U.S. GRAINS COUNCIL

# 2018/2019 CORN HARVEST QUALITY REPORT

# ACKNOWLEDGEMENTS



Developing a report of this scope and breadth in a timely manner requires participation by a number of individuals and organizations. The U.S. Grains Council (Council) is grateful to Lee Singleton, Chris Schroeder, Lisa Eckel and Alex Harvey of Centrec Consulting Group, LLC (Centrec) for their oversight and coordination in developing this report. They were supported by a team of experts that helped in analysis and report writing. External team members include Drs. Tom Whitaker, Lowell Hill, Marvin R. Paulsen and Fred Below. In addition, the Council is indebted to the Illinois Crop Improvement Association's Identity Preserved Grain Laboratory (IPG Lab) and Champaign-Danville Grain Inspection (CDGI) for providing the corn quality testing services.

Finally, this report would not be possible without the thoughtful and timely participation by local grain elevators across the United States. We are grateful for their time and effort in collecting and providing samples during their very busy harvest time.

# GREETINGS FROM THE COUNCIL



The U.S. Grains Council (USGC) has completed its eighth annual corn quality survey and is pleased to present the findings in this *2018/2019 Corn Harvest Quality Report*.

The Council is committed to the furtherance of global food security and mutual economic benefit through trade. To promote the continuous expansion of trade, this report is offered to assist buyers in making well-informed decisions by providing reliable and timely information about the quality of the current U.S. crop.

The majority of this year's corn crop had a Good or Excellent crop condition rating during growth, leading to a projected record yield and the third-largest U.S. corn crop on record at 371.52 MMT (14,626 million bushels). While domestic use of corn by the U.S. during the 2018/2019 marketing year is projected to be the highest on record, the ample supply provided by this crop is also expected to result in record exports, with the United States accounting for an estimated 37.4 percent of global corn exports during the marketing year.

As in previous reports, the *2018/2019 Corn Harvest Quality Report* provides information about the quality of the current U.S. crop at harvest as it enters international merchandising channels. Corn quality observed by buyers will be further affected by subsequent handling, blending and storage conditions. A second Council report, the *2018/2019 Corn Export Cargo Quality Report*, will measure corn quality at export terminals at the point of loading for international shipment and will be available in early 2019. The Council's series of quality reports uses consistent and transparent methodology to allow for insightful comparisons across time. This enables buyers to make well-informed decisions and have confidence in the capacity and reliability of the U.S. corn market.

The Council's mission is one of developing markets, enabling trade and improving lives. To help fulfill this mission, the Council is pleased to offer this report as a service to our partners. We hope that it continues in its role of providing accurate and timely insight into the quality of the U.S. corn crop to our valued trade partners.

WHEN TRADE WORKS, THE WORLD WINS

Sincerely,

Jim Stitzlein
Chairman, U.S. Grains Council
December 2018

The representative samples tested for the *2018/2019 Corn Harvest Quality Report* indicate the overall quality of the 2018 corn crop was better than the average of the previous five crop years (5YA[1]) on many attributes. Nearly 94% of the samples met the standards for U.S. No. 2 grade. The 2018 U.S. corn crop is entering the market channel with lower average total damage, broken corn and foreign material (BCFM), moisture and stress cracks; and higher average test weight, oil concentration, 100-k weight and true density relative to the 5YA. The following highlights the key harvest results from the 2018 crop:

## Grade Factors and Moisture

- Average test weight of 58.4 lb/bu (75.1 kg/hl), with 90.3% above the limit for No. 1 grade corn, and 98.2% above the limit for No. 2 grade. Similar to 2017 and higher than the 5YA, this test weight indicates good kernel filling and maturation.
- Low levels of BCFM (0.7%), slightly lower than 2017 and the 5YA. In 2018, 98.1% of the samples were below the limit for No. 2 grade, which indicates little cleaning should be required. This is similar to 2017 and 2016, when 98% and 99% of samples, respectively, were below the limit for No. 2 grade for BCFM.
- Average total damage of 1.5% was higher than 2017 but lower than 2016 and the 5YA, and 97.1% of the samples were below the total damage limit for No. 2 grade.
- There was no observed heat damage in any samples received.
- Lower elevator moisture content (16.0%) than 2017 and the 5YA, but similar to 2016 which was also a good field drying year. The distribution shows 24.7% of the samples were above 17% moisture content as compared to 36% and 29% in 2017 and 2016, respectively. This distribution indicates fewer samples required artificial drying in 2018 than in 2017.

## Chemical Composition

- Protein concentration (8.5% dry basis) was slightly lower than in 2017 and 2016 but similar to the 5YA.
- Higher starch concentration (72.5% dry basis) than 2017, same as 2016 but lower than the 5YA.
- Average oil concentration of (4.0% dry basis), lower than 2017, same as 2016 and higher than the 5YA.

**U.S. Corn Grades and Grade Requirements**

| Grade | Minimum Test Weight per Bushel (Pounds) | Maximum Limits of: Damaged Kernels — Heat Damaged (Percent) | Maximum Limits of: Damaged Kernels — Total (Percent) | Maximum Limits of: Broken Corn and Foreign Material (Percent) |
|---|---|---|---|---|
| U.S. No. 1 | 56.0 | 0.1 | 3.0 | 2.0 |
| U.S. No. 2 | 54.0 | 0.2 | 5.0 | 3.0 |
| U.S. No. 3 | 52.0 | 0.5 | 7.0 | 4.0 |
| U.S. No. 4 | 49.0 | 1.0 | 10.0 | 5.0 |
| U.S. No. 5 | 46.0 | 3.0 | 15.0 | 7.0 |

[1] *5YA represents the simple average of the quality factor's average or standard deviation from the 2014/2015, 2015/2016, 2016/2017, 2017/2018 and 2018/2019 Harvest Reports.*

## *Physical Factors*

- The 2018 crop had a low percentage of stress cracks (5%), same as 2017, higher than 2016 but lower than the 5YA, with 89.0% of the samples having less than 10% stress cracks.
- Average stress crack index (11.5), lower than 2017 and the 5YA but higher than 2016 which was also a good field drying year. Susceptibility to breakage should remain relatively low.
- Lower 100-k weight (35.07 g) than 2017 but similar to 2016 and higher than the 5YA, signifying generally smaller kernels than 2017 but similar to previous years.
- Average kernel volume of 0.28 $cm^3$, lower than 2017, but similar to 2016 and the 5YA.
- Average true density of 1.265 $g/cm^3$, higher than 2017, 2016 and the 5YA.
- Higher average whole kernels (93.0%) than 2017, lower than 2016 and similar the 5YA.
- Average horneous endosperm of 81%, similar to 2017 and the 5YA but higher than 2016. This indicates kernel hardness similar to last year and the 5YA.

## *Mycotoxins*

- All but one sample, or 99.5%, of the 2018 corn samples, tested below the U.S. Food and Drug Administration (FDA) action level for aflatoxin of 20 ppb.
- In 2018, 100% of the corn samples tested below the 5 ppm FDA advisory level for deoxynivalenol (DON), same as in 2017 and 2016. In addition, 74.6% of the samples tested below the U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) "Lower Conformance Level", a lower proportion than in 2017. This decrease may be attributed to weather conditions that were more conducive to DON development in 2018 than in 2017.

The *U.S. Grains Council 2018/2019 Corn Harvest Quality Report* has been designed to help international buyers of U.S. corn understand the initial quality of U.S. yellow commodity corn as it enters the merchandising channel. This is the eighth annual measurement survey of the quality of the U.S. corn crop at harvest. Eight years of results are showing patterns in the impact of weather and growing conditions on the quality of U.S. corn as it comes out of the field.

An unseasonably-cold April 2018 in most of the United States was followed by warm, favorable conditions for planting in May. Planting and emergence were initially delayed by these conditions, but crop progress soon reached levels similar to the 5-year average (5YA) by mid-May. Warm, wet weather during the vegetative stage encouraged rapid growth and healthy-looking plants, producing a crop with a combined Good to Excellent condition rating that remained at or above 67% all season and is projected to have the highest average yield on record.

This year's fast crop maturation allowed for rapid harvest progress in many regions of the country, signified by harvest progress remaining well above the 5YA throughout September. However, abundant rains hindered harvest in October, and progress regressed back to the 5YA.

Overall, the growing conditions in 2018 resulted in a crop with high test weight averages and kernels that were both relatively large and dense. BCFM, stress cracks and whole kernels were also below or close to the 5YA.

These observations show quality differences among the eight years, but overall, the *2018/2019 Harvest Report* indicates good quality corn entering the market channel. Slightly over 77% of the samples met all grade factor requirements for No. 1 grade, and nearly 94% met the grade factor requirements for No. 2 grade. In addition, total damage and moisture levels were each slightly lower than the 5YA, which should be good for storability.

Eight years of data have laid the foundation for evaluating trends and the factors that impact corn quality. In addition, the cumulative *Harvest Report* measurement surveys enable export buyers to make year-to-year comparisons and assess patterns of corn quality based on crop growing conditions across the years.

This *2018/2019 Harvest Report* is based on 618 yellow commodity corn samples taken from defined areas within 12 of the top corn-producing and exporting states. Inbound samples were collected from local grain elevators to measure and analyze quality at the point of origin and to provide representative information about the variability of the quality characteristics across the diverse geographic regions.

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The sampling areas in the 12 states are divided into three general groupings that are labeled Export Catchment Areas (ECAs). These three ECAs are identified by the three major pathways to export markets:

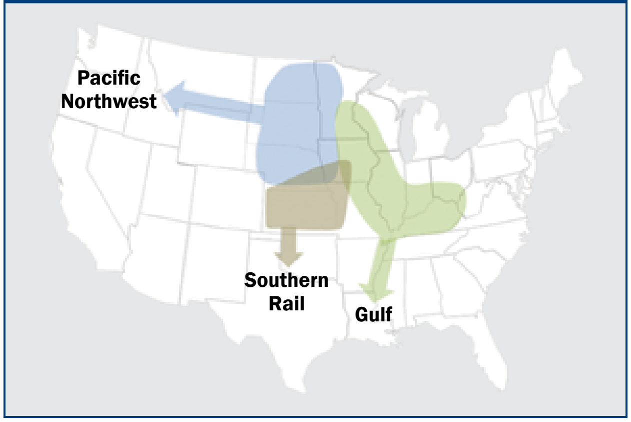
- The Gulf ECA consists of areas that typically export corn through U.S. Gulf ports;
- The Pacific Northwest ECA includes areas exporting corn through Washington, Oregon and California ports; and
- The Southern Rail ECA comprises areas generally exporting corn to Mexico by rail from inland subterminals.

Sample test results are reported at the U.S. Aggregate level and for each of the three ECAs, providing a general perspective on the geographic variability of U.S. corn quality.

The quality characteristics of the corn identified at harvest establish the foundation for the quality of the grain ultimately arriving at the export customers' doors. However, as corn passes through the U.S. marketing system, it is mingled with corn from other locations; aggregated into trucks, barges and railcars; and stored, loaded and unloaded several times. Therefore, the quality and condition of the corn change between the initial market entry and the export elevator. For this reason, the *2018/2019 Harvest Report* should be considered carefully in tandem with the *U.S. Grains Council 2018/2019 Corn Export Cargo Quality Report* that will follow early in 2019. As always, the quality of an export cargo of corn is established by the contract between buyer and seller, and buyers are free to negotiate any quality factor that is important to them.

This report provides detailed information on each of the quality factors tested, including averages and standard deviations for the aggregate of all samples, and for each of the three ECAs. The "Quality Test Results" section summarizes the following quality factors:

**EXPORT CATCHMENT AREAS**




- Grade Factors: test weight, broken corn and foreign material (BCFM), total damage and heat damage
- Moisture
- Chemical Composition: protein, starch and oil concentrations
- Physical Factors: stress cracks/stress crack index, 100-kernel weight, kernel volume, kernel true density, whole kernels and horneous (hard) endosperm
- Mycotoxins: aflatoxin and deoxynivalenol (DON) or vomitoxin

In addition, this *Harvest Report* includes brief descriptions of the U.S. crop and weather conditions; U.S. corn production, usage and outlook; detailed descriptions of survey, statistical analysis and testing analysis methods; and a new, historical perspective section displaying the average of each quality factor from all eight reports.

Included in this *2018/2019 Harvest Report* is a simple average of the quality factors' annual averages and standard deviations of the previous five *Harvest Reports*. These simple averages are calculated for the U.S. Aggregate and each of the three ECAs and are referred to as the "5YA" in the report.

# A. GRADE FACTORS

The U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) has established numerical grades, definitions and standards for measurement of many quality attributes. The attributes that determine the numerical grades for corn are test weight, broken corn and foreign material (BCFM), total damage and heat damage. A table displaying the numerical requirements for these attributes is included in the "U.S. Corn Grades and Conversions" section of this report.

## SUMMARY: GRADE FACTORS AND MOISTURE

- Average U.S. Aggregate test weight (58.4 lb/bu or 75.1 kg/hl) was the same as 2017 and slightly higher than in 2016 and the 5YA. It was well above the limit for U.S. No. 1 grade corn.
- As in previous years, the average test weight was above the minimum for U.S. No. 1 grade in all ECAs.
- Average U.S. Aggregate BCFM (0.7%) was lower than 2017 and the 5YA (both 0.8%), same as 2016, and well below the maximum for U.S. No. 1 grade (56 lb/bu).
- BCFM levels in almost all (98.1%) of the corn samples were equal to or below the 3% maximum allowed for No. 2 grade.
- Average BCFM differed by no more than 0.1% between all three ECAs.
- Average U.S. Aggregate broken corn (0.5%) was lower than last year and the 5YA, but the same as 2016.
- Average U.S. Aggregate foreign material (0.2%) was same as last year and the 5YA, but higher than 2016.
- Total damage in the U.S. Aggregate samples averaged 1.5% in 2018, higher than in 2017, lower than in 2016 and the 5YA and well below the limit for U.S. No. 1 grade (3%). A total of 89.2% of samples contained 3% or less damaged kernels.
- The Pacific Northwest ECA had the lowest total damage in 2018, 2017, 2016 and the 5YA, while the Gulf ECA had the highest or tied for the highest total damage for 2018, 2017, 2016 and the 5YA. Average total damage values in all ECAs were well below the limit for U.S. No. 1 grade (3.0%).
- No heat damage was reported on any of the samples, the same as 2017, 2016 and the 5YA.
- Average U.S. Aggregate moisture content in 2018 (16.0%) was lower than in 2017 and the 5YA but similar to 2016.
- The 2018 average moisture contents for the Gulf and Pacific Northwest ECAs (both 16.1%) were higher than the Southern Rail ECA (15.5%). Average moisture levels for the Southern Rail ECA were lowest among all ECAs for 2018, 2017, 2016 and the 5YA. There were fewer high moisture samples in the 2018 crop than in the 2017 and 2016, with 24.7% of the samples containing more than 17% moisture, compared to 36% in 2017 and 29% in 2016. This distribution indicates less drying was required in 2018 than in the previous year.
- Even with lower moisture contents in 2018 than in 2017, care should still be taken to monitor and maintain moisture levels sufficiently low to prevent possible mold growth during storage.

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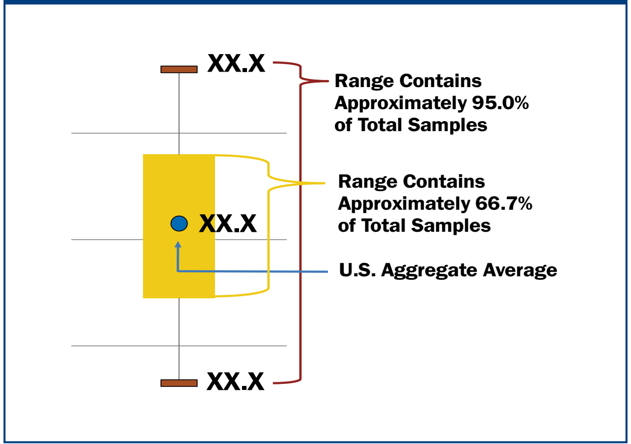
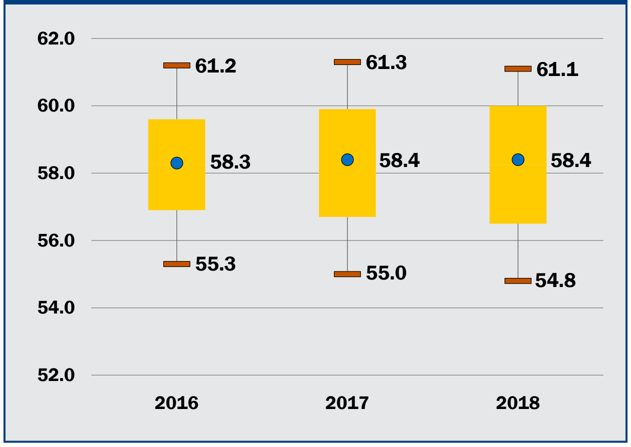
## GRADE FACTORS VS. AGGREGATE 3-YEAR COMPARISON

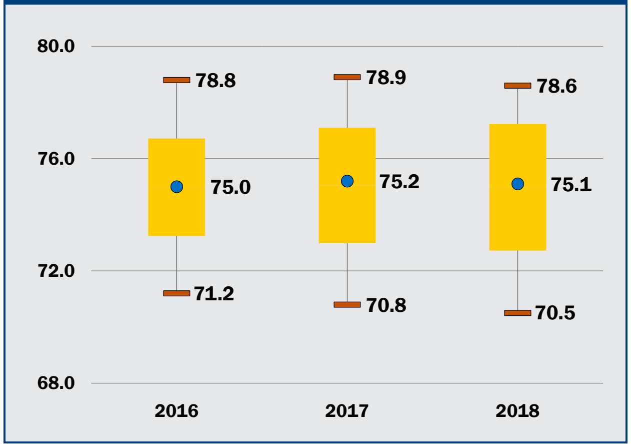
### HOW TO READ THE CHARTS



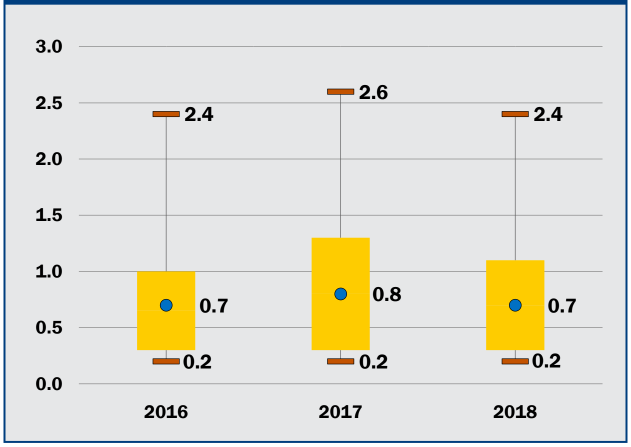

### TEST WEIGHT (lb/bu)



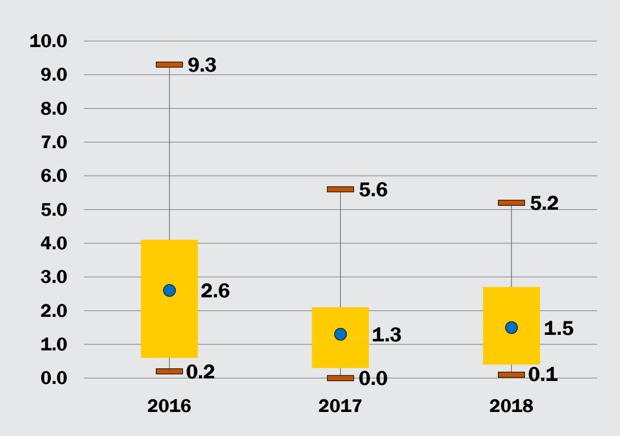

### TEST WEIGHT (kg/hl)



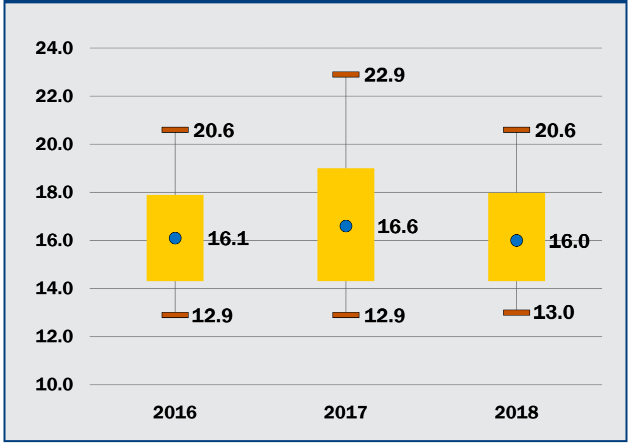

### BCFM (%)




### TOTAL DAMAGE (%)




### MOISTURE (%)



## Test Weight

Test weight (weight per volume) is a measure of bulk density and is often used as a general indicator of overall quality and as a gauge of endosperm hardness for alkaline cookers and dry millers. High test weight corn takes up less storage space than the same weight of corn with a lower test weight. Test weight is initially impacted by genetic differences in the structure of the kernel. However, it is also affected by moisture content, method of drying, physical damage to the kernel (broken kernels and scuffed surfaces), foreign material in the sample, kernel size, stress during the growing season and microbiological damage. When sampled and measured at the point of delivery from the farm at a given moisture content, high test weight generally indicates high quality, high percent of horneous (or hard) endosperm and sound, clean corn. Test weight is positively correlated with true density and reflects kernel hardness and good maturation conditions.

### *Results*

- Average U.S. Aggregate test weight in 2018 (58.4 lb/bu) was the same as 2017 (58.4 lb/bu), but higher than 2016 (58.3 lb/bu) and the 5YA (58.1 lb/bu).
- Average U.S. Aggregate test weight in 2018 was well above the minimum for U.S. No. 1 grade (56 lb/bu).
- U.S. Aggregate test weight standard deviation in 2018 (1.20 lb/bu) was similar to 2017 (1.21 lb/bu) and 2016 (1.22 lb/bu), but lower than the 5YA (1.27 lb/bu).

| U.S. Grade Minimum Test Weight |
|---|
| No. 1: 56.0 lbs |
| No. 2: 54.0 lbs |
| No. 3: 52.0 lbs |

- The range in values among the 2018 harvest samples (52.3 to 62.1 or 9.8 lb/bu) was less than 2017 harvest samples (52.1 to 62.7 lb/bu or 10.6 lb/bu) and 2016 (51.5 to 61.9 lb/bu or 10.4 lb/bu).
- The 2018 test weight values were distributed with 90.3% of the samples at or above the factor limit for U.S. No. 1 grade (56 lb/bu). This distribution was similar to 2017 (92%) and 2016 (95%) above 56 lb/bu. In 2018, 98.2% of the samples were above the limit for U.S. No. 2 grade (54 lb/bu), compared to 100% in 2017 and 2016.
- Average test weight was above the limit for U.S. No. 1 grade in all ECAs. The Gulf (58.6 lb/bu) and Southern Rail (58.9 lb/bu) ECAs had the highest average test weights. The Pacific Northwest ECA (57.5 lb/bu) had the lowest test weight in 2018, 2017, 2016 and the 5YA.
- Besides having the lowest test weight in 2018, the Pacific Northwest ECA had the highest variability, as indicated by its higher standard deviation (1.37 lb/bu), compared to the Gulf (1.13 lb/bu) and Southern Rail (1.19 lb/bu) ECAs.

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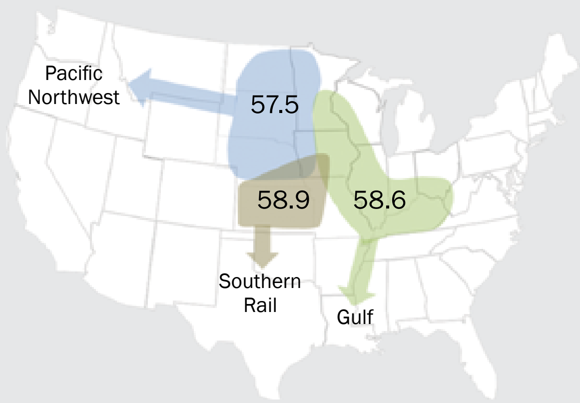
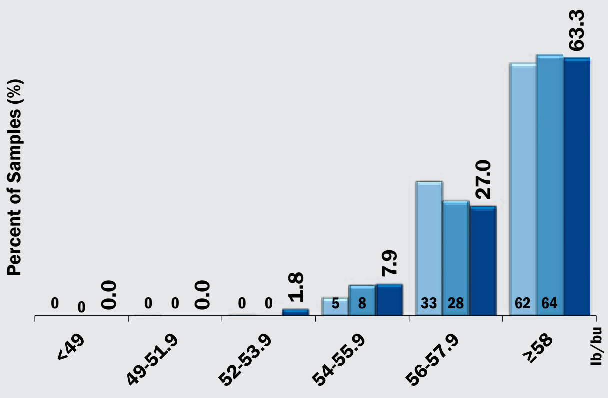
## TEST WEIGHT (lb/bu)

### EXPORT CATCHMENT AREA AVERAGE



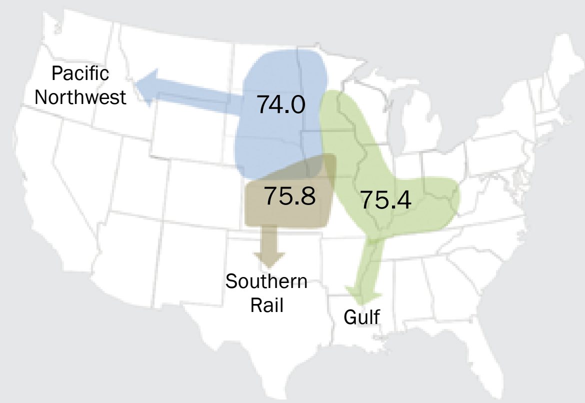

### U.S. AGGREGATE



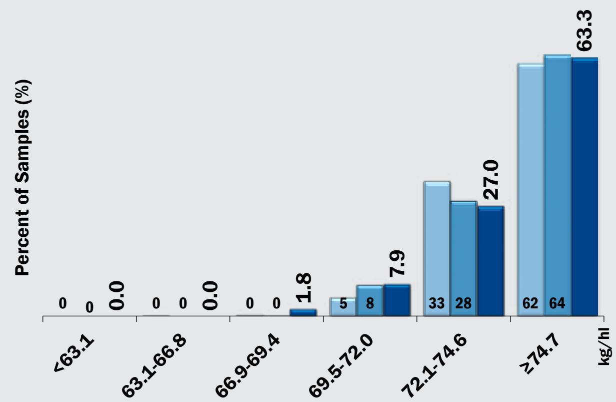

| | Avg (lb/bu) | Std Dev (lb/bu) |
|---|---|---|
| 2018 | 58.4 | 1.20 |
| 2017 | 58.4 | 1.21 |
| 2016 | 58.3 | 1.22 |

## TEST WEIGHT (kg/hl)

### EXPORT CATCHMENT AREA AVERAGE




### U.S. AGGREGATE




| | Avg (kg/hl) | Std Dev (kg/hl) |
|---|---|---|
| 2018 | 75.1 | 1.54 |
| 2017 | 75.2 | 1.55 |
| 2016 | 75.0 | 1.57 |

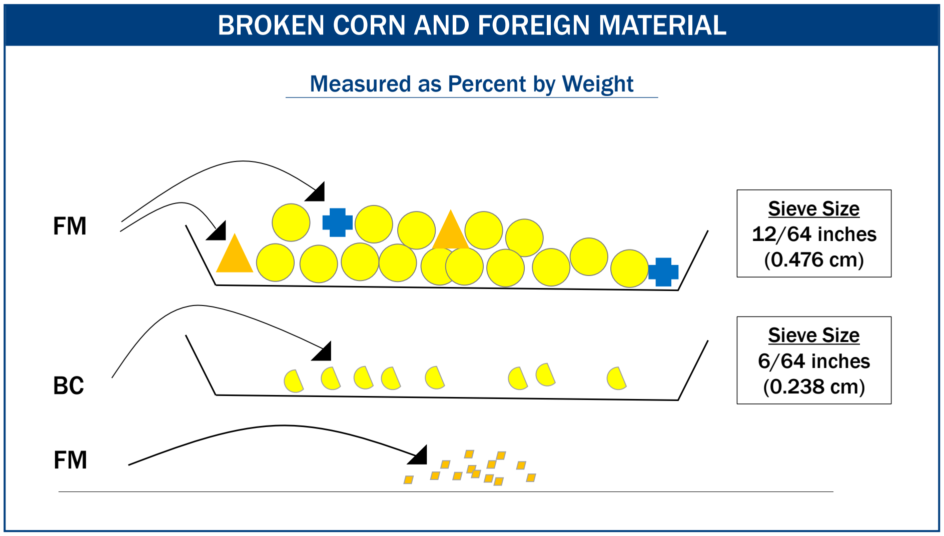
## Broken Corn and Foreign Material (BCFM)

Broken corn and foreign material (BCFM) is an indicator of the amount of clean, sound corn available for feeding and processing. The lower the percentage of BCFM, the less foreign material and/or fewer broken kernels are in a sample. Higher levels of BCFM in farm-originated samples generally stem from harvesting practices and/or weed seeds in the field. BCFM levels will normally increase during drying and handling, depending on the methods used and the soundness of the kernels. More stress cracks at harvest will also result in an increase in broken kernels and BCFM during subsequent handling.

Broken corn (BC) is defined as corn and any other material (such as weed seeds) small enough to pass through a 12/64$^{th}$-inch round-hole sieve, but too large to pass through a 6/64$^{th}$-inch round-hole sieve.

Foreign material (FM) is defined as any non-corn material too large to pass through a 12/64$^{th}$-inch round-hole sieve, as well as all fine material small enough to pass through a 6/64$^{th}$-inch round-hole sieve.

The diagram shown below illustrates the measurement of broken corn and foreign material for the U.S. corn grades.



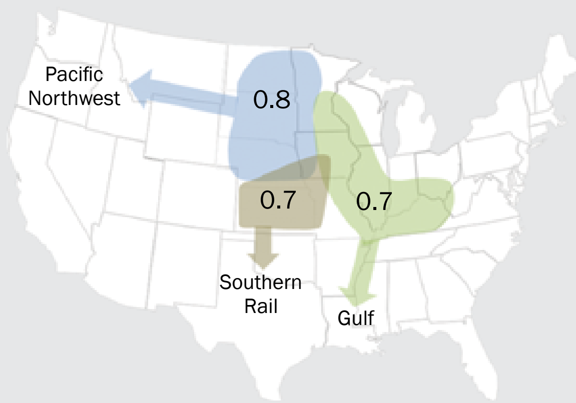
## *Results*

- Average U.S. Aggregate BCFM in 2018 (0.7%) was lower than 2017 (0.8%), same as 2016 (0.7%), below the 5YA (0.8%) and well below the maximum for U.S. No. 1 grade (2.0%).
- The variability of BCFM in the 2018 crop, based on standard deviation (0.51%), was less than 2017 (0.57%) and the 5YA (0.55%) but greater than 2016 (0.45%).
- The range between minimum and maximum BCFM values in 2018 (7.5%) was similar to 2017 (7.3%) but more than 2016 (4.0%). The 2018 samples were distributed with 95.3% of the samples below the maximum BCFM level for U.S. No. 1 grade (2.0%), compared to 95% in 2017 and 97% in 2016. BCFM levels in nearly all samples (98.1%) were equal to or below the maximum 3% limit for No. 2 grade.
- Average BCFM for the Gulf, Pacific Northwest and Southern Rail ECAs (0.7%, 0.8% and 0.7%, respectively) differed by 0.1% across the ECAs. The difference in average BCFM across ECAs was 0.0 to 0.1% in 2017, 2016 and the 5YA.

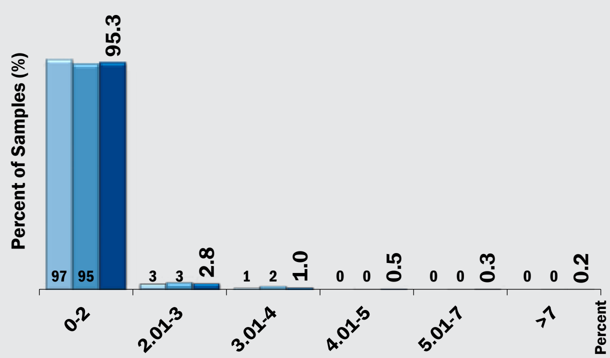
| U.S. Grade BCFM Maximum Limits |
|---|
| No. 1: 2.0% |
| No. 2: 3.0% |
| No. 3: 4.0% |

### BROKEN CORN AND FOREIGN MATERIAL (%)

#### EXPORT CATCHMENT AREA AVERAGE




#### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 0.7 | 0.51 |
| 2017 | 0.8 | 0.57 |
| 2016 | 0.7 | 0.45 |

## Broken Corn

Broken corn in U.S. grades is based on particle size and usually includes a small percent of the non-corn material. Broken corn is more subject to mold and insect damage than whole kernels, and it can cause problems in handling and processing. When not spread or stirred in a storage bin, broken corn tends to stay in the center of the bin, while whole kernels are likely to gravitate outward to the edges. The center area in which broken corn tends to accumulate is known as a "spout-line." If desired, the spout-line can be reduced by drawing this grain out of the center of the bin.

### *Results*

- Broken corn in the U.S. Aggregate samples averaged 0.5% in 2018, slightly lower than 2017 and the 5YA (0.6%) and the same as 2016 (0.5%).
- The variability of broken corn for the 2018 crop was similar to previous years and the 5YA, as measured by standard deviations. Standard deviations for 2018, 2017, 2016 and the 5YA were 0.33%, 0.39%, 0.34% and 0.39%, respectively.
- The range in broken corn values in 2018 (3.6%), was between 2017 (3.5%) and 2016 (3.8%).
- The 2018 samples were distributed with 12.6% having 1.0% or more broken corn, compared to 19% in 2017 and 9% in 2015.
- The percentage of broken corn was fairly consistent across the Gulf, Pacific Northwest and Southern Rail ECAs (with averages of 0.5%, 0.6% and 0.5%, respectively).
- The distribution chart on the next page, displaying broken corn as a percentage of BCFM, shows that in 55.5% of the samples, BCFM consisted of at least 80% broken corn. These results were similar to what was found in previous years.

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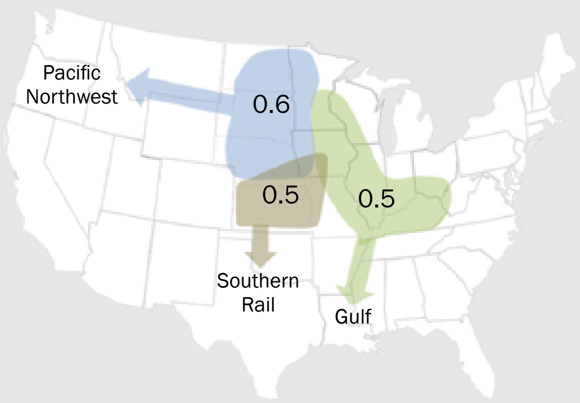
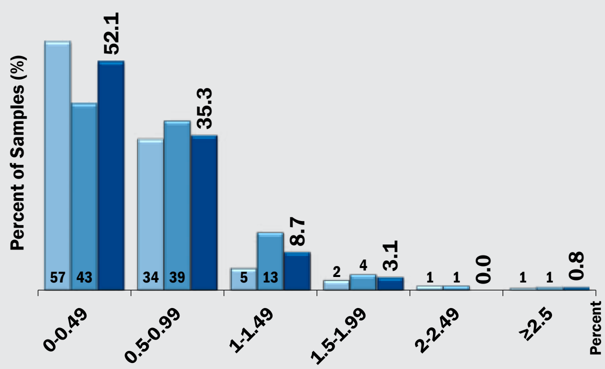
## BROKEN CORN (%)

### EXPORT CATCHMENT AREA AVERAGE



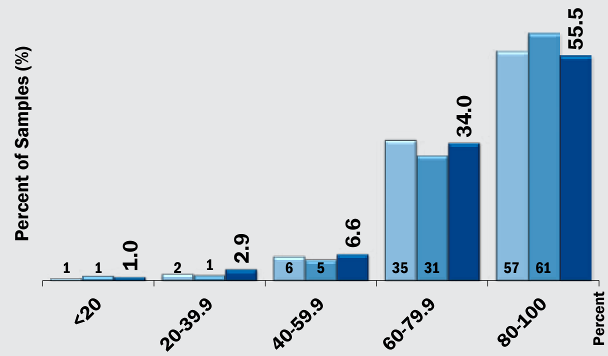

### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 0.5 | 0.33 |
| 2017 | 0.6 | 0.39 |
| 2016 | 0.5 | 0.34 |

## BROKEN CORN (%)

### BROKEN CORN AS A PERCENT OF BCFM



## Foreign Material

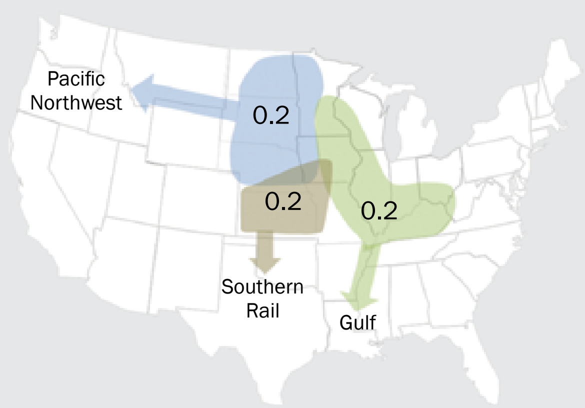
Foreign material is important because it has reduced feeding or processing value. It is also generally higher in moisture content than corn and therefore creates a potential for deterioration of corn quality during storage. Additionally, foreign material contributes to the spout-line (as mentioned in Broken Corn). It also has the potential to create more quality problems than broken corn, due to its higher moisture level.

### *Results*

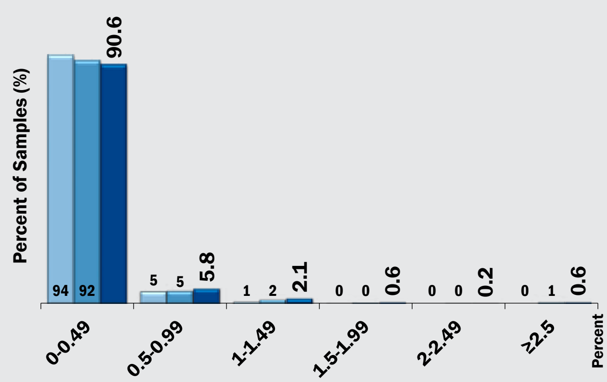
- Foreign material in the U.S. Aggregate samples averaged 0.2% in 2018 and 2017, higher than in 2016 (0.1%), but the same as in the 5YA (0.2%). Combines, which are designed to remove most fine material, appear to be functioning well, given the consistently low level of foreign material found across the years.
- Variability, measured by standard deviation, among the U.S. Aggregate samples in 2018 (0.26%) was similar to 2017 (0.25%), higher than in 2016 (0.16%) but nearly the same as the 5YA (0.22%).
- Foreign material in the 2018 samples showed a wider range (0.0 to 7.3%) than samples from 2017 (0 to 6.3%) and 2016 (0 to 1.6%).
- In the 2018 crop, 90.6% of the samples contained less than 0.5% foreign material, essentially the same as 2017 (92%) and 2016 (94%).
- The percentages of foreign material for the Gulf, Pacific Northwest and Southern Rail ECAs were all 0.2%. All ECAs had average foreign material values of 0.2% in 2018, 2017 and the 5YA. In 2016 all ECAs had average foreign material of 0.1 or 0.2%.

**FOREIGN MATERIAL (%)**

EXPORT CATCHMENT AREA AVERAGE




U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 0.2 | 0.26 |
| 2017 | 0.2 | 0.25 |
| 2016 | 0.1 | 0.16 |

## Total Damage

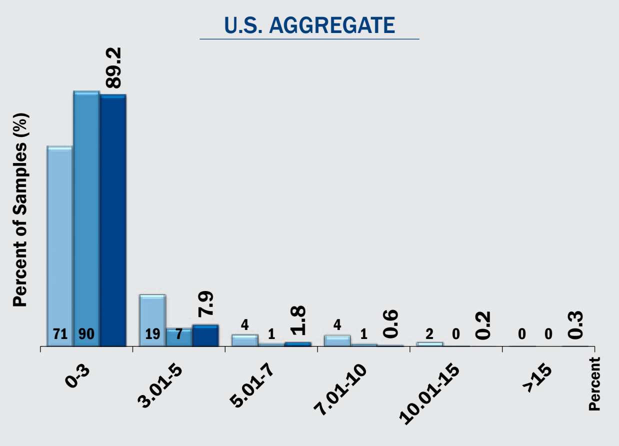
Total damage is the percentage of kernels and pieces of kernels that are visually damaged in some way, including damage from heat, frost, insects, sprouting, disease, weather, ground, germ and mold. Most of these types of damage result in some sort of discoloration or change in kernel texture. Damage does not include broken pieces of grain that are otherwise normal in appearance.

Mold damage is usually associated with higher moisture contents and warm temperatures during the growing season and/or during storage. There are several field molds, such as *Diplodia*, *Aspergillus*, *Fusarium* and *Gibberella*, that can lead to mold-damaged kernels during the growing season if the weather conditions are conducive to their development. While some fungi that produce mold damage can also produce mycotoxins, not all fungi do produce mycotoxins. Chances of mold decrease as corn is dried and cooled to lower temperatures.

### *Results*

- Average U.S. Aggregate total damage in 2018 (1.5%) was higher than in 2017 (1.3%), lower than 2016 (2.6%) but similar to the 5YA (1.6%). The 2018 total damage average was well below the limit for U.S. No. 1 grade (3.0%).
- Total damage variability in the 2018 crop, as measured by the standard deviation (1.25%), was higher than 2017 (1.09%) and the 5YA (1.19%), but lower than 2016 (1.61%).
- The range for total damage in 2018 (0 to 19.3%) was higher than in 2017 (0.0 to 13.6%) and was lower than in 2016 (0.0 to 23.1%).
- Total damage in the 2018 samples was distributed with 89.2% of the samples having 3% or less and 97.1% having 5% or less damaged kernels, compared to 2017 with 90% and 97%, and 2016 with 71% and 90%, respectively.

**TOTAL DAMAGE (%)**

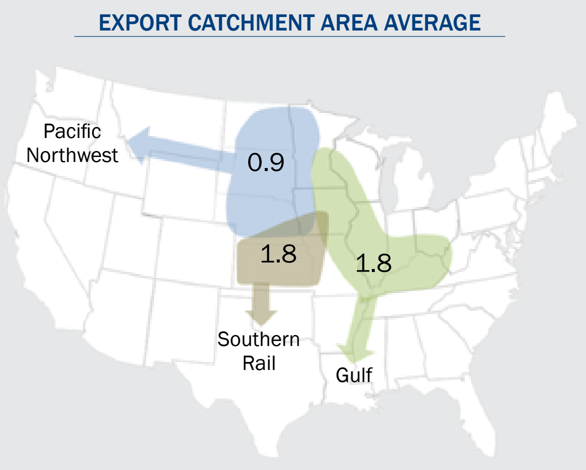



| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 1.5 | 1.25 |
| 2017 | 1.3 | 1.09 |
| 2016 | 2.6 | 1.61 |

- Average total damage by ECA was 1.8% for Gulf, 0.9% for Pacific Northwest and 1.8% for Southern Rail. The Pacific Northwest ECA had the lowest average total damage, and the Gulf ECA had the highest or tied for the highest total damage for 2018, 2017, 2016 and the 5YA.
- Average total damage values in all ECAs were well below the limit for U.S. No. 1 grade (3.0%).

| U.S. Grade Total Damage Maximum Limits |
|---|
| No. 1: 3.0% |
| No. 2: 5.0% |
| No. 3: 7.0% |

**TOTAL DAMAGE (%)**




## Heat Damage

Heat damage is a subset of total damage and has separate allowances in the U.S. Grade standards. Heat damage can be caused by microbiological activity in warm, moist grain or by high heat applied during drying. Heat damage is seldom present in corn delivered directly from farms at harvest.

### *Results*

- There was no heat damage reported in any of the 2018 samples, the same results as 2017, 2016 and the 5YA.
- The absence of heat damage likely was due in part to fresh samples coming directly from farm to elevator with minimal artificial drying.

| U.S. Grade Heat Damage Maximum Limits |
|---|
| No. 1: 0.1% |
| No. 2: 0.2% |
| No. 3: 0.5% |

# B. MOISTURE

Moisture content is reported on official grade certificates, and maximum moisture content is usually specified in the contract. However, moisture is not a grade factor, therefore, it does not determine which numerical grade will be assigned to the sample. Moisture content is important because it affects the amount of dry matter being sold and purchased. Moisture content is also an indicator of whether a need exists for drying, has potential implications for storability and affects test weight. Higher moisture content at harvest increases the chance of kernel damage during harvesting and drying. Moisture content and the amount of drying required will also affect stress cracks, breakage and germination.

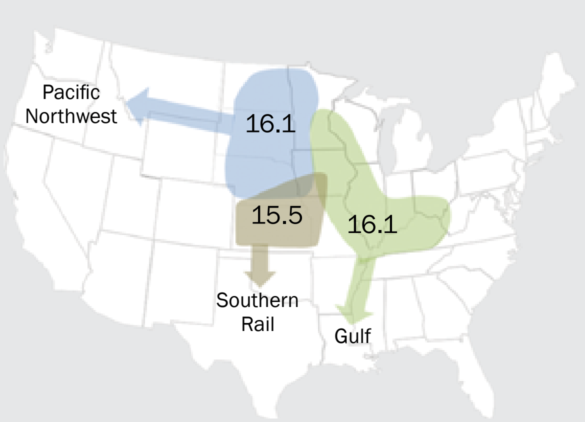
Extremely wet grain may be a precursor to high mold damage later in storage or transport. While the weather during the growing season affects yield, grain composition and the development of the grain kernels, grain harvest moisture is influenced largely by crop maturation, the timing of harvest and harvest weather conditions. General moisture storage guidelines suggest that 14% is the maximum moisture content for storage up to 6 to 12 months for good quality, clean corn under aerated storage under typical U.S. Corn Belt conditions, and 13% or lower moisture content is recommended for storage of more than one year.[1]

## *Results*[2]

- Over eight years average U.S. Aggregate moisture has ranged from a low of 15.3% in the 2012 drought year to a high of 17.3% in 2013. In 2018, the average U.S. Aggregate moisture content recorded at the elevator was 16.0%, which was lower than 2017 (16.6%), 2016 (16.1%) and the 5YA (16.5%).
- U.S. Aggregate moisture standard deviation in 2018 (1.58%) was lower than 2017 (1.90%) and the 5YA (1.80%) but slightly higher than 2016 (1.47%).

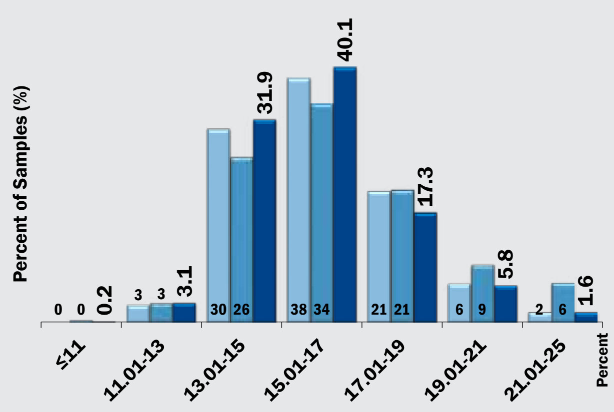
**MOISTURE (%)**

EXPORT CATCHMENT AREA AVERAGE




**MOISTURE (%)**

U.S. AGGREGATE

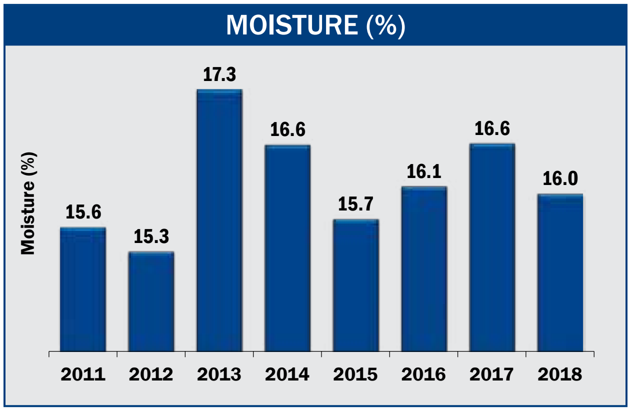


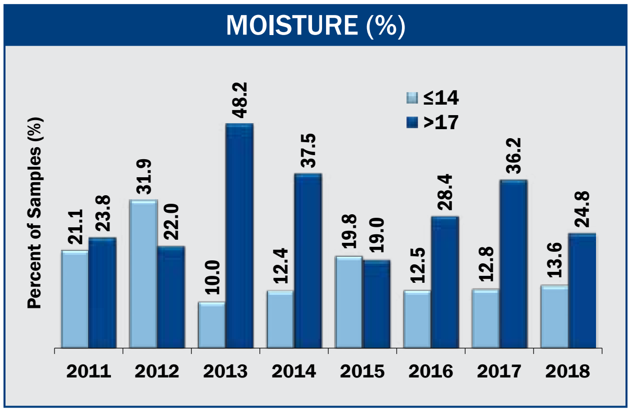

| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 16.0 | 1.58 |
| 2017 | 16.6 | 1.90 |
| 2016 | 16.1 | 1.47 |

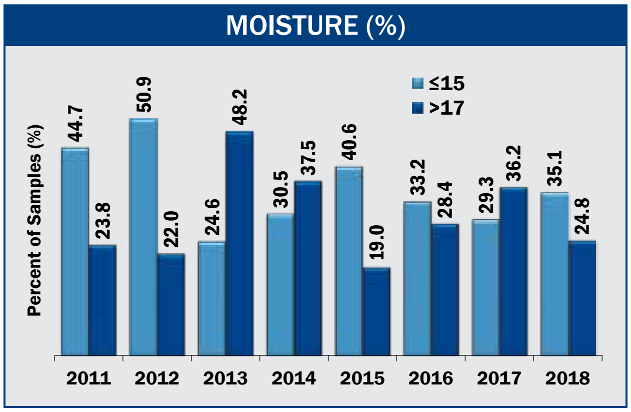
[1] *WPS-13. 1988. Grain drying, handling and storage handbook. Midwest Plan Service No. 13. Iowa State University, Ames, IA 50011*

[2] *Differences between the histograms in this section are solely due to rounding.*

- The range in moisture content values in 2018 (10.1 to 25.0%) was similar to 2017 (9.0 to 24.4%) and 2016 (11.2 to 23.7%).
- There were fewer high-moisture samples in the 2018 samples than those in the 2017 and 2016, with 24.8% of the samples containing more than 17% moisture, compared to 36.2% in 2017 and 28.4% in 2016. This distribution indicates that the 2018 crop required less drying than the 2017 and 2016 crops.
- In the 2018 crop, 13.6% of the samples contained 14% or less moisture compared to 12.8% in the 2017 samples and 12.5% in the 2016 samples. Moisture content values of 14% and below are generally considered a safe level for longer-term storage and transport.
- The 2018 moisture values were distributed with 35.1% of the samples containing 15% or less moisture. The base moisture used by elevators for discounts is generally 15%. This moisture content is considered safe for storage for short periods during low wintertime temperatures.
- The average moisture contents for corn from the Gulf and Pacific Northwest ECAs (both 16.1%) were higher than that from the Southern Rail ECA (15.5%).
- Average moisture levels for the Southern Rail ECA were lowest among all ECAs for 2018, 2017, 2016 and the 5YA. Samples from the Southern Rail usually contain lower moisture content due to generally favorable weather conditions for grain dry-down.
- Moisture contents in the 2018 samples were somewhat lower than in 2017 and the 5YA, but care should still be taken to monitor and maintain moisture levels sufficiently low to prevent possible mold growth.



## SUMMARY: GRADE FACTORS AND MOISTURE

| | 2018 Harvest | | | | | 2017 Harvest | | | 2016 Harvest | | | 5 Year Avg. (2013-2017) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 618 | 58.4 | 1.20 | 52.3 | 62.1 | 627 | 58.4 | 1.21 | 624 | 58.3 | 1.22 | 58.1 | 1.27 |
| Test Weight (kg/hl) | 618 | 75.1 | 1.54 | 67.3 | 79.9 | 627 | 75.2 | 1.55 | 624 | 75.0 | 1.57 | 74.8 | 1.64 |
| BCFM (%) | 618 | 0.7 | 0.51 | 0.0 | 7.5 | 627 | 0.8* | 0.57 | 624 | 0.7* | 0.45 | 0.8 | 0.55 |
| Broken Corn (%) | 618 | 0.5 | 0.33 | 0.0 | 3.6 | 627 | 0.6* | 0.39 | 624 | 0.5 | 0.34 | 0.6 | 0.39 |
| Foreign Material (%) | 618 | 0.2 | 0.26 | 0.0 | 7.3 | 627 | 0.2 | 0.25 | 624 | 0.1* | 0.16 | 0.2 | 0.22 |
| Total Damage (%) | 618 | 1.5 | 1.25 | 0.0 | 19.3 | 627 | 1.3* | 1.09 | 624 | 2.6* | 1.61 | 1.6 | 1.19 |
| Heat Damage (%) | 618 | 0.0 | 0.00 | 0.0 | 0.0 | 627 | 0.0 | 0.00 | 624 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 618 | 16.0 | 1.58 | 10.1 | 25.0 | 627 | 16.6* | 1.90 | 624 | 16.1 | 1.47 | 16.5 | 1.80 |
| **Gulf** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 587 | 58.6 | 1.13 | 52.3 | 62.1 | 612 | 58.6 | 1.18 | 612 | 58.4* | 1.24 | 58.2 | 1.27 |
| Test Weight (kg/hl) | 587 | 75.4 | 1.46 | 67.3 | 79.9 | 612 | 75.4 | 1.52 | 612 | 75.1* | 1.59 | 75.0 | 1.63 |
| BCFM (%) | 587 | 0.7 | 0.50 | 0.0 | 7.5 | 612 | 0.8* | 0.58 | 612 | 0.7 | 0.45 | 0.8 | 0.55 |
| Broken Corn (%) | 587 | 0.5 | 0.32 | 0.0 | 3.6 | 612 | 0.6* | 0.39 | 612 | 0.5 | 0.34 | 0.6 | 0.39 |
| Foreign Material (%) | 587 | 0.2 | 0.26 | 0.0 | 7.3 | 612 | 0.2 | 0.27 | 612 | 0.2* | 0.17 | 0.2 | 0.22 |
| Total Damage (%) | 587 | 1.8 | 1.41 | 0.0 | 19.3 | 612 | 1.6* | 1.33 | 612 | 3.2* | 1.88 | 1.9 | 1.41 |
| Heat Damage (%) | 587 | 0.0 | 0.00 | 0.0 | 0.0 | 612 | 0.0 | 0.00 | 612 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 587 | 16.1 | 1.58 | 10.1 | 25.0 | 612 | 17.0* | 2.06 | 612 | 16.2 | 1.48 | 16.7 | 1.87 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 288 | 57.5 | 1.37 | 52.3 | 62.1 | 291 | 57.7 | 1.28 | 301 | 58.0* | 1.19 | 57.3 | 1.29 |
| Test Weight (kg/hl) | 288 | 74.0 | 1.77 | 67.3 | 79.9 | 291 | 74.2 | 1.65 | 301 | 74.6* | 1.53 | 73.8 | 1.66 |
| BCFM (%) | 288 | 0.8 | 0.58 | 0.1 | 5.4 | 291 | 0.9 | 0.55 | 301 | 0.7* | 0.45 | 0.9 | 0.60 |
| Broken Corn (%) | 288 | 0.6 | 0.39 | 0.1 | 3.2 | 291 | 0.7 | 0.40 | 301 | 0.6 | 0.35 | 0.7 | 0.42 |
| Foreign Material (%) | 288 | 0.2 | 0.24 | 0.0 | 4.0 | 291 | 0.2 | 0.23 | 301 | 0.1* | 0.13 | 0.2 | 0.24 |
| Total Damage (%)[2] | 288 | 0.9 | 0.83 | 0.0 | 11.2 | 291 | 0.6* | 0.49 | 301 | 1.0 | 0.75 | 0.6 | 0.56 |
| Heat Damage (%) | 288 | 0.0 | 0.00 | 0.0 | 0.0 | 291 | 0.0 | 0.00 | 301 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 288 | 16.1 | 1.75 | 10.1 | 25.0 | 291 | 16.1 | 1.78 | 301 | 15.9 | 1.50 | 16.0 | 1.73 |
| **Southern Rail** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 355 | 58.9 | 1.19 | 53.6 | 61.9 | 393 | 58.8 | 1.21 | 395 | 58.5* | 1.22 | 58.4 | 1.27 |
| Test Weight (kg/hl) | 355 | 75.8 | 1.53 | 69.0 | 79.7 | 393 | 75.6 | 1.56 | 395 | 75.4* | 1.57 | 75.2 | 1.64 |
| BCFM (%) | 355 | 0.7 | 0.44 | 0.0 | 7.5 | 393 | 0.8* | 0.52 | 395 | 0.7* | 0.43 | 0.8 | 0.50 |
| Broken Corn (%) | 355 | 0.5 | 0.28 | 0.0 | 1.9 | 393 | 0.7* | 0.39 | 395 | 0.5 | 0.31 | 0.6 | 0.36 |
| Foreign Material (%) | 355 | 0.2 | 0.25 | 0.0 | 7.3 | 393 | 0.2 | 0.19 | 395 | 0.2* | 0.16 | 0.2 | 0.20 |
| Total Damage (%) | 355 | 1.8 | 1.23 | 0.0 | 15.3 | 393 | 1.3* | 0.97 | 395 | 2.5* | 1.78 | 1.5 | 1.10 |
| Heat Damage (%) | 355 | 0.0 | 0.00 | 0.0 | 0.0 | 393 | 0.0 | 0.00 | 395 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 355 | 15.5 | 1.35 | 10.1 | 22.0 | 393 | 15.8* | 1.48 | 395 | 15.7* | 1.35 | 15.9 | 1.53 |

*Indicates average was significantly different from 2018, based on a 2-tailed t-test at the 95% level of significance.*

[1]*Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

[2]*The Relative ME for predicting the harvest population average exceeded ±10%*

# C. CHEMICAL COMPOSITION

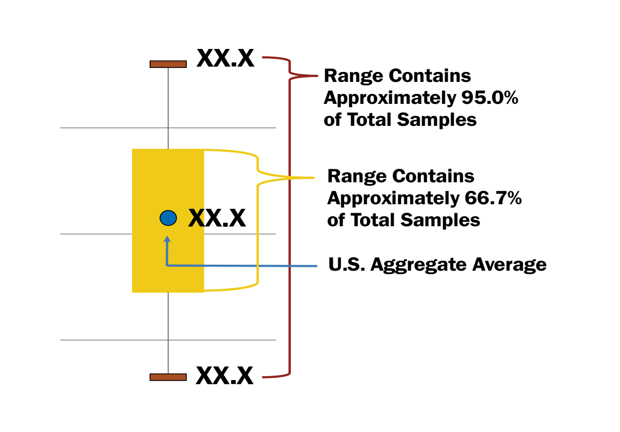
The chemical composition of corn consists primarily of protein, starch and oil. While these attributes are not graded factors, they are of significant interest to end users. Chemical composition values provide additional information related to nutritional value for livestock and poultry feeding, for wet milling uses and other processing uses of corn. Unlike many physical attributes, chemical composition values are not expected to change significantly during storage or transit.

## SUMMARY: CHEMICAL COMPOSITION

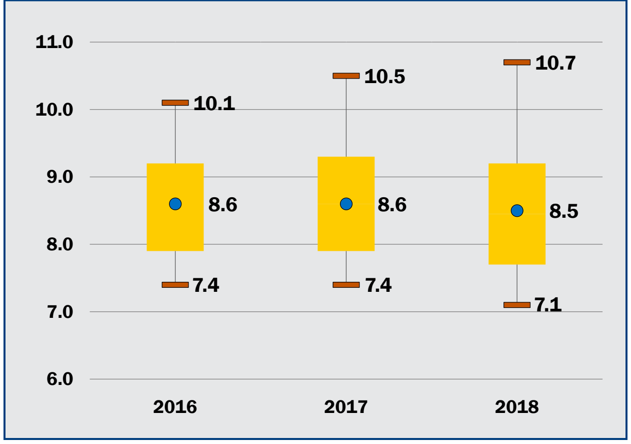
- Average U.S. Aggregate protein concentration in 2018 (8.5% dry basis) was lower than in 2017 and 2016 (both 8.6%) but same as the 5YA (8.5%).
- The Gulf ECA had lower protein concentrations than the other ECAs in 2018, 2017, 2016 and the 5YA.
- Average U.S. Aggregate starch concentration in 2018 (72.5% dry basis) was similar to 2017 and 2016 but lower than the 5YA (73.1%).
- The Gulf ECA had higher starch concentrations than the Pacific Northwest and Southern Rail ECAs in 2018, 2017, 2016 and the 5YA.
- Average U.S. Aggregate oil concentration in 2018 (4.0% dry basis) was lower than in 2017 (4.1%), same as 2016 (4.0%) and higher than the 5YA (3.9%).
- The variability in chemical concentrations was similar for 2018, 2017 and 2016, based on similar standard deviations for protein, starch and oil.
- Oil concentration averages for Gulf, Pacific Northwest and Southern Rail ECAs were all 4.0%. Oil concentrations averages have varied by 0.1% or less among the ECAs for 2018, 2017, 2016 and the 5YA.

## CHEMICAL COMPOSITION VS. AGGREGATE 3-YEAR COMPARISON

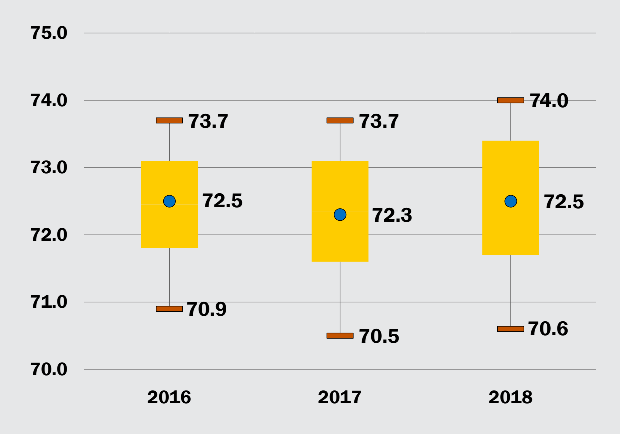
### HOW TO READ THE CHARTS



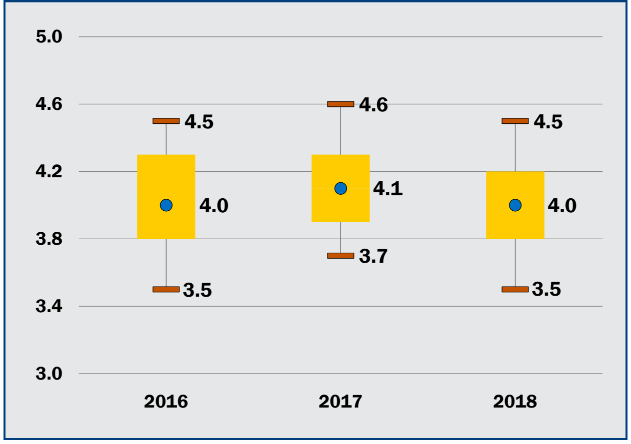

### PROTEIN (Dry Basis %)




### STARCH (Dry Basis %)




### OIL (Dry Basis %)



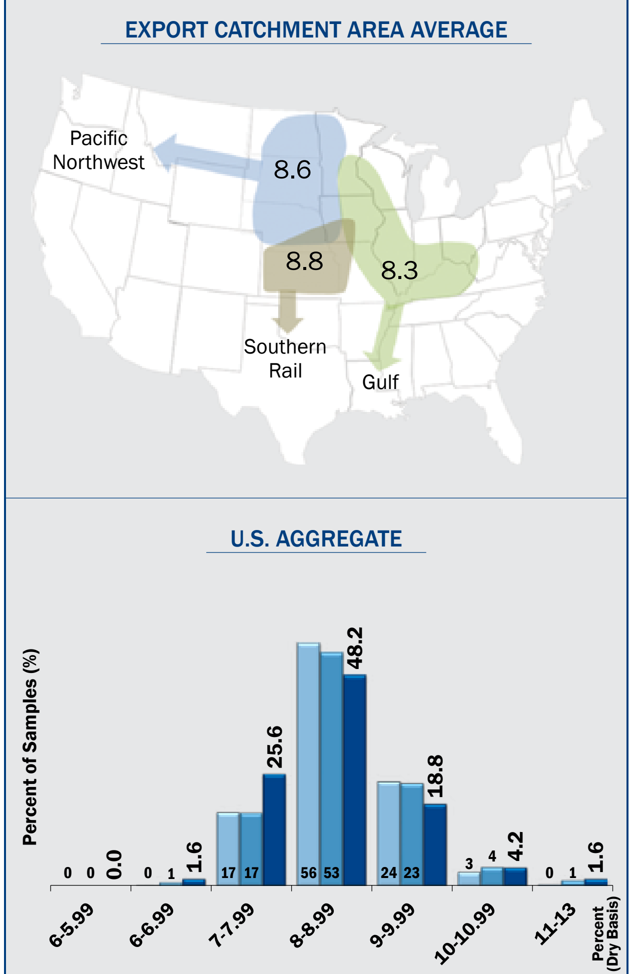
## Protein

Protein is very important for poultry and livestock feeding because it supplies essential sulfur-containing amino acids and helps to improve feed conversion efficiency. Protein concentration tends to decrease with decreased available soil nitrogen and in years with high crop yields. Protein is usually inversely related to starch concentration. Results are reported on a dry basis.

### *Results*

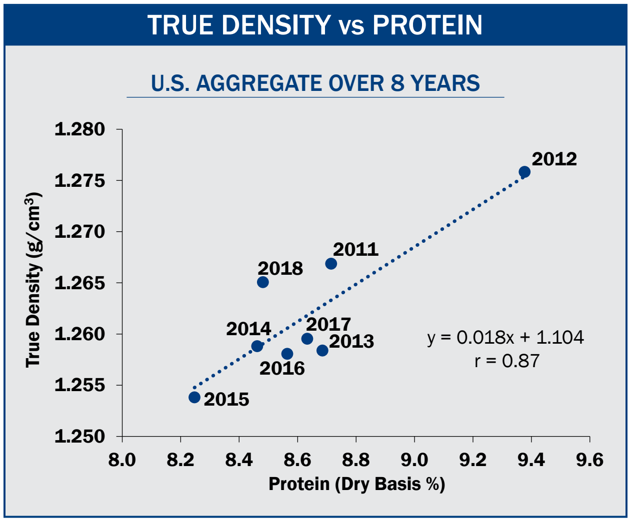
- Average U.S. Aggregate protein concentration in 2018 averaged 8.5%, lower than 2017 and 2016 (both 8.6%), but same as the 5YA (8.5%).
- Average U.S. Aggregate protein standard deviation in 2018 (0.53%) was similar to 2017 (0.55%), 2016 (0.50%) and the 5YA (0.56%).
- The range in protein concentration in 2018 (6.6 to 11.9%) was similar to ranges in 2017 (6.4 to 12.2%) and 2016 (6.8 to 11.7%).
- Protein concentrations in 2018 were distributed with 27.2% below 8.0%, 48.2% between 8.0 and 8.99% and 24.6% above 9.0%. The protein distribution in 2018 shows a higher number of low protein samples than in 2017 and 2016.
- Protein concentration averages for Gulf, Pacific Northwest and Southern Rail ECAs were 8.3%, 8.6% and 8.8%, respectively. The Gulf ECA had the lowest protein for 2018, 2017, 2016 and the 5YA.

**PROTEIN (%)**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 8.5 | 0.53 |
| 2017 | 8.6 | 0.55 |
| 2016 | 8.6 | 0.50 |

- Based on U.S. Aggregate averages over the past eight years, as protein concentration increases, true density also increases (resulting in a correlation coefficient of 0.87), as shown in the figure to the right. In general, protein concentration appears to be lower in years with lower true density and higher in years with higher true density.




## Starch

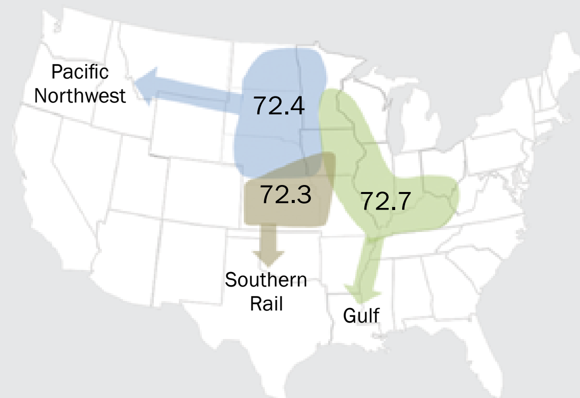
Starch is an important factor for corn used by wet millers and dry-grind ethanol manufacturers. High starch concentration is often indicative of good kernel growing/filling conditions and reasonably moderate kernel densities. Starch is usually inversely related to protein concentration. Results are reported on a dry basis.

### *Results*

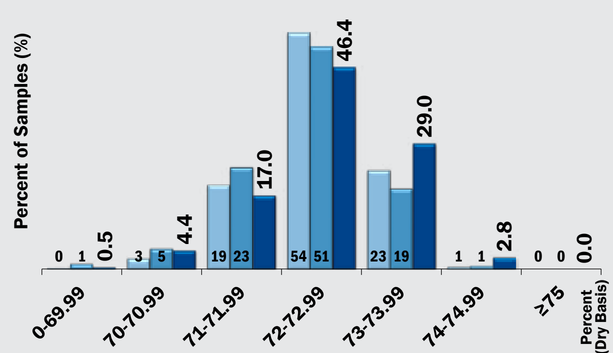
- Average U.S. Aggregate starch concentration in 2018 (72.5%) was similar to 2017 (72.3%) and 2016 (72.5%) but lower than the 5YA (73.1%).
- U.S. Aggregate starch standard deviation in 2018 (0.62%) was similar to 2017 (0.65%), 2016 (0.59%) and the 5YA (0.63%).
- Starch concentration range in 2018 (68.9 to 74.6%) was similar to 2017 (69.0 to 74.2%) and 2016 (69.2 to 74.3%).
- Starch concentrations in 2018 were distributed with 21.9% of the samples below 72.0%, 46.4% between 72.0 and 72.99% and 31.8% at 73.0% and higher. This distribution shows a higher number of samples at starch levels above 73% in 2018 than in 2017 and 2016.

**STARCH (%)**

EXPORT CATCHMENT AREA AVERAGE

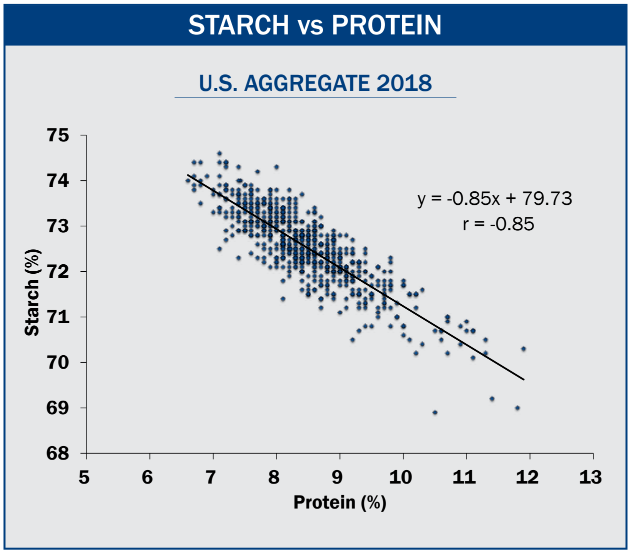



U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 72.5 | 0.62 |
| 2017 | 72.3 | 0.65 |
| 2016 | 72.5 | 0.59 |

- Starch concentration averages for the Gulf, Pacific Northwest and Southern Rail ECAs were 72.7%, 72.4% and 72.3%, respectively. Starch concentration averages were highest in the Gulf ECA in 2018, 2017, 2016 and the 5YA. Thus, the Gulf ECA had the highest starch and lowest protein in 2018, 2017, 2016 and the 5YA.
- Since starch and protein are the two largest components in corn, when the percentage of one goes up, the other usually goes down. This relationship is illustrated in the adjacent figure showing a negative correlation (-0.85) between starch and protein.




## Oil

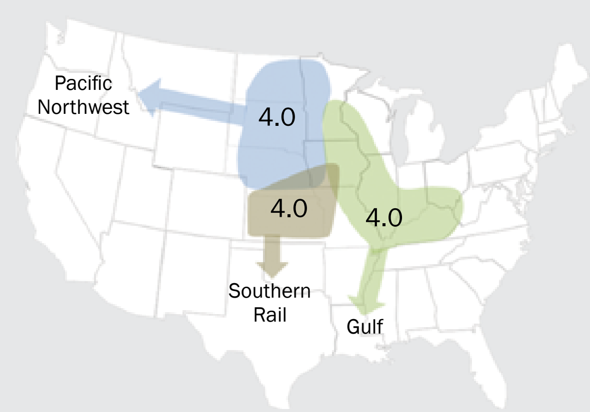
Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilized and provides certain essential fatty acids. Oil is also an important co-product of corn wet and dry milling. Results are reported on a dry basis.

### *Results*

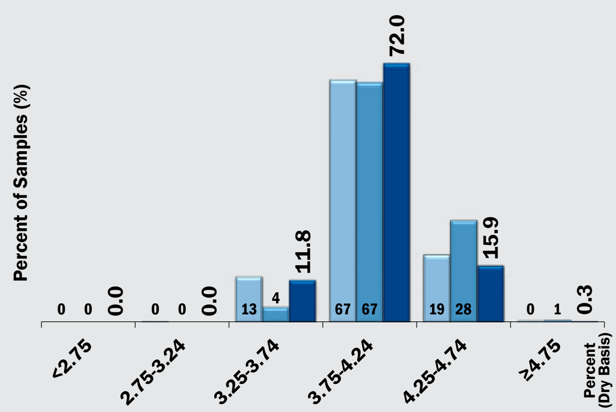
- Average U.S. Aggregate oil concentration in 2018 (4.0%) was lower than in 2017 (4.1%), same as 2016 (4.0%) and higher than the 5YA (3.9%).
- U.S. Aggregate oil standard deviation in 2018 (0.22%) was the same as 2017, similar to 2016 (0.23%) but lower than the 5YA (0.28%).
- Oil concentration range in 2018 (3.3 to 5.2%) was similar to 2017 (3.3 to 5.5%) and 2016 (3.2 to 4.9%).
- Oil concentrations in 2018 were distributed with 11.8% of the samples at 3.74% or lower, 72.0% of samples at 3.75 to 4.24% and 16.2% at 4.25% and higher. The distribution in 2018 showed a lower number of samples with oil concentrations at 4.25% or higher than in 2017, but the distribution was similar to that in 2016.
- Oil concentration averages for Gulf, Pacific Northwest and Southern Rail ECAs were all 4.0%. Oil concentrations averages have varied by 0.1% or less among the ECAs for 2018, 2017, 2016 and the 5YA.

**OIL (%)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 4.0 | 0.22 |
| 2017 | 4.1 | 0.22 |
| 2016 | 4.0 | 0.23 |

U.S. GRAINS COUNCIL

## SUMMARY: CHEMICAL FACTORS

| | 2018 Harvest | | | | | 2017 Harvest | | | 2016 Harvest | | | 5 Year Avg. (2013-2017) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 618 | 8.5 | 0.53 | 6.6 | 11.9 | 627 | 8.6* | 0.55 | 624 | 8.6* | 0.50 | 8.5 | 0.56 |
| Starch (Dry Basis %) | 618 | 72.5 | 0.62 | 68.9 | 74.6 | 627 | 72.3* | 0.65 | 624 | 72.5 | 0.59 | 73.1 | 0.63 |
| Oil (Dry Basis %) | 618 | 4.0 | 0.22 | 3.3 | 5.2 | 627 | 4.1* | 0.22 | 624 | 4.0 | 0.23 | 3.9 | 0.28 |
| **Gulf** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 587 | 8.3 | 0.50 | 6.6 | 11.9 | 612 | 8.5* | 0.54 | 612 | 8.5* | 0.48 | 8.4 | 0.55 |
| Starch (Dry Basis %) | 587 | 72.7 | 0.61 | 68.9 | 74.6 | 612 | 72.4* | 0.64 | 612 | 72.6* | 0.59 | 73.2 | 0.63 |
| Oil (Dry Basis %) | 587 | 4.0 | 0.23 | 3.3 | 5.2 | 612 | 4.1* | 0.22 | 612 | 4.0* | 0.24 | 3.9 | 0.29 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 288 | 8.6 | 0.60 | 6.6 | 11.9 | 291 | 8.9* | 0.58 | 301 | 8.8* | 0.55 | 8.8 | 0.59 |
| Starch (Dry Basis %) | 288 | 72.4 | 0.64 | 69.0 | 74.4 | 291 | 71.9* | 0.68 | 301 | 72.2* | 0.60 | 72.9 | 0.62 |
| Oil (Dry Basis %) | 288 | 4.0 | 0.21 | 3.3 | 4.7 | 291 | 4.1* | 0.21 | 301 | 4.1* | 0.22 | 3.8 | 0.26 |
| **Southern Rail** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 355 | 8.8 | 0.55 | 6.7 | 11.9 | 393 | 8.8 | 0.54 | 395 | 8.7* | 0.51 | 8.7 | 0.58 |
| Starch (Dry Basis %) | 355 | 72.3 | 0.63 | 70.2 | 74.6 | 393 | 72.3 | 0.62 | 395 | 72.4* | 0.59 | 73.0 | 0.61 |
| Oil (Dry Basis %) | 355 | 4.0 | 0.21 | 3.3 | 4.7 | 393 | 4.1* | 0.21 | 395 | 4.1* | 0.23 | 3.9 | 0.27 |

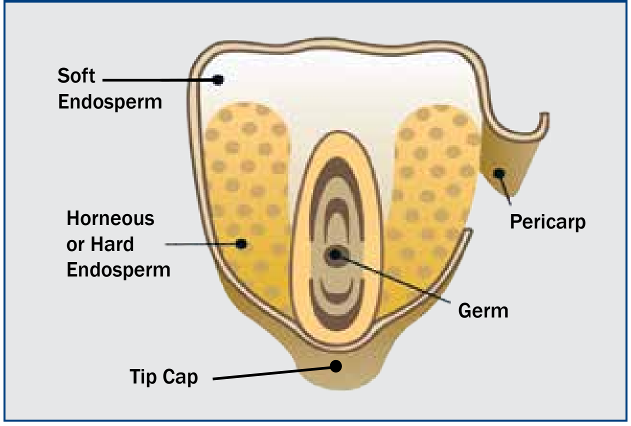
**Indicates average was significantly different from 2018, based on a 2-tailed t-test at the 95% level of significance.*

*[1]Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

# D. PHYSICAL FACTORS

Physical factors are other quality attributes that are neither grade factors nor chemical composition. Physical factors include stress cracks, kernel weight, kernel volume and true density, percent whole kernels and percent horneous (hard) endosperm. Tests for these physical factors provide additional information about the processing characteristics of corn for various uses, as well as corn's storability and potential for breakage in handling. These quality attributes are influenced by the physical composition of the corn kernel, which is in turn affected by genetics and growing and handling conditions. Corn kernels are made up of four parts: the germ or embryo, the tip cap, the pericarp or outer covering and the endosperm. The endosperm represents about 82% of the kernel and consists of soft (also referred to as floury or opaque) endosperm and of horneous (also called hard or vitreous) endosperm, as shown above. The endosperm contains primarily starch and protein, the germ contains oil and some proteins and the pericarp and tip cap are mostly fiber.

CORN KERNEL



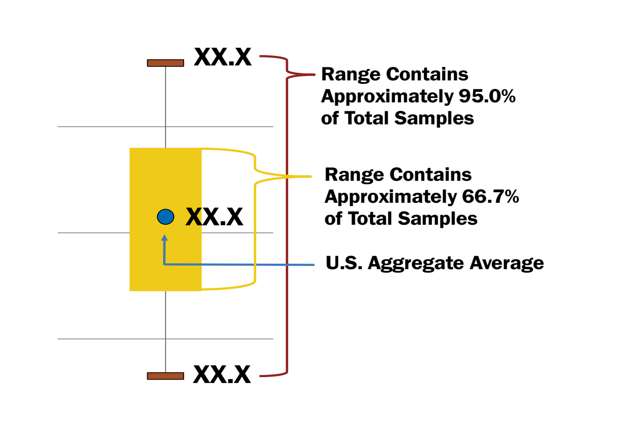

*Source: Adapted from Corn Refiners Association, 2011*

## SUMMARY: PHYSICAL FACTORS

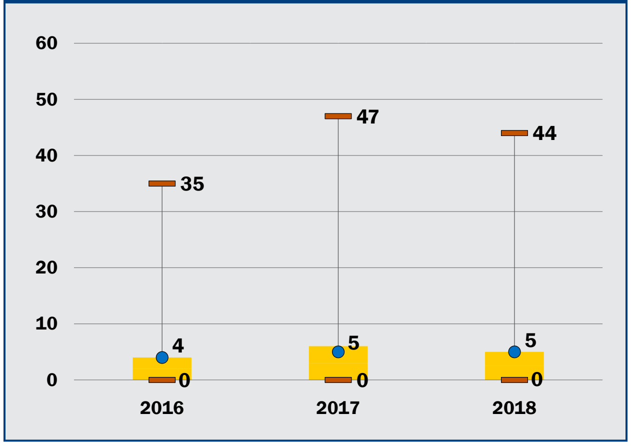
- Average U.S. Aggregate stress cracks (5%) and stress crack index (SCI) (11.5) were close to 2017 and slightly lower than the 5YA, indicating corn's susceptibility to breakage in 2018 may be similar to 2017 and slightly better than the 5YA.
- Among the ECAs, the Southern Rail ECA had the lowest stress crack averages and lowest SCI averages in 2018, 2017, 2016 and the 5YA.
- Average U.S. Aggregate 100-k weight in 2018 (35.07 g) was lower than 2017, similar to 2016 but higher than the 5YA.
- Average U.S. Aggregate kernel volume in 2018 (0.28 $cm^3$) was lower than 2017 but same as 2016 and the 5YA. There was also a lower percentage of large kernels in 2018 than in 2017 but similar to 2016 and previous years.
- The Pacific Northwest ECA had the lowest 100-k weight average and the lowest kernel volume of the ECAs in 2018, 2017, 2016 and the 5YA.
- U.S. Aggregate kernel true density averaged 1.265 $g/cm^3$ in 2018, was higher than in 2017, 2016 and the 5YA. True density kernel distributions above 1.275 $g/cm^3$ in 2018 indicate harder corn than in 2017 and 2016. Of the ECAs, the Pacific Northwest had the lowest true density and lowest test weights in 2018, 2017, 2016 and the 5YA.
- U.S. Aggregate whole kernels averaged 93.0% in 2018, higher than in 2017, lower than 2016 but similar to the 5YA.
- Average U.S. Aggregate horneous (hard) endosperm (81%) was same as 2017 and the 5YA, but higher than 2016 (79%). Average aggregate horneous endosperm in all ECAs was within one percentage point in 2018, 2017, 2016 and the 5YA. Average horneous endosperm tends to increase in years with higher true density.

## PHYSICAL FACTORS VS. AGGREGATE 3-YEAR COMPARISON

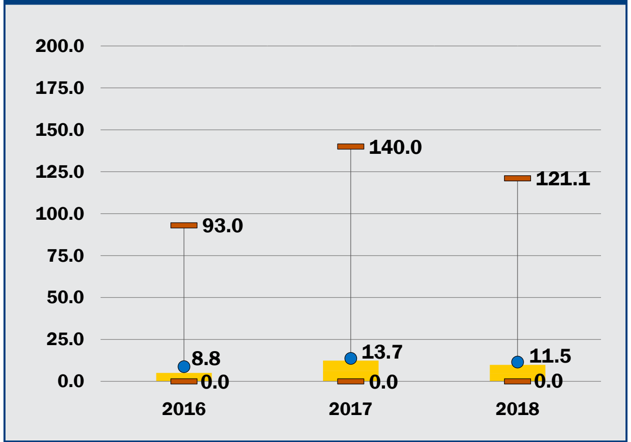
### HOW TO READ THE CHARTS



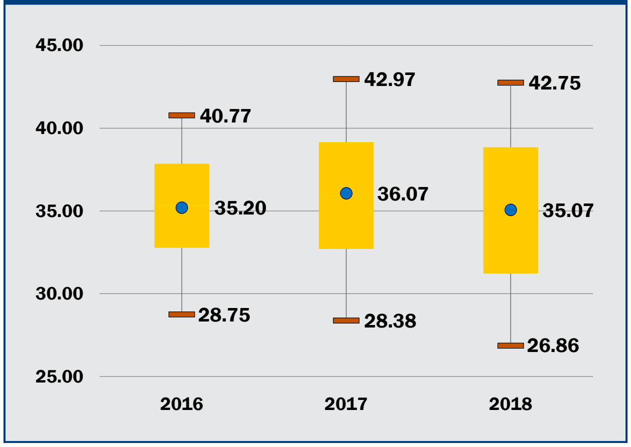

### STRESS CRACKS (%)



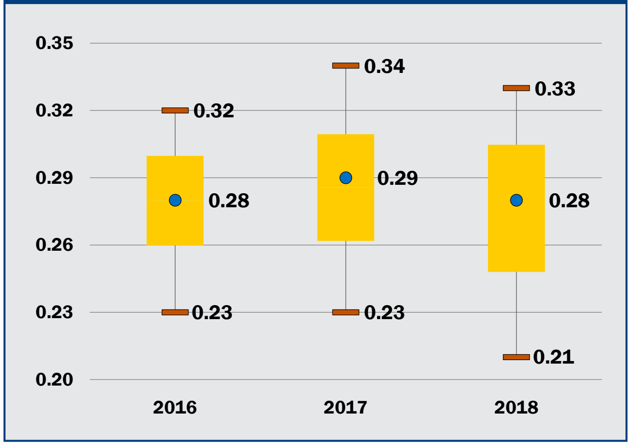

### STRESS CRACK INDEX



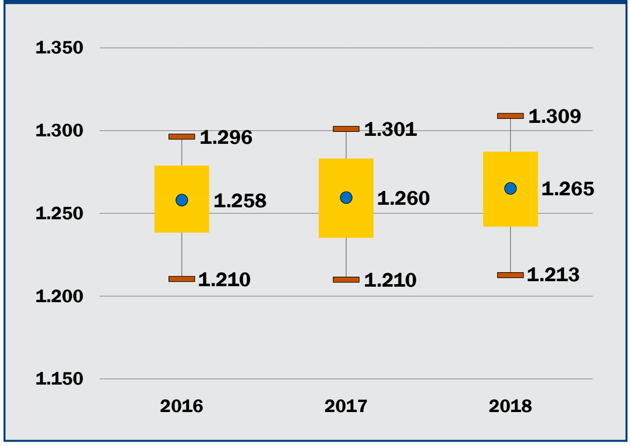

### 100-KERNEL WEIGHT (g)



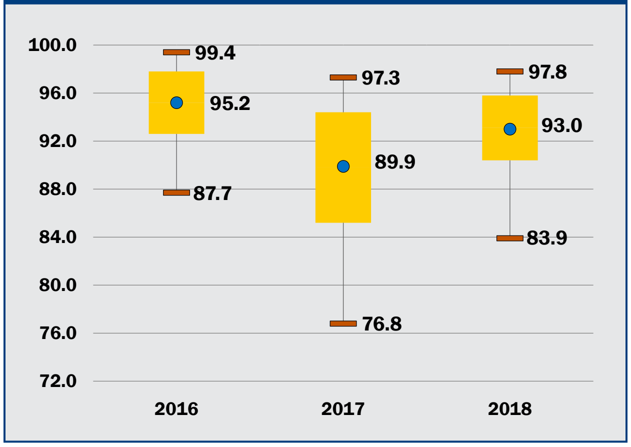
KERNEL VOLUME ($cm^3$)



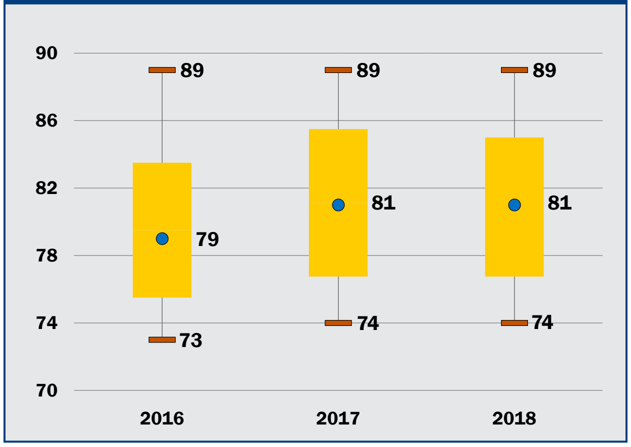

TRUE DENSITY ($g/cm^3$)




WHOLE KERNELS (%)




HORNEOUS ENDOSPERM (%)



## Stress Cracks

Stress cracks are internal fissures in the horneous (hard) endosperm of a corn kernel. The pericarp (or outer covering) of a stress-cracked kernel is typically not damaged, so the kernel may appear unaffected at first glance, even if stress cracks are present.

Stress crack measurements include "stress cracks" (the percentage of kernels with at least one crack) and stress crack index (SCI), which is the weighted average of single, double and multiple stress cracks. "Stress cracks" measures only the number of kernels with stress cracks, whereas SCI shows the severity of stress cracking. For example, if half the kernels have only single stress cracks, "stress cracks" is 50% and the SCI is 50 (50 x 1). However, if half the kernels have multiple stress cracks (more than two cracks), indicating a higher potential for handling breakage, "stress cracks" remains at 50%, but the SCI becomes 250 (50 x 5). Lower values for "stress cracks" and the SCI are always more desirable. In years with high levels of stress cracks, the SCI provides valuable information, because high SCI numbers (perhaps 300 to 500) indicate the sample had a very high percentage of multiple stress cracks. Multiple stress cracks are generally more detrimental to quality changes than single stress cracks.

The cause of stress cracks is pressure buildup due to moisture and temperature gradients within the kernel's horneous endosperm. This can be likened to the internal cracks that appear when an ice cube is dropped into a lukewarm beverage. The internal stresses do not build up as much in the soft, floury endosperm as in the hard, horneous endosperm; therefore, corn with a higher percentage of horneous endosperm is more susceptible to stress cracking than softer grain. A kernel may vary in severity of stress cracking and can have one, two, or multiple stress cracks. The most common cause of stress cracks is high-temperature drying that rapidly removes moisture. The impact of high levels of stress cracks on various uses includes:

- General: Increased susceptibility to breakage during handling. This may lead to processors needing to remove more broken corn during cleaning operations and a possible reduction in grade and/or value.
- Wet Milling: Lower starch yields due to the increased difficulty in separating starch and protein. Stress cracks may also alter steeping requirements.
- Dry Milling: The lower yield of large flaking grits (the prime product of many dry milling operations).
- Alkaline Cooking: Non-uniform water absorption leading to overcooking or undercooking, which affects the process balance.

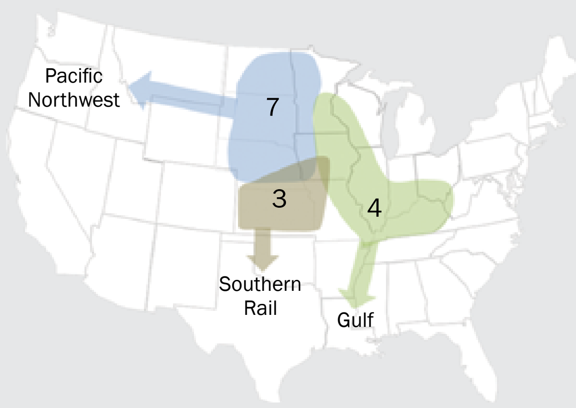
Growing conditions will affect crop maturity, timeliness of harvest and the need for artificial drying, which will influence the degree of stress cracking found from region to region. For example, late maturity or late harvest caused by weather-related factors, such as rain-delayed planting or cool temperatures, may increase the need for artificial drying, thus potentially increasing the occurrence of stress cracks.

## Results

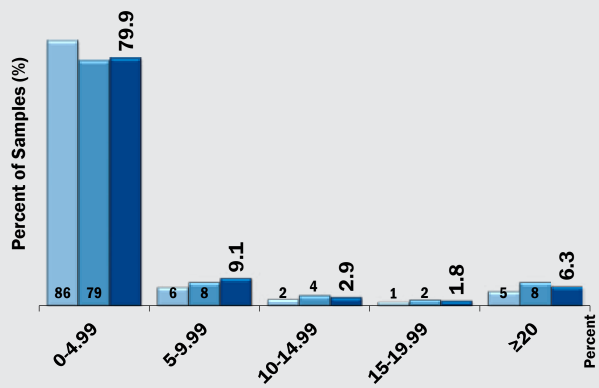
- U.S. Aggregate stress cracks in 2018 averaged 5%, same as 2017, higher than 2016 (4%) but lower than the 5YA (6%).
- U.S. Aggregate stress cracks standard deviation in 2018 (6%) was similar to 2017 (8%), 2016 (6%) and the 5YA (7%).
- Stress cracks ranged from 0 to 88% in 2018, similar to the ranges in 2017 (0 to 90%) and 2016 (0 to 84%).
- The percentage of samples with less than 10% stress cracks in 2018 (89.0%) was similar to 2017 (87%) but lower than 2016 (92%). Also, in 2018, 6.3% of the samples had stress cracks above 20%, which is intermediate to 2017 (8%) and 2016 (5%).
- Stress crack distributions indicate that 2018 corn should be similar in breakage susceptibility to 2017 but slightly higher than in 2016.
- Stress crack averages in 2018 for Gulf, Pacific Northwest and Southern Rail ECAs were 4%, 7% and 3%, respectively. Among all ECAs, the Southern Rail had the lowest stress cracks in 2018, 2017, 2016 and the 5YA.

### STRESS CRACKS (%)

#### EXPORT CATCHMENT AREA AVERAGE




#### U.S. AGGREGATE

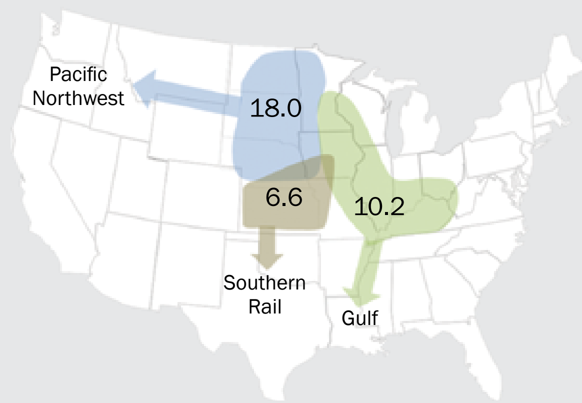



| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 5 | 6 |
| 2017 | 5 | 8 |
| 2016 | 4 | 6 |

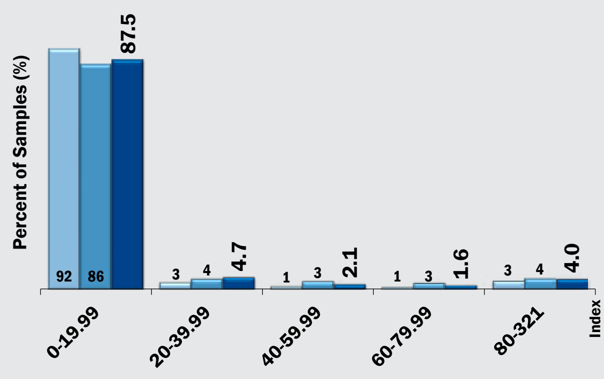
- U.S. Aggregate SCI in 2018 averaged 11.5, lower than 2017 (13.7) and the 5YA (14.4) but higher than in 2016 (8.8).
- U.S. Aggregate SCI standard deviation in 2018 (16.8) was slightly lower than in 2017 (23.6) and the 5YA (22.9).
- Of the 2018 samples, 92.2% had SCI of less than 40, which is similar to 2017 (90%) and 2016 (95%). Of the 2018 samples, 4.0% had a SCI of 80 or higher, compared to 4% of the 2017 samples and 3% of the 2016 samples. Thus, SCI distribution in 2018 was similar to those in 2017 and 2016.
- SCI averages for the Gulf, Pacific Northwest and Southern Rail ECAs were 10.2, 18.0 and 6.6, respectively. The Southern Rail ECA had the lowest SCI in 2018, 2017, 2016 and the 5YA. The low SCI found for the Southern Rail ECA is likely related to more favorable field drying potential typically found in the states that constitute the Southern Rail ECA.
- The 2018 crop had a combined good-to-excellent condition rating that remained between 77 to 68% for most of the season. Silking percentages were ahead of previous years, enabling good maturation and grain-filling conditions. Harvest started early but then further harvesting was delayed by rain. Average moistures (16.0%) were below 2017 and the 5YA. September temperatures for much of the corn belt were average to much above average which likely led to good drying conditions and opportunity for reasonably low stress cracks and SCI. The 2016 year stands out for earliest planting and emergence, highest ratings for good-to-excellent crop condition and earliest harvest. That year had the lowest stress cracks (4%) and SCI (8.8) with low moisture (16.1%). However, 2018 ranks close behind with stress cracks (5%) and SCI (11.5) and lower moisture (16.0%).

**STRESS CRACK INDEX (SCI)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg | Std Dev |
|---|---|---|
| 2018 | 11.5 | 16.8 |
| 2017 | 13.7 | 23.6 |
| 2016 | 8.8 | 16.6 |

## 100-Kernel Weight

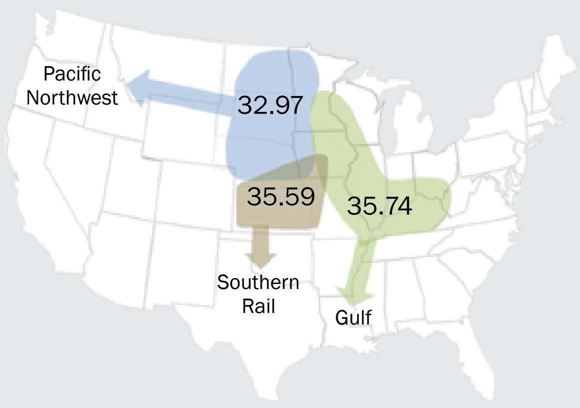
100-kernel (100-k) weight (reported in grams) indicates a larger kernel size as 100-k weight increases. Kernel size affects drying rates. As for kernel size increases, the volume-to-surface-area ratio becomes higher, and as the ratio gets higher, drying becomes slower. In addition, large, uniform-sized kernels often enable higher flaking grit yields in dry milling. Kernel weights tend to be higher for specialty varieties of corn that have high amounts of horneous (hard) endosperm.

### *Results*

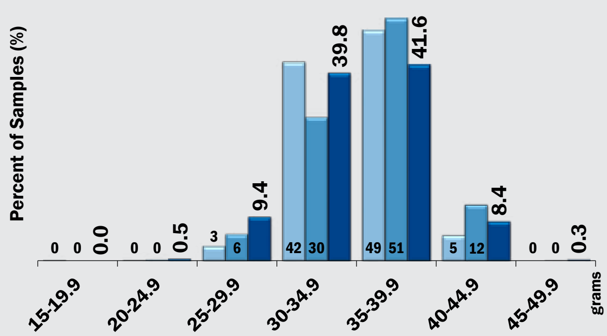
- U.S. Aggregate 100-k weight in 2018 averaged 35.07g, lower than in 2017 (36.07 g), similar to 2016 (35.20 g) but higher than the 5YA (34.61 g).
- Variability in the 2018 U.S. Aggregate 100-k weight (standard deviation of 2.84 g) was higher than 2017 (2.53 g) and 2016 (2.43 g) but similar to the 5YA (2.62 g).
- 100-k weight range in 2018 (23.86 to 45.88 g) was similar to 2017 (23.06 to 46.44 g) and 2016 (18.91 to 44.17 g).
- The 100-k weights in 2018 were distributed with 50.3% of the samples having 100-k weight of 35 g or greater, compared to 63% in 2017 and 54% in 2016. This distribution indicates a slightly lower percentage of large kernels were found in 2018 compared to 2017, but the distribution was close to that in 2016.
- Average 100-k weight was lowest for the Pacific Northwest ECA (32.97 g), compared to the Gulf (35.74 g) and Southern Rail (35.59 g) ECAs. The Pacific Northwest ECA had the lowest 100-k weight in 2018, 2017, 2016 and the 5YA.

**100-K WEIGHT (g)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (g) | Std Dev (g) |
|---|---|---|
| 2018 | 35.07 | 2.84 |
| 2017 | 36.07 | 2.53 |
| 2016 | 35.20 | 2.43 |

## Kernel Volume

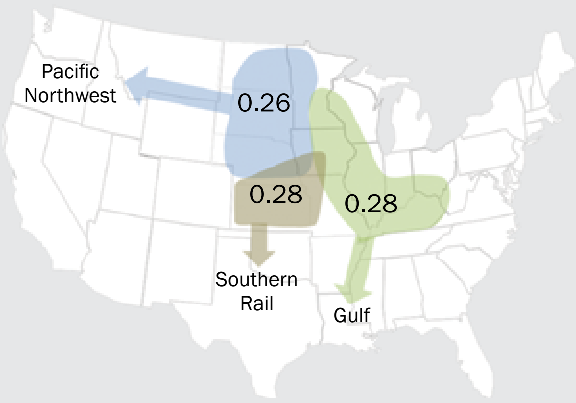
Kernel volume, measured in cubic centimeters ($cm^3$), is often indicative of growing conditions. If conditions are dry, kernels may be smaller than average. If drought hits later in the season, kernels may have lower fill. Small or round kernels are more difficult to degerm. Additionally, small kernels may lead to increased cleanout losses for processors and higher yields of fiber.

### *Results*

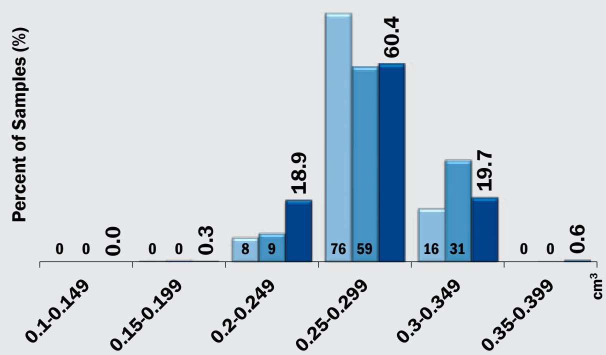
- U.S. Aggregate kernel volume averaged 0.28 $cm^3$ in 2018, lower than 2017 (0.29 $cm^3$) but same as in 2016 and the 5YA (both 0.28 $cm^3$).
- Kernel volume variability was constant across the years. The standard deviation for U.S. Aggregate kernel volume was 0.02 $cm^3$ for 2018, 2017, 2016 and the 5YA.
- Kernel volume range in 2018 (0.19 to 0.36 $cm^3$) was similar to 2017 (0.18 to 0.36 $cm^3$) and 2016 (0.16 to 0.34 $cm^3$).
- The kernel volumes in 2018 were distributed with 20.3% of the samples having kernel volumes of 0.30 $cm^3$ or greater, compared to 2017 (31%) and 2016 (16%). This distribution indicates there was a lower percentage of large kernels in 2018 compared to 2017, but the distribution was similar to 2016.
- Kernel volume for the Gulf, Pacific Northwest and Southern Rail ECAs averaged 0.28 $cm^3$, 0.26 $cm^3$ and 0.28 $cm^3$, respectively. Among the ECAs, the Pacific Northwest ECA had the lowest average kernel volume in 2018, 2017, 2016 and the 5YA.

**KERNEL VOLUME ($cm^3$)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg ($cm^3$) | Std Dev ($cm^3$) |
|---|---|---|
| 2018 | 0.28 | 0.02 |
| 2017 | 0.29 | 0.02 |
| 2016 | 0.28 | 0.02 |

## Kernel True Density

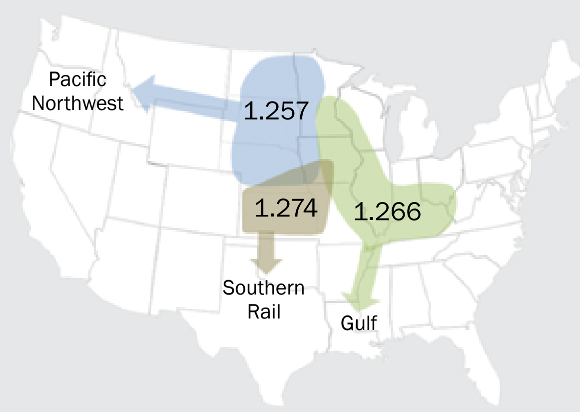
Kernel true density is calculated as the weight of a 100-k sample divided by the volume, or displacement, of those 100 kernels and is reported as grams per cubic centimeter (g/cm³). True density is a relative indicator of kernel hardness, which is useful for alkaline processors and dry millers. True density may be affected by the genetics of the corn hybrid and the growing environment. Corn with higher density is typically less susceptible to breakage in handling than lower density corn but is also more at risk for the development of stress cracks if high-temperature drying is employed. True densities above 1.30 g/cm³ indicate very hard corn, which is typically desirable for dry milling and alkaline processing. True densities near the 1.275 g/cm³ level and below tend to be softer, but process well for wet milling and feed use.

### *Results*

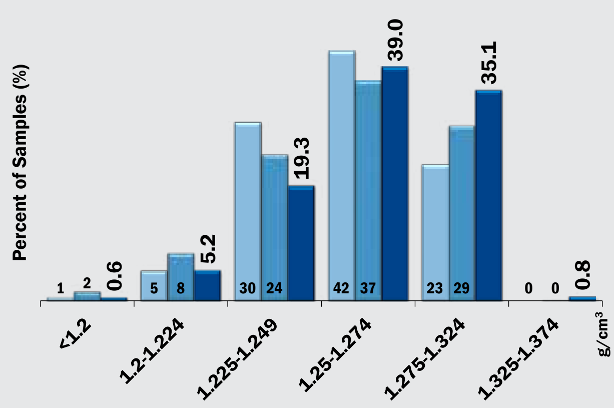
- Average U.S. Aggregate kernel true density in 2018 (1.265 g/cm³) was higher than in 2017 (1.260 g/cm³), 2016 and the 5YA (both 1.258 g/cm³). Over the past eight years, true densities have tended to be higher in years with higher protein.
- Variability, based on the standard deviation, in 2018 (0.018 g/cm³) was same as 2017 and 2016 (both 0.018 g/cm³) and similar to the 5YA (0.019 g/cm³).
- True densities in 2018 ranged from 1.167 to 1.374 g/cm³ compared to 1.135 to 1.332 g/cm³ in 2017 and 1.162 to 1.320 g/cm³ in 2016.
- About 35.9% of the 2018 samples had true densities at or above 1.275 g/cm³, compared to 29% in 2017 and 23% in 2016. Since corn with values above 1.275 g/cm³ is often considered to represent hard corn and values below 1.275 g/cm³ is often considered to represent soft corn, this kernel distribution indicates slightly harder corn in 2018 than in 2017 and 2016.
- In 2018, kernel true densities for the Gulf, Pacific Northwest and Southern Rail ECAs averaged 1.266 g/cm³, 1.257 g/cm³ and 1.274 g/cm³, respectively. The Pacific Northwest ECA's average true density and test weight were lower than the other ECAs' values in 2018, 2017, 2016 and the 5YA.

**KERNEL TRUE DENSITY (g/cm³)**

**EXPORT CATCHMENT AREA AVERAGE**



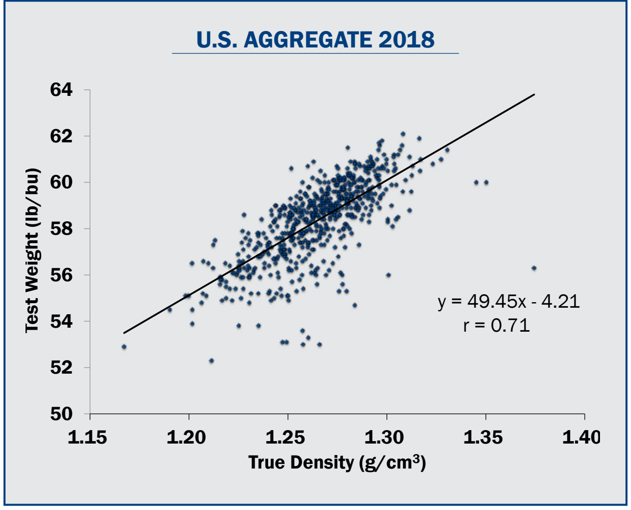

**U.S. AGGREGATE**




| | Avg (g/cm³) | Std Dev (g/cm³) |
|---|---|---|
| 2018 | 1.265 | 0.018 |
| 2017 | 1.260 | 0.018 |
| 2016 | 1.258 | 0.018 |

- Test weight, also known as bulk density, is based on the amount of mass contained in a quart cup. While test weight is influenced by true density, as shown in the adjacent figure (resulting in a correlation coefficient of 0.71), it is also affected by moisture content, pericarp damage (whole kernels), breakage and other factors. In 2018, test weight was 58.4 lb/bu, which was the same as 2017 and similar to 2016 (58.3 lb/bu).

**TEST WEIGHT vs TRUE DENSITY**




## Whole Kernels

Though the name suggests some inverse relationship between whole kernels and BCFM, the whole kernels test conveys different information than the broken corn portion of the BCFM test. Broken corn is defined solely by the size of the material. Whole kernels, as the name implies, is the percent of fully intact kernels in the sample with no pericarp damage or kernel pieces chipped away.

The exterior integrity of the corn kernel is very important for two key reasons. First, it affects water absorption for alkaline cooking and steeping operations. Kernel nicks or pericarp cracks allow water to enter the kernel faster than intact or whole kernels. Too much water uptake during cooking can result in loss of soluble, non-uniform cooking, expensive shutdown time and/or products that do not meet specifications. Some companies pay contracted premiums for corn delivered above a specified level of whole kernels.

Second, intact whole kernels are less susceptible to storage molds and breakage in handling. While hard endosperm lends itself to the preservation of more whole kernels than soft corn, the primary factor in delivering whole kernels is harvesting and handling. This begins with proper combine adjustment followed by the severity of kernel impacts due to conveyors and number of handlings required from the farm field to the end user. Each subsequent handling will generate additional breakage. Actual amounts of breakage increase exponentially as moisture decreases, drop heights increase and/or a kernel's velocity at impact increases.[3] In addition, harvesting at higher moisture contents (e.g., greater than 25%) will usually lead to soft pericarps and more pericarp damage to corn than when harvesting at lower moisture levels.

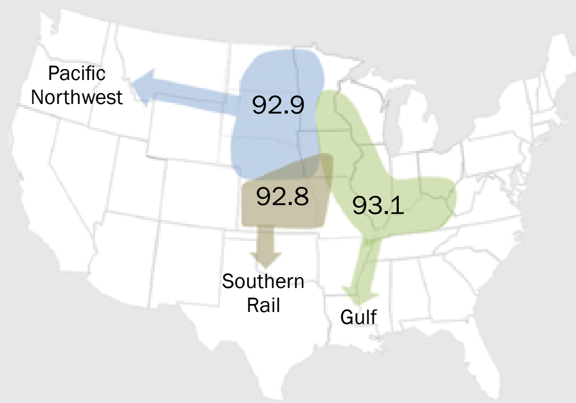
[3] *Foster, G. H. and L. E. Holman. 1973. Grain Breakage Caused by Commercial Handling Methods. USDA. ARS Marketing Research Report Number 968.*

## Results

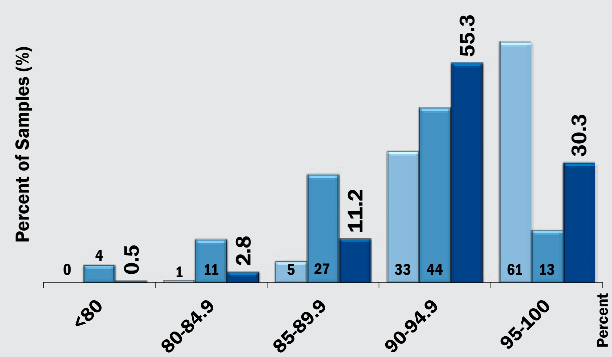
- U.S. Aggregate whole kernels averaged 93.0% in 2018, higher than in 2017 (89.9%), lower than in 2016 (95.2%) but similar to the 5YA (93.2%).
- The 2018 whole kernel standard deviation (3.0%) was lower than in 2017 (4.6%) but similar to 2016 (2.7%) and the 5YA (3.4%).
- Whole kernel range in 2018 (66.0 to 98.6%) was similar to 2017 (67.0 to 99.2%) and 2016 (80.6 to 100.0%).
- Of the 2018 samples, 85.6% had 90% or higher whole kernels, compared to 2017 (57%) and 2016 (94%). This distribution indicates 2018 had a higher percentage of whole kernels than the samples for 2017. The lower percentage of whole kernels in 2017 may in part be due to the exceptionally large kernel sizes found in 2017, which may have a weaker kernel structure than that of small kernels, leading to more cracking and chipping during combining and handling.
- Whole kernel averages for Gulf, Pacific Northwest and Southern Rail ECAs were 93.1%, 92.9% and 92.8%, respectively.

### WHOLE KERNELS (%)

#### EXPORT CATCHMENT AREA AVERAGE




#### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 93.0 | 3.0 |
| 2017 | 89.9 | 4.6 |
| 2016 | 95.2 | 2.7 |

## Horneous (Hard) Endosperm

The horneous (hard) endosperm test measures the percent of horneous or hard endosperm out of the total endosperm in a kernel, with a potential value from 70 to 100%. The greater the amount of horneous endosperm relative to soft endosperm, the harder the corn kernel is said to be. The degree of hardness is important depending on the type of processing. A hard corn is needed to produce high yields of large flaking grits in dry milling. Hard to medium hardness is desired for alkaline cooking. Medium to soft hardness is used for wet milling and livestock feeding.

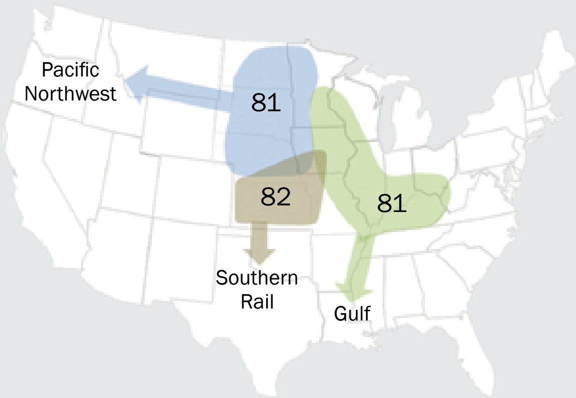
Hardness has been correlated to breakage susceptibility, feed utilization/efficiency and starch digestibility. As a test of overall hardness, there is no good or bad value for horneous endosperm; there is only a preference by different end users for particular ranges. Many dry millers and alkaline cookers would like greater than 85% horneous endosperm, while wet millers and feeders would typically like values between 70 and 85%. However, there are certainly exceptions in user preference.

### *Results*

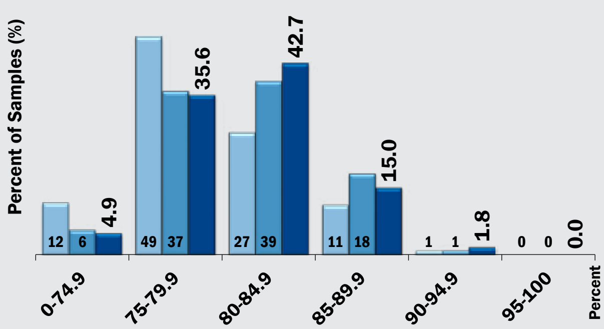
- Average U.S. Aggregate horneous endosperm in 2018 (81%) was same as 2017 and the 5YA (both 81%) but higher than 2016 (79%).
- U.S. Aggregate standard deviation for horneous endosperm was 3% in 2018, lower than 2017, 2016 and the 5YA (all 4%).
- The 2018 horneous endosperm range (72 to 92%) was similar to 2017 (71 to 92%) and 2016 (71 to 93%).
- Of the 2018 samples, 40.5% contained less than 80% horneous endosperm, which was a lower percentage than in 2017 (43%) and 2016 (61%). This indicates 2018 and 2017 had similar percentages of soft endosperm, but the percentage was much lower than 2016.
- Average horneous endosperm for the Gulf, Pacific Northwest and Southern Rail ECAs was 81%, 81% and 82%, respectively. Average horneous endosperm varied by no more than 0.1% across all ECAs during 2018, 2017, 2016 and the 5YA.
- The figure on the adjacent page shows a weak but positive relationship (a correlation coefficient of 0.64) between horneous endosperm and true density for the 2018 samples.
- The next figure shows the average U.S. Aggregate horneous endosperm and true density values over the past eight years. This illustrates that the average U.S. Aggregate horneous endosperm increases with true density (with a correlation coefficient of r = 0.84); thus, horneous endosperm tends to be higher in years when average true density is higher.

## HORNEOUS ENDOSPERM (%)

### EXPORT CATCHMENT AREA AVERAGE



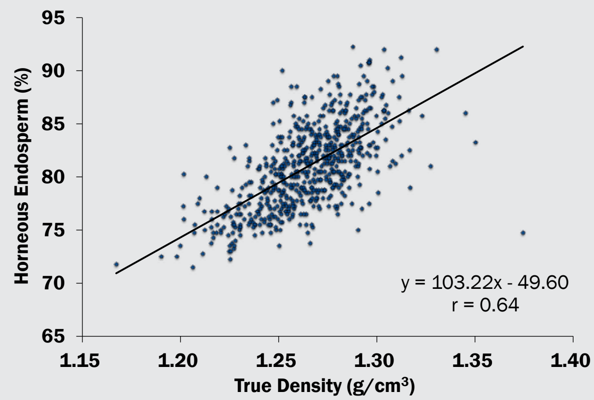

### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2018 | 81 | 3 |
| 2017 | 81 | 4 |
| 2016 | 79 | 4 |

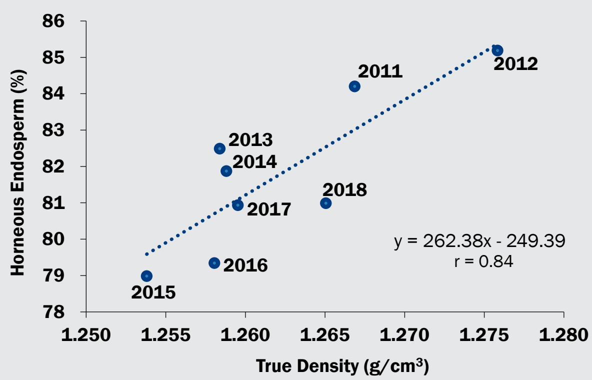
## HORNEOUS ENDOSPERM vs TRUE DENSITY

### U.S. AGGREGATE 2018




## HORNEOUS ENDOSPERM vs TRUE DENSITY

### U.S. AGGREGATE OVER 8 YEARS



## SUMMARY: PHYSICAL FACTORS

| | 2018 Harvest | | | | | 2017 Harvest | | | 2016 Harvest | | | 5 Year Avg. (2013-2017) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | | | | | | | | |
| Stress Cracks (%) | 618 | 5 | 6 | 0 | 88 | 627 | 5 | 8 | 624 | 4* | 6 | 6 | 7 |
| Stress Crack Index[2] | 618 | 11.5 | 16.8 | 0 | 304 | 627 | 13.7 | 23.6 | 624 | 8.8* | 16.6 | 14.4 | 22.9 |
| 100-Kernel Weight (g) | 618 | 35.07 | 2.84 | 23.86 | 45.88 | 627 | 36.07* | 2.53 | 624 | 35.20 | 2.43 | 34.61 | 2.62 |
| Kernel Volume ($cm^3$) | 618 | 0.28 | 0.02 | 0.19 | 0.36 | 627 | 0.29* | 0.02 | 624 | 0.28* | 0.02 | 0.28 | 0.02 |
| True Density ($g/cm^3$) | 618 | 1.265 | 0.018 | 1.167 | 1.374 | 627 | 1.260* | 0.018 | 624 | 1.258* | 0.018 | 1.258 | 0.019 |
| Whole Kernels (%) | 618 | 93.0 | 3.0 | 66.0 | 98.6 | 627 | 89.9* | 4.6 | 624 | 95.2* | 2.7 | 93.2 | 3.4 |
| Horneous Endosperm (%) | 618 | 81 | 3 | 72 | 92 | 627 | 81 | 4 | 624 | 79* | 4 | 81 | 4 |
| **Gulf** | | | | | | | | | | | | | |
| Stress Cracks (%) | 587 | 4 | 5 | 0 | 88 | 612 | 6* | 8 | 612 | 4* | 6 | 6 | 8 |
| Stress Crack Index[2] | 587 | 10.2 | 15.2 | 0 | 304 | 612 | 15.2* | 26.5 | 612 | 8.9 | 17.6 | 15.7 | 25.9 |
| 100-Kernel Weight (g) | 587 | 35.74 | 2.86 | 23.86 | 45.88 | 612 | 36.94* | 2.45 | 612 | 35.54 | 2.49 | 35.22 | 2.65 |
| Kernel Volume ($cm^3$) | 587 | 0.28 | 0.02 | 0.19 | 0.36 | 612 | 0.29* | 0.02 | 612 | 0.28 | 0.02 | 0.28 | 0.02 |
| True Density ($g/cm^3$) | 587 | 1.266 | 0.017 | 1.167 | 1.374 | 612 | 1.262* | 0.018 | 612 | 1.259* | 0.018 | 1.260 | 0.019 |
| Whole Kernels (%) | 587 | 93.1 | 3.0 | 66.0 | 98.6 | 612 | 90.0* | 4.7 | 612 | 95.0* | 2.7 | 93.2 | 3.4 |
| Horneous Endosperm (%) | 587 | 81 | 3 | 72 | 92 | 612 | 81 | 4 | 612 | 79* | 4 | 81 | 4 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Stress Cracks (%)[2] | 288 | 7 | 8 | 0 | 88 | 291 | 5* | 7 | 301 | 5* | 7 | 6 | 7 |
| Stress Crack Index[2] | 288 | 18.0 | 24.5 | 0 | 289 | 291 | 12.9* | 20.2 | 301 | 10.3* | 17.5 | 14.0 | 19.6 |
| 100-Kernel Weight (g) | 288 | 32.97 | 2.67 | 23.86 | 45.42 | 291 | 33.39 | 2.68 | 301 | 33.96* | 2.21 | 32.34 | 2.49 |
| Kernel Volume ($cm^3$) | 288 | 0.26 | 0.02 | 0.19 | 0.35 | 291 | 0.27* | 0.02 | 301 | 0.27* | 0.02 | 0.26 | 0.02 |
| True Density ($g/cm^3$) | 288 | 1.257 | 0.018 | 1.167 | 1.374 | 291 | 1.249* | 0.018 | 301 | 1.253* | 0.016 | 1.248 | 0.019 |
| Whole Kernels (%) | 288 | 92.9 | 3.1 | 73.6 | 98.6 | 291 | 89.4* | 4.8 | 301 | 95.7* | 2.7 | 93.0 | 3.6 |
| Horneous Endosperm (%) | 288 | 81 | 3 | 72 | 91 | 291 | 81 | 4 | 301 | 79* | 3 | 80 | 3 |
| **Southern Rail** | | | | | | | | | | | | | |
| Stress Cracks (%)[2] | 355 | 3 | 4 | 0 | 84 | 393 | 4* | 6 | 395 | 3 | 4 | 4 | 5 |
| Stress Crack Index[2] | 355 | 6.6 | 11.9 | 0 | 304 | 393 | 9.0* | 16.8 | 395 | 5.8 | 11.0 | 8.5 | 13.5 |
| 100-Kernel Weight (g) | 355 | 35.59 | 2.98 | 23.86 | 45.88 | 393 | 36.26* | 2.65 | 395 | 35.67 | 2.50 | 35.14 | 2.67 |
| Kernel Volume ($cm^3$) | 355 | 0.28 | 0.02 | 0.19 | 0.36 | 393 | 0.29* | 0.02 | 395 | 0.28* | 0.02 | 0.28 | 0.02 |
| True Density ($g/cm^3$) | 355 | 1.274 | 0.019 | 1.198 | 1.374 | 393 | 1.265* | 0.018 | 395 | 1.261* | 0.018 | 1.262 | 0.018 |
| Whole Kernels (%) | 355 | 92.8 | 2.7 | 82.6 | 98.6 | 393 | 90.0* | 4.3 | 395 | 95.1* | 2.6 | 93.3 | 3.3 |
| Horneous Endosperm (%) | 355 | 82 | 3 | 72 | 92 | 393 | 81 | 3 | 395 | 80* | 4 | 81 | 4 |

**Indicates average was significantly different from 2018, based on a 2-tailed t-test at the 95% level of significance.*

*[1]Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

*[2]The Relative ME for predicting the harvest population average exceeded ±10%.*

# E. MYCOTOXINS

Mycotoxins are toxic compounds produced by fungi that occur naturally in grains. When consumed at elevated levels, mycotoxins may cause sickness in humans and animals. While several mycotoxins have been found in corn grain, aflatoxin and deoxynivalenol (DON) or vomitoxin are considered to be two of the important mycotoxins.

As in the previous *Harvest Reports*, a subset of the 2018 harvest samples were tested for aflatoxin and DON for this year's report. Since the production of mycotoxins is heavily influenced by growing conditions, the objective of the *Harvest Report* is strictly to report on instances when aflatoxin or DON are detected in the corn crop at harvest. No specific levels of the mycotoxins are reported.

The *Harvest Report* review of mycotoxins is NOT intended to predict the presence or level at which mycotoxins might appear in U.S. corn exports. Due to the multiple stages of the U.S. grain merchandising channel and the laws and regulations guiding the industry, the levels at which mycotoxins appear in corn exports are less than what might first appear in the corn as it comes out of the field. In addition, this report is not meant to imply that this assessment will capture all the instances of mycotoxins across the 12 states or three Export Catchment Areas (ECAs) surveyed. The *Harvest Report's* results should be used only as one indicator of the potential for mycotoxin presence in the corn as the crop comes out of the field. As the Council accumulates several years of the *Harvest Reports*, year-to-year patterns of mycotoxin presence in corn at harvest will be seen. The *U.S. Grains Council 2018/2019 Corn Export Cargo Quality Report* will report corn quality at export points and will be a more accurate indication of mycotoxin presence in the 2018/2019 U.S. corn export shipments.

## Assessing the Presence of Aflatoxin and DON

At least 25% of the minimum number of targeted samples (600) were tested to assess the impact of the 2018 growing conditions on total aflatoxin and DON development in the U.S. corn crop. The sampling criteria, described in the "Survey and Statistical Analysis Methods" section, resulted in a total number of 181 samples tested for mycotoxins.

A threshold established by the U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) as the "Lower Conformance Level" (LCL) was used to determine if a detectable level of the mycotoxin appeared in the sample. The LCLs for the FGIS-approved analytical kits and used for this 2018/2019 report were 5.0 parts per billion (ppb) for aflatoxin and 0.5 parts per million (ppm) for DON. The FGIS LCL was higher than the Limit of Detection (LOD) specified by the kit manufacturer of 2.7 ppb and 0.1 ppm for aflatoxin and DON, respectively. Details on the testing methodology employed in this study for the mycotoxins are in the "Testing Analysis Methods" section.

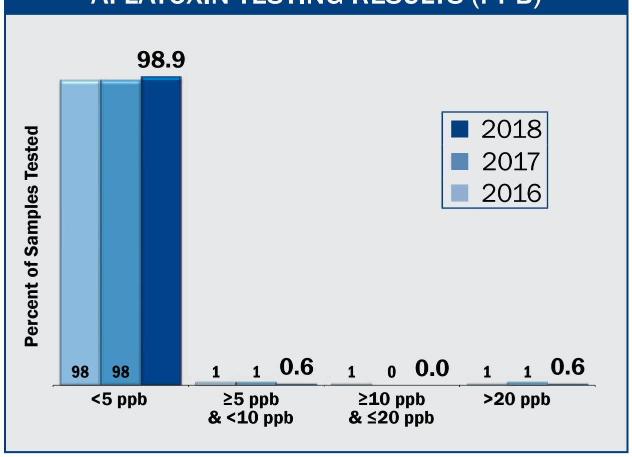
### *Results: Aflatoxin*

A total of 181 samples was analyzed for aflatoxin in 2018, compared to 180 and 177 samples tested for aflatoxin in 2017 and 2016, respectively. Results of the 2018 survey are as follows:

- One hundred seventy-nine (179) samples, or 98.9% of the 181 samples, had no detectable levels of aflatoxin (below the FGIS LCL of 5.0 ppb). This is close to the percentage of the samples tested with no detectable levels of aflatoxin in 2017 and 2016 (both 98%).
- One sample (1), or 0.6% of the 181 samples, showed aflatoxin levels greater than or equal to 5 ppb, but less than 10 ppb. This percentage is almost identical to 2017 and 2016 (both 1%).
- No samples (0), or 0.0% of the 181 samples, showed an aflatoxin level greater than or equal to 10 ppb, but less than or equal to the U.S. Food and Drug Administration (FDA) action level of 20 ppb. This percentage is similar or identical to both 2017 (0%) and 2016 (1%).
- One sample (1), or 0.6% of the 181 samples, showed an aflatoxin level greater than the FDA action level of 20 ppb. This percentage is almost identical to 2017 and 2016 (both 1%).
- These results denote that 180 samples, or 99.5% of the 181 sample test results in 2018, were below or equal to the FDA action level of 20 ppb, compared to 99% of the samples tested in both 2017 and 2016.

The fact that the 2018 crop season percentage (98.9%) of samples below the FGIS LCL of 5.0 ppb was similar to 2017 and 2016 (both 98%) may be due, in part, to favorable weather conditions in 2018 (see the "Crop and Weather Conditions" section for more information on 2018 growing conditions). Most of the growing area received ample moisture during pollination and grain-fill in 2018, and as a result, the corn plants were not under stress.

**AFLATOXIN TESTING RESULTS (PPB)**



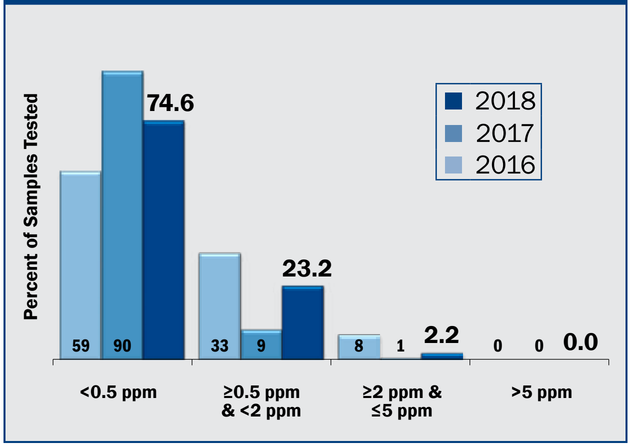
## Results: Deoxynivalenol (DON) or Vomitoxin

A total of 181 samples was analyzed collectively for DON in 2018, compared to 180 and 177 samples tested for DON in 2017 and 2016, respectively. Results of the 2018 survey are as follows:

- One hundred thirty-five (135) samples, or 74.6% of the 181 samples, had no detectable levels of DON (below the FGIS LCL of 0.5 ppm). This percentage for 2018 is lower than in 2017 (90%) and higher than in 2016 when 59% of the samples tested had no detectable levels of DON.
- Forty-two (42) samples, or 23.2% of the 181 samples, tested greater than or equal to 0.5 ppm, but less than 2 ppm. This percentage for 2018 is much higher than in 2017 (9%) and lower than in 2016 when 33% of the samples tested at or above 0.5 ppm, but less than 2 ppm.
- Four (4) samples, or 2.2% of the 181 samples, tested greater than or equal to 2 ppm, but less than or equal to the FDA advisory level of 5 ppm. This percentage for 2018 is slightly higher than in 2017 (1%) and lower than in 2016 (8%).
- All 181 samples, or 100%, tested below or equal to the FDA advisory level of 5 ppm, which was the same as was observed in 2017 and 2016.

While the samples in the 2018, 2017 and 2016 surveys were all below 5 ppm, there was a significant decrease in the percentage of samples below 0.5 ppm in 2018 (74.6%), compared to 2017 (90%), but not as low as 2016 (59%). Having a lower percentage of samples in 2018 testing below the 0.5 ppm than in 2017 may be attributed to wetter than usual weather conditions that were more conducive to DON development in 2018.

DON TESTING RESULTS (PPM)



## Background: Mycotoxins General

The levels at which fungi produce mycotoxins are impacted by the fungus type and the environmental conditions under which the corn is produced and stored. Because of these differences, mycotoxin production varies across the U.S. corn-producing areas and across years. In some years, the growing conditions across the corn-producing regions might not produce elevated levels of any mycotoxins. In other years, the environmental conditions in a particular area might be conducive to the production of a particular mycotoxin to levels that impact the corn's use for human and livestock consumption. Humans and livestock are sensitive to mycotoxins at varying levels. As a result, the U.S. Food and Drug Administration (FDA) has issued action levels for aflatoxin and advisory levels for DON by intended use.

**Action levels** specify precise limits of contamination above which the agency is prepared to take regulatory action. Action levels are a signal to the industry that the FDA believes it has scientific data to support regulatory and/or court action if a toxin or contaminant is present at levels exceeding the action level if the agency chooses to do so. If imports or domestic feed supplements are analyzed in accordance with valid methods and found to exceed applicable action levels, they are considered adulterated and may be seized and removed from interstate commerce by the FDA.

**Advisory levels** provide guidance to the industry concerning levels of a substance present in food or feed that are believed by the agency to provide an adequate margin of safety to protect human and animal health. While the FDA reserves the right to take regulatory enforcement action, enforcement is not the fundamental purpose of an advisory level.

A source of additional information is the National Grain and Feed Association (NGFA) guidance document titled "FDA Mycotoxin Regulatory Guidance" found at *http://www.ngfa.org/wp-content/uploads/NGFAComplianceGuide-FDARegulatoryGuidanceforMycotoxins8-2011.pdf*.

## Background: Aflatoxin

The most important type of mycotoxin associated with corn grain is aflatoxin. There are several types of aflatoxin produced by different species of *Aspergillus*, with the most prominent species being *A. flavus*. The growth of the fungus and aflatoxin contamination of grain can occur in the field prior to harvest or in storage. However, contamination prior to harvest is considered to cause most of the problems associated with aflatoxin. *A. flavus* grows well in hot, dry environmental conditions or where drought occurs over an extended period of time. It can be a serious problem in the southern United States, where hot and dry conditions are more common. The fungus usually attacks only a few kernels on the ear and often penetrates kernels through wounds produced by insects. Under drought conditions, it also grows down silks into individual kernels.

There are four types of aflatoxin naturally found in foods – aflatoxins B1, B2, G1 and G2. These four aflatoxins are commonly referred to as "aflatoxin" or "total aflatoxin." Aflatoxin B1 is the most commonly found aflatoxin in food and feed and is also the most toxic. Research has shown that B1 is a potent, naturally-occurring carcinogen in animals, with a strong link to human cancer incidence. Additionally, dairy cattle will metabolize aflatoxin to a different form of aflatoxin called aflatoxin M1, which may accumulate in milk.

Aflatoxin expresses toxicity in humans and animals primarily by attacking the liver. The toxicity can occur from short-term consumption of very high doses of aflatoxin-contaminated grain or long-term ingestion of low levels of aflatoxin, possibly resulting in death for poultry, the most sensitive of the animal species. Livestock may experience reduced feed efficiency or reproduction, and both human and animal immune systems may be suppressed as a result of ingesting aflatoxin.

The FDA has established action levels for aflatoxin M1 in milk intended for human consumption and aflatoxin in human food, grain and livestock feed (see table below).

The FDA has established additional policies and legal provisions concerning the blending of corn with levels of aflatoxin exceeding these threshold levels. In general, the FDA currently does not permit the blending of corn containing aflatoxin with uncontaminated corn to reduce the aflatoxin content of the resulting mixture to levels acceptable for use as human food or animal feed.

Corn exported from the United States must be tested for aflatoxin according to federal law. Unless the contract exempts this requirement, testing must be conducted by FGIS. Corn above the FDA action level of 20 ppb cannot be exported unless other strict conditions are met. This results in relatively low levels of aflatoxin in exported grain.

| Aflatoxin Action Level | Criteria |
|---|---|
| 0.5 ppb (Aflatoxin M1) | Milk intended for human consumption |
| 20 ppb | For corn and other grains intended for immature animals (including immature poultry) and for dairy animals, or when the animal's destination is not known |
| 20 ppb | For animal feeds, other than corn or cottonseed meal |
| 100 ppb | For corn and other grains intended for breeding beef cattle, breeding swine or mature poultry |
| 200 ppb | For corn and other grains intended for finishing swine of 100 pounds or greater |
| 300 ppb | For corn and other grains intended for finishing (i.e., feedlot) beef cattle and for cottonseed meal intended for beef cattle, swine or poultry |

*Source: FDA and USDA GIPSA, http://www.gipsa.usda.gov/fgis/publication/broch/b-aflatox.pdf*

## Background: Deoxynivalenol (DON) or Vomitoxin

Deoxynivalenol (DON) or vomitoxin is another mycotoxin of concern to some importers of corn grain. It is produced by certain species of *Fusarium*, the most important of which is *Fusarium graminearum* (*Gibberellazeae*) which also causes Gibberella ear rot (or red ear rot). *Gibberellazeae* can develop when cool or moderate and wet weather occurs at flowering. The fungus grows down the silks into the ear, and in addition to producing DON, it produces conspicuous red discoloration of kernels on the ear. The fungus can also continue to grow and rot ears when corn is left standing in the field. Mycotoxin contamination of corn caused by *Gibberellazeae* is often associated with excessive postponement of harvest and/or storage of high-moisture corn.

DON is mostly a concern with monogastric animals, where it may cause irritation of the mouth and throat. As a result, the animals may eventually refuse to eat the DON-contaminated corn and may have low weight gain, diarrhea, lethargy and intestinal hemorrhaging. It may cause suppression of the immune system, resulting in susceptibility to a number of infectious diseases.

The FDA has issued advisory levels for DON. For products containing corn, the advisory levels are:

- 5 ppm in grains and grain co-products for swine, not to exceed 20% of their diet;
- 10 ppm in grains and grain co-products for chickens and cattle, not to exceed 50% of their diet; and
- 5 ppm in grains and grain co-products for all other animals, not to exceed 40% of their diet.

FGIS is not required to test for DON on corn bound for export markets but will perform either a qualitative or quantitative test for DON at the buyer's request.

# A. 2018 HARVEST HIGHLIGHTS

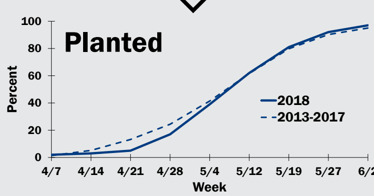
Weather plays a large role in the corn planting process, growing conditions and grain development in the field, which, in turn, impacts final grain yield and quality. Overall, 2018 was characterized by a hot, wet vegetative period (the period of growth between germination and pollination), followed by a warm pollination time then a grain-filling period with diverse weather, finishing with an intermittent harvest. This crop was planted late, but quickly grew, starting with a relatively high crop condition rating[1] but finalized near the five-year average (5YA). In addition to the U.S. Department of Agriculture (USDA) predicting a record corn yield for 2018, the crop had higher average test weight, oil, 100-k weight and true density, and fewer stress cracks and broken corn relative to the 5YA. The following highlights the key events of the 2018 growing season:

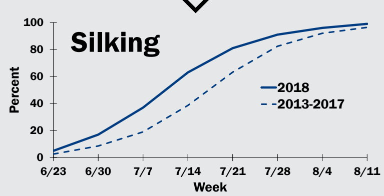
- Planting season was delayed but compressed, starting the plants quickly and uniformly in warm weather.
- Vegetative period in May and June was hot; the mostly dry May turned rainy in June, making fertilizer available during grain ear initiation and the rapid growth that finishes this stage.
- Pollination (silking stage) occurred two weeks earlier than average, setting grain fill in the heat of the summer, decreasing relative starch accumulation.
- Early grain development was accompanied by dry conditions in the Gulf ECA, while the Pacific Northwest ECA and Southern Rail ECA received abundant rain in July.
- Wet conditions in August during grain fill in the Pacific Northwest and Gulf ECAs promoted oil accumulation and good test weight.
- The combination of accelerated development and a hot August sped maturation, dry-down and initial harvest, but harvest was then delayed by abundant precipitation.

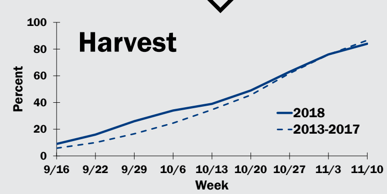
The following sections describe how the 2018 growing season weather impacted corn yield and grain quality in the U.S. Corn Belt.

**GROWING CONDITIONS AND IMPACT ON CROP DEVELOPMENT**

| Average planting, but hot, more precipitation in the vegetative phase | Wet at pollination in West, dry to the East (Gulf ECA), average to cool temperatures | Warm, wet grain fill in Gulf ECA, fast harvest progress slowed with October rains |
|---|---|---|




| Uniform fast crop development | Good pollination and early grain fill, with generally minor leaf disease pressure | Good test weight, hard endosperm, protein, and oil |
|---|---|---|

[1] *The U.S. Department of Agriculture (USDA) rates the U.S. corn crop weekly during the production cycle. The rating is based on yield potential and plant stress due to a number of factors, including extreme temperatures, excessive or insufficient moisture, disease, insect damage and/or weed pressure.*

# B. PLANTING AND EARLY GROWTH CONDITIONS

*Cold April led to late, compressed planting time*

Weather factors impacting corn yield and quality include the amount of precipitation and the temperature just prior to and during the corn-growing season. These weather factors interact with the corn variety planted and the soil fertility. Grain yield is a function of the number of plants per acre, the number of kernels per plant and the weight of each kernel. Cold or wet weather at planting could reduce plant numbers or hinder plant growth, which may result in lower yields per area. Some dryness at planting and early growth time is beneficial, as it promotes a deeper root system to access water better later in the season and keeps nitrogen fertilizer available for later plant growth.

Overall in 2018, April was very cold across the entire United States Corn Belt, delaying planting. Yet dry conditions and a hot May combined for quick planting and emergence. The heat continued during vegetative growth, advancing the crop to pollination two weeks earlier than the 5YA. Abundant rainfall in June tempered the heat, but also may have led to nitrogen fertilizer loss, decreasing final grain protein concentration, especially in the Pacific Northwest ECA.

In the Pacific Northwest ECA in May, the northern areas were drought-stressed, while southern areas of this ECA, such as Nebraska, were much wetter than normal, leading to plant stress. June continued warm and wet, quickly advancing plant development, but also promoting leaf diseases.

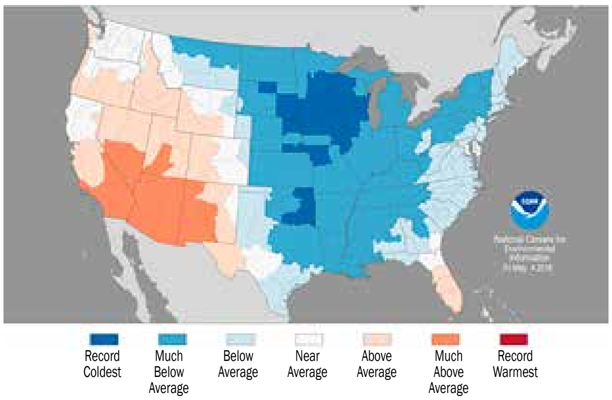
The majority of the Gulf ECA in May was dry, except for a band across the north-central portion that had flooding after planting, removing some of the fertilizer needed for optimal growth. June continued warm and wet, quickly advancing plant development, but also promoting leaf diseases.

The Southern Rail ECA was warm and fairly wet during vegetative growth, quickly advancing plant development, but also promoting leaf diseases.

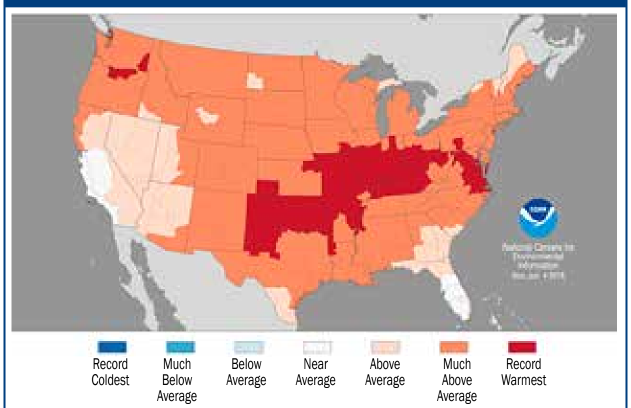
## DIVISIONAL AVERAGE TEMPERATURE RANKS

(Period: 1895-2018)

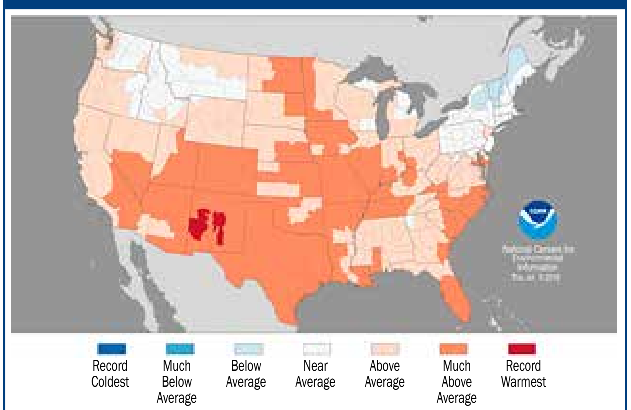
### APRIL 2018




### MAY 2018




### JUNE 2018

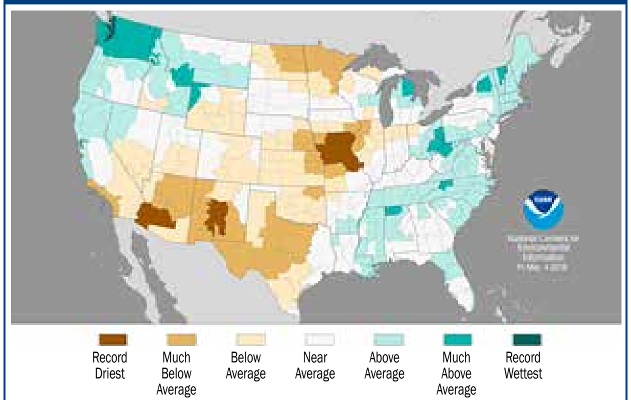



*Source: NOAA/Regional Climate Centers*

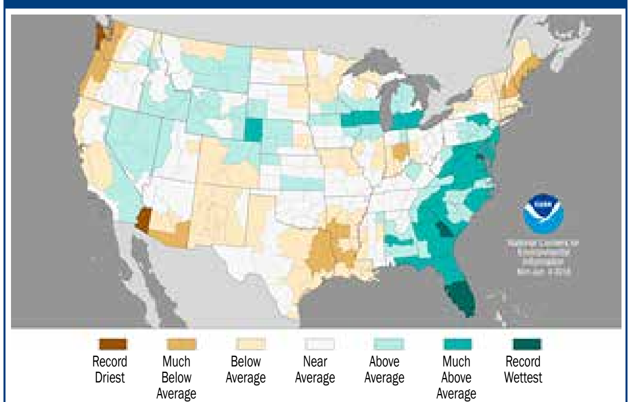
## DIVISIONAL PRECIPITATION RANKS

(Period: 1895-2018)

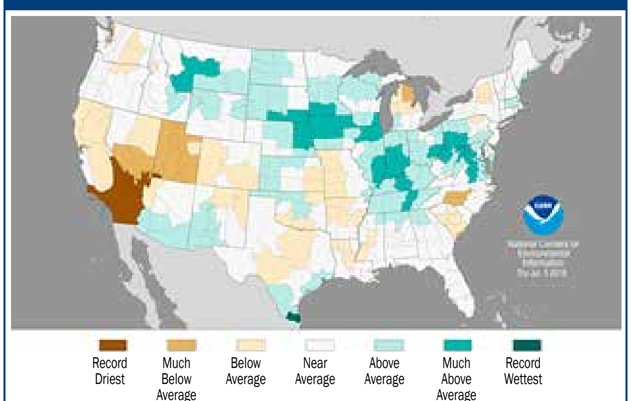
### APRIL 2018




### MAY 2018




### JUNE 2018




*Source: NOAA/Regional Climate Centers*

# C. POLLINATION AND GRAIN-FILL CONDITIONS

### *Grain-fill conditions favored high test weight and oil*

Corn pollination typically occurs in July, and at pollination time, greater-than-average temperatures or lack of rain typically reduce the number of kernels. The weather conditions during the early grain-filling period in July and August are critical to determining final grain composition. At pollination, moderate rainfall and cooler-than-average temperatures, especially overnight temperatures, lead to higher starch and oil levels and increased yields. Less rainfall and high temperatures, especially in the second half of grain-fill (August to September), lead to more protein. Nitrogen also remobilizes from the leaves to the grain during late grain-filling, leading to increases in grain protein and hard endosperm.

In 2018, the heat experienced during the vegetative period caused pollination to occur two weeks early. Leaf diseases were prevalent in some regions, and heat-stress was offset by rainfall during grain-fill, changing the combined good-to-excellent crop condition rating from between 72 to 78% during early growth to near 68% by the end of the season. The crop quickly matured through grain-fill, with relatively high greater kernel weight and test weight.

In the Pacific Northwest ECA, July and August experienced average to cool temperatures. July was very rainy, too. The later-half of grain-fill was cooler than average with abundant rainfall. These conditions may have contributed to slightly higher starch and slightly lower protein concentrations compared to the previous crop.

While the Gulf ECA was dry during pollination in July, grain-filling in August and September had abundant rainfall that moderated the relatively hot temperatures. The heat accompanied by rain encouraged minor leaf disease pressure, restricting starch accumulation, but promoting greater oil level and test weight.

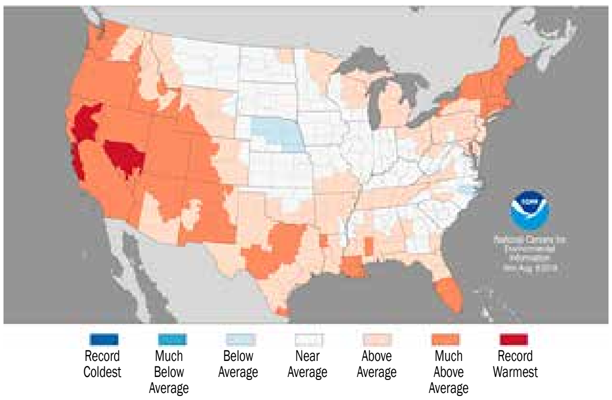
Overall, the Southern Rail ECA had weather similar to the Pacific Northwest ECA, but cooler and wetter in August and September. Growing conditions in the Southern Rail ECA were good for increasing test weight over the 5YA.

U.S. GRAINS COUNCIL

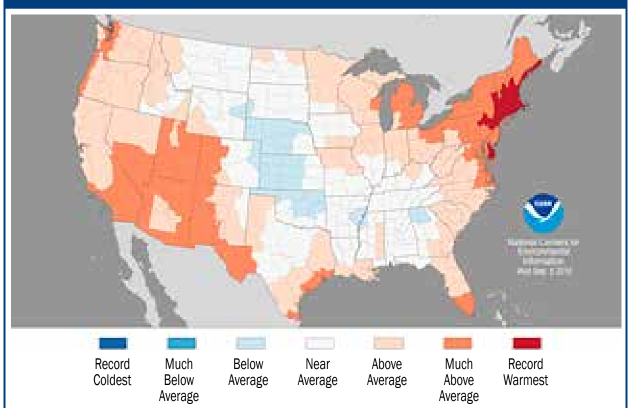
## DIVISIONAL AVERAGE TEMPERATURE RANKS

(Period: 1895-2018)

### JULY 2018




### AUGUST 2018

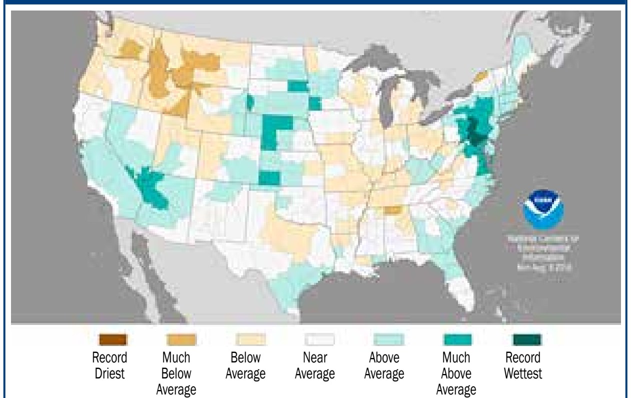



*Source: NOAA/Regional Climate Centers*

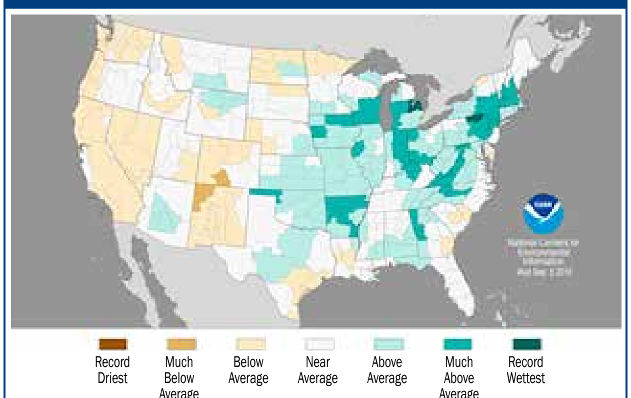
## DIVISIONAL PRECIPITATION RANKS

(Period: 1895-2018)

### JULY 2018




### AUGUST 2018




*Source: NOAA/Regional Climate Centers*

# D. HARVEST CONDITIONS

## *Quick start in the Gulf ECA, but weather then moderated harvest progress*

At the end of the growing season, the rate of dry-down of the grain depends on sunshine, temperature, humidity levels and soil moisture. Corn can most effectively dry down with the least adverse impact on quality amid sunny, warm and dry days. One weather concern at the end of the growing season is freezing temperatures. Early freezing before the grain can sufficiently dry down may lead to lower yield, test weight and/or stress cracking. Also, grain harvested at high moisture content may eventually lead to greater breakage since it may require artificial drying.

Typically, 20% of the U.S. corn crop is harvested by the start of October. However, in 2018 the warm weather in September matured the crop quickly, about two weeks ahead of average. Therefore, a greater-than average percentage of the crop was harvested in September, especially in the Gulf ECA. However, rains were persistent in late September and October throughout the Corn Belt, and harvest progress slowed, especially in the Pacific Northwest ECA.

*Fusarium*-based ear mold (Gibberella ear rot) is promoted by cool and/or wet conditions soon after pollination. The end of June 2018 saw rains tapering off in the Gulf ECA, and July temperatures were fairly average during this critical period. The mycotoxin deoxynivalenol (DON) or vomitoxin that is produced by *Fusarium* is often associated with harvest delay or storage of high-moisture corn. The 2018 crop matured quickly, so there were few instances of high-moisture corn.

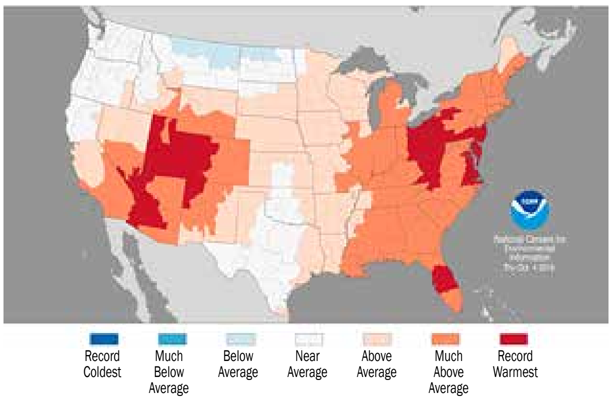
Additionally, aflatoxin production is favored by hot temperatures, low precipitation and drought conditions. While it was warm in a large central portion of the corn-growing region during vegetative growth, the plants had ample water supply. As a result, the prevalence of aflatoxin was low in this year's samples.

U.S. GRAINS COUNCIL

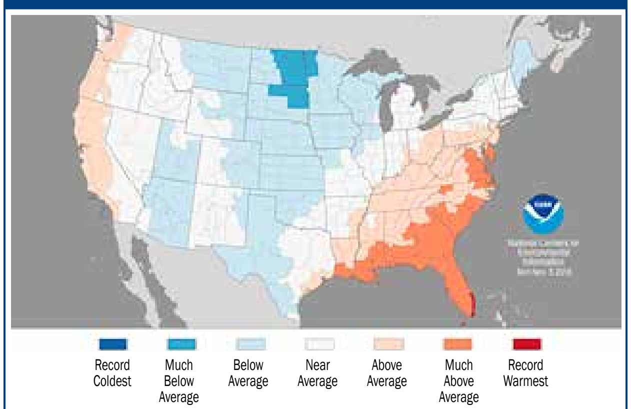
## DIVISIONAL AVERAGE TEMPERATURE RANKS

(Period: 1895-2018)

### SEPTEMBER 2018




### OCTOBER 2018

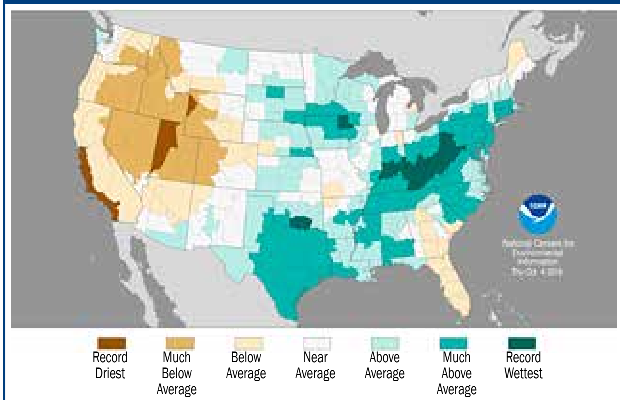



*Source: NOAA/Regional Climate Centers*

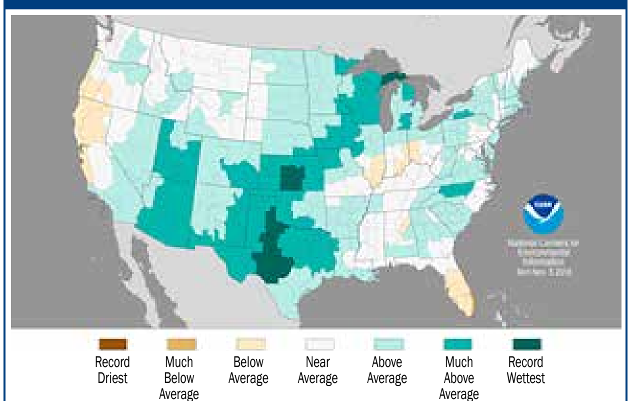
## DIVISIONAL PRECIPITATION RANKS

(Period: 1895-2018)

### SEPTEMBER 2018




### OCTOBER 2018

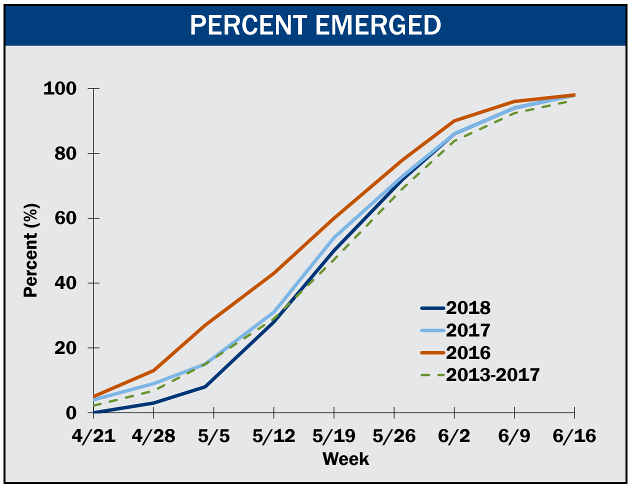



*Source: NOAA/Regional Climate Centers*

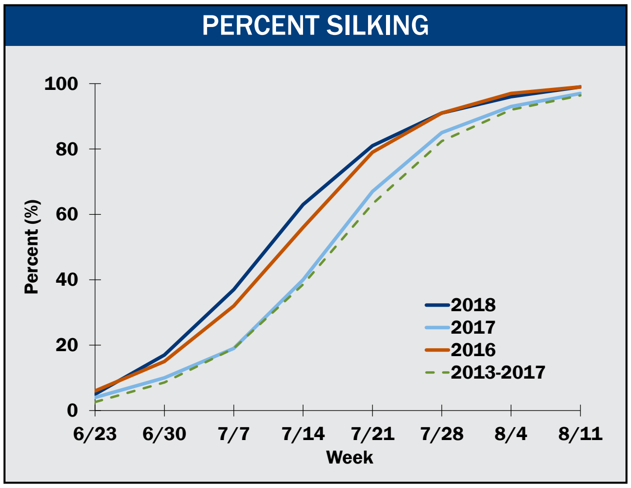
# E. COMPARISON OF 2018 TO 2017, 2016 AND THE 5YA

### *2018 grew and developed quickly, creating good quality and record yields*

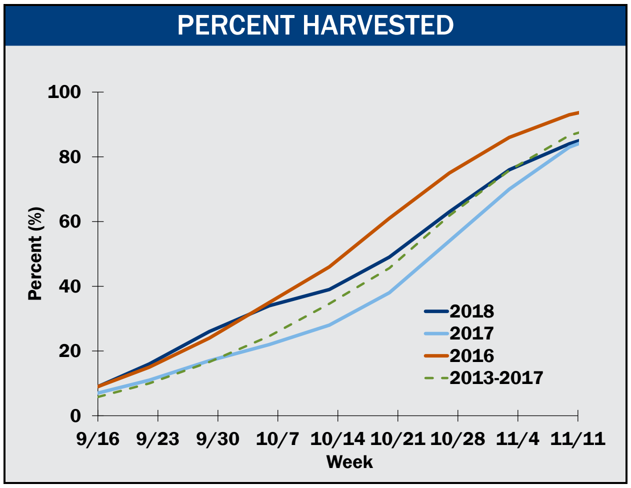
The 2016 crop was planted and emerged earlier than average, and the crop in 2017 required a large proportion of replanting. Cold weather in 2018 delayed planting from the 5YA pace. But warm weather led to near-to-earlier than the 5YA emergence for all three years. Vegetative growth for all three years was faster than the 5YA, especially for 2018 and 2016. Rains mostly tapered off in the Pacific Northwest and Southern Rail ECAs in July 2017, and the Gulf ECA in 2018, which helped to maximize pollination, while the Gulf ECA in July 2017 was similar to 2016, with plentiful rains during early grain-fill.



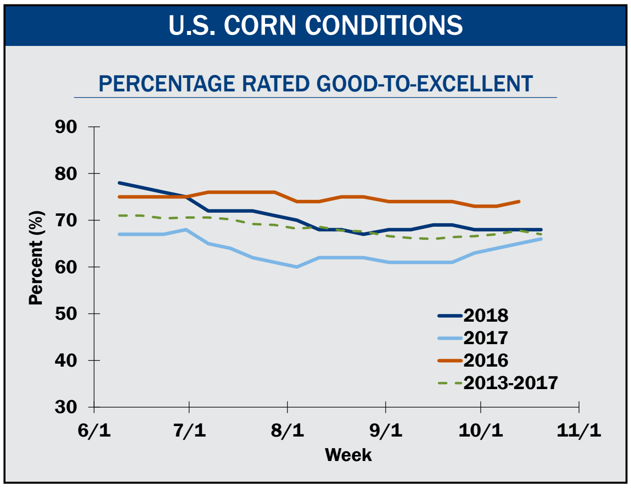

The grain-fill period in 2018 was faster than the 5YA in the Gulf ECA that had continued warm weather, while the Pacific Northwest and the Southern Rail ECAs had cooler weather. August 2017 provided cool weather throughout the Corn Belt, in contrast to a very warm August 2016, which inhibited maximum starch accumulation. In 2017, the moderate temperatures and delayed maturity prolonged grain-fill through September, about 10% behind the 5YA.



The quick start of the 2018 harvest can be attributed to the warm weather earlier in the season, advancing the crop maturation approximately two weeks ahead of the 5YA. In contrast, the 2017 harvest was greatly delayed compared to the 5YA by late maturation of the plants and wet fields. The 2016 harvest was also earlier than the 5YA but progressed at a more regular pace than 2018.




The corn crop in 2018 had a combined good-to-excellent condition rating[2] that started greatly above the 5YA, with excellent early growth, but the heat and leaf diseases moderated the condition rating to near the 5YA of approximately 70% by season's end, signifying good plant health, which then led to good photosynthesis, kernel size and yield. For 2017, the crop condition rating remained between 60-68%, yet still had record yields. In 2016, the crop had near 75% good-to-excellent condition ratings through most of the season.



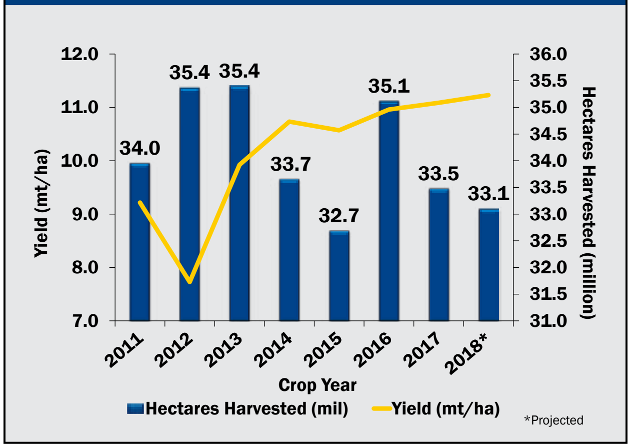

*[2]A 'Good' rating means that yield prospects are normal. Moisture levels are adequate and disease, insect damage, and weed pressures are minor. An 'Excellent' rating means that yield prospects are above normal, and the crop is experiencing little or no stress. Disease, insect damage and weed pressures are insignificant.*

# A. U.S. CORN PRODUCTION[1]

## U.S. Average Production and Yields

- According to the December 2018 U.S. Department of Agriculture (USDA) World Agricultural Supply and Demand Estimates (WASDE) report, average U.S. corn yield for the 2018 crop is projected to be 11.23 mt/ha (178.9 bu/ac). This is 0.14 mt/ha (2.3 bu/ac) higher than the average yield for the 2017 corn crop and the highest average yield on record.
- The number of hectares harvested in 2018 is projected to be 33.10 million (81.8 mil ac). This is 0.38 mil ha (0.9 mil ac) less than in 2017 and is slightly less than the average of 33.67 mil ha (83.2 mil ac) harvested from 2008 through 2017.
- While 2018 saw the seventh-highest number of harvested hectares in the past decade, the 2018 crop experienced the highest average yield on record, thereby producing a crop estimated to be the third-largest U.S. corn crop on record at 371.52 mmt (14,626 mil bu). This crop is estimated to be 13.26 mmt (522 mil bu) smaller than 2016's record crop (384.78 mmt or 15,148 mil bu).

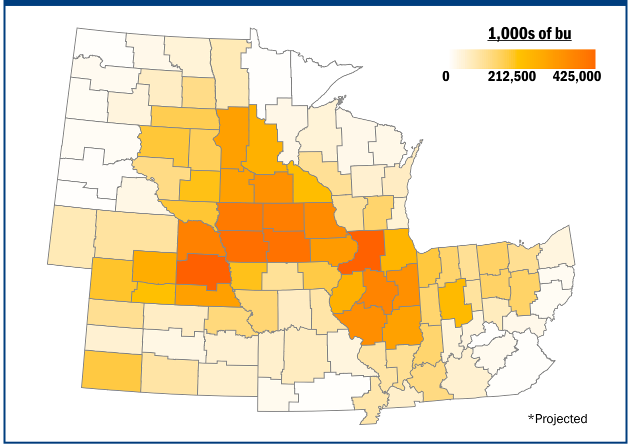
U.S. CORN YIELD AND HARVESTED AREA




## ASD and State-Level Production

The geographic areas included in the *2018/2019 Corn Harvest Quality Report* encompass the highest corn-producing areas in the United States. This can be seen on the map showing projected 2018 corn production by USDA Agricultural Statistical District (ASD). These states represent approximately 95% of U.S. corn exports.[2]

U.S. CORN PRODUCTION BY ASD (2018*)



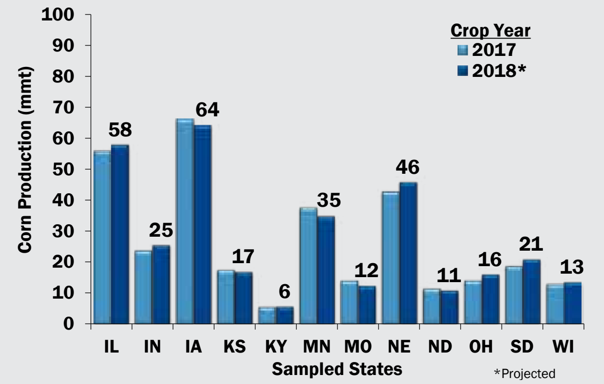

*Source: USDA NASS and Centrec Estimates*

[1] *mt - metric ton; mmt - million metric tons; ha - hectare; bu - bushel; mil bu - million bushels; ac - acre.*

[2] *Source: USDA NASS, USDA GIPSA and Centrec estimates.*

Mostly slight differences in state-level yields and harvested acres were observed between the corn crop produced in 2017 and the 2018 crop. While production decreased or remained the same from 2017 in 5 of the 12 key corn-producing states, only Missouri experienced decreases in production greater than 10% compared to their 2017 crops.

## U.S. CORN PRODUCTION BY STATE




*Source: USDA NASS*

The U.S. Corn Production table summarizes the changes in production between each state's 2017 and projected 2018 corn crops, including an indication of the relative changes in harvested acres and yield. A green bar indicates a relative increase and a red bar indicates a relative decrease from 2017 to projected 2018. This illustrates that 2018 harvested acres remained similar to 2017 for 11 of the 12 surveyed states. With a projected decrease of 10%, only North Dakota saw a change in harvested acres of greater than 5% compared to its 2017 crop. State-level average yields were generally higher in 2018 relative to 2017. Out of the 8 states expecting higher average yields, South Dakota is expected to have the largest increase in yield relative to its 2017 crop (14%). Only 4 states are projected to see a decline in average yields relative to 2017. Missouri is expected to see its state-level average yield fall by 15%, making it the only state projected to see a decline in yield over 5%.

## U.S. CORN PRODUCTION

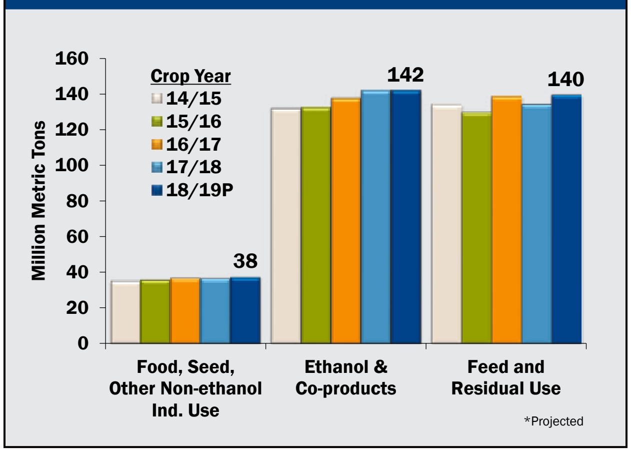
| | | | Difference | | Relative % Change† | |
|---|---|---|---|---|---|---|
| State | 2017 | 2018* | MMT | Percent | Acres | Yield |
| Illinois | 55.9 | 57.9 | 2.0 | 3.5% | | |
| Indiana | 23.7 | 25.5 | 1.7 | 7.4% | | |
| Iowa | 66.2 | 64.1 | (2.1) | -3.1% | | |
| Kansas | 17.4 | 16.8 | (0.6) | -3.4% | | |
| Kentucky | 5.5 | 5.6 | 0.1 | 2.2% | | |
| Minnesota | 37.6 | 34.8 | (2.8) | -7.4% | | |
| Missouri | 14.0 | 12.3 | (1.7) | -12.1% | | |
| Nebraska | 42.8 | 45.8 | 3.1 | 7.2% | | |
| North Dakota | 11.4 | 10.8 | (0.6) | -5.0% | | |
| Ohio | 14.1 | 16.0 | 1.9 | 13.6% | | |
| South Dakota | 18.7 | 20.9 | 2.2 | 11.6% | | |
| Wisconsin | 12.9 | 13.5 | 0.5 | 4.2% | | |
| Total U.S. | 370.9 | 371.5 | 0.6 | 0.2% | | |

†*Green indicates higher than previous year and red indicates lower than previous year; bar height indicates the relative amount.*
**Projected*
*Source: USDA NASS*

# B. U.S. CORN USE AND ENDING STOCKS

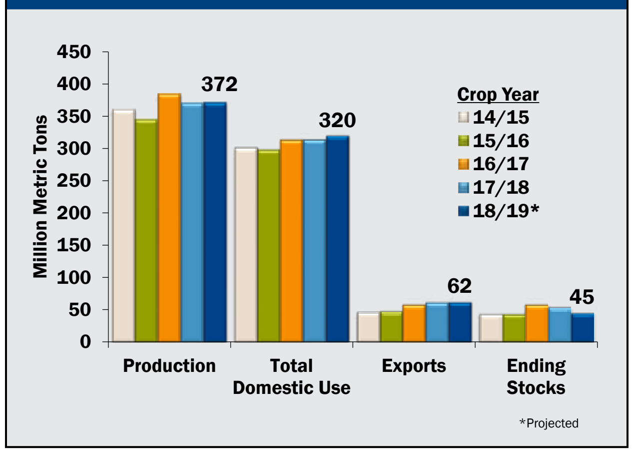
- U.S. corn use for food, seed and other non-ethanol industrial purposes has remained consistent over the past four completed marketing years.
- While domestic consumption of gasoline has stalled during since MY14/15, increasing ethanol exports has led to slight annual increases in the amount of corn used for ethanol production during this period.
- Direct consumption of corn as a feed ingredient in domestic livestock and poultry rations has remained strong, due to ample corn supplies and competitive corn prices relative to other feed ingredients.
- Strong export demand and relatively large crops have led to slight annual increases in U.S. corn exports since MY14/15.
- Ending stocks peaked following the record 2016 crop and decreased only slightly following a 2017 crop that was still the second largest on record.

**U.S. CORN USE**




Source: USDA WASDE and ERS

**U.S CORN PRODUCTION & DISAPPEARANCE**




Source: USDA WASDE and ERS

# C. OUTLOOK

## U.S. Outlook

- The projected third-largest U.S. corn crop on record has created an abundant supply of corn for MY18/19. This ample supply has continued to keep downward pressure on corn prices since their peak in MY12/13. The ample supply and low prices are major factors driving the projected domestic use of corn in MY18/19 to be the highest on record.
- Corn use for food, seed and non-ethanol industrial (FSI) purposes is expected to remain largely unchanged in MY18/19 compared to MY17/18, continuing the pattern of the previous four marketing years.
- Projected MY18/19 corn use for ethanol is the same as MY17/18. Corn use for ethanol

is influenced, in part, by domestic gasoline demand, with low gasoline prices supporting increased consumption and the expansion of the domestic ethanol market. While gasoline prices have remained relativity low, consumption has stalled, leaving strong export ethanol demand responsible for corn use for ethanol remaining steady.

- Domestic corn use for feed and residual use is expected to be 5.13 mmt higher (3.8% increase) in MY18/19 than in MY17/18. Feed demand for corn is expected to be supported by low corn prices, thereby decreasing the feed costs and a large inventory of livestock and poultry.
- While U.S. corn exports during MY18/19 are projected to be only about 0.5% higher than MY17/18, exports for MY18/19 are projected to be the highest on record.
- MY18/19 corn ending stocks are projected to be 16.8% lower than the previous marketing year. Strong domestic and export demand is partially responsible for this decrease as well as two historically large corn crops in MY16/17 and MY17/18 creating large ending stocks in those years.
- In terms of the stocks-to-use ratio, the record 2016 crop's ratio was 15.6%, the highest since was MY05/06 (17.5%). This ratio has fallen the last two years with MY18/19 projected to have a ratio of 11.9%, which is similar to the average from the past 10 completed marketing years (11.6%).

## International Outlook[3]

### *Global Supply*

- Global corn production during MY18/19 is expected to be slightly higher than MY17/18 due to slightly larger crops in key corn-producing countries.
- Higher production for MY18/19 in Brazil, Argentina and Ukraine will offset lower production in China, India and the European Union.
- In addition to higher projected U.S. exports, total non-U.S. exports are also expected to be slightly higher in MY18/19 than in MY17/18.
- Exports from key non-U.S. exporting countries are expected to increase from Argentina and Brazil.

### *Global Demand*

- Global corn use is expected to rise from 1,086.23 mmt in MY17/18 to 1,131.31 mmt in MY18/19, approximately a 4% annual increase.
- With the exception of South Africa, Japan and Canada, corn use is anticipated to be higher in MY18/19 than in MY17/18 for the major corn-consuming countries and areas, which China accounting for the largest increase of any country (13.00 mmt).
- An increase in year-over-year imports is expected globally in MY18/19. Decreases in imports by Canada, Japan and Turkey will be countered by increases in projected MY18/19 corn imports by the European Union, Vietnam, China and Saudi Arabia.

[3]*USDA/Foreign Agricultural Service–Production, Supply and Distribution Database*

## U.S. CORN SUPPLY AND USAGE SUMMARY BY MARKETING YEAR

| Metric Units | 14/15 | 15/16 | 16/17 | 17/18 | 18/19* |
|---|---|---|---|---|---|
| **Acreage (million hectares)** | | | | | |
| Planted | 36.68 | 35.64 | 38.06 | 36.52 | 36.07 |
| Harvested | 33.66 | 32.69 | 35.12 | 33.48 | 33.12 |
| Yield (mt/ha) | 10.73 | 10.57 | 10.96 | 11.09 | 11.23 |
| **Supply (million metric tons)** | | | | | |
| Beginning stocks | 31.29 | 43.97 | 44.12 | 58.25 | 54.36 |
| Production | 361.09 | 345.51 | 384.78 | 370.96 | 371.52 |
| Imports | 0.80 | 1.72 | 1.45 | 0.91 | 1.14 |
| **Total Supply** | **393.19** | **391.20** | **430.35** | **430.15** | **427.15** |
| **Usage (million metric tons)** | | | | | |
| Food, seed, other non-ethanol ind. use | 35.48 | 36.19 | 36.91 | 36.91 | 37.59 |
| Ethanol and co-products | 132.09 | 132.69 | 137.98 | 142.37 | 142.25 |
| Feed and residual | 134.23 | 129.91 | 138.95 | 134.58 | 139.71 |
| Exports | 47.42 | 48.29 | 58.27 | 61.93 | 62.23 |
| **Total Use** | **349.22** | **347.07** | **372.10** | **375.76** | **381.78** |
| Ending Stocks | 43.97 | 44.12 | 58.25 | 54.36 | 45.24 |
| Average Farm Price ($/mt**) | 145.66 | 142.12 | 132.28 | 132.28 | 125.98-157.47 |

| English Units | 14/15 | 15/16 | 16/17 | 17/18 | 18/19* |
|---|---|---|---|---|---|
| **Acreage (million acres)** | | | | | |
| Planted | 90.6 | 88.0 | 94.0 | 90.2 | 89.1 |
| Harvested | 83.1 | 80.8 | 86.7 | 82.7 | 81.8 |
| Yield (bu/ac) | 171.0 | 168.4 | 174.6 | 176.6 | 178.9 |
| **Supply (million bushels)** | | | | | |
| Beginning stocks | 1,232 | 1,731 | 1,737 | 2,293 | 2,140 |
| Production | 14,216 | 13,602 | 15,148 | 14,604 | 14,626 |
| Imports | 32 | 68 | 57 | 36 | 45 |
| **Total Supply** | **15,479** | **15,401** | **16,942** | **16,934** | **16,816** |
| **Usage (million bushels)** | | | | | |
| Food, seed, other non-ethanol ind. use | 1,397 | 1,425 | 1,453 | 1,453 | 1,480 |
| Ethanol and co-products | 5,200 | 5,224 | 5,432 | 5,605 | 5,600 |
| Feed and residual | 5,284 | 5,114 | 5,470 | 5,298 | 5,500 |
| Exports | 1,867 | 1,901 | 2,294 | 2,438 | 2,450 |
| **Total Use** | **13,748** | **13,664** | **14,649** | **14,793** | **15,030** |
| Ending Stocks | 1,731 | 1,737 | 2,293 | 2,140 | 1,781 |
| Average Farm Price ($/bu**) | 3.70 | 3.61 | 3.36 | 3.36 | 3.25-3.95 |

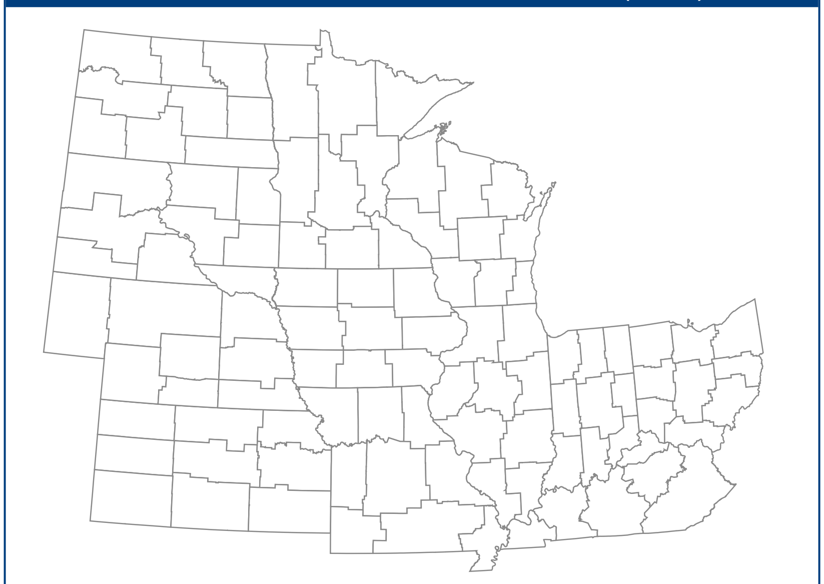
**Projected*
***Farm prices are weighted averages based on volume of farm shipment.*
*Average farm price for 18/19P based on WASDE December projected price.*
*Source: USDA WASDE and ERS*

## A. OVERVIEW

The key points for the survey design and sampling and statistical analysis for this *2018/2019 Harvest Report* are as follows:

- Following the methodology developed for the previous seven *Harvest Reports*, the samples were proportionately stratified according to Agricultural Statistical Districts (ASDs) across 12 key corn-producing states representing approximately 95% of U.S. corn exports.
- A total of 608 samples collected from the 12 states was targeted to achieve a maximum ±10% relative margin of error (Relative ME) at the 95% confidence level.
- A total of 618 unblended corn samples pulled from inbound farm-originated trucks were received from local elevators from August 27 through November 28, 2018, and tested.
- A proportionate stratified sampling technique was used for the mycotoxin testing across the ASDs in the 12 states surveyed for the other quality factors. This sampling resulted in 181 samples being tested for aflatoxin and deoxynivalenol (DON) or vomitoxin.
- Weighted averages and standard deviations following standard statistical techniques for proportionate stratified sampling were calculated for the U.S. Aggregate and the three Export Catchment Areas (ECAs).
- To evaluate the statistical validity of the samples, the Relative ME was calculated for each of the quality attributes at the U.S. Aggregate and the three ECA levels. The Relative ME for stress cracks was above ±10% for the Pacific Northwest and Southern Rail ECAs, while the Relative ME for stress crack index (SCI) was above ±10% for the U.S. Aggregate and across the three ECAs. In addition, total damage in the Pacific Northwest ECA also had a Relative ME above ±10%. While the lower level of precision for these quality factors is less than desired, these levels of Relative ME do not invalidate the estimates.
- Two-tailed t-tests at the 95% confidence level were calculated to measure statistical differences between the 2018 and 2017 and the 2018 and 2016 quality factor averages.

**AGRICULTURAL STATISTICAL DISTRICTS (ASDs)**



# B. SURVEY DESIGN AND SAMPLING

## Survey Design

For this *2018/2019 Harvest Report*, the target population was yellow commodity corn from the 12 key U.S. corn-producing states representing approximately 95% of U.S. corn exports.[1] A ***proportionate stratified, random sampling*** technique was applied to ensure a sound statistical sampling of the U.S. corn crop at the first stage of the market channel. Three key characteristics define the sampling technique: the ***stratification*** of the population to be sampled, the ***sampling proportion*** per stratum and the ***random sample*** selection procedure.

***Stratification*** involves dividing the survey population of interest into distinct, non-overlapping subpopulations called strata. For this study, the survey population was corn produced in areas likely to export corn to foreign markets. The U.S. Department of Agriculture (USDA) divides each state into several Agricultural Statistical Districts (ASDs) and estimates corn production for each ASD. The USDA corn production data, accompanied by foreign export estimates, were used to define the survey population in the 12 key corn-producing states. The ASDs were the subpopulations or strata used for this corn quality survey. From those data, the Council calculated each ASD's proportion of the total production and foreign exports to determine the ***sampling proportion*** (the percent of total samples per ASD) and ultimately, the number of corn samples to be collected from each ASD. The number of samples collected for the *2018/2019 Harvest Report* differed among the ASDs, due to their different shares of estimated production and foreign export levels.

The ***number of samples collected was established*** so the Council could estimate the true averages of the various quality factors with a certain level of precision. The level of precision chosen for the *2018/2019 Harvest Report* was a relative margin of error (Relative ME) no greater than ±10%, estimated at a 95% level of confidence. A Relative ME of ±10% is a reasonable target for biological data such as these corn quality factors.

To determine the number of samples for the targeted Relative ME, ideally, the population variance (i.e., the variability of the quality factor in the corn at harvest) for each of the quality factors should be used. The more variation among the levels or values of a quality factor, the more samples needed to estimate the true mean with a given confidence limit. In addition, the variances of the quality factors typically differ from one another. As a result, different sample sizes for each of the quality factors would be needed for the same level of precision.

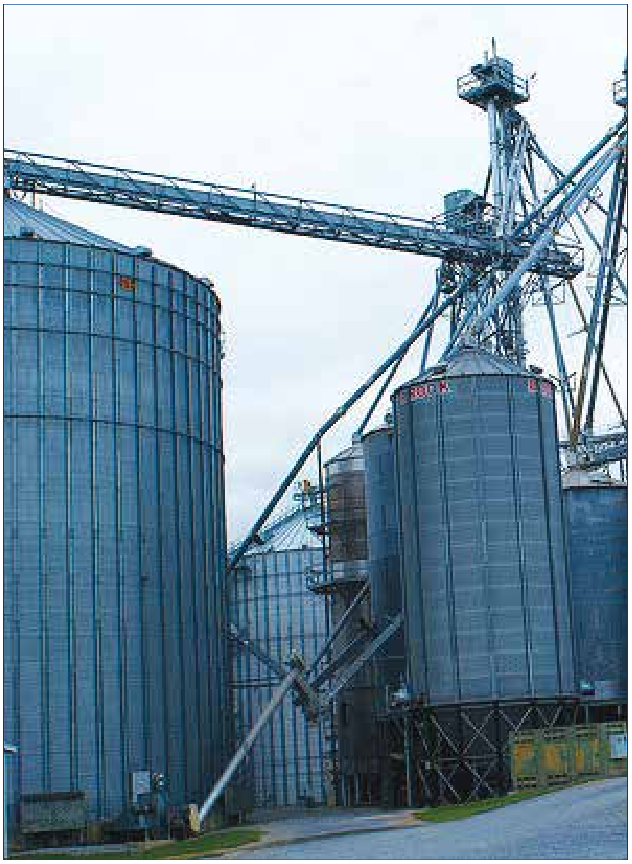
Since the population variances for the 18 quality factors evaluated for this year's corn crop were not known, the variance estimates from the *2017/2018 Harvest Report* were used as proxies. The variances and ultimately the estimated number of samples needed for the Relative ME of ±10% for 15 quality factors were calculated using the 2017 results of 627 samples. Broken corn, foreign material and heat damage were not examined. Stress cracks and stress crack index (SCI), with a Relative ME of 11% and 13%, respectively, were the only quality factors for which the Relative ME exceeded ±10% for the U.S. Aggregate. Based on these data, a minimum sample size of 600 would allow the Council to estimate the true averages of the quality characteristics with the desired level of precision for the U.S. Aggregate, with the exception of stress cracks and SCI. However, the targeted number of samples became 608, due to the rounding of the targeted number of samples per ASD and the criterion of a minimum of two samples per ASD.

[1] *Source: USDA NASS, USDA GIPSA and Centrec estimates.*

The same approach of proportionate stratified sampling was used for the mycotoxin testing of the corn samples as for the testing of the grade, moisture, chemical and physical characteristics. In addition to using the same sampling approach, the same level of precision of a Relative ME of ±10%, estimated at a 95% level of confidence, was desired. Testing at least 25% of the minimum number of samples (600) was estimated to provide that level of precision. In other words, testing at least 150 samples would provide a 95% confidence level that the percent of tested samples with aflatoxin results below the U.S. Food and Drug Administration (FDA) action level of 20 parts per billion (ppb) would have a Relative ME of ±10%. In addition, it was estimated that the percent of tested samples with DON results below the FDA advisory level of 5 parts per million (ppm) would also have a Relative ME of ±10%, estimated at a 95% level of confidence. The proportionate stratified sampling approach also required testing at least one sample from each ASD in the sampling area. To meet the sampling criteria of testing 25% of the minimum number of samples (600) and at least one sample from each ASD, the targeted number of samples to test for mycotoxins was 181 samples.

## Sampling

The ***random selection*** process was implemented by soliciting local grain elevators in the 12 states by email and phone. Postage-paid sample kits were mailed to elevators agreeing to provide the 2050- to 2250-gram corn samples requested. Elevators were told to avoid sampling loads of old crop corn from farmers cleaning out their bins for the current crop. The individual samples were pulled from inbound farm-originated trucks when the trucks underwent the elevators' normal testing procedures. The number of samples each elevator provided for the survey depended on the targeted number of samples needed from the ASD along with the number of elevators willing to provide samples. Each sampling kit mailed to the participating locations contained bags to collect a maximum of four samples. A total of 618 unblended corn samples pulled from inbound farm-originated trucks was received from local elevators from August 27 through November 28, 2018, and tested.



# C. STATISTICAL ANALYSIS

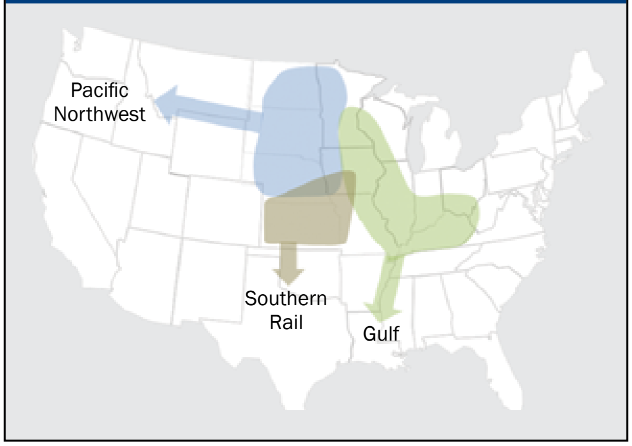
The sample test results for the grade factors, moisture, chemical composition and physical factors were summarized as the U.S. Aggregate and also by three composite groups that supply corn to each of three major export channels, labeled Export Catchment Areas (ECAs), as follows:

- The Gulf ECA consists of areas that typically export corn through the U.S. Gulf ports;
- The Pacific Northwest ECA includes areas that export corn through Washington, Oregon and California ports; and
- The Southern Rail ECA comprises areas generally exporting corn to Mexico by rail from inland subterminals.

In analyzing the sample test results, the Council followed the standard statistical techniques employed for proportionate stratified sampling, including ***weighted averages*** and ***standard deviations***. In addition to the weighted averages and standard deviations for the U.S. Aggregate, weighted averages and standard deviations were estimated for the composite ECAs. The geographic areas from which exports flow to each of these ECAs overlap due to available transportation modes. Therefore, composite statistics for each ECA were calculated based on estimated proportions of grain flowing to each ECA. As a result, corn samples could be reported in more than one ECA. These estimations were based on industry input, export data and evaluation of studies of grain flow in the United States.

The *2018/2019 Harvest Report* contains a simple average of the quality factors' averages and standard deviations of the previous five *Harvest Reports (2013/2014, 2014/2015, 2015/2016, 2016/2017 and 2017/2018)*. These simple averages are calculated for the U.S. Aggregate and each of the three ECAs and are referred to as the "5YA" in the text and summary tables of the report.

**EXPORT CATCHMENT AREAS**




The Relative ME was calculated for each of the quality factors for the U.S. Aggregate and each of the ECAs. The table below displays all Relative MEs exceeding ±10% by quality factor and composite grouping.

| | Relative ME | | |
|---|---|---|---|
| | Total Damage | Stress Cracks | SCI |
| U.S. Aggregate | | | 12% |
| Gulf ECA | | | 12% |
| Pacific Northwest ECA | 11% | 13% | 16% |
| Southern Rail ECA | | 15% | 19% |

While the lower level of precision for these quality factors is less than desired, these levels of Relative ME do not invalidate the estimates. Footnotes in the summary tables for the quality factors indicate the attributes for which the Relative ME exceeds ±10%.

References in the "Quality Test Results" section to statistical and/or significant differences between results in the *2017/2018 Harvest Report* and the *2018/2019 Harvest Report*, and in the *2016/2017 Harvest Report* and the *2018/2019 Harvest Report*, were validated by two-tailed t-tests at the 95% confidence level.

The *2018/2019 Corn Harvest Quality Report* samples (each about 2200 grams) were sent directly from the local grain elevators to the Illinois Crop Improvement Association's Identity Preserved Grain Laboratory (IPG Lab) in Champaign, Illinois. Upon arrival, the samples were dried, if needed, to a suitable moisture content to prevent any subsequent deterioration during the testing period. Next, the samples were split into two 1100-gram subsamples using a Boerner divider, while keeping the attributes of the grain sample evenly distributed between the two subsamples. One subsample was delivered to the Champaign-Danville Grain Inspection (CDGI), Urbana, Illinois, for grading. CDGI is the official grain inspection service provider for east-central Illinois as designated by U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS). The grade testing procedures were in accordance with FGIS's *Grain Inspection Handbook* and are described in the following section. The other subsample was analyzed at IPG Lab for the chemical composition and other physical factors, following either industry norms or well-established procedures in practice for many years. IPG Lab has received accreditation under the ISO/IEC 17025:2005 International Standard for many of the tests. The full scope of accreditation is available at *http://www.ilcrop.com/labservices*.

# A. GRADE FACTORS

## Test Weight

Test weight is a measure of the volume of grain that is required to fill a Winchester bushel (2,150.42 cubic inches) to capacity. Test weight is a part of the FGIS Official U.S. Standards for Corn grading criteria.

The test involves filling a test cup of known volume through a funnel held at a specific height above the test cup to the point where grain begins to pour over the sides of the test cup. A strike-off stick is used to level the grain in the test cup, and the grain remaining in the cup is weighed. The weight is then converted to and reported in the traditional U.S. unit, pounds per bushel (lb/bu).

## Broken Corn and Foreign Material (BCFM)

Broken corn and foreign material (BCFM) is part of the FGIS Official U.S. Standards for Grain and grading criteria.

The BCFM test determines the amount of all matter that passes through a 12/64$^{th}$-inch round-hole sieve and all matter other than corn that remains on the top of the sieve. BCFM measurement can be separated into broken corn and foreign material. Broken corn is defined as all material passing through a 12/64$^{th}$-inch round-hole sieve and retained on a 6/64$^{th}$-inch round-hole sieve. Foreign material is defined as all material passing through the 6/64$^{th}$-inch round-hole sieve and the coarse non-corn material retained on top of the 12/64$^{th}$-inch round-hole sieve. BCFM is reported as a percentage of the initial sample by weight.

## Total Damage/Heat Damage

Total damage is part of the FGIS Official U.S. Standards for Grain grading criteria.

A representative working sample of 250 grams of BCFM-free corn is visually examined by a trained and licensed inspector for content of damaged kernels. Types of damage include blue-eye mold, cob rot, dryer-damaged kernels (different from heat-damaged kernels), germ-damaged kernels, heat-damaged kernels, insect-bored kernels, mold-damaged kernels, mold-like substance, silk-cut kernels, surface mold (blight), mold (pink *Epicoccum*) and sprout-damaged kernels. Total damage is reported as the weight percentage of the working sample that is total damaged grain.

Heat damage is a subset of total damage and consists of kernels and pieces of corn kernels that are materially discolored and damaged by heat. Heat-damaged kernels are determined by a trained and licensed inspector visually inspecting a 250-gram sample of BCFM-free corn. Heat damage, if found, is reported separately from total damage.

# B. MOISTURE

The moisture recorded by the elevators' electronic moisture meters at the time of delivery is reported. Electronic moisture meters sense an electrical property of grains called the dielectric constant that varies with moisture. The dielectric constant rises as moisture content increases. Moisture is reported as a percent of total wet weight.

# C. CHEMICAL COMPOSITION

## NIR Proximate Analysis

The chemical composition (protein, oil and starch concentrations) of corn is measured using near-infrared (NIR) transmission spectroscopy. The technology uses unique interactions of specific wavelengths of light with each sample. It is calibrated to traditional chemistry methods, to predict the concentrations of protein, oil and starch in the sample. This procedure is nondestructive to the corn.

Chemical composition tests for protein, oil and starch were conducted using a 550- to 600-gram sample in a whole-kernel Foss Infratec 1241 Near-Infrared Transmittance (NIR) instrument. The NIR was calibrated to chemical tests, and the standard errors of predictions for protein, oil and starch were about 0.22%, 0.26% and 0.65%, respectively. Comparisons of the Foss Infratec 1229 used in *Harvest Reports* prior to 2016 to the Foss Infratec 1241 on 21 laboratory check samples showed the instruments averaged within 0.25%, 0.26% and 0.25% points of each other for protein, oil and starch, respectively. Results are reported on a dry basis percentage (percent of non-water material).

U.S. GRAINS COUNCIL

# D. PHYSICAL FACTORS

## 100-Kernel Weight, Kernel Volume and Kernel True Density

The 100-kernel weight is determined from the average weight of two 100-kernel replicates using an analytical balance that measures to the nearest 0.1 mg. The averaged 100-kernel weight is reported in grams.

The kernel volume for each 100-kernel replicate is calculated using a helium pycnometer and is expressed in cubic centimeters ($cm^3$) per kernel. Kernel volumes usually range from 0.14 to 0.36 $cm^3$ per kernel for small and large kernels, respectively.

True density of each 100-kernel sample is calculated by dividing the mass (or weight) of the 100 externally sound kernels by the volume (displacement) of the same 100 kernels. The two replicate results are averaged. True density is reported in grams per cubic centimeter ($g/cm^3$). True densities typically range from 1.20 to 1.30 $g/cm^3$ at "as is" moisture contents of about 12 to 15%.

## Stress Crack Analysis

Stress cracks are evaluated by using a backlit viewing board to accentuate the cracks. A sample of 100 intact kernels with no external damage is examined kernel by kernel. The light passes through the horneous or hard endosperm so the severity of the stress crack damage in each kernel can be evaluated. Kernels are sorted into four categories: (1) no cracks; (2) one crack; (3) two cracks; and (4) more than two cracks. Stress cracks, expressed as a percent, are all kernels containing one, two, or more than two cracks divided by 100 kernels. Lower levels of stress cracks are always better since higher levels of stress cracks lead to more breakage in handling. If stress cracks are present, singles are better than doubles or multiples. Some corn end users will specify by contract the acceptable level of cracks based on the intended use.

Stress crack index (SCI) is a weighted average of the stress cracks. This measurement indicates the severity of stress cracking. SCI is calculated as:

$$SCI = [SSC \times 1] + [DSC \times 3] + [MSC \times 5]$$

Where

- SSC is the percentage of kernels with only one crack;
- DSC is the percentage of kernels with exactly two cracks; and
- MSC is the percentage of kernels with more than two cracks.

The SCI can range from 0 to 500, with a high number indicating numerous multiple stress cracks in a sample, which is undesirable for most uses.

## Whole Kernels

In the whole kernels test, 50 grams of cleaned (BCFM-free) corn are inspected kernel by kernel. Cracked, broken, or chipped grain, along with any kernels showing significant pericarp damage, are removed. The whole kernels are then weighed, and the result is reported as a percentage of the original 50-gram sample. Some companies perform the same test, but report the "cracked & broken" percentage. A whole kernels score of 97% equates to a cracked & broken rating of 3%.

## Horneous (Hard) Endosperm

The horneous (or hard) endosperm test is performed by visually rating 20 externally sound kernels, placed germ facing up, on a backlit viewing board. Each kernel is rated for the estimated portion of the kernel's total endosperm that is horneous endosperm. Soft endosperm is opaque and will block light, while horneous endosperm is translucent. The rating is made from standard guidelines based on the degree to which the soft endosperm at the crown of the kernel extends down toward the germ. The average of horneous endosperm ratings for the 20 externally sound kernels is reported. Ratings of horneous endosperm are made on a scale of 70 to 100%, though most individual kernels fall in the 70 to 90% range.

## E. MYCOTOXINS

Detection of mycotoxins in corn is complex. The fungi producing the mycotoxins often do not grow uniformly in a field or across a geographic area. As a result, the detection of any mycotoxin in corn, if present, is highly dependent upon the concentration and distribution of the mycotoxin among kernels in a lot of corn, whether a truck load, a storage bin, or a railcar.

The objective of the FGIS sampling process is to minimize underestimating or overestimating the true mycotoxin concentration, since accurate results are imperative for corn exports. However, the objective of the *2018/2019 Corn Harvest Quality Report* assessment of mycotoxins is only to report the frequency of occurrences of the mycotoxin in the current crop, and not to report specific levels of the mycotoxin in corn exports.

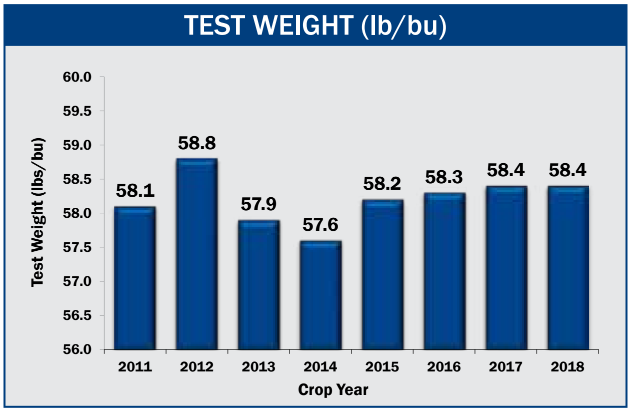
To report the frequency of occurrences of aflatoxin and deoxynivalenol (DON) or vomitoxin for the *2018/2019 Corn Harvest Quality Report*, IPG Lab performed the mycotoxin testing using FGIS protocol and approved test kits. FGIS's protocol requires a minimum of a 908-gram (2-pound) sample from trucks to grind for aflatoxin testing and approximately a 200-gram sample to grind for DON testing. For this study, a 1000-gram laboratory sample was subdivided from the 2-kg survey sample of shelled kernels for the aflatoxin analysis. The 1-kg survey sample was ground in a Romer Model 2A mill so that 60-75% would pass a 20-mesh screen. From this well-mixed ground material, a 50-gram test portion was removed for each mycotoxin tested. EnviroLogix AQ 309 BG and AQ 304 BG quantitative test kits were used for the aflatoxin and DON analysis, respectively. The DON was extracted with water (5:1), while the aflatoxin were extracted with buffered water (3:1). The extracts were tested using the Envirologix QuickTox lateral flow strips, and the mycotoxins were quantified by the QuickScan system.

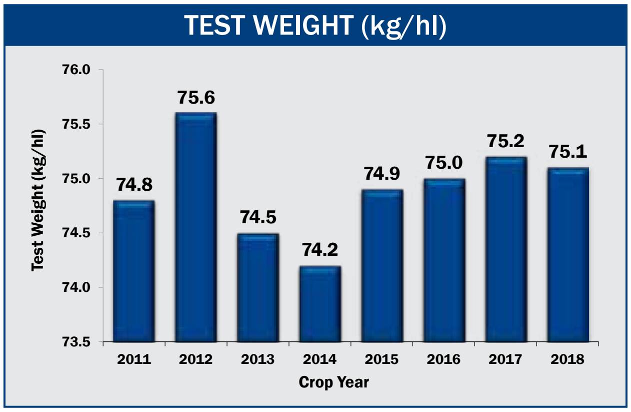
The EnviroLogix quantitative test kits report specific concentration levels of the mycotoxin if the concentration level exceeds a specific level called a "Limit of Detection" (LOD). The LOD is defined as the lowest concentration level that can be measured with an analytical method that is statistically different from measuring an analytical blank (absence of a mycotoxin). The LOD will vary among different types of mycotoxins, test kits and commodity combinations. The LODs for the EnviroLogix AQ 309 BG and AQ 304 BG are 2.7 parts per billion (ppb) for aflatoxin and 0.1 parts per million (ppm) for DON.

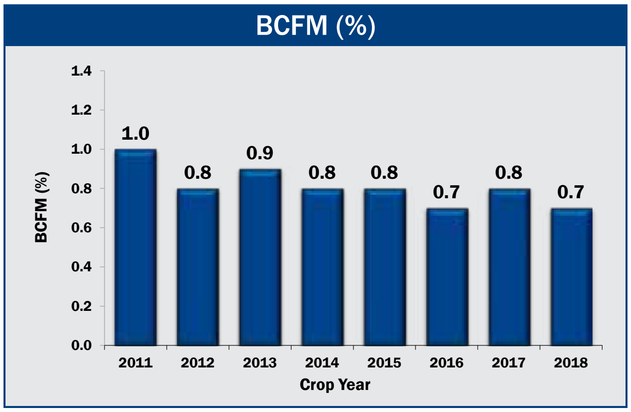
A letter of performance has been issued by FGIS for the quantification of aflatoxin and DON using the Envirologix AQ 309 BG and AQ 304 BG kits, respectively.

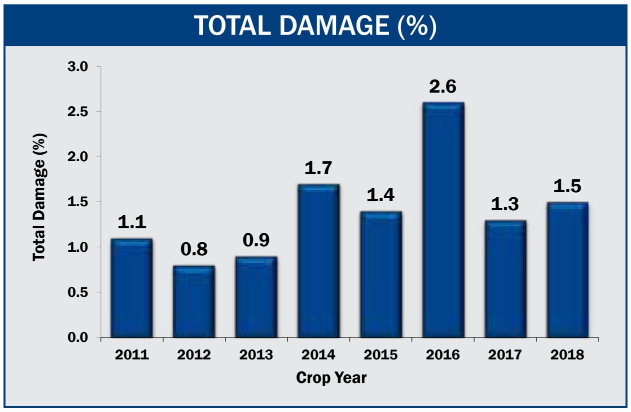
# A. GRADE FACTORS AND MOISTURE

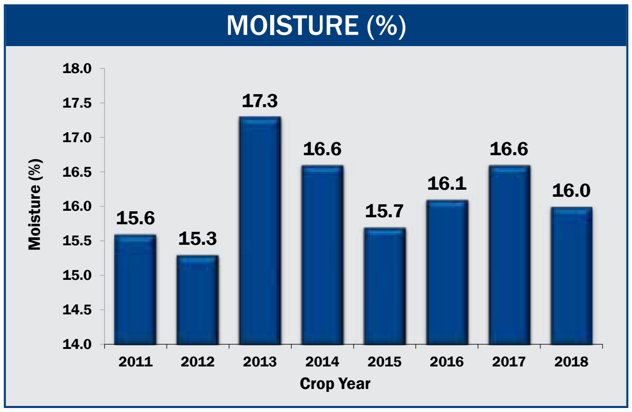
Since 2011, the U.S. Grains Council's Corn Harvest Quality Reports have provided clear, concise and consistent information about the quality of each U.S. crop entering international merchandising channels. This series of quality reports has used consistent and transparent methodology to allow for insightful comparisons across time. The following charts display the average U.S. Aggregate from all eight reports for each quality factor tested to provide historical context to this year's results.



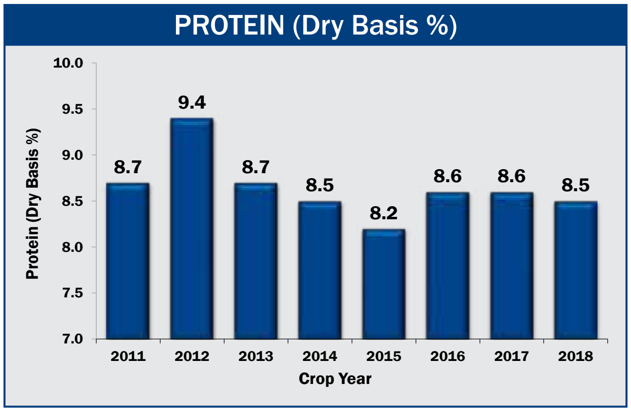



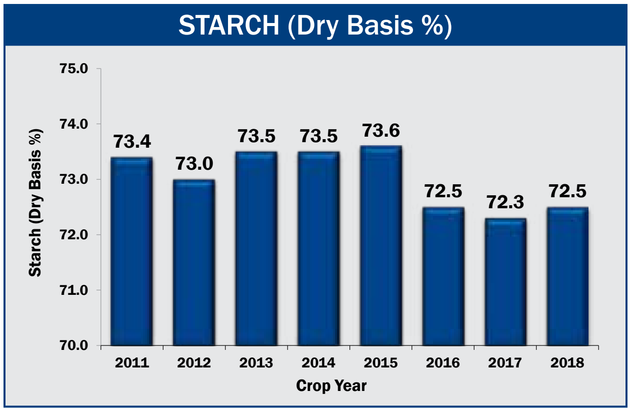



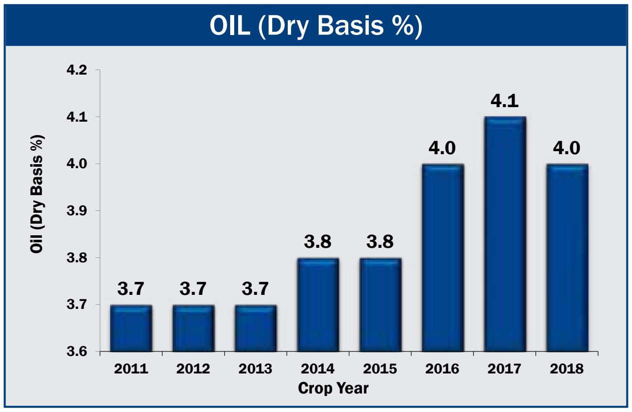



# B. CHEMICAL COMPOSITION

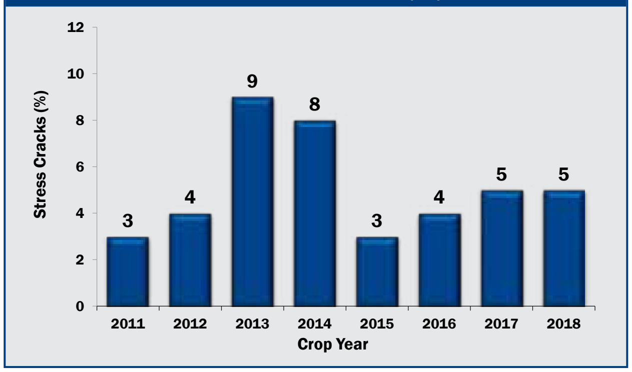


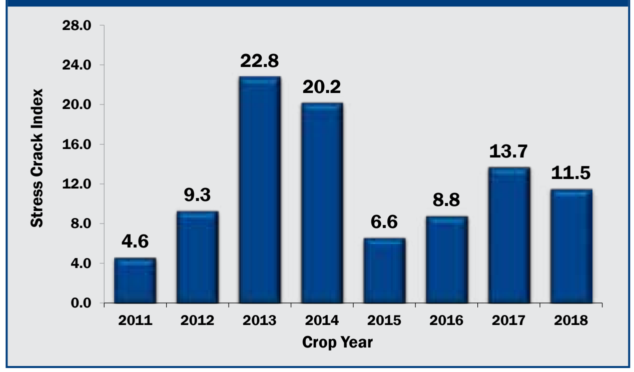



# C. PHYSICAL FACTORS

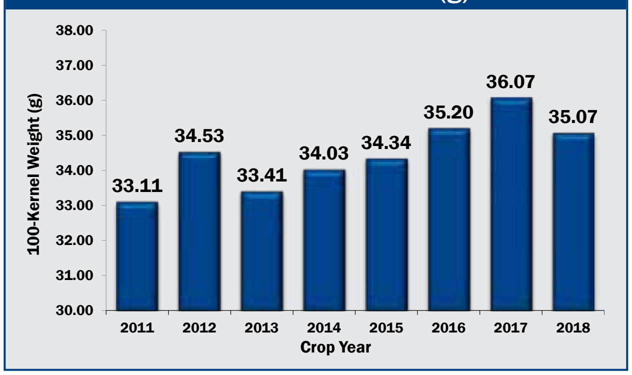
## STRESS CRACKS (%)



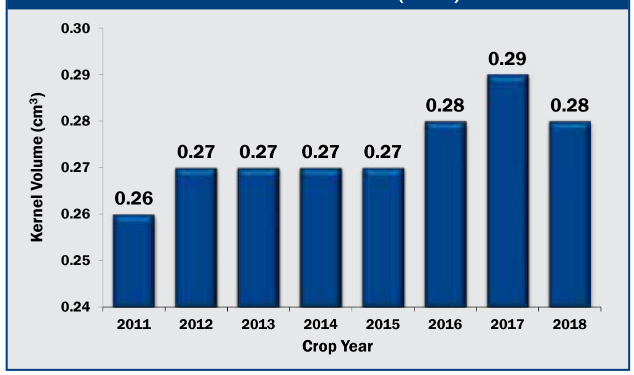

## STRESS CRACK INDEX



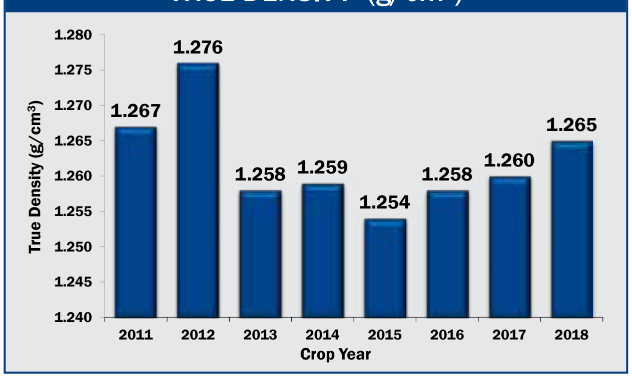

## 100-KERNEL WEIGHT (g)



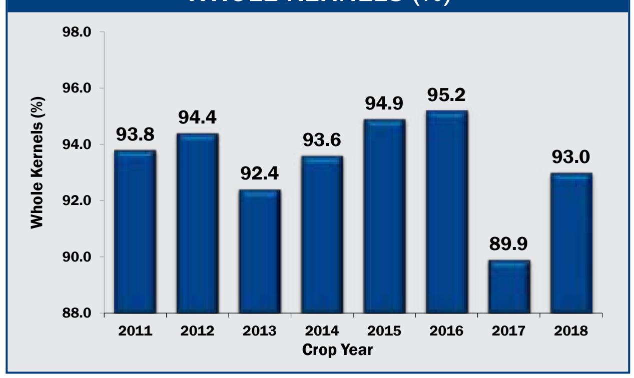

## KERNEL VOLUME ($cm^3$)



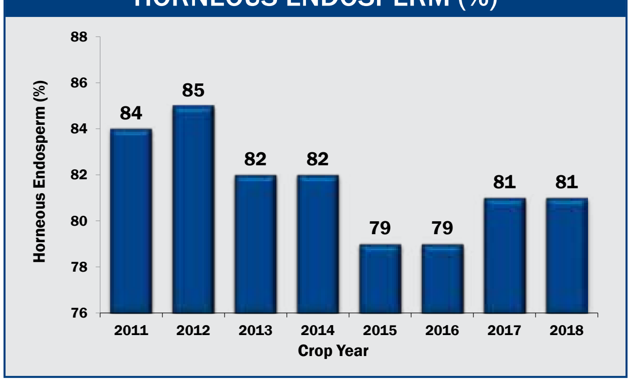

## TRUE DENSITY ($g/cm^3$)




## WHOLE KERNELS (%)

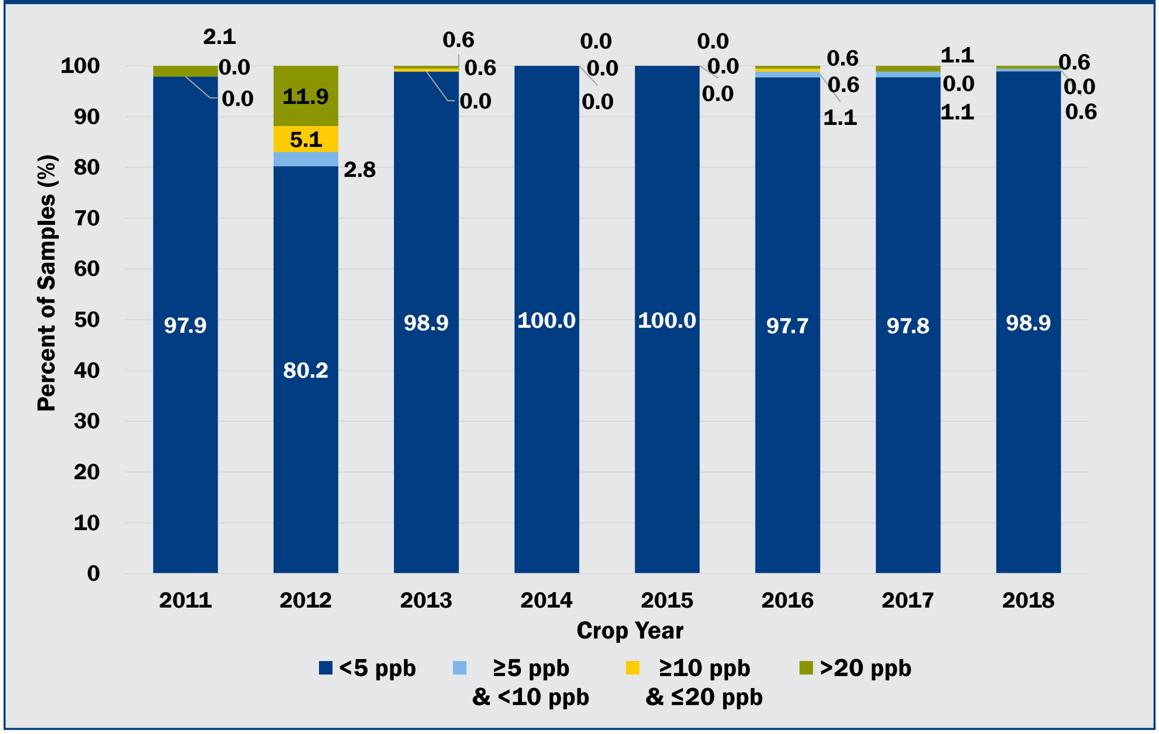



## HORNEOUS ENDOSPERM (%)

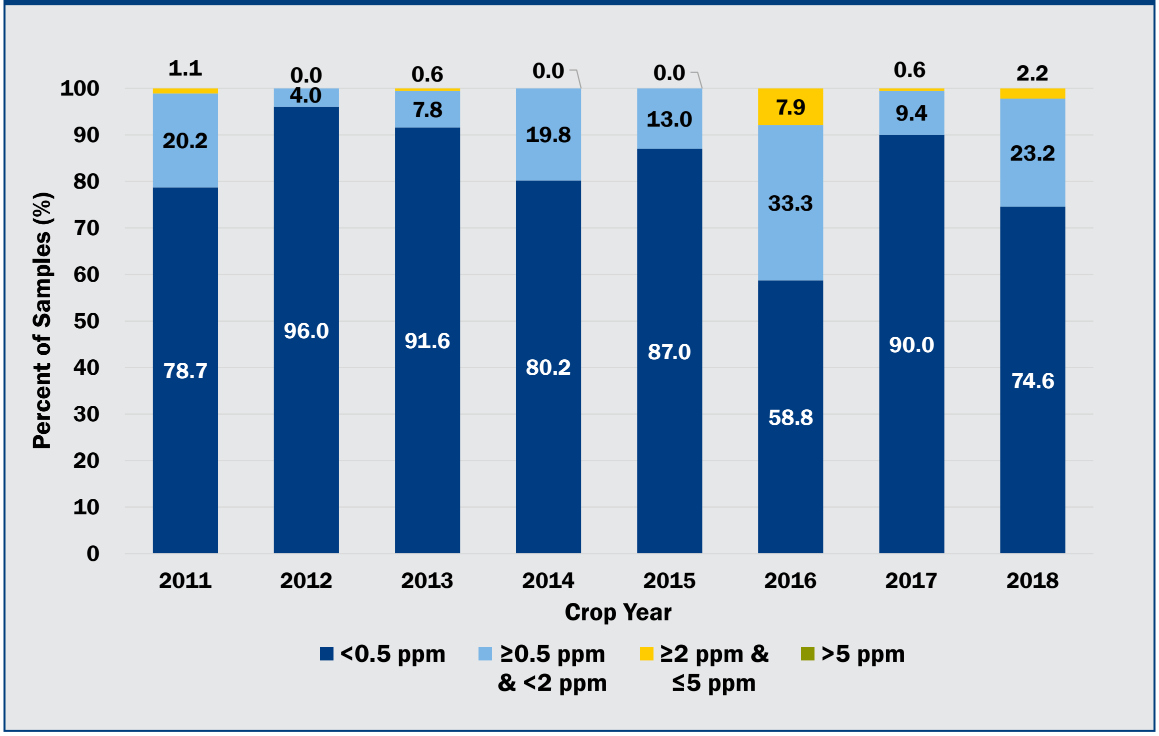


## D. MYCOTOXINS

AFLATOXIN RESULTS (ppb)




DEOXYNIVALENOL (DON) RESULTS (ppm)



## U.S. CORN GRADES AND GRADE REQUIREMENTS

| | | Maximum Limits of | | |
|---|---|---|---|---|
| | | Damaged Kernels | | |
| Grade | Minimum Test Weight per Bushel (Pounds) | Heat Damaged (Percent) | Total (Percent) | Broken Corn and Foreign Material (Percent) |
| U.S. No. 1 | 56.0 | 0.1 | 3.0 | 2.0 |
| U.S. No. 2 | 54.0 | 0.2 | 5.0 | 3.0 |
| U.S. No. 3 | 52.0 | 0.5 | 7.0 | 4.0 |
| U.S. No. 4 | 49.0 | 1.0 | 10.0 | 5.0 |
| U.S. No. 5 | 46.0 | 3.0 | 15.0 | 7.0 |

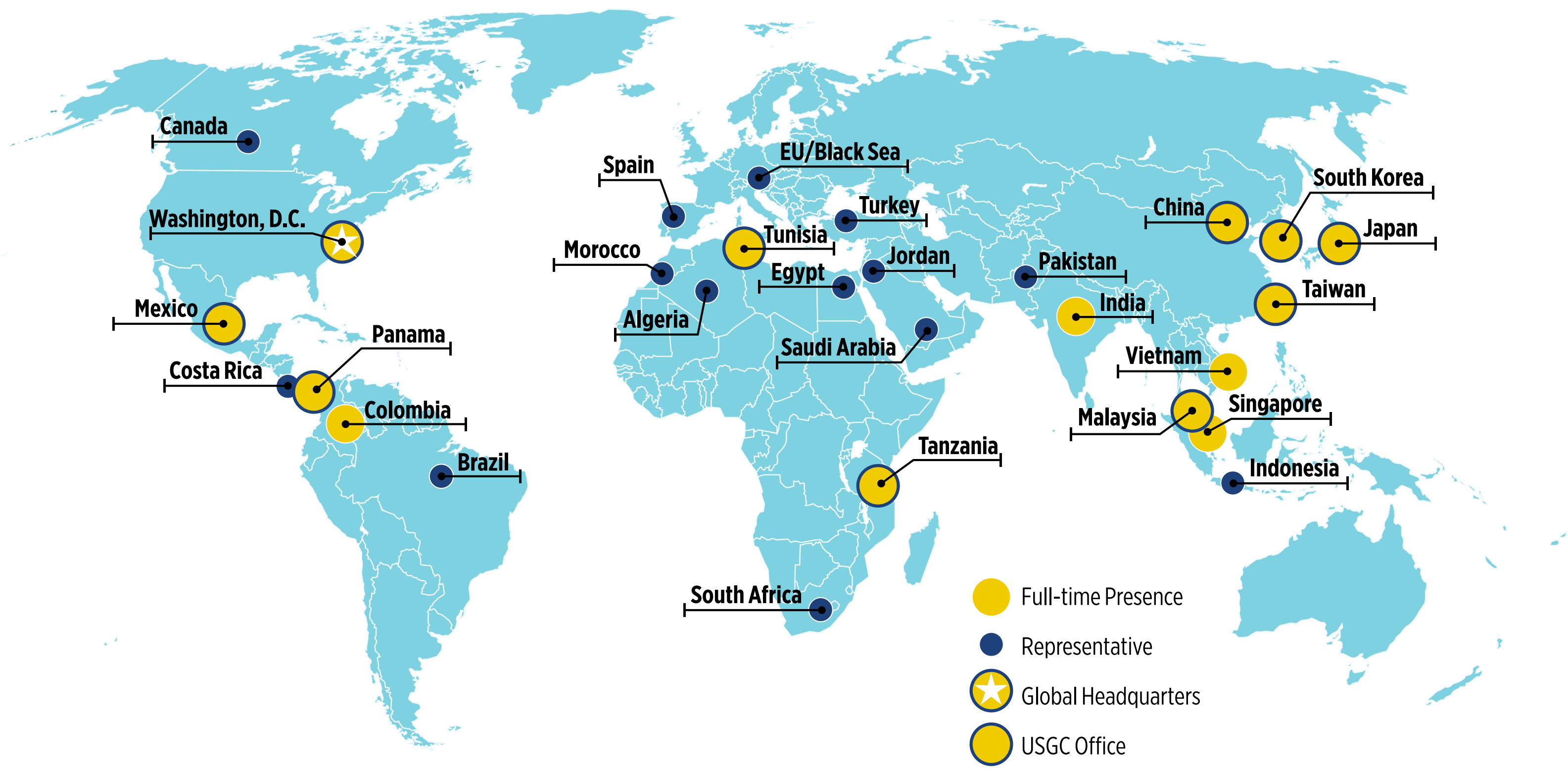
U.S. Sample Grade is corn that: (a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or (b) Contains stones with an aggregate weight in excess of 0.1 percent of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria spp.*), 2 or more castor beans (*Ricinus communis L.*), 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cockleburs (*Xanthium spp.*), or similar seeds singly or in combination, or animal filth in excess of 0.20 percent in 1,000 grams; or (c) Has a musty, sour, or commercially objectionable foreign odor; or (d) Is heating or otherwise of distinctly low quality.

Source: Code of Federal Regulations, Title 7, Part 810, Subpart D, United States Standards for Corn

## U.S. AND METRIC CONVERSIONS

| Corn Equivalents | | Metric Equivalents | |
|---|---|---|---|
| 1 bushel = | 56 pounds (25.40 kilograms) | 1 pound = | 0.4536 kg |
| 39.368 bushels = | 1 metric ton | 1 hundredweight = | 100 pounds or 45.36 kg |
| 15.93 bushels/acre = | 1 metric ton/hectare | 1 metric ton = | 2204.6 lbs |
| 1 bushel/acre = | 62.77 kilograms/hectare | 1 metric ton = | 1000 kg |
| 1 bushel/acre = | 0.6277 quintals/hectare | 1 metric ton = | 10 quintals |
| 56 lbs/bushel = | 72.08 kg/hectoliter | 1 quintal = | 100 kg |
| | | 1 hectare = | 2.47 acres |

# U.S. GRAINS COUNCIL

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