
21	Early spring freezes	4.11
16	Spring frost is unpredictable	4.11
27	Degree day model tool that will assist with succession planting	4.11
28	U2U Useful to Usable webpage (historical and forecast Growing Degree Day)	4.11
8	Heat spells in July and August affects planting and harvest time	3.89
29	Variety that can withstand severe weather (high heat) close to harvest	3.89
4	Cool weather increases germination time	3.78
9	Temperature affects corn maturity	3.78
11	Precipitation at the time planting	3.56
2	Early in the year temperature	3.44
17	Spring soil moisture	3.44
12	When we plant in April and May we never know what the weather will be in July	3.00
14	When will June planting will ready to harvest?	3.00
31	Forecast on fall freeze to guide last planting or extend your planting	2.56
30	Fall freezes can affect sweet corn harvest.	2.11
	Count Std. Dev. Variance Min Max Average Median	
	18 0.65 0.42 2.11 4.78 3.68 3.83	
2. Soil moisture & variety selection		3.22
5	Factors that affect yield	4.33
51	Variety selection	4.33
3	Spring ground temperature (ground starts warming up; see how early you can plant; ground is usually worked up nice; early March;	3.89
24	Precipitation and the timing of spray	3.78
15	Varietal selection based on weather and temperature	3.44
13	When will March 20 planting be ready in July?	3.22
20	One cannot only depend on rain, might need to irrigate	2.22
19	Irrigation is important and dependent on soil type	2.00
18	Southwest Iowa might need irrigation and so is the Southeast	1.78
	Count Std. Dev. Variance Min Max Average Median	
	9 0.93 0.87 1.78 4.33 3.22 3.44	

One uncertainty in my production system I have difficulty managing is...

								Average Rating
3. Crop rotation & fertility								3.60
6	Matching supply to demand							4.44
41	Soil fertility rate and timing							4.44
10	Spacing of planting schedules							3.89
7	Unpredictability in supply and demand							3.89
42	Cost of nitrogen							3.56
57	Decision making and information delivery							3.44
44	Sweet corn followed by field corn: not good							3.33
43	Crop rotations are important							3.33
45	Annual rye can cause issues with soil drying in the spring							2.11
	Count	Std. Dev.	Variance	Min	Max	Average	Median	
	9	0.66	0.44	2.11	4.44	3.6	3.56	
4. Labor								3.42
52	Labor							3.89
53	Politics affect labor							3.56
54	Timing of labor							3.33
55	Not many people available at the time of harvest.							3.33
56	E-verify regulations							3.00
	Count	Std. Dev.	Variance	Min	Max	Average	Median	
	5	0.29	0.09	3.00	3.89	3.42	3.33	
5. Insects								3.56
32	Earworm control. Grocery stores expect perfection; need to spray 2-3 days to avoid earworm problem							4.44
46	Resistance to insecticides being used for corn earworm							4.33
35	Forecasting for insects							4.22
33	High heat will accelerate reproduction of corn earworm egg and larval growth							3.89
34	Frequent spraying							3.56
47	Alternating Warrior II and Hero, was working ok but now we are seeing some resistance later planted corn							3.56
23	One needs to spray more the Se type sweet corn							2.89
48	Corigen is expensive							2.56
22	Bt vs non-Bt.							2.56
	Count	Std. Dev.	Variance	Min	Max	Average	Median	
	9	0.7	0.49	2.56	4.44	3.56	3.56	
6. Weeds								3.51
36	Weed management							4.44
50	Raccoons, birds, deer, black birds							4.11
38	Weeds are not responding to herbicide sprays							3.89
49	Wildlife issues							3.56
37	Late planting of sweet corn are difficult with respect to weeds							3.22
39	Site selection for weed management							3.22
40	Smut contamination							2.11
	Count	Std. Dev.	Variance	Min	Max	Average	Median	
	7	0.71	0.5	2.11	4.44	3.51	3.56	

Appendix II. Iowa sweet corn growers' ranked statements

Iowa sweet corn grower statements sorted by rating (high to low) derived from the prompt, “One uncertainty in my production system I have difficulty managing is...” and rated based on, “How critical is it to reduce levels of uncertainty in your production system related to this statement to make better decisions? (1 = not critical; 2 = somewhat critical; 3 = moderately critical; 4 = very critical; 5 = extremely critical).”

One uncertainty in my production system I have difficulty managing is...

Statement Number		Average Rating
1	Weather forecasting	4.78
6	Matching supply to demand	4.44
41	Soil fertility rate and timing	4.44
32	Earworm control. Grocery stores expect perfection; need to spray 2-3 days to avoid earworm problem	4.44
36	Weed management	4.44
25	Heat units (Growing Degree Days)	4.33
5	Factors that affect yield	4.33
51	Variety selection	4.33
46	Resistance to insecticides being used for corn earworm	4.33
26	Forecasting heat units three months earlier	4.22
35	Forecasting for insects	4.22
21	Early spring freezes	4.11
16	Spring frost is unpredictable	4.11
27	Degree day model tool that will assist with succession planting	4.11
28	U2U Useful to Usable webpage (historical and forecast Growing Degree Day)	4.11
50	Raccoons, birds, deer, black birds	4.11
8	Heat spells in July and August affects planting and harvest time	3.89
29	Variety that can withstand severe weather (high heat) close to harvest	3.89
3	Spring ground temperature (ground starts warming up; see how early you can plant; ground is usually worked up nice; early March)	3.89
10	Spacing of planting schedules	3.89
7	Unpredictability in supply and demand	3.89
52	Labor	3.89
33	High heat will accelerate reproduction of corn earworm egg and larval growth	3.89
38	Weeds are not responding to herbicide sprays	3.89
4	Cool weather increases germination time	3.78
9	Temperature affects corn maturity	3.78
24	Precipitation and the timing of spray.	3.78
11	Precipitation at the time planting	3.56
42	Cost of nitrogen	3.56
53	Politics affect labor	3.56
34	Frequent spraying	3.56

One uncertainty in my production system I have difficulty managing is...

Statement Number		Average Rating
47	Alternating Warrior II and Hero, was working ok but now we are seeing some resistance later planted corn	3.56
49	Wildlife issues	3.56
2	Early in the year temperature	3.44
17	Spring soil moisture	3.44
15	Varietal selection based on weather and temperature	3.44
57	Decision making and information delivery	3.44
44	Sweet corn followed by field corn: not good	3.33
43	Crop rotations are important	3.33
54	Timing of labor	3.33
55	Not many people available at the time of harvest	3.33
13	When will March 20 planting be ready in July?	3.22
37	Late planting of sweet corn are difficult with respect to weeds	3.22
39	Site selection for weed management	3.22
12	When we plant in April and May we never know what the weather will be in July	3.00
14	When will June planting will ready to harvest?	3.00
56	E-verify regulations	3.00
23	One needs to spray more the Se type sweet corn.	2.89
31	Forecast on fall freeze to guide last planting or extend your planting	2.56
48	Corigen is expensive	2.56
22	Bt vs non-Bt	2.56
20	One cannot only depend on rain, might need to irrigate	2.22
30	Fall freezes can affect sweet corn harvest	2.11
45	Annual rye can cause issues with soil drying in the spring	2.11
40	Smut contamination	2.11
19	Irrigation is important and dependent on soil type	2.00
18	Southwest Iowa might need irrigation and so is the Southeast	1.78