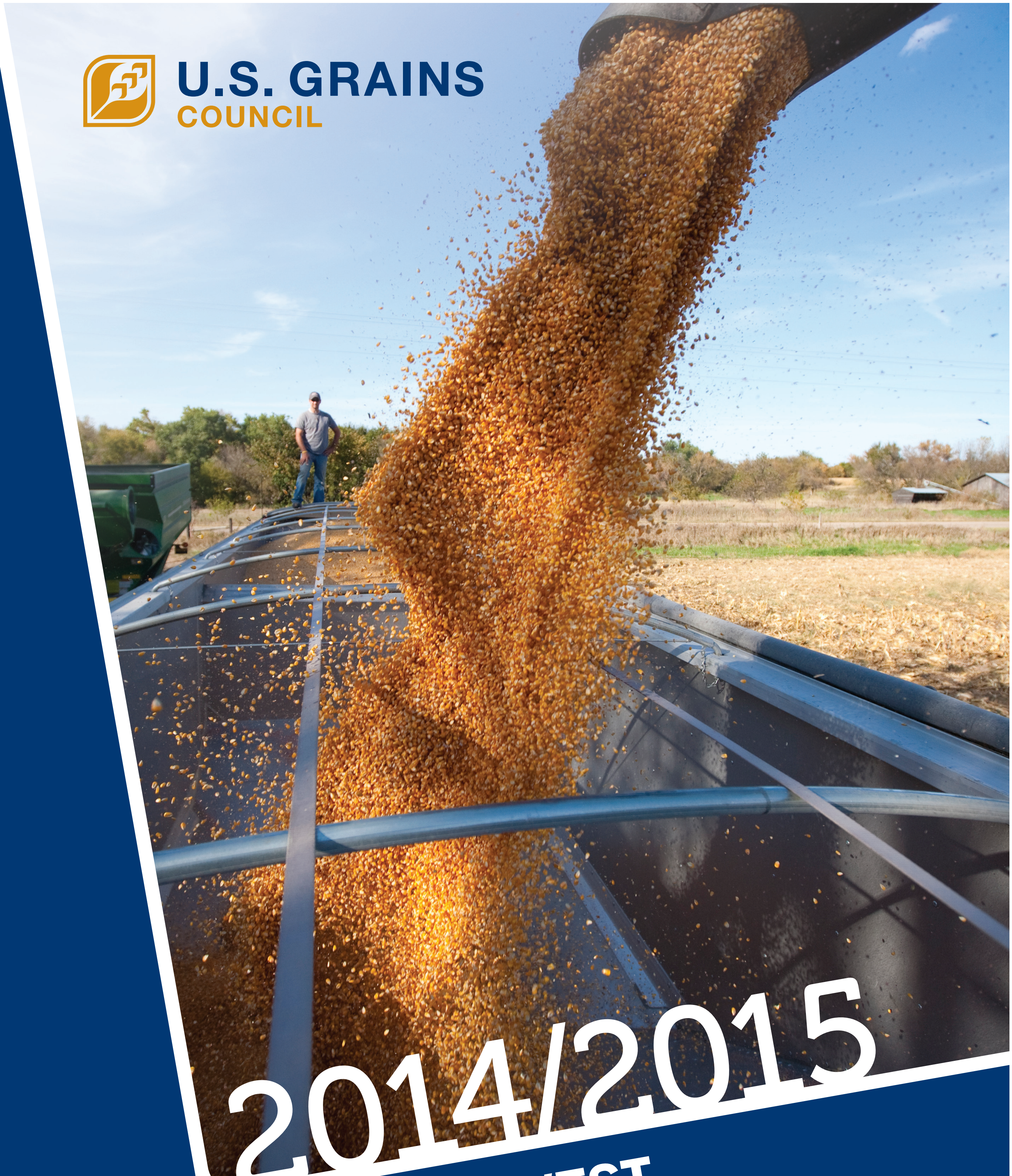
U.S. GRAINS COUNCIL



# 2014/2015 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 Dr. Sharon Bard and Mr. Chris Schroeder of Centrec Consulting Group, LLC (Centrec) for their oversight and coordination in developing this report. They were supported by internal staff along with a team of experts that helped in data gathering, 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) that provided 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.*

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# GREETINGS FROM THE COUNCIL

The U.S. Grains Council is pleased to provide our customers and members with the *U.S. Grains Council Corn Harvest Quality Report 2014/15*, the fourth in an annual series.

Accurate and timely information on crop quality helps buyers make better informed decisions, increases confidence in the capacity and reliability of the market, and assists nations around the world in achieving food security through trade. It is our goal that the *Harvest Report* offers a transparent view of the United States' most recent crop as it comes out of the field.

The *Harvest Report 2014/2015* was delayed slightly because of a cool, wet spring in the U.S. Corn Belt, which led to late planting and a late harvest. We were fortunate to experience near ideal growing conditions this crop year in many parts of the United States, and we are anticipating an abundant crop for the second year in a row.

As in past editions, the *Harvest Report 2014/2015* provides information about the quality of the current U.S. crop at harvest as it enters international merchandising channels, using consistent methodology to allow for comparison with past years' quality.

Corn quality observed by buyers will be further affected by subsequent handling, blending and storage conditions. A second Council report, the *Corn Export Cargo Quality Report*, measures corn quality at export terminals at the point of loading for international shipment and should be available in March 2015.

The U.S. Grains Council is committed to global food security and mutual economic benefit through trade. As a bridge between international corn buyers and the world's largest and most sophisticated agricultural production and export system, the Council offers this report as a service to our partners around the world in support of our mission of *Developing Markets, Enabling Trade and Improving Lives*.

Sincerely,

Ron Gray

Ron Gray
Chairman
U.S. Grains Council
December 2014

# I. HARVEST QUALITY HIGHLIGHTS

The 2014 U.S. corn growing season experienced later than normal planting, a cool summer and a delayed harvest, resulting in higher harvest moistures than in 2012 yet lower than in 2013. Nonetheless, overall corn quality is good and U.S. corn producers experienced record high yields in 2014, resulting in the largest U.S. corn crop on record.

The overall quality of the 2014 corn crop for many factors was good, with 88% that would grade No. 2 or better. The 2014 corn crop is entering the marketing channel with the following characteristics:

## GRADE FACTORS AND MOISTURE

- Test weight of 57.6 lb/bu (74.2 kg/hl), with 77.4% above the limit for No. 1 grade corn, and 94.7% above the limit for No. 2. While lower than 2013 and 3YA[1], this test weight indicates good kernel filling and maturation.
- Low levels of BCFM (0.8%), with 96.2% below the limit for No. 1 grade, indicating little cleaning will be required.
- Significantly higher total damage (1.7%) than previous years, with a wider distribution. However, 94.8% of the samples were still below the limit for No. 2 corn. The samples at the upper limit of the distribution may require special attention to prevent further deterioration.
- Lower elevator moisture content (16.6%) than 2013, but higher than 3YA. The distribution shows a lower percentage above 17% moisture, indicating less drying of high moisture corn than in 2013 and therefore potential for fewer stress cracks.

## CHEMICAL COMPOSITION

- Lower protein concentration (8.5% dry basis) than 2013, 2012 and 3YA. The lower protein concentration is likely attributable to higher yields in 2014 than in the previous years.
- Comparable starch concentration (73.5% dry basis) to 2013 and higher than 3YA, indicating relatively good kernel filling and maturation, which will be beneficial for wet millers.
- Higher oil concentration of 3.8% dry basis than 2013, 2012, and 3YA.

## PHYSICAL FACTORS

- Lower stress cracks (8%) and stress crack index (20.2) than 2013 yet higher than 3YA, with 79.3% of samples having stress cracks less than 10%. This indicates susceptibility to breakage may be slightly less than last year.
- Consistent kernel volumes (0.27 $cm^3$) with 2013, 2012 and 3YA.
- Lower true density (1.259 $g/cm^3$), horneous endosperm (82%) and test weight than 3YA, indicating a softer corn. However, there is still a good supply of corn suitable for dry milling – 30.2% of the samples above 1.275 true density, 62.1% of the samples above 80% horneous endosperm, and 48.0% of the samples above 58 lb/bu test weight.
- Significantly higher whole kernels (93.6%) than 2013 and close to 3YA.

## MYCOTOXINS

- Significantly lower incidences of aflatoxins detected compared to the 2012 corn crop and analogous incidence compared to the 2013 corn crop. 100% of the 2014 corn samples tested below the FDA aflatoxin action level of 20 ppb.
- 100% of the corn samples tested below the FDA advisory levels for DON (5 ppm for hogs and other animals and 10 ppm for chicken and cattle) (same as in 2013 and 2012). However, greater incidences of DON (percent of samples testing positive for DON) were detected in the 2014 corn crop compared to the 2013 and 2012 crops.

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[1] *3YA represents the simple average of the quality factor's average or standard deviation from the Harvest Reports 2011/12, 2012/13 and 2013/14.*

# II. INTRODUCTION

The *U.S. Grains Council Corn Harvest Quality Report 2014/15* 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 fourth annual measurement survey of the quality of the U.S. corn crop at harvest. With four years of results, patterns in the impact of weather and growing conditions on the quality of the U.S. corn as it comes out of the field are surfacing.

Similar to the 2013 crop year, 2014 started with a cool and wet planting season. The summer of 2014 was cooler than average, slowing maturation a week behind average but not as delayed as in 2013. Harvest at the beginning of both 2014 and 2013 was delayed by multiple weeks of rain and cold temperatures. The 2012 crop year was defined by its early planting season and a severe drought prompting early plant maturity and harvest. These differences in the growing season conditions contributed to the quality differences of the corn crop years as they reached the first stage in the merchandising channel. In 2014, higher yields resulted in lower protein and accompanying high starch concentration compared to the previous years. The late start to the growing season and harvest conditions in 2014 contributed to higher average moisture contents than in 2012, higher total damage, and stress cracks similar to but slightly lower than 2013. True density, horneous endosperm and test weight were all lower than the average of the *Harvest Reports 2011/12, 2012/13* and *2013/14* (referred to as 3YA), indicating a softer corn. BCFM remained low in 2014.

These observations show quality differences among the three years, but overall, the *Harvest Quality Report 2014/15* indicates good quality corn entering the 2014/15 market channel. 59% of the samples meet all requirements for No. 1 grade and 88% meet No. 2 grade or better. While the maximum values in moisture and total damage suggest judicious management for storage, average values show a crop that will store and handle well as it moves through the market channel to export.

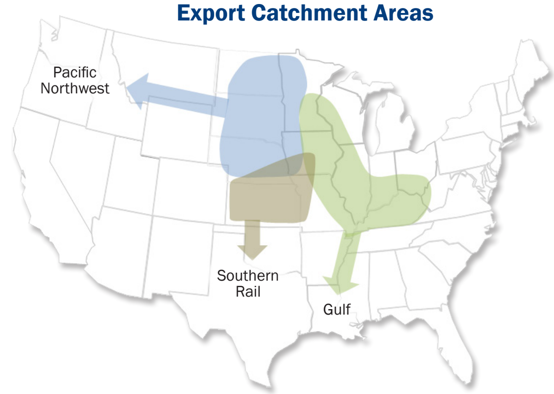
Four years of data are laying the foundation for evaluating trends and the factors that impact corn quality. In addition, the cumulative *Harvest Report* measurement surveys are increasing in value by enabling export buyers to make year-to-year comparisons and assess patterns of corn quality based on crop growing conditions across the years.

This *Harvest Report 2014/15* is based on 629 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 observe quality at the point of origin and to provide representative information about the variability of the quality characteristics across the diverse geographic regions.

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:

1. The Gulf ECA consists of areas that typically export corn through U.S. Gulf ports;
2. The Pacific Northwest (PNW) ECA includes areas exporting corn through Pacific Northwest and California ports; and
3. The Southern Rail ECA comprises areas generally exporting corn to Mexico.

**Export Catchment Areas**




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 rail cars, stored, and loaded and unloaded several times. Therefore, the quality and condition of the corn change from the initial market entry

## II. INTRODUCTION (continued)

to the export elevator. For this reason, the *Harvest Report 2014/15* should be considered carefully in tandem with the *U.S. Grains Council Corn Export Cargo Quality Report 2014/15* that will follow early in 2015. 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:

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

In addition, this *Harvest Report* includes brief descriptions of the U.S. crop and weather conditions; U.S. corn production, usage and outlook; and detailed descriptions of survey and statistical analysis methods, and testing methods.

New to this *Harvest Report 2014/15* is a simple average of the quality factors' averages and standard deviations of the previous three *Harvest Reports* (*2011/12, 2012/13* and *2013/14*). These simple averages are calculated for the U.S. Aggregate and each of the three ECAs and are referred to as "3YA" in the report.

# A. Grade Factors

The U.S. Department of Agriculture's Federal Grain Inspection Service (FGIS) has established numerical grades, definitions and standards for measurement of many quality attributes. The attributes which determine the numerical grades for corn are test weight, broken corn and foreign material (BCFM), total damage, and heat damage. The table for "U.S. Corn Grades and Grade Requirements" is provided on page 52 of this report.

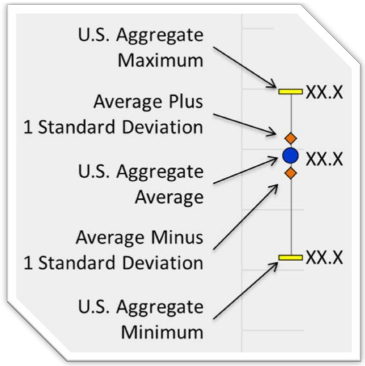
## SUMMARY: GRADE FACTORS AND MOISTURE

- *Although U.S. Aggregate average test weight in 2014 (57.6 lb/bu or 74.2 kg/hl) was lower than in 2013, 2012, and 3YA, it was still above the limit for No. 1 grade corn (56 lb/bu or 72.08 kg/hl).*
- *U.S. Aggregate average test weight was above the minimum for No. 1 grade in all ECAs.*
- *U.S. Aggregate average BCFM in 2014 (0.8% consisting primarily of broken corn) was less than in 2013 (0.9%) and for 3YA (0.9%) and well below the maximum for No. 1 grade (2%). Low BCFM indicates minimal cleaning required for corn delivered to first handler and should facilitate good aeration airflow during storage.*
- *BCFM levels in almost all (98.4%) of the corn samples were at or below the maximum of 3% allowed for No. 2 grade.*
- *Average BCFM, BC, and FM differed little among the three ECAs.*
- *U.S. Aggregate average total damage in 2014 (1.7%) was significantly higher than in previous years, which may be due in part to the delayed harvest in 2014 compared to previous years but still below the limit for No. 1 grade (2.0%). Most of the samples (83.8%) contained 3% or less damaged kernels, indicating that the corn should have good quality and store well.*
- *The relatively wide range of total damage between minimum and maximum values (with 5.3% of the samples containing more than 5% total damage) may require special attention to segregation when drying and storing.*
- *Total damage levels were highest in the Gulf ECA (2.2%) and lowest in the Pacific Northwest ECA (0.4%). The high level of total damage in the Gulf ECA may have been related to weather conditions prior to harvest, a delayed harvest, and the lower potential for field drying in the Gulf ECA.*
- *Total damage was consistently higher in the Gulf ECA than in the other two ECAs for 2014, 2013, and 2012.*
- *No heat damage was reported on any of the samples.*
- *Of the inbound elevator samples, 88.2% would grade No. 2 or better on all grade determining factors. Most elevators use No. 2 grade criteria as the base for pricing and discounts in domestic transactions. As corn moves through the market channel, subsequent handling, drying, and storage may lower the quality.*
- *U.S. Aggregate average moisture content (16.6%) was significantly lower than 2013 (17.3%) but higher than 2012 and 3YA. The wide range with higher maximum values may require more segregation by moisture content, and careful attention to drying and storage practices. More drying will be required for the 37.5% of corn containing more than 17%.*
- *Elevator moistures were consistently higher in the Gulf ECA than in the other two ECAs for 2014, 2013, 2012 and 3YA, which was likely due in part to comparatively lower potential for field drying in many parts of the Gulf ECA.*
- *The larger range in moisture contents may require more segregation by moisture content.*
- *Drying at the point of first delivery may result in additional stress cracking and breakage as the corn moves to export.*

## III. QUALITY TEST RESULTS (continued)

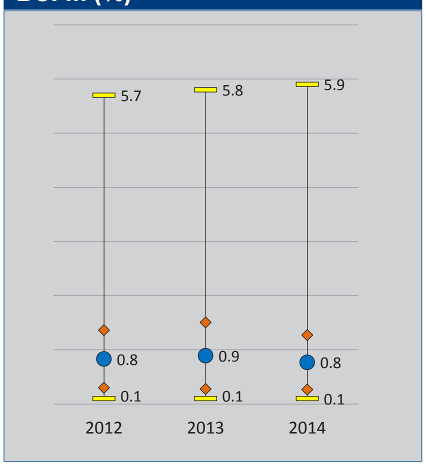
### Test Weight (lb/bu)


### How to Read the Charts

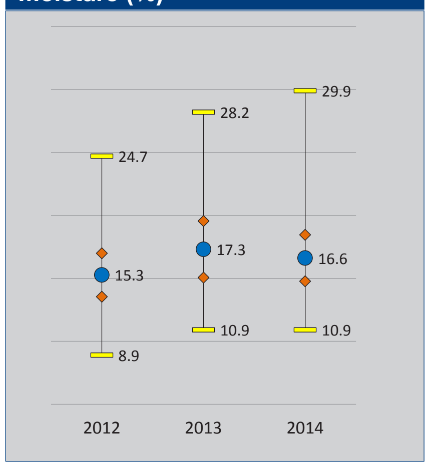



### Test Weight (kg/hl)

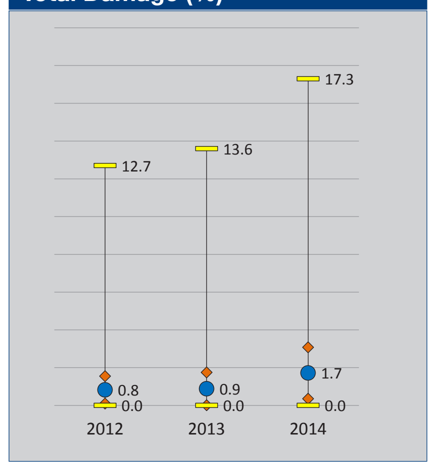

### BCFM (%)




### Moisture (%)




### Total Damage (%)



## 1. Test Weight

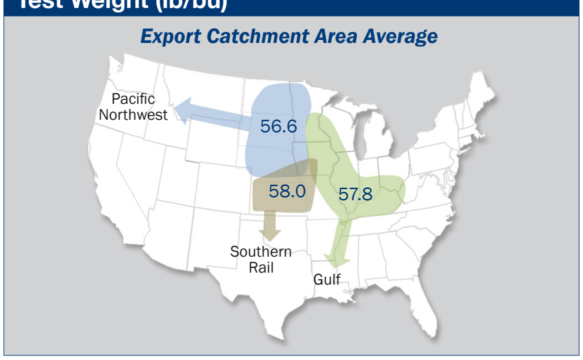
| U.S. Grade Minimum Test Weight |
|---|
| No. 1: 56.0 lbs |
| No. 2: 54.0 lbs |
| No. 3: 52.0 lbs |

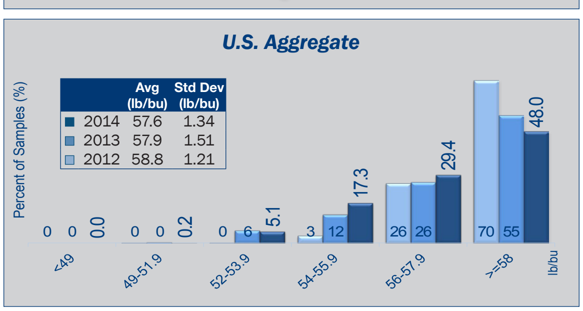
Test weight (weight per volume) is a measure of bulk density and is often used as a general indicator of overall quality and as a gauge of endosperm hardness for alkaline cookers and dry millers. High test weight corn will take up less storage space than the same weight of corn with a lower test weight. 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 highly correlated with true density and reflects kernel hardness and kernel maturity.

### RESULTS

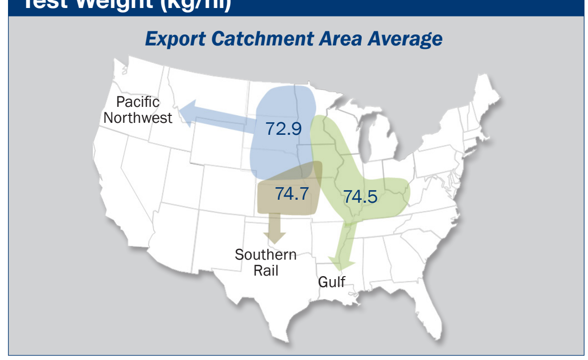
- U.S. Aggregate average test weight in 2014 was 57.6 lb/bu (74.2 kg/hl) compared to 57.9 lb/bu (74.5 kg/hl) in 2013 and 58.8 lb/bu (75.6 kg/hl) in 2012.
- While the 2014 U.S. Aggregate average test weight was below 3YA of 58.2 lb/bu, (75.0 kg/hl), it was still above the minimum for No. 1 grade (56 lb/bu).
- Sample values were more uniform in the 2014 crop relative to 2013, as indicated by the lower U.S. Aggregate standard deviation (1.34 lb/bu). Standard deviation for 2013 was 1.51 lb/bu.
- The range in values was also smaller among 2014 samples – 10.6 lb/bu in 2014 compared to 12.0 lb/bu and 13.1 lb/bu in 2013 and 2012, respectively.
- The 2014 test weight values were distributed with 77.4% of the samples at or above the factor limit for No. 1 grade (56 lb/bu) compared to 81.5% in 2013. In the 2014 crop, 94.7% of the samples were above the limit for No. 2 grade, compared to 93% in 2013.
- Average test weight for each ECA was also above the limit for No. 1 grade. The Gulf and Southern Rail ECAs had the highest average test weights, 57.8 lb/bu and 58.0 lb/bu, respectively. The Pacific Northwest ECA's lower test weight (56.6 lb/bu) occurred in 2013 and 3YA.
- The Pacific Northwest ECA also had the highest standard deviation (1.36 lb/bu) compared to the Gulf (1.34 lb/bu) and Southern Rail (1.30 lb/bu) ECAs. The lower test weight in the Pacific Northwest was accompanied by greater variability.

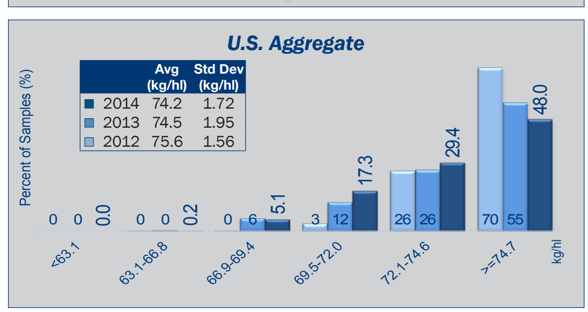
**Test Weight (lb/bu)**




**Test Weight (kg/hl)**



## 2. Broken Corn and Foreign Material (BCFM)

Broken corn and foreign material (BCFM) is an indicator of the amount of clean, sound corn available for feed 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 combine settings 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. Increased stress cracks at harvest will also result in an increase in broken kernels and BCFM during subsequent handling.

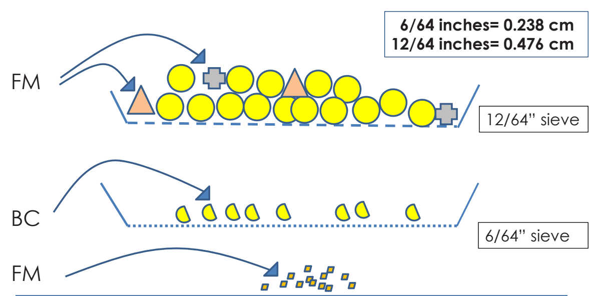
| U.S. Grade BCFM Maximum Limits |
|---|
| No. 1: 2.0% |
| No. 2: 3.0% |
| No. 3: 4.0% |

Broken corn is defined as corn and any other material small enough to pass through a 12/64th-inch round-hole sieve, but too large to pass through a 6/64th-inch round-hole sieve.

Foreign material is defined as any non-corn material too large to pass through a 12/64th-inch round-hole sieve, in addition to all fine material small enough to pass through a 6/64th-inch round-hole sieve.

The diagram to the right illustrates the procedure for measuring the factor of broken corn and foreign material for the U.S. corn grades.

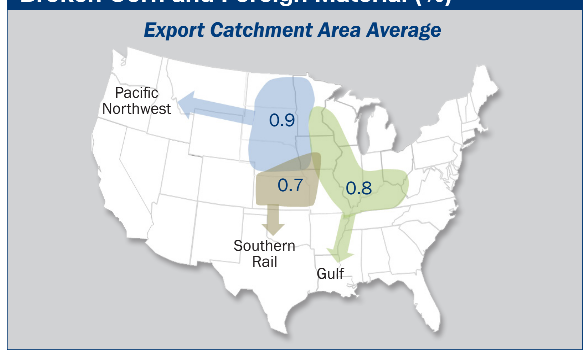
BCFM (Measured as Percent by Weight)

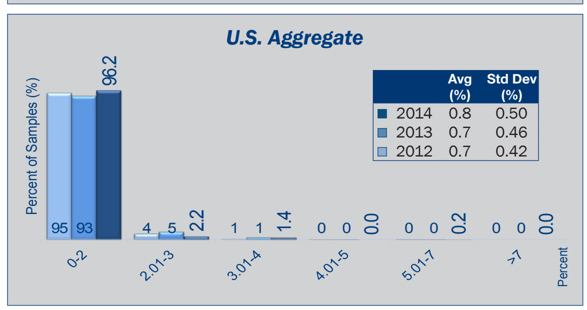



### RESULTS

- U.S. Aggregate average BCFM in the 2014 crop (0.8%) was less than in 2013 (0.9%), and 3YA (0.9%), well below the maximum for No. 1 grade (2.0%).
- The 2014 crop was more uniform in BCFM than 3YA and previous years' crops as indicated by standard deviations (0.50% for 2014 crop and 0.60% for 3YA). The range between minimum and maximum values was very similar for the three years.
- The 2014 samples were distributed with 96.2% of the samples below the maximum for No. 1 grade, with BCFM 2% or less, compared to 93% and 95% in 2013 and 2012, respectively.
- Average BCFM among the ECAs differed little from the U.S. Aggregate average and 3YA. BCFM varied by no more than 0.2 percentage points among the ECAs.

**Broken Corn and Foreign Material (%)**



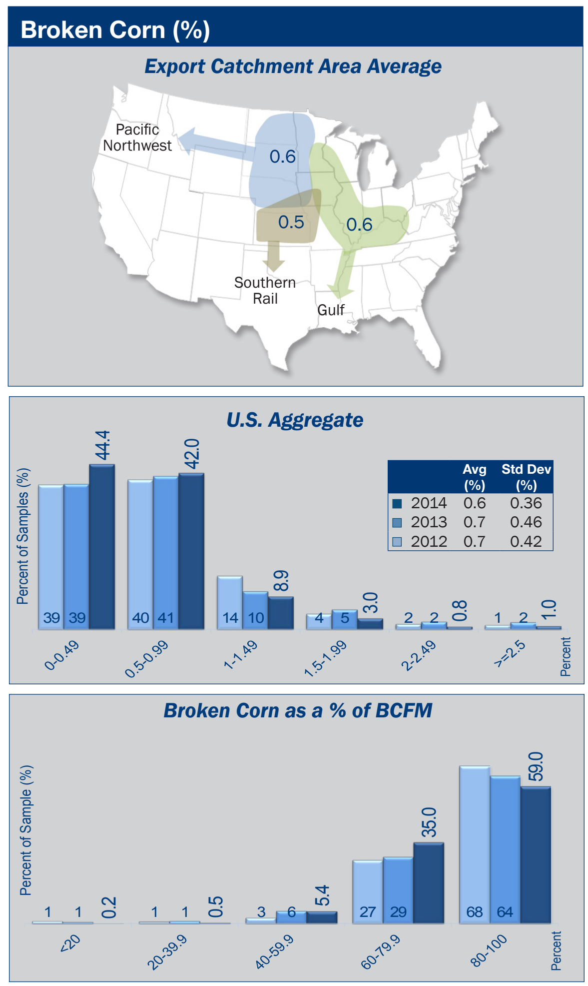



## 3. Broken Corn

Broken corn in U.S. grades is based on particle size and usually includes a small percent of 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 "spoutline." If desired, the spoutline can be reduced by drawing this grain out of the center of the bin.

### RESULTS

- Broken corn in the U.S. Aggregate samples averaged 0.6% in the 2014 crop, slightly lower than the levels in 2013, 2012 and for 3YA (all 0.7%).
- The 2014 crop was more uniform on the factor of broken corn than the previous two crops, with a U.S. Aggregate standard deviation of 0.36% compared to 0.46% in 2013 and 0.42% in 2012. The range between minimum and maximum values in 2014 was also smaller than in 2013 and 2012.
- The 2014 samples were distributed with 44.4% of the samples less than 0.5% broken corn and 86.4% less than 1.0% broken corn, indicating more samples with low levels of breakage than in previous years.
- The distribution chart to the right, displaying broken corn as a percent of BCFM, shows that in nearly all samples, BCFM consisted primarily of broken corn, as was found in previous years.
- The percent of broken corn in the three ECAs differed by less than 0.1 percentage point.



*III. QUALITY TEST RESULTS (continued)*

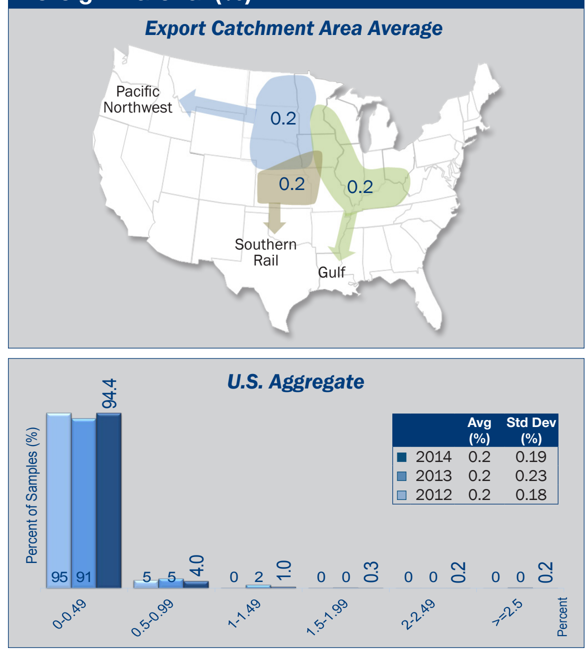
## 4. Foreign Material

Foreign material is of importance because it has little feed or processing value. It is also generally higher in moisture content than the corn and therefore creates a potential for deterioration of corn quality during storage. Foreign material also contributes to the spoutline and has the possibility of creating more quality problems than broken corn because of the higher moisture level, as mentioned above.

### RESULTS

- Foreign material in the U.S. Aggregate samples averaged 0.2% in 2014, the same as in 2013 and 2012 and for 3YA.
- Variability among the U.S. Aggregate samples in 2014 was lower than in 2013, with a standard deviation of 0.19% compared to 0.23% in 2013, 0.18% in 2012 and 0.20% for 3YA.
- In the 2014 crop, 94.4% of the samples contained less than 0.5% foreign material, slightly higher than in 2013 but similar to 2012.
- All ECAs had average foreign material values equal to 0.2%.

**Foreign Material (%)**



## 5. Total Damage

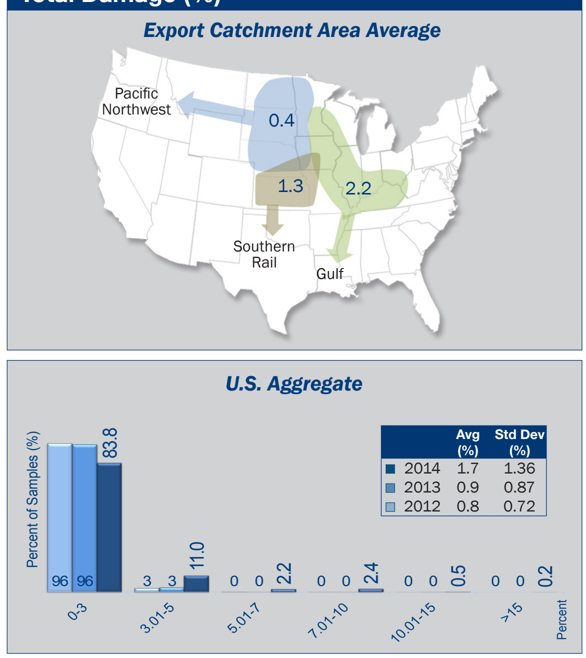
| U.S. Grade Total Damage Maximum Limits |
|---|
| No. 1: 3.0% |
| No. 2: 5.0% |
| No. 3: 7.0% |

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 content and high temperature in growing and/or storage. Mold damage and the associated potential for mycotoxins is the damage factor of greatest concern. Mold damage can occur prior to harvest as well as during temporary storage at high moisture and high temperature levels before delivery.

### RESULTS

**Total Damage (%)**




- Total damage in the U.S. Aggregate samples averaged 1.7% in 2014, significantly higher than 2013 (0.9%). Although much higher than 3YA (0.9%), 2014 total damage was still well below the limit for No. 1 grade (3%). Total damage may have been higher in part due to delayed harvest in 2014 compared to previous years.
- Total damage levels were more variable among samples in the 2014 crop than in previous years, with higher U.S. Aggregate standard deviation (1.36% compared to 0.84% for 3YA), and a wider range between minimum and maximum values (minimum value of 0 across all three years and a maximum value of 17.3% in 2014 compared to 13.6% and 12.7% in 2013 and 2012, respectively).
- Total damage in the 2014 samples was distributed with 83.8% of the samples having 3% or less damaged kernels, and 94.8% having 5% or less.
- Average total damage in the Gulf ECA was 2.2%. Moisture may have been a contributing factor since the Gulf had the highest average moisture (16.9%) and the sample with the highest maximum moisture (29.9%). The Pacific Northwest ECA had the lowest total damage (0.4%). The higher damage and higher average moistures found in the Gulf ECA may have been due in part to weather conditions that provided a lower potential for field drying in the Gulf ECA.
- Average total damage values in all ECAs were well below the limit for U.S. No. 1 corn (3.0%), but individual samples as high as 17.3% will require special attention to prevent further deterioration in storage and shipment as this corn moves through the market channel.

## 6. 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 at harvest directly from farms.

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

### RESULTS

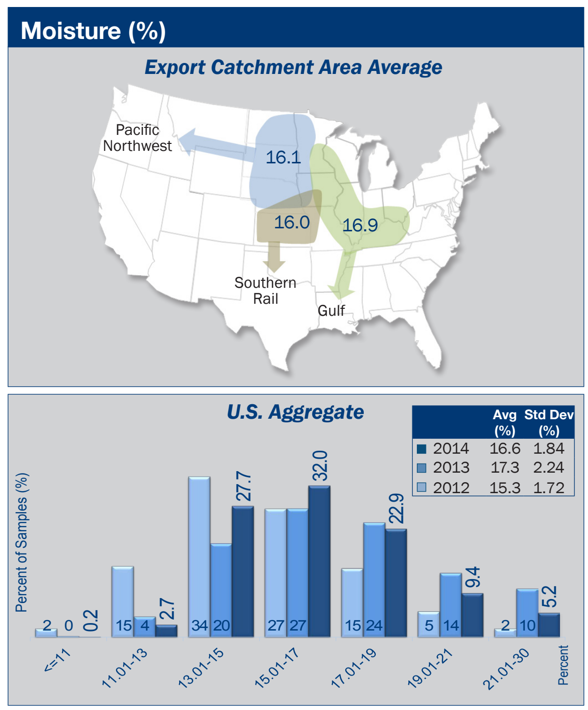
- There was no heat damage reported in any of the samples, the same results as in 2013 and 2012.
- The absence of heat damage likely was due in part to fresh samples coming directly from farm to elevator with minimal prior drying.

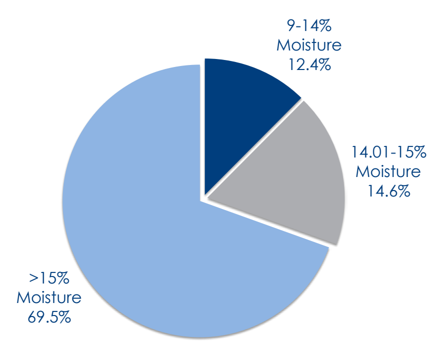
# B. Moisture

Moisture content is reported on official grade certificates, but does not determine which numerical grade will be assigned to the sample. Moisture content affects the amount of dry matter being sold and purchased. Moisture is also an indicator for potential drying, has potential implications for storability, and affects test weight. Higher moisture content at harvest increases the chance of kernel damage occurring 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 and the development of the grain, grain harvest moisture is influenced largely by the timing of harvest and harvest weather conditions.

## RESULTS

- The U.S. Aggregate moisture recorded at the elevator in the 2014 samples averaged 16.6%, significantly lower than 2013 (17.3%), but higher than 2012 (15.3%) and 3YA (16.0%).
- The moisture content of the 2014 samples at harvest was less variable than the 2013 crop, as indicated by the lower standard deviation (1.84% in 2014 compared to 2.24% in 2013), but very close to 3YA of 1.84%.
- The range was greater among the 2014 samples than among the 2013 samples – 10.9 to 29.9% in 2014 compared to 10.9 to 28.2% in 2013.
- The 2014 moisture values were distributed with 30.6% of the samples containing 15% or less moisture. This is the base moisture used by most elevators for discounts and is a level considered safe for storage for short periods during low winter-time temperatures.
- In the 2014 crop, 12.4% contained 14% or less moisture compared to 10.0% in 2013 and 31.7% in 2012. Moisture of 14% is generally considered a safe level for longer–term storage and transport.
- The distribution of moisture levels in the 2014 crop indicates 37.5% of the samples were above 17%, compared to 48% in 2013 and only 22% in 2012. Both the 2014 and 2013 crops had a requirement for more drying than in 2012.
- The average moisture contents for corn from the Gulf, Pacific Northwest, and Southern Rail ECAs were 16.9%, 16.1% and 16.0%, respectively. The Gulf ECA average moisture content has been consistently higher than the other ECAs in the previous two years and for 3YA, likely due to weather conditions providing lower drying potential for the Gulf ECA than for other ECAs.



## III. QUALITY TEST RESULTS (continued)

### SUMMARY: GRADE FACTORS AND MOISTURE

| | 2014 Harvest | | | | | 2013 Harvest | | | 2012 Harvest | | | 3 Year Avg. (2011-2013) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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) | 629 | 57.6 | 1.34 | 51.9 | 62.5 | 610 | 57.9* | 1.51 | 637 | 58.8* | 1.21 | 58.2 | 1.41 |
| Test Weight (kg/hl) | 629 | 74.2 | 1.72 | 66.8 | 80.4 | 610 | 74.5* | 1.95 | 637 | 75.6* | 1.56 | 75.0 | 1.81 |
| BCFM (%) | 629 | 0.8 | 0.50 | 0.1 | 5.9 | 610 | 0.9* | 0.61 | 637 | 0.8* | 0.53 | 0.9 | 0.60 |
| Broken Corn (%) | 629 | 0.6 | 0.36 | 0.1 | 3.3 | 610 | 0.7* | 0.46 | 637 | 0.7* | 0.42 | 0.7 | 0.47 |
| Foreign Material (%) | 629 | 0.2 | 0.19 | 0.0 | 5.5 | 610 | 0.2 | 0.23 | 637 | 0.2 | 0.18 | 0.2 | 0.20 |
| Total Damage (%)[2] | 629 | 1.7 | 1.36 | 0.0 | 17.3 | 609 | 0.9* | 0.87 | 637 | 0.8* | 0.72 | 0.9 | 0.84 |
| Heat Damage (%) | 629 | 0.0 | 0.00 | 0.0 | 0.0 | 610 | 0.0 | 0.00 | 637 | 0.0 | 0.0 | 0.0 | 0.00 |
| Moisture (%) | 629 | 16.6 | 1.84 | 10.9 | 29.9 | 610 | 17.3* | 2.24 | 637 | 15.3* | 1.72 | 16.0 | 1.84 |
| **Gulf** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 583 | 57.8 | 1.34 | 51.9 | 62.5 | 557 | 58.1* | 1.49 | 566 | 58.8* | 1.24 | 58.4 | 1.40 |
| Test Weight (kg/hl) | 583 | 74.5 | 1.73 | 66.8 | 80.4 | 557 | 74.8* | 1.91 | 566 | 75.6* | 1.59 | 75.2 | 1.80 |
| BCFM (%) | 583 | 0.8 | 0.48 | 0.1 | 5.9 | 557 | 0.8* | 0.59 | 566 | 0.8 | 0.52 | 0.9 | 0.58 |
| Broken Corn (%) | 583 | 0.6 | 0.37 | 0.1 | 3.3 | 557 | 0.7* | 0.45 | 566 | 0.7* | 0.41 | 0.7 | 0.45 |
| Foreign Material (%) | 583 | 0.2 | 0.15 | 0.0 | 5.5 | 557 | 0.2 | 0.22 | 566 | 0.1 | 0.18 | 0.2 | 0.20 |
| Total Damage (%)[2] | 583 | 2.2 | 1.72 | 0.0 | 17.3 | 556 | 0.9* | 0.95 | 566 | 0.9* | 0.84 | 1.0 | 0.96 |
| Heat Damage (%) | 583 | 0.0 | 0.00 | 0.0 | 0.0 | 557 | 0.0 | 0.00 | 566 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 583 | 16.9 | 1.93 | 10.9 | 29.9 | 557 | 17.7* | 2.38 | 566 | 15.8* | 1.81 | 16.5 | 1.95 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 262 | 56.6 | 1.36 | 51.9 | 62.5 | 259 | 56.5 | 1.60 | 321 | 58.8* | 1.15 | 57.5 | 1.44 |
| Test Weight (kg/hl) | 262 | 72.9 | 1.75 | 66.8 | 80.4 | 259 | 72.8 | 2.06 | 321 | 75.7* | 1.48 | 74.1 | 1.85 |
| BCFM (%) | 262 | 0.9 | 0.62 | 0.1 | 5.9 | 259 | 1.1* | 0.70 | 321 | 0.9 | 0.58 | 1.0 | 0.67 |
| Broken Corn (%) | 262 | 0.6 | 0.38 | 0.1 | 2.8 | 259 | 0.8* | 0.49 | 321 | 0.7* | 0.47 | 0.8 | 0.51 |
| Foreign Material (%) | 262 | 0.2 | 0.31 | 0.0 | 5.5 | 259 | 0.3 | 0.28 | 321 | 0.2* | 0.17 | 0.2 | 0.23 |
| Total Damage (%)[2] | 262 | 0.4 | 0.39 | 0.0 | 7.4 | 259 | 0.6* | 0.64 | 321 | 0.5 | 0.40 | 0.6 | 0.47 |
| Heat Damage (%) | 262 | 0.0 | 0.00 | 0.0 | 0.0 | 259 | 0.0 | 0.00 | 321 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 262 | 16.1 | 1.75 | 10.9 | 25.0 | 259 | 16.4 | 2.08 | 321 | 13.9* | 1.42 | 15.0 | 1.59 |
| **Southern Rail** | | | | | | | | | | | | | |
| Test Weight (lb/bu) | 371 | 58.0 | 1.30 | 52.0 | 62.5 | 313 | 58.3* | 1.56 | 366 | 58.6* | 1.19 | 58.5 | 1.38 |
| Test Weight (kg/hl) | 371 | 74.7 | 1.67 | 66.9 | 80.4 | 313 | 75.1* | 2.00 | 366 | 75.5* | 1.53 | 75.3 | 1.78 |
| BCFM (%) | 371 | 0.7 | 0.45 | 0.1 | 5.9 | 313 | 0.9* | 0.63 | 366 | 0.9* | 0.53 | 1.0 | 0.61 |
| Broken Corn (%) | 371 | 0.5 | 0.31 | 0.1 | 2.8 | 313 | 0.7* | 0.46 | 366 | 0.7* | 0.42 | 0.8 | 0.47 |
| Foreign Material (%) | 371 | 0.2 | 0.20 | 0.0 | 5.5 | 313 | 0.2 | 0.25 | 366 | 0.2 | 0.18 | 0.2 | 0.20 |
| Total Damage (%)[2] | 371 | 1.3 | 1.00 | 0.0 | 14.6 | 313 | 1.0* | 0.74 | 366 | 0.7* | 0.60 | 1.0 | 0.75 |
| Heat Damage (%) | 371 | 0.0 | 0.00 | 0.0 | 0.0 | 313 | 0.0 | 0.00 | 366 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 371 | 16.0 | 1.54 | 10.9 | 25.0 | 313 | 16.6* | 1.74 | 366 | 14.7* | 1.75 | 15.4 | 1.64 |

**Indicates averages in 2013 were significantly different from 2014, and 2012 averages were significantly different from 2014 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]One result of extremely high total damage was dropped because the sample showed evidence of mold developing during transit as a result of 27.9% moisture.*

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

# C. Chemical Composition

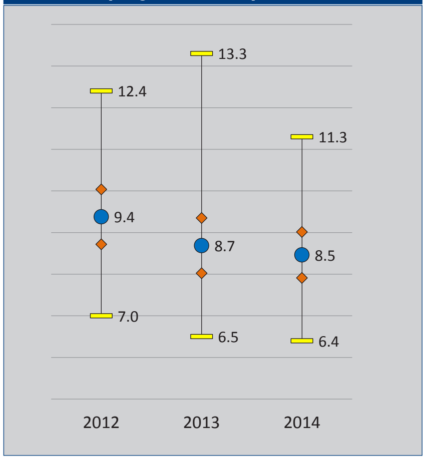
Chemical composition of corn is important because the components of protein, starch and oil are of significant interest to end users. The chemical composition attributes are not grade factors. However, they provide additional information related to nutritional value for livestock and poultry feeding, 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 transport.

## SUMMARY: CHEMICAL COMPOSITION

- *The lower U.S. Aggregate average protein concentration in 2014 (8.5% dry basis) compared to 3YA (8.9%) is likely attributable to higher yields in 2014 than in any of the previous three years. During the 2014 growing season, available nitrogen was distributed over more metric tons of corn per hectare (or more bushels per acre), causing protein concentration to be lower than in 2013 (8.7%) and the drought year (2012 with 9.4% protein).*
- *U.S. Aggregate starch average concentration was higher in 2014 (73.5% dry basis) than 3YA (73.3%). The higher starch indicates good kernel filling that should be desirable for corn wet milling.*
- *U.S. Aggregate oil average concentration in 2014 (3.8% dry basis) was higher than in 2013, 2012, and 3YA (3.7% for each).*
- *Chemical composition was more uniform in 2014 than in the previous two years (based on lower standard deviations for protein, starch and oil).*
- *Among ECAs in 2014, the Gulf had lowest protein (8.4%), highest starch (73.6%), and highest oil (3.8%). In comparing 3YA among ECAs, the Gulf again had lowest protein (8.9%), and it tied for highest starch with Pacific Northwest (73.3%).*

## III. QUALITY TEST RESULTS (continued)

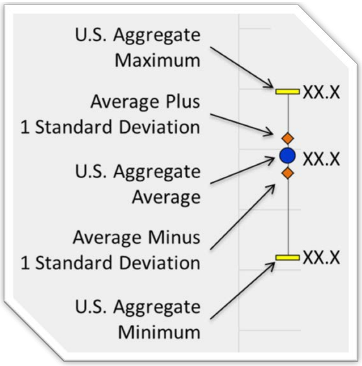
### Protein (Dry Basis %)




### Starch (Dry Basis %)


### Oil (Dry Basis %)


### How to Read the Charts



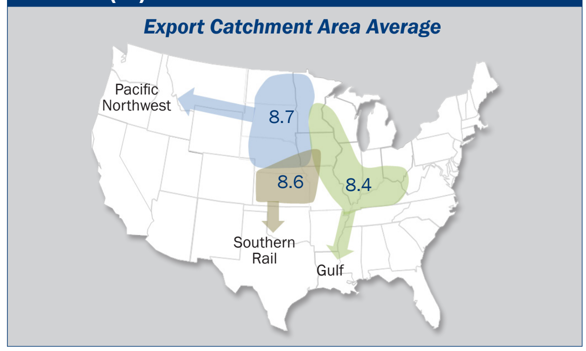
## 1. Protein

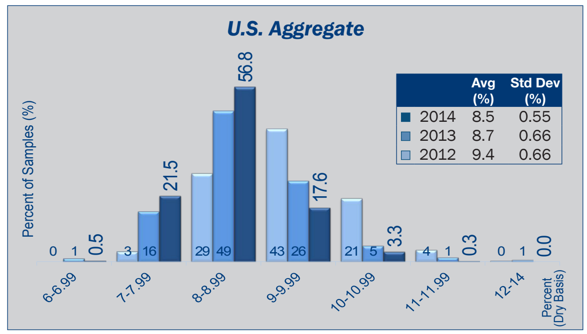
Protein is very important for poultry and livestock feeding. It supplies essential sulfur-containing amino acids and helps to improve feed conversion efficiency. Protein is usually inversely related to starch concentration. Results are reported on a dry basis.

### RESULTS

- In 2014, U.S. Aggregate protein concentration averaged 8.5%, which was significantly lower than 8.7% in 2013, 9.4% in 2012, and 8.9% for 3YA.
- U.S. Aggregate protein standard deviation in 2014 (0.55%) was lower than in 2013 (0.66%), in 2012 (0.66%) and for 3YA (0.64%).
- Protein concentration range was lower in 2014 (6.4 to 11.3%) than in 2013 (6.5 to 13.3%) and in 2012 (7.0 to 12.4%).
- Protein concentration in 2014 was distributed with 22.0% below 8.0%, 56.8% between 8.0% and 8.99%, and 21.2% at or above 9.0%. The protein distribution in 2014 shows a lower percentage of samples with high levels of protein than in 2013 or 2012.
- Protein concentration averages for Gulf, Pacific Northwest, and Southern Rail ECAs were 8.4%, 8.7%, and 8.6%, respectively. The Gulf ECA had the lowest protein for 2014, 2013, 2012 and 3YA.

**Protein (%)**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2014 | 8.5 | 0.55 |
| 2013 | 8.7 | 0.66 |
| 2012 | 9.4 | 0.66 |

- Over the past four crop years, 11 of the 12 surveyed states have shown a negative relationship between average state corn yield and average state protein concentration. In general, when their average yield has gone up, average protein concentration has gone down.

*III. QUALITY TEST RESULTS (continued)*

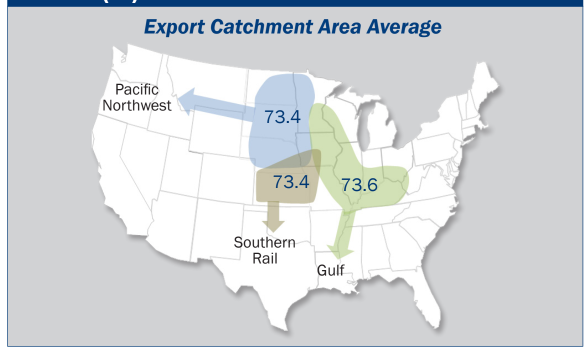
## 2. Starch

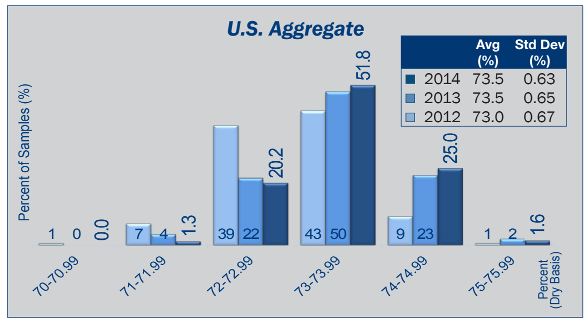
Starch is an important factor for corn used by wet millers and dry-grind ethanol manufacturers. High starch concentration is often indicative of good kernel maturation/filling conditions and reasonably moderate kernel densities. Starch is usually inversely related to protein concentration. Results are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

### RESULTS

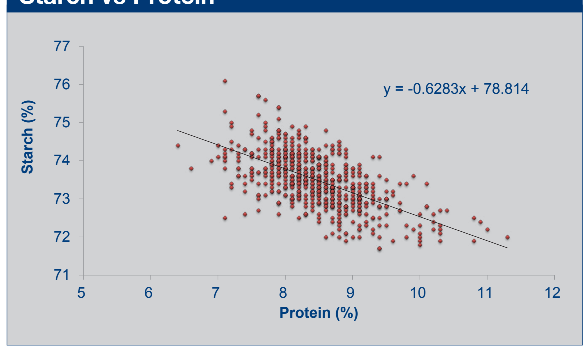
- U.S. Aggregate starch concentration averaged 73.5% in 2014, same as 73.5% in 2013, significantly higher than 73.0% in 2012 and above 73.3% for 3YA.
- U.S. Aggregate starch standard deviation in 2014 (0.63%) was lower than in 2013 (0.65%), in 2012 (0.67%) and for 3YA (0.65%).
- Starch concentration range was lower in 2014 (71.7 to 76.1%) than in 2013 (71.1 to 75.9%) and in 2012 (70.6 to 75.6%).
- Starch concentration in 2014 was distributed with 21.5% between 70.0 and 72.99%, 51.8% between 73.0 and 73.99%, and 26.6% equal to or greater than 74.0%, and was similar to the 2013 distribution.
- Starch concentration averages for the Gulf, Pacific Northwest, and Southern Rail ECAs were 73.6%, 73.4% and 73.4%, respectively. Starch concentration averages were highest in the Gulf ECA in 2014, 2013 and 2012. Thus, the Gulf ECA had highest starch and lowest protein in each of the last three years.
- 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 weak but negative correlation (-0.61) between starch and protein.

**Starch (%)**




**Starch vs Protein**



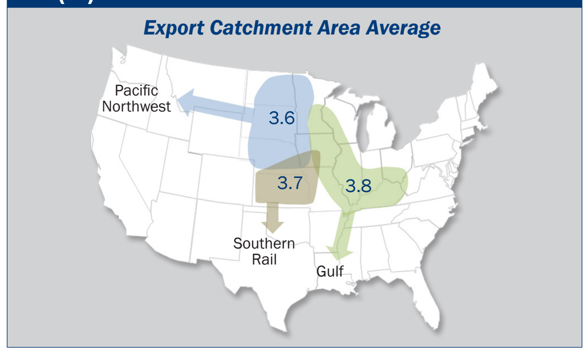
## 3. Oil

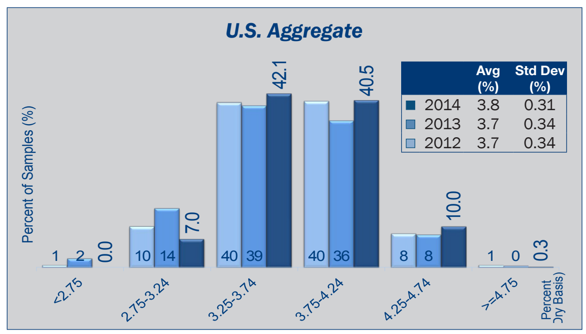
Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilized, and provides certain essential fatty acids. Oil is also an important co-product of corn wet and dry milling. Results are reported on a dry basis.

### RESULTS

- U.S. Aggregate oil concentration averaged 3.8% in 2014, higher than 3.7% in 2013 and 2012 and for 3YA.
- U.S. Aggregate oil standard deviation in 2014 (0.31%) was lower than in 2013 and 2012 (0.34% both years) and for 3YA (0.33%).
- Oil concentration ranged from 2.8 to 5.0% in 2014, 2.0 to 5.0% in 2013, and 1.7 to 5.5% in 2012.
- Oil concentration in 2014 was distributed with 49.1% of the samples at 3.74% or lower, 40.5% of samples at 3.75% to 4.24% and 10.3% at 4.25% and higher. The distribution shows more samples had higher oil levels than in 2013 or 2012.
- Oil concentration averages for Gulf, Pacific Northwest, and Southern Rail ECAs were 3.8%, 3.6% and 3.7%, respectively. Oil concentration averages were higher for the Gulf and Southern Rail ECAs than for the Pacific Northwest for 2014, 2013 and 3YA.

**Oil (%)**



## III. QUALITY TEST RESULTS (continued)

### SUMMARY: CHEMICAL FACTORS

| | 2014 Harvest | | | | | 2013 Harvest | | | 2012 Harvest | | | 3 Year Avg. (2011-2013) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 %) | 629 | 8.5 | 0.55 | 6.4 | 11.3 | 610 | 8.7* | 0.66 | 637 | 9.4* | 0.66 | 8.9 | 0.64 |
| Starch (Dry Basis %) | 629 | 73.5 | 0.63 | 71.7 | 76.1 | 610 | 73.5* | 0.65 | 637 | 73.0* | 0.67 | 73.3 | 0.65 |
| Oil (Dry Basis %) | 629 | 3.8 | 0.31 | 2.8 | 5.0 | 610 | 3.7 | 0.34 | 637 | 3.7 | 0.34 | 3.7 | 0.33 |
| **Gulf** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 583 | 8.4 | 0.55 | 6.4 | 11.3 | 557 | 8.5* | 0.64 | 566 | 9.3* | 0.66 | 8.9 | 0.64 |
| Starch (Dry Basis %) | 583 | 73.6 | 0.64 | 71.7 | 76.1 | 557 | 73.5* | 0.67 | 566 | 73.1* | 0.67 | 73.3 | 0.66 |
| Oil (Dry Basis %) | 583 | 3.8 | 0.32 | 2.8 | 5.0 | 557 | 3.7* | 0.35 | 566 | 3.8* | 0.35 | 3.7 | 0.34 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 262 | 8.7 | 0.56 | 6.4 | 11.3 | 259 | 9.1* | 0.69 | 321 | 9.4* | 0.67 | 9.0 | 0.63 |
| Starch (Dry Basis %) | 262 | 73.4 | 0.60 | 71.7 | 75.4 | 259 | 73.4* | 0.61 | 321 | 72.8* | 0.66 | 73.3 | 0.61 |
| Oil (Dry Basis %) | 262 | 3.6 | 0.29 | 2.8 | 4.6 | 259 | 3.5* | 0.33 | 321 | 3.7* | 0.31 | 3.6 | 0.30 |
| **Southern Rail** | | | | | | | | | | | | | |
| Protein (Dry Basis %) | 371 | 8.6 | 0.57 | 6.9 | 11.0 | 313 | 9.1* | 0.78 | 366 | 9.5* | 0.64 | 9.2 | 0.68 |
| Starch (Dry Basis %) | 371 | 73.4 | 0.60 | 71.7 | 76.1 | 313 | 73.2* | 0.64 | 366 | 72.9* | 0.68 | 73.1 | 0.65 |
| Oil (Dry Basis %) | 371 | 3.7 | 0.28 | 2.8 | 4.6 | 313 | 3.7 | 0.34 | 366 | 3.7 | 0.32 | 3.7 | 0.33 |

**Indicates averages in 2013 were significantly different from 2014, and 2012 averages were significantly different from 2014 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 include other quality attributes that are neither grading factors nor chemical composition. Tests for physical factors provide additional information about the processing characteristics of corn for various uses, as well as its storability and potential for breakage in handling. The storability, the ability to withstand handling, and the processing performance of corn are influenced by corn's morphology. Corn kernels are morphologically 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 to the right. The endosperm contains primarily starch and protein, the germ contains oil and some proteins, and the pericarp and tip cap are mostly fiber.

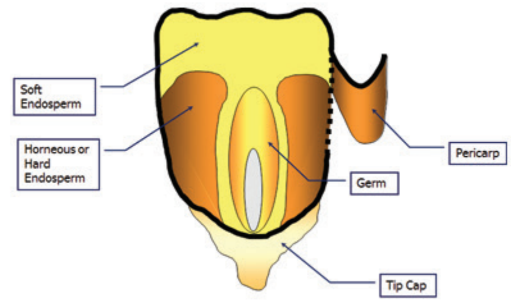



***Illustration courtesy of K. D. Rausch University of Illinois***

## SUMMARY: PHYSICAL FACTORS

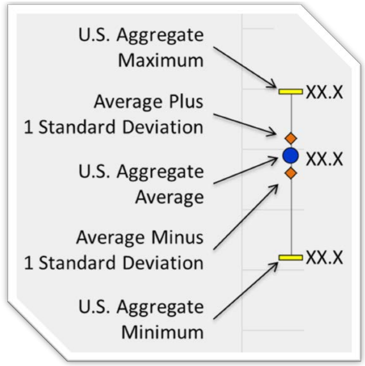
- *U.S. Aggregate average stress cracks and stress crack index (SCI) in 2014 were slightly lower than in 2013 but higher than 3YA for each factor, indicating corn's susceptibility to breakage will be similar to or slightly less than last year. Among the ECAs, the Southern Rail ECA has had the lowest SCI in 2014, 2013, 2012 and for 3YA. The Southern Rail ECA also had the lowest stress crack percentages in 2013, 2012 and for 3YA.*
- *U.S. Aggregate average 100-k weights (34.03 g) in 2014 were higher than in 2013 (33.41 g) and for 3YA (33.69 g), but were lower than the drought year of 2012 (34.53 g).*
- *Average kernel volumes (0.27 $cm^3$) for the U.S. Aggregate in 2014 were the same as those in 2013, 2012 and 3YA (all 0.27 $cm^3$).*
- *Of the ECAs, the Pacific Northwest had lowest kernel volume and 100-k weights in 2014, 2013 and for 3YA.*
- *Kernel true densities averaged 1.259 $g/cm^3$ for U.S. Aggregate corn in 2014, which was nearly same as 1.258 $g/cm^3$ in 2013, close to 1.267 $g/cm^3$ for 3YA, but significantly lower than 1.276 $g/cm^3$ in 2012.*
- *Fewer kernels were distributed with true densities above 1.275 $g/cm^3$ indicating softer corn in 2014 than in 2012 but similar to 2013.*
- *Of the ECAs, the Pacific Northwest had the lowest true density and lowest test weights in 2014, 2013 and for 3YA.*
- *Whole kernels averaged 93.6% for U.S. Aggregate corn, which was higher than 92.4% in 2013 but nearly the same as 93.5% for 3YA.*
- *Horneous endosperm averaged 82% for U.S. Aggregate corn in 2014, the same as 82% in 2013, significantly lower than 85% in 2012 and lower than 84% for 3YA. Horneous endosperm was similar to 2013 but softer than that found in the drought year, 2012.*
- *The factors including horneous endosperm, true density and test weight appear to change in the same direction, with higher values in a drought year (2012) and lower values in a high-yielding year (2014). The multiple survey results indicate kernel volumes stayed relatively constant between drought and high-yielding years.*

The following tests reflect these intrinsic parts of the corn kernels, in addition to the growing and handling conditions that affect corn quality.

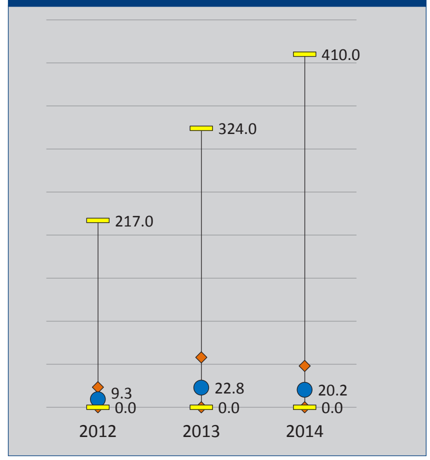
## III. QUALITY TEST RESULTS (continued)

### Stress Cracks (%)

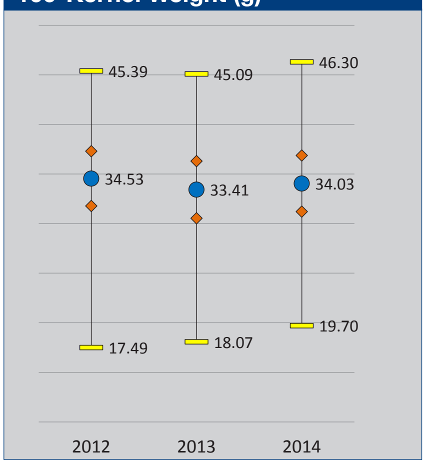

### How to Read the Charts




### Stress Crack Index

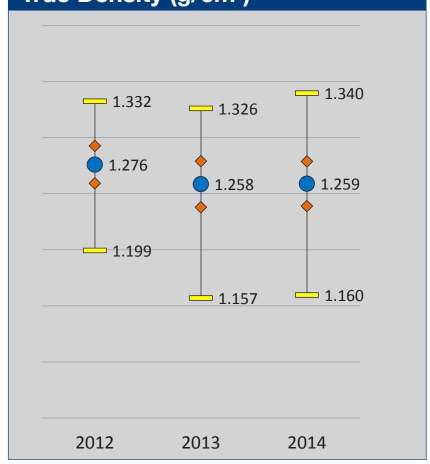



### 100-Kernel Weight (g)

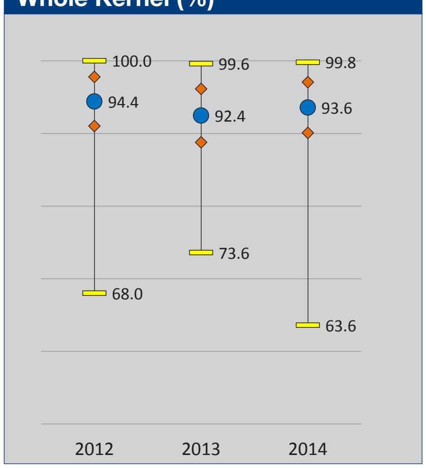



### Kernel Volume (cm³)

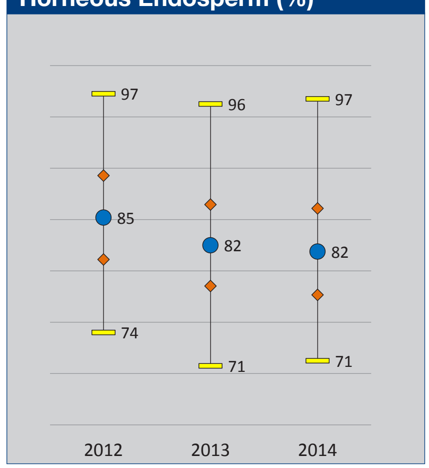

### True Density (g/cm³)




### Whole Kernel (%)




### Horneous Endosperm (%)



## 1. Stress Cracks

Stress cracks are internal fissures in the horneous (hard) endosperm of a corn kernel. The pericarp of a stress-cracked kernel is typically not damaged, so the outward appearance of the kernel may appear unaffected even though stress cracks are present.

The cause of stress cracks is pressure buildup due to large 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 kernels. A kernel may have one, two, or multiple stress cracks. High-temperature drying is the most common cause of stress cracks. The impact of high levels of stress cracks on various uses includes:

- General: Increased susceptibility to breakage during handling, leading to increased broken corn needing to be removed during cleaning operations for processors, and possible reduced grade.
- Wet Milling: Lower starch yield because the starch and protein are more difficult to separate. Stress cracks may also alter steeping requirements.
- Dry Milling: 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.

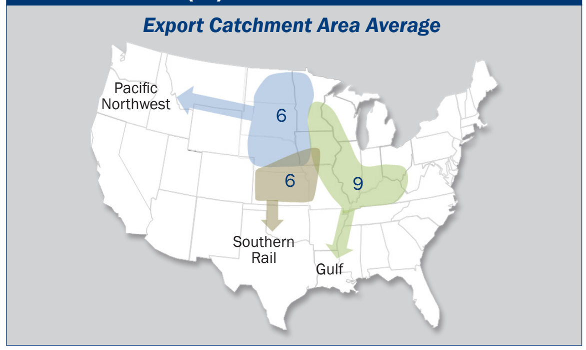
Stress crack measurements include stress cracks (the percent of kernels with at least one crack) and stress crack index (SCI), which is the weighted average of single, double and multiple stress cracks. Stress cracks measure only the number of kernels with stress cracks, whereas SCI shows the severity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

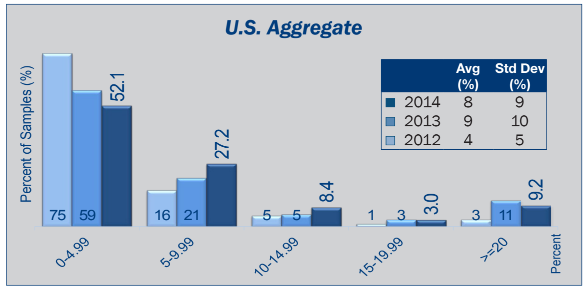
*III. QUALITY TEST RESULTS (continued)*

## RESULTS

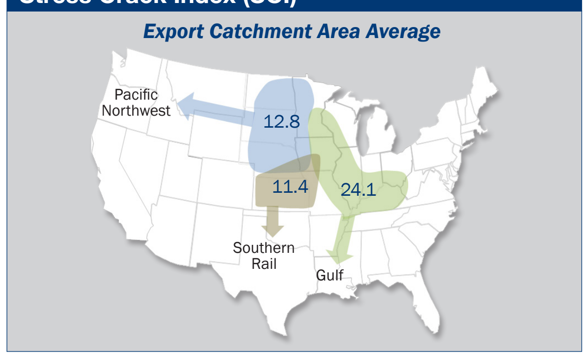
- Stress cracks of U.S. Aggregate corn averaged 8% in 2014, which was below 9% in 2013 but higher than 4% in 2012 and 5% for 3YA.
- U.S. Aggregate stress cracks standard deviation was 9% in 2014 compared to 10% in 2013 and 6% for 3YA.
- Stress cracks ranged from 0 to 100% in 2014, whereas the ranges were from 0 to 86% and 0 to 63% in 2013 and 2012, respectively.
- Stress cracks distribution in 2014 showed 79.3% of samples with less than 10% stress cracks (80.0% in 2013 and 91% in 2012). In 2014, there were 9.2% with stress cracks above 20%, which is below the 11% in 2013 but much higher than the 3% in 2012. Stress crack distributions indicate the 2014 corn had similar or slightly lower susceptibility to breakage than that found in 2013.
- Stress cracks averages for the Gulf, Pacific Northwest, and Southern Rail ECAs were 9%, 6% and 6%, respectively.
- SCI had a U.S. Aggregate average of 20.2, which is less than 22.8 in 2013 but significantly higher than 9.3 in 2012.
- U.S. Aggregate SCI standard deviation in 2014 was 27.7, compared to 35.1 in 2013 and 18.4 for 3YA.
- The SCI had a range of 0 to 410, which is wider than the range in 2013 (0 to 324) and 2012 (0 to 217).
- Of the 2014 samples, 88.4% had SCI of less than 40, which is higher than the 86.0% of the 2013 samples. While the percentage of 7.2% of the 2014 samples that had SCI greater than 80 is similar to the 9.0% in 2013, the proportion is higher than the 2.0% in 2012. This distribution may indicate more artificial drying was likely done in 2014 and 2013 than in 2012. However, SCI distributions for 2014 indicate similar or slightly lower numbers of kernels with multiple stress cracks than for 2013.

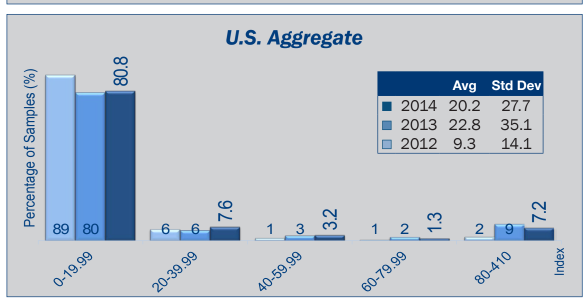
**Stress Cracks (%)**




**Stress Crack Index (SCI)**




- SCI averages for the Gulf, Pacific Northwest, and Southern Rail ECAs were 24.1, 12.8 and 11.4, respectively. The 3YA for SCI by ECA was also lowest for the Southern Rail ECA.
- The Southern Rail ECA had the lowest stress cracks and SCI of the ECAs in 2014, 2013 and 2012, and for 3YA with the exception of having the same stress crack levels as in the Pacific Northwest ECA in 2014. The lower stress cracks and SCI found for the Southern Rail ECA is likely related to greater field drying potential that is typically found in the states comprising the Southern Rail ECA.

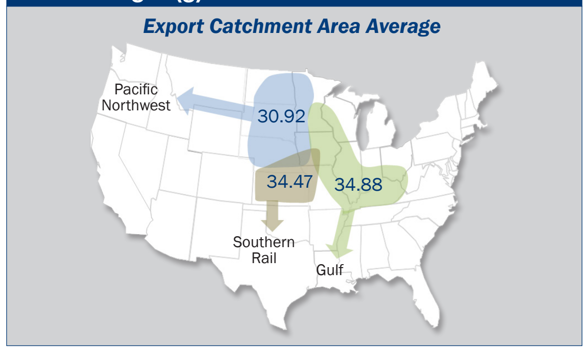
## 2. 100-Kernel Weight

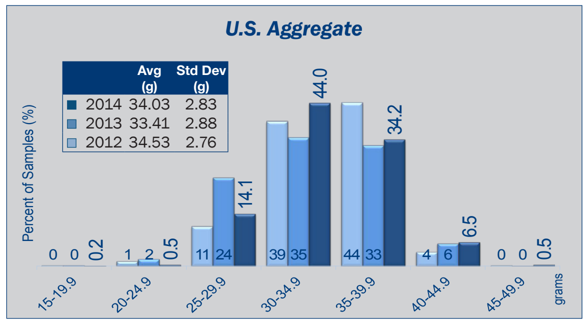
100-kernel (100-k) weight indicates larger kernel size as 100-k weights increase. Kernel size affects drying rates. As kernel size increases, the volume-to-surface area ratio becomes higher, and as the ratio gets higher, drying becomes slower. In addition, large uniform-sized kernels often enable higher 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

- 100-k weights of U.S. Aggregate samples averaged 34.03 g in 2014, which was significantly higher than 33.41 g in 2013, significantly lower than 34.53 g in 2012, and higher than 33.69 g for 3YA.
- U.S. Aggregate 100-k weight standard deviation of 2.83 g in 2014 was close to 2.88 g in 2013 and 2.76 g for 3YA.
- 100-k weight ranges were slightly lower in 2014 (19.70 to 46.30 g) compared to 2013 (18.07 to 45.09 g) and 2012 (17.49 to 45.39 g).
- The 100-k weights in 2014 were distributed so that 41.2% of the samples had 100-k weights of 35 g or greater, compared to 39% in 2013 and 48% in 2012.
- 100-k weights were lowest for the Pacific Northwest ECA, with 30.92 g compared to the Gulf and Southern Rail ECAs that averaged 34.88 g and 34.47 g, respectively. The Pacific Northwest ECA also had the lowest 100-k weights in 2013 and for 3YA.

**100-k Weight (g)**



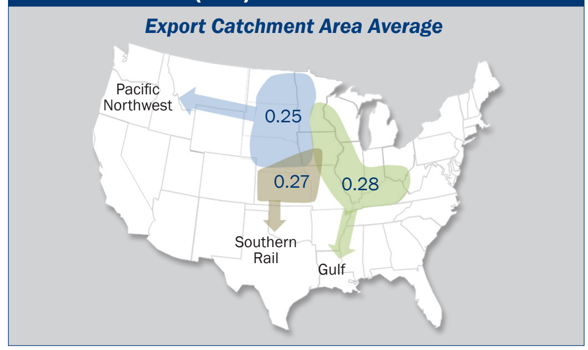
## 3. Kernel Volume

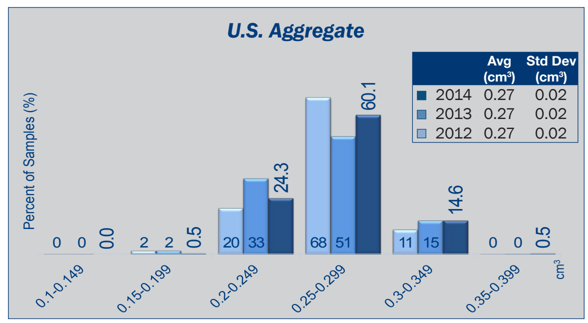
Kernel volume in $cm^3$ is often indicative of growing conditions. If conditions are dry, kernels may be smaller than average. If drought hits later in the season, kernels may have lower fill. Small or round kernels are more difficult to degerm. Additionally, small kernels may lead to increased cleanout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

### RESULTS

- Kernel volume averaged 0.27 $cm^3$ for U.S. Aggregate corn in 2014, which was unchanged from 0.27 $cm^3$ in 2013 and 2012 and for 3YA.
- The standard deviation for U.S. Aggregate kernel volume remained constant at 0.02 $cm^3$ for 2014, 2013, 2012 and 3YA.
- Kernel volumes ranged from 0.16 to 0.36 $cm^3$ in 2014, 0.15 to 0.36 $cm^3$ in 2013 and 0.14 to 0.35 $cm^3$ in 2012.
- The kernel volumes in 2014 were distributed so that 15.1% of the samples had kernel volumes of 0.3 $cm^3$ or greater, compared to 15% in 2013 and 11% in 2012.
- Kernel volumes for the Gulf, Pacific Northwest and Southern Rail ECAs averaged 0.28 $cm^3$, 0.25 $cm^3$, and 0.27 $cm^3$, respectively.
- The Pacific Northwest ECA had lower kernel volumes than the other two ECAs in 2014, 2013 and for 3YA.

**Kernel Volume ($cm^3$)**



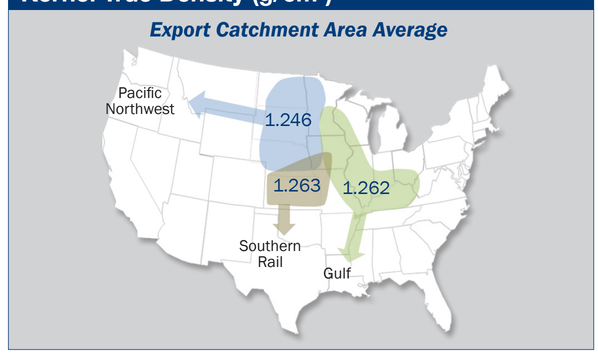
## 4. Kernel True Density

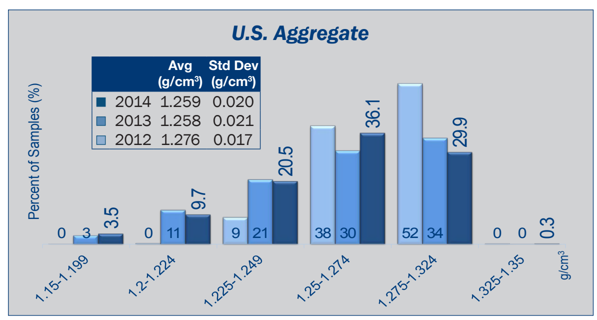
Kernel true density is calculated as the weight of a 100-k sample divided by the volume, or displacement, of those 100 kernels. True density is a relative indicator of kernel hardness, which is useful for alkaline processors and dry millers. True density, as a relative indicator of hardness, may be affected 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 it is also more at risk for the development of stress cracks if high-temperature drying is employed. True densities above 1.30 g/cm$^3$ would indicate very hard corn desirable for dry milling and alkaline processing. True densities near the 1.275 g/cm$^3$ level and below tend to be softer, but will process well for wet milling and feed use.

### RESULTS

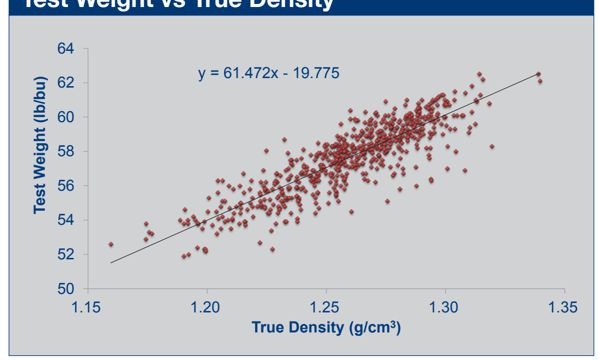
- Kernel true density averaged 1.259 g/cm$^3$ for U.S. Aggregate corn in 2014, which was similar to 1.258 g/cm$^3$ in 2013, significantly lower than 1.276 g/cm$^3$ in 2012 and lower than 1.267 g/cm$^3$ for 3YA.
- The true density standard deviation for U.S. Aggregate corn was 0.020 g/cm$^3$ in 2014, 0.021 g/cm$^3$ in 2013, 0.017 g/cm$^3$ in 2012, and 0.019 g/cm$^3$ for 3YA.
- True densities ranged from 1.160 to 1.340 g/cm$^3$ in 2014, 1.157 to 1.326 g/cm$^3$ in 2013, and 1.199 to 1.332 g/cm$^3$ in 2012.
- Kernel true densities in 2014 were distributed so that only 30.2% of the samples were at or above 1.275 g/cm$^3$, compared to 34.0% of the samples in 2013 and 52.0% in 2012. Since values above 1.275 g/cm$^3$ are often considered to be hard corn and those below soft corn, this kernel distribution indicates a higher percentage of samples with lower true density than in 2012 but was similar in softness to 2013.
- In 2014, kernel true densities for the Gulf, Pacific Northwest and Southern Rail ECAs averaged 1.262 g/cm$^3$, 1.246 g/cm$^3$, and 1.263 g/cm$^3$, respectively. Pacific Northwest true densities, in addition to test weights, were lowest among ECAs in 2014 and 2013 and for 3YA.
- Similarly, test weight was significantly lower in 2014 (57.6 lb/bu) than in 2013 (57.9 lb/bu) and 2012 (58.8 lb/bu). The adjacent figure illustrates the positive relationship between kernel true density and test weight for the 2014 samples.

**Kernel True Density (g/cm³)**




**Test Weight vs True Density**



## 5. 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.

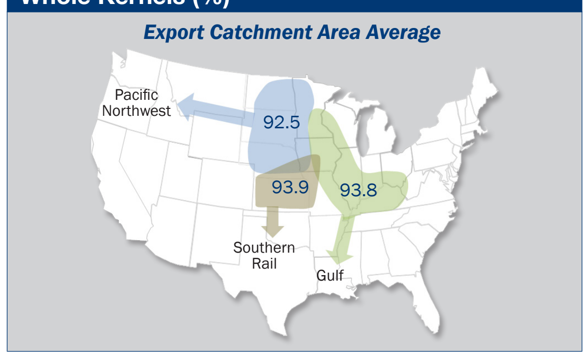
The exterior integrity of the corn kernel is very important for two key reasons. First, it affects water absorption for alkaline cooking and steeping operations. Kernel nicks or pericarp cracks allow water to enter the kernel faster than intact or whole kernels. Too much water uptake during cooking can result in loss of solubles, 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.

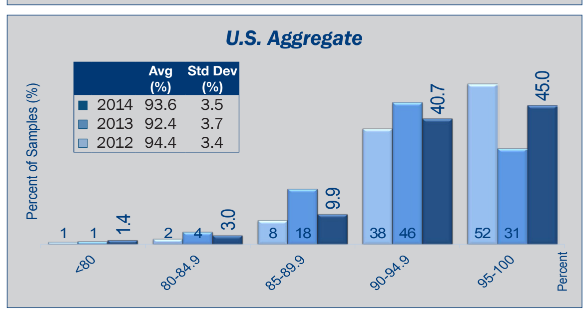
Second, fully intact whole kernels are less susceptible to storage molds and breakage in handling. While hard endosperm lends itself to preservation of more whole kernels than soft corn, the primary factor in delivering whole kernels is harvesting and handling. This begins with proper combine adjustment 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. Harvesting at higher moisture contents (e.g., greater than 25%) will usually lead to more pericarp damage to corn than harvesting at lower moisture levels (less than 18%).

### RESULTS

- Whole kernels averaged 93.6% for U.S. Aggregate corn, which was significantly higher than 92.4% in 2013, significantly lower than 94.4% in 2012, and similar to 93.5% for 3YA.
- The whole kernel standard deviation for the U.S. Aggregate was 3.5%, which was lower than 3.7% for 2013 and 3YA, but similar to 3.4% for 2012.
- Whole kernels ranged from 63.6% to 99.8% in 2014, 73.6 to 99.6% in 2013 and 68.0 to 100% in 2012.
- Of the 2014 samples, 85.7% had 90% or higher whole kernels, compared to 77% in 2013 and 90% in 2012.
- Whole kernels averages for Gulf, Pacific Northwest, and Southern Rail were 93.8%, 92.5%, and 93.9%, respectively. Whole kernels were lowest for Pacific Northwest (92.5%) in 2014, but the 3YA of each ECA illustrates there was little variation among the ECAs.

**Whole Kernels (%)**



## 6. Horneous Endosperm

The horneous endosperm test measures the percent of horneous or hard endosperm, 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. Hard corn is needed to produce high yields of large flaking grits in dry milling. Medium-high to medium hardness is desired for alkaline cooking. Moderate to soft hardness is used for wet milling and livestock feeding.

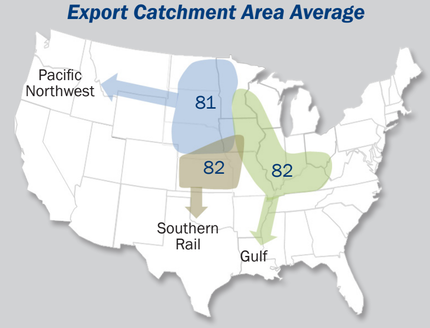
Hardness has been correlated to breakage susceptibility, feed utilization/efficiency and starch digestibility. As a test of overall hardness, there is no good or bad value for horneous endosperm; there is only a preference by different end users for particular ranges. Many dry millers and alkaline cookers would like greater than 90% horneous endosperm, while wet millers and feeders would typically like values between 70% and 85%. However, there are certainly exceptions in user preference.

### RESULTS

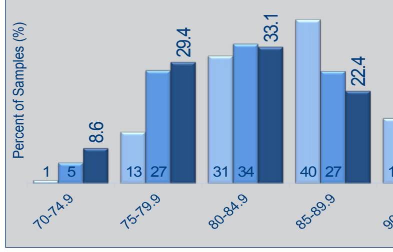
- Horneous endosperm averaged 82% for U.S. Aggregate corn in 2014, which was the same as 82% in 2013, significantly lower than 85% in 2012, and lower than 84% for 3YA.
- U.S. Aggregate standard deviation for horneous endosperm was 4%, the same as in 2013 and 2012 and for 3YA.
- Horneous endosperm ranged more widely in 2014 (71 to 97%) than in 2013 (71 to 96%) and 2012 (74 to 97%).
- Of the 2014 samples, 62.1% were equal to or greater than 80% horneous endosperm, which was below 67% in 2013 and far below 86% in 2012.
- Horneous endosperm averages for Gulf, Pacific Northwest, and Southern Rail were 82%, 81%, and 82%, respectively. Of the ECAs, the Pacific Northwest was lowest in horneous endosperm in 2014 and 2013, and for 3YA.
- As mentioned in the true density section, the Pacific Northwest ECA was lowest in true density in 2014, 2013 and for 3YA. The adjacent figure shows the weak but positive relationship (a correlation coefficient of 0.74) between horneous endosperm and true density for the 2014 samples.

**Horneous Endosperm (%)**

*Export Catchment Area Average*

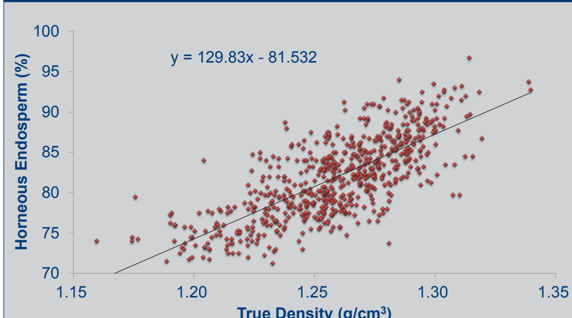



*U.S. Aggregate*




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2014 | 82 | 4 |
| 2013 | 82 | 4 |
| 2012 | 85 | 4 |

**Horneous Endosperm vs True Density**



*III. QUALITY TEST RESULTS (continued)*

## SUMMARY: PHYSICAL FACTORS

| | 2014 Harvest | | | | | 2013 Harvest | | | 2012 Harvest | | | 3 Year Avg. (2011-2013) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 (%) | 629 | 8 | 9 | 0 | 100 | 610 | 9* | 10 | 637 | 4* | 5 | 5 | 6 |
| Stress Crack Index[2] | 629 | 20.2 | 27.7 | 0 | 410 | 610 | 22.8* | 35.1 | 637 | 9.3* | 14.1 | 12.2 | 18.4 |
| 100-Kernel Weight (g) | 629 | 34.03 | 2.83 | 19.70 | 46.30 | 610 | 33.41* | 2.88 | 637 | 34.53* | 2.76 | 33.69 | 2.76 |
| Kernel Volume ($cm^3$) | 629 | 0.27 | 0.02 | 0.16 | 0.36 | 610 | 0.27 | 0.02 | 637 | 0.27 | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 629 | 1.259 | 0.020 | 1.160 | 1.340 | 610 | 1.258* | 0.021 | 637 | 1.276* | 0.017 | 1.267 | 0.019 |
| Whole Kernels (%) | 629 | 93.6 | 3.5 | 63.6 | 99.8 | 610 | 92.4* | 3.7 | 637 | 94.4* | 3.4 | 93.5 | 3.7 |
| Horneous Endosperm (%) | 629 | 82 | 4 | 71 | 97 | 610 | 82* | 4 | 637 | 85* | 4 | 84 | 4 |
| **Gulf** | | | | | | | | | | | | | |
| Stress Cracks (%)[2] | 583 | 9 | 10 | 0 | 100 | 556 | 9* | 11 | 566 | 4* | 5 | 5 | 6 |
| Stress Crack Index[2] | 583 | 24.1 | 33.3 | 0 | 410 | 556 | 23.5* | 39.5 | 566 | 9.9* | 15.5 | 12.7 | 20.4 |
| 100-Kernel Weight (g) | 583 | 34.88 | 2.90 | 25.16 | 46.30 | 556 | 34.10 | 2.94 | 566 | 34.79 | 2.78 | 34.18 | 2.78 |
| Kernel Volume ($cm^3$) | 583 | 0.28 | 0.02 | 0.20 | 0.36 | 556 | 0.27* | 0.02 | 566 | 0.27* | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 583 | 1.262 | 0.020 | 1.160 | 1.340 | 556 | 1.261* | 0.020 | 566 | 1.276* | 0.017 | 1.269 | 0.019 |
| Whole Kernels (%) | 583 | 93.8 | 3.3 | 63.6 | 99.8 | 556 | 92.4* | 3.8 | 566 | 94.4* | 3.5 | 93.6 | 3.7 |
| Horneous Endosperm (%) | 583 | 82 | 4 | 71 | 97 | 556 | 83* | 4 | 566 | 85* | 4 | 84 | 4 |
| **Pacific Northwest** | | | | | | | | | | | | | |
| Stress Cracks (%)[2] | 262 | 6 | 6 | 0 | 56 | 259 | 10* | 10 | 321 | 4* | 4 | 6 | 6 |
| Stress Crack Index[2] | 262 | 12.8 | 17.1 | 0 | 204 | 259 | 27.4* | 31.1 | 321 | 8.5* | 11.5 | 13.7 | 16.4 |
| 100-Kernel Weight (g) | 262 | 30.92 | 2.57 | 19.70 | 44.13 | 259 | 30.33* | 2.70 | 321 | 34.07* | 2.51 | 31.89 | 2.60 |
| Kernel Volume ($cm^3$) | 262 | 0.25 | 0.02 | 0.16 | 0.34 | 259 | 0.24* | 0.02 | 321 | 0.27* | 0.02 | 0.25 | 0.02 |
| True Density ($g/cm^3$) | 262 | 1.246 | 0.021 | 1.160 | 1.339 | 259 | 1.241* | 0.022 | 321 | 1.277* | 0.016 | 1.257 | 0.019 |
| Whole Kernels (%) | 262 | 92.5 | 4.4 | 64.8 | 99.8 | 259 | 92.5* | 3.3 | 321 | 94.1* | 3.3 | 93.4 | 3.5 |
| Horneous Endosperm (%) | 262 | 81 | 4 | 71 | 97 | 259 | 80* | 3 | 321 | 86* | 4 | 83 | 4 |
| **Southern Rail** | | | | | | | | | | | | | |
| Stress Cracks (%)[2] | 371 | 6 | 6 | 0 | 62 | 312 | 5* | 6 | 366 | 3* | 4 | 4 | 4 |
| Stress Crack Index[2] | 371 | 11.4 | 15.3 | 0 | 230 | 312 | 11.7* | 16.5 | 366 | 7.2* | 10.6 | 7.2 | 10.0 |
| 100-Kernel Weight (g) | 371 | 34.47 | 2.83 | 25.54 | 46.30 | 312 | 34.23* | 2.87 | 366 | 33.89* | 3.07 | 33.83 | 2.91 |
| Kernel Volume ($cm^3$) | 371 | 0.27 | 0.02 | 0.21 | 0.36 | 312 | 0.27* | 0.02 | 366 | 0.27* | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 371 | 1.263 | 0.019 | 1.174 | 1.340 | 312 | 1.267* | 0.020 | 366 | 1.275* | 0.016 | 1.272 | 0.018 |
| Whole Kernels (%) | 371 | 93.9 | 3.2 | 68.6 | 99.8 | 312 | 92.5* | 3.5 | 366 | 94.7* | 2.9 | 93.5 | 3.4 |
| Horneous Endosperm (%) | 371 | 82 | 4 | 72 | 97 | 312 | 83* | 4 | 366 | 85* | 4 | 84 | 4 |

**Indicates averages in 2013 were significantly different from 2014, and 2012 averages were significantly different from 2014 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, aflatoxins and deoxynivalenol (DON or vomitoxin) are considered to be two of the important mycotoxins.

As in 2012 and 2013, the 2014 harvest samples were tested for aflatoxins and DON for this year's report. Since the production of mycotoxins is heavily influenced by growing conditions, the objective of the *Harvest Quality Report* is strictly to report on instances when aflatoxins or DON are detected in the corn crop at harvest. No specific levels of the mycotoxins are reported.

The *Harvest Quality 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 Quality 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 Quality Report*, year-to-year patterns of mycotoxin presence in corn at harvest will be seen. The *U.S. Grains Council Corn Export Cargo Quality Report 2014/15* will report corn quality at export points and will be a more accurate indication of mycotoxin presence in the 2014/15 U.S. corn export shipments.

## 1. Assessing the Presence of Aflatoxins and DON

A weighted and systematic testing of at least 25% of the targeted 600 samples across the entire sampled area was conducted to assess the impact of the 2014 growing conditions on total aflatoxins and DON development in the U.S. corn crop. The sampling criteria, described in the "Survey and Statistical Analysis Methods" section, resulted in a targeted number of 182 samples tested for mycotoxins.

A threshold referred to as the Limit of Detection (LOD) was used to determine whether or not a detectable level of the mycotoxin appeared in the sample. The LOD for the analytical kits used for this 2014/15 report was 2.5 parts per billion (ppb) for aflatoxins and 0.3 parts per million (ppm) for DON. Details on the testing methodology employed in this study for the mycotoxins are in the "Testing Analysis Methods" section.

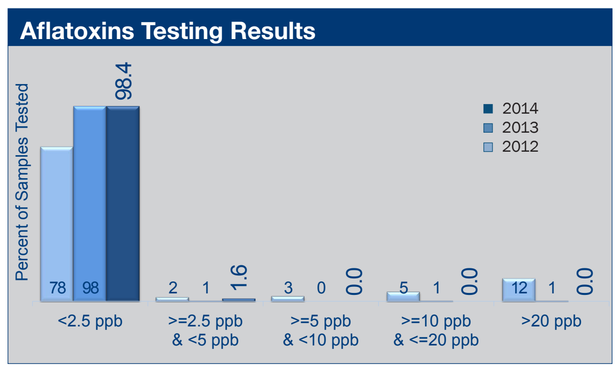
*III. QUALITY TEST RESULTS (continued)*

## 2. Aflatoxins Testing Results

A total of 182 samples were analyzed for aflatoxins in 2014. This is about the same number of samples (179) tested for aflatoxins in 2013. Results of the 2014 survey are as follows:

- One hundred seventy-nine (179) samples, or 98.4% of the 182 samples, had no detectable levels of aflatoxins (below the 2.5 ppb LOD). In 2013 and 2012, 98.3% and 78.0% of the samples tested had no detectable levels of aflatoxins, respectively.
- Three samples (3), or 1.6% of the 182 samples, showed aflatoxin levels greater than or equal to the LOD of 2.5 ppb, but less than 5 ppb.
- No samples (0), or 0.0% of the 182 samples, showed aflatoxin levels greater than or equal to 5 ppb, but less than 10 ppb.
- No samples (0), or 0.0%, of the 182 samples, showed aflatoxin levels greater than or equal to 10 ppb, but less than or equal to the FDA action level of 20 ppb.
- These results denote that 182 samples, or 100% of the 182 sample test results in 2014, were below or equal to the FDA action level of 20 ppb, compared to 99.4% and 88.1% of the samples tested in 2013 and 2012, respectively.

Comparing the 2014 aflatoxin survey results to the 2013 and 2012 survey results suggests that there were about the same level of incidents of aflatoxins among all ASDs in 2014 as in the 2013 crop seasons. Both 2014 and 2013 had a higher percentage of samples below the LOD than 2012. No samples exceeded the FDA action level in 2014 compared to 1 (<1%) in 2013 and 21 (11.9%) in 2012, which may be due, in part, to more favorable (less stressful) weather conditions in 2014 (see the "Crop and Weather Conditions" section for more information on the 2014 growing conditions). Weather was cool and wet during pollination and grain fill in 2014 and as a result, the corn plants were not under stress. These conditions were not conducive to aflatoxin formation.



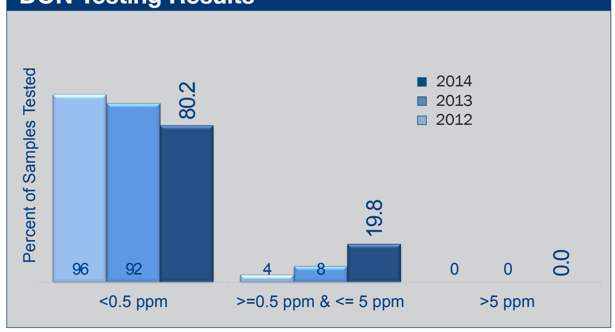
## 3. DON (Deoxynivalenol or Vomitoxin) Testing Results

A total of 182 samples were analyzed collectively for DON in 2014. This is about the same number of samples (179) tested for DON in 2013. Results of the 2014 survey are shown below:

- One hundred forty-six (146) samples, or 80.2% of the 182 samples, tested less than the 0.5 ppm.
- Thirty-six (36) samples, or 19.8% of the 182 samples, tested greater than or equal to 0.5 ppm, but less than or equal to the FDA advisory level of 5 ppm.
- All 182 samples, or 100%, tested below or equal to the FDA advisory level of 5 ppm.
- The 2014 percentage for samples that tested below 0.5 ppm (80.2%) is lower than both 2013 (91.6%) and 2012 (96.0%).
- In 2014, 100% percent of the samples tested at or below 5 ppm, which is the same as was observed in 2013 and 2012.

Comparing the 2014 DON survey results to 2013 and 2012 survey results indicates that there was a smaller percentage of samples with DON results below the LOD in 2014 than in 2013 and 2012 crop seasons. While all survey results were below 5 ppm for all three years, a smaller percentage of samples fell below 0.5 ppm in 2014 than in 2013 and 2012. This may be attributed to wet and cool conditions during flowering and/or a delayed harvest in 2014.

**DON Testing Results**




## 4. Mycotoxin Background: General

The levels at which the fungi produce the 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 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 aflatoxins 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 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 import 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 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 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 Regulatory Guidance for Toxins and Contaminants" found at http://www.ngfa.org/wp-content/uploads/NGFAComplianceGuide-FDARegulatoryGuidanceforMycotoxins8-2011.pdf.

## 5. Mycotoxin Background: Aflatoxins

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. 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 “aflatoxins” or “total aflatoxins.” 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.

Aflatoxins express 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 aflatoxins, possibly resulting in death in poultry and ducks, 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 aflatoxins.

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

FDA has established additional policies and legal provisions concerning the blending of corn with levels of aflatoxins exceeding these threshold levels. In general, 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 aflatoxins 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 aflatoxins in exported grain.

| Aflatoxins 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/Publications/fgis/broch/b-aflatox.pdf**

## 6. Mycotoxin Background: DON (Deoxynivalenol) or Vomitoxin

DON 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.

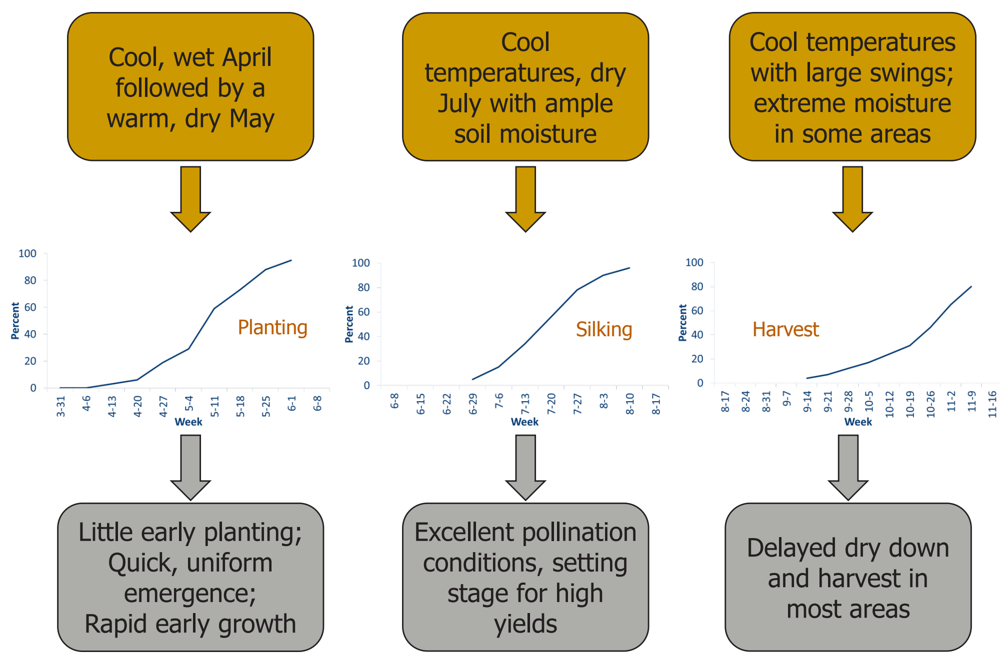
# IV. CROP AND WEATHER CONDITIONS

## 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, 2014 was a cool, wet year with delayed planting and delayed harvest. However, the crop was quite uniform in maturity and had the best crop condition rating during reproductive growth in the past ten years, with record harvests expected. The following highlights the key events of the 2014 growing season:

- A cold, wet spring prevented early planting, but warm May soils led to uniform emergence.
- Excellent pollination conditions then cool summer temperatures with ample rainfall encouraged starch and oil accumulation in more kernels, with less protein concentration.
- Pollination conditions were favorable for high yield, but also for Diplodia in some locations.
- Cool temperatures and flooding delayed maturity and harvesting, especially in the northern areas.
- An early freeze affecting 20% of the corn growing area, leading to some kernel immaturity, which with delayed harvest may have led to more drying and possible corn stress cracks.

The following sections describe how the 2014 growing season weather impacted the corn yield and grain quality in the U.S. Corn Belt.




[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.*

# A. Planting and Early Growth Conditions - Spring (March - May)

*Cold spring, rain in the north decreased early planting*

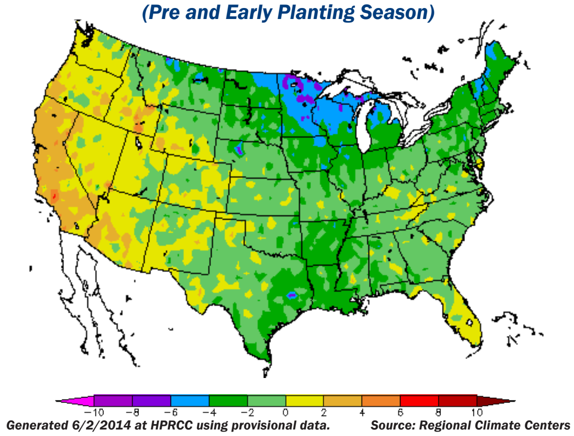
Weather factors impacting corn yield and quality include the amount of precipitation and the temperature just prior to and during the corn-growing season. These weather factors interact with the corn variety planted and the soil fertility. Grain yield is a function of the number of plants per acre, the 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. Some dryness at planting and early growth time is beneficial, as it promotes a deeper root system to access water later in the season.

Overall, for the key corn-growing areas in 2014, a cold spring led to a less than average amount of April planting. However, May had warm, dry weather, resulting in 30% of the corn planted in one week, thereby returning planting progress to the long-term average. Only a few areas with excessive rain had poor emergence due to the soil crusting over, making it difficult for the corn shoot to push through.

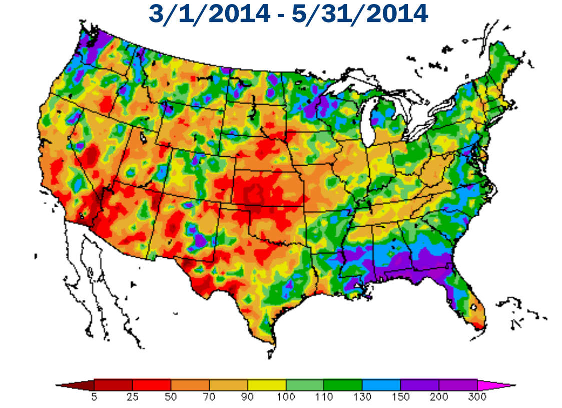
More specifically, the majority of the Gulf and the Pacific Northwest ECAs experienced a cold spring, with additional planting delays from abundant rainfall in the northern states. Therefore, most farmers had to wait until May for the soil to dry out enough to plant. However, this delay allowed for the soil to warm up quickly and led to excellent, uniform emergence, and rapid early growth.

The Southern Rail ECA had an average to cool spring, but continued to have below average precipitation. This dry weather allowed planting and emergence progress to be close to the historical average.

**Departure from Normal Temperature (ºF)**
**3/1/2014 - 5/31/2014**
***(Pre and Early Planting Season)***




**Percent of Normal Precipitation (%)**
**3/1/2014 - 5/31/2014**

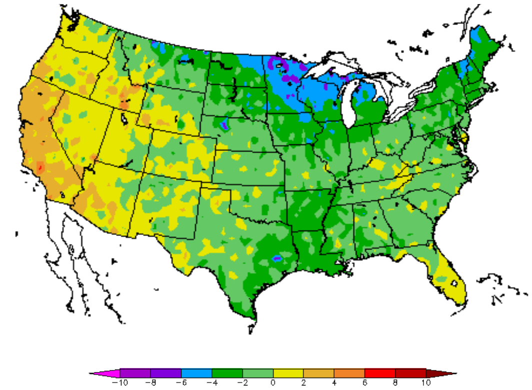


# B. Pollination and Grain-Fill Conditions - Summer (June - August)

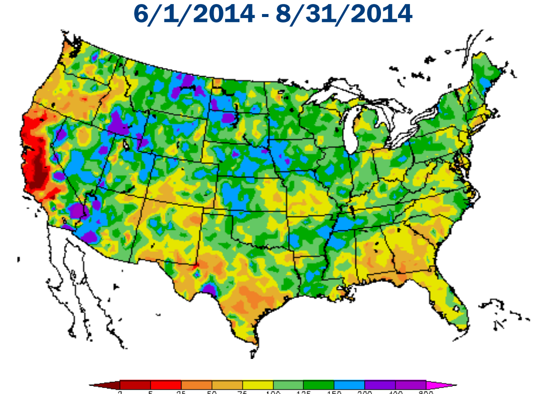
*Wet June, cool June and July favored pollination and starch accumulation, but delayed maturity*

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 grain-filling period in July and August are critical to determining final grain composition. During this time, moderate rainfall and cooler than average temperatures, especially overnight temperatures, promote starch and oil accumulation and increased yields. Moderate rainfall and warm temperatures in the second half of grain-fill (August to September) also aid continued nitrogen uptake and photosynthesis. Nitrogen also remobilizes from the leaves to the grain during grain-filling, leading to increases in grain protein and density.

**Departure from Normal Temperature (°F)**
**6/1/2014 - 8/31/2014**




**Percent of Normal Precipitation (%)**
**6/1/2014 - 8/31/2014**




In June 2014, abundant rainfall throughout the corn-growing regions flooded fields, and removed some of the nitrogen fertilizer from the soil before the plant could accumulate it, thereby reducing the final grain protein concentration. However, the rain in June helped to minimize the multi-year drought conditions in the Southern Rail ECA.

In July of 2014, there was excellent pollination, primarily due to cool, sunny conditions in the Pacific Northwest and Gulf ECAs. In addition, ample soil moisture favored second ears in some fields. Late July saw the return of major storms. This wet weather from late pollination time into August may have encouraged Diplodia and Gibberella ear rots in some areas. Additionally, cool temperatures and ample rain promoted photosynthesis, longer ears, and greater than average starch concentration. Unfortunately, the ample rains may have removed some of the nitrogen fertilizer in 2014, preventing maximum uptake and grain protein concentration.

In the Southern Rail ECA, the weather was abnormally dry and cold in July, but residual moisture from June helped plant growth. The cool weather probably prevented Aspergillus mold formation, which prefers hot and dry conditions after pollination. During grain-fill, the weather warmed up above average, but continued with dry conditions, and led to greater than average starch and decreased protein concentration.

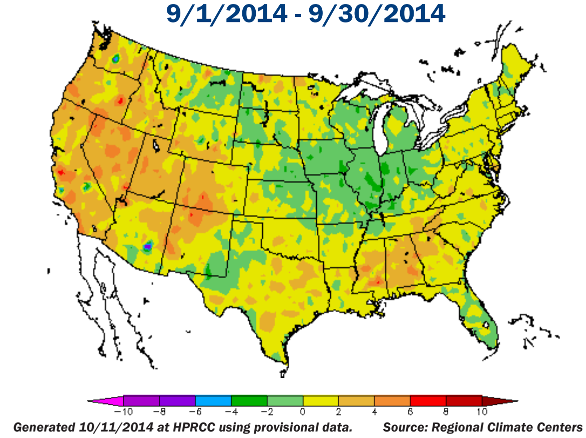
## C. Harvest Conditions (September - October +)

*Cool, wet weather delayed maturation and harvest; up to 30% had early freeze*

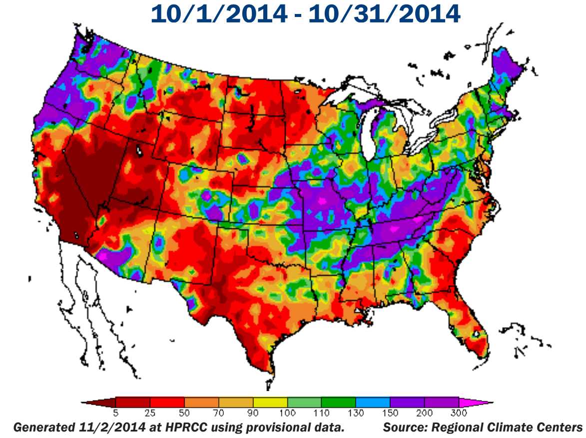
At the end of the growing season, dry down of the grain is dependent upon sunshine, temperature, humidity levels, seed hybrid and soil dryness. Corn can most effectively dry down with the least adverse impact on quality with sunny, warm days with low humidity. Another weather concern at the end of the growing season is freezing temperatures. Early freezing before the grain can sufficiently naturally dry down may lead to lower yield, lower test weight, and/or stress cracking. Also, if harvested early, higher-moisture grain may be susceptible to greater breakage than drier grain.

Typically, 80% of the U.S. corn crop is harvested by the end of October. However, in 2014, the cool summer temperatures initially delayed maturity. Harvest was further delayed by rainy weather and continued cool temperatures, primarily in the Gulf and Pacific Northwest ECAs, but also in the eastern half of the Southern Rail ECA. There was a scattered early freeze in mid-September in the northern Gulf and Pacific Northwest ECAs, affecting less than 3% of the corn crop. However, the crop experienced a more widespread freeze and snowfall in early October, this time affecting 20% of the corn production area. At that time, approximately 30% of the corn crop was not at full maturity and susceptible to frost damage, which could include reduced yields, lower test weights and stress-cracking, and may take a longer time to dry down. Producers also may artificially dry this grain. Alternatively, these plants may be harvested for silage, thereby removing the lesser-quality grain from the market stream.

**Departure from Normal Temperature (ºF)**
**9/1/2014 - 9/30/2014**




**Percent of Normal Precipitation (%)**
**10/1/2014 - 10/31/2014**



## D. Comparison of 2014 to 2013, 2012, and the Three-Year Average

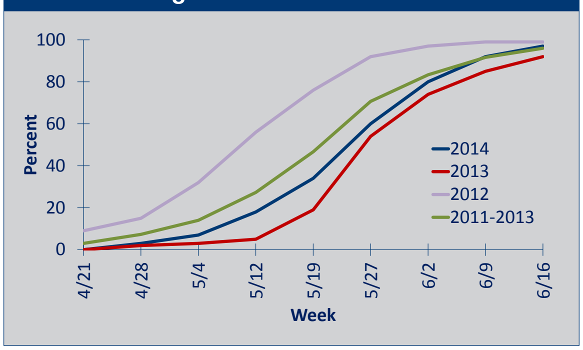
*2014 was cool like 2013, but had more rain and record yields*

In contrast to the very dry spring of 2012 with early planting, 2014 had delayed average planting, due to cold, wet conditions. However, by mid-May, the majority of planting was similar to 3YA, and about a week earlier than in 2013. The vegetative growth rate and silking time of 2014 was similar to 3YA, in contrast to the early silking time of the hot, dry 2012, and the delayed stage in 2013. This silking and pollination time of 2014 extended for a longer duration than 2013. Additionally, in a majority of the corn-growing region, the rains tapered off, allowing for a greater number of kernels to be pollinated, establishing the potential for record yields.

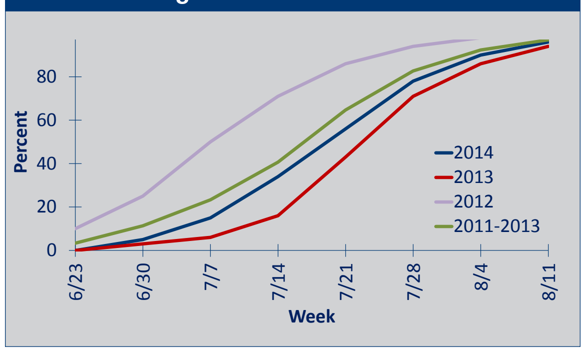
Similar to 2013, the summer of 2014 was cooler than 3YA, and much cooler than the drought of 2012. In contrast to the temporary drought of 2013, the summer of 2014 had ample rain and more soil moisture, promoting more grain, yield, and oil, but less protein. Harvest in both 2014 and 2013 was later than 3YA due to multiple weeks of rain and freezing temperatures.

Throughout much of 2014, the corn crop had the greatest Good + Excellent condition percentage compared to the past 10 years, signifying good plant health, leading to greater photosynthesis, starch accumulation and yield. In contrast, the corn crop in 2013 was rated better than 3YA, but less than 2014, due to the short-term intense heat and drought. The severity of the drought and heat wave in 2012 rapidly decreased the crop condition, starch accumulation, and yield, but increased grain test weight and protein concentration.

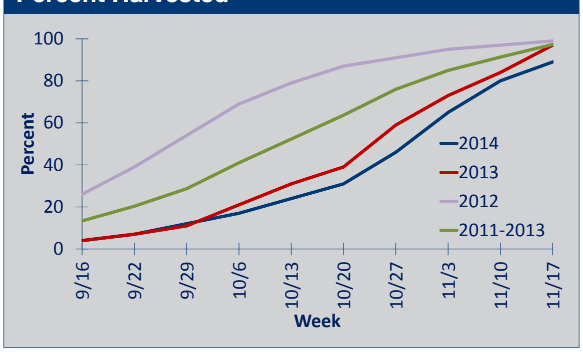
**Percent Emerged**



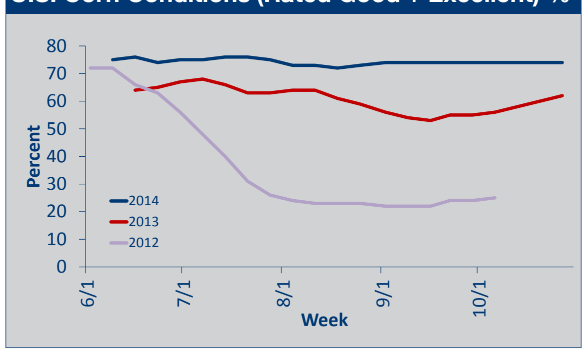

**Percent Silking**




**Percent Harvested**




**U.S. Corn Conditions (Rated Good + Excellent) %**




[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.*

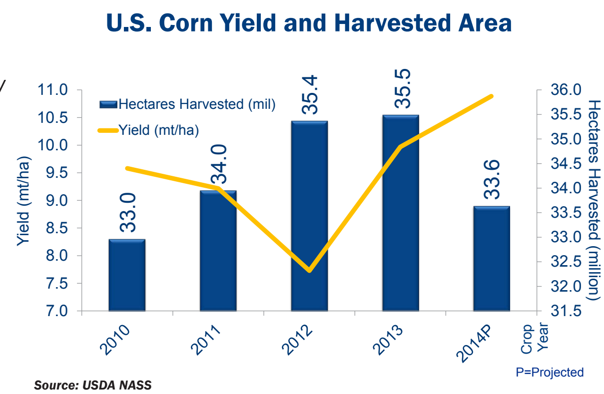
# V. U.S. CORN PRODUCTION, USAGE AND OUTLOOK

## A. U.S. Corn Production[1]

### 1. U.S. Average Production and Yields

- According to the November 2014 USDA World Agricultural Supply and Demand Estimates (WASDE) report, average U.S. corn yield for the 2014 crop is projected to be 10.9 mt/ha (173.4 bu/ac). This is 0.9 mt/ha (14.6 bu/ac) higher than the 2013 corn crop and the highest average yield on record.

- The number of hectares harvested in 2014 is projected to be 33.6 million (83.1 mil ac). This is 1.9 mil ha (4.6 mil ac) less than in 2013, which was the largest number of harvested hectares over the last 80 years. The projected 33.6 mil ha harvested in 2014 ranks sixth over the last 80 years and fifth-highest in the past 10 years.




- Total U.S. corn production for 2014 is projected to be 366.0 mmt (14,407 mil bu). This is about 12.3 mmt (482 mil bu) higher than 2013 and the largest U.S. corn crop on record.

- While 2014 saw slightly lower harvested hectares than in 2013, significantly higher yields in key U.S. corn-producing areas in 2014 resulted in projected record total production.

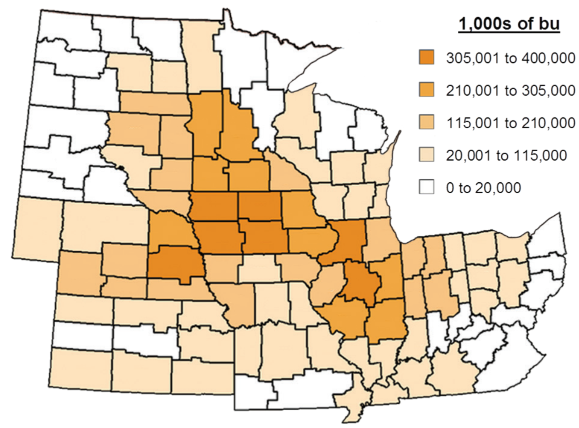
[1] *mt - metric ton; mmt - million metric tons; ha - hectare; bu - bushel; mil bu - million bushels; ac - acre.*

## V. U.S. CORN PRODUCTION, USAGE AND OUTLOOK (continued)

### 2. ASD and State-Level Production

The geographic areas included in the *Harvest Report* encompass the highest corn-producing areas in the United States. This can be seen on the map showing projected 2014 corn production by USDA Agricultural Statistical District (ASD).

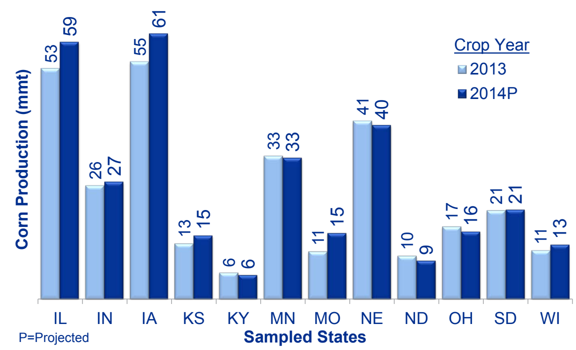
**U.S. Corn Production by ASD (2014P)**




Source: USDA NASS and Centrec Estimates

The record size of the 2014 corn crop was primarily driven by significantly higher production in Illinois, Iowa and Missouri compared to 2013. Of the remaining nine states, Indiana, Kansas, South Dakota and Wisconsin had slightly higher production, while Minnesota had about the same level of production, and Kentucky, Nebraska, North Dakota and Ohio had slightly lower production.

**U.S. Corn Production by State**




Source: USDA NASS

The U.S. Corn Production table summarizes the differences in both quantity (mmt) and percentages between 2013 and projected 2014 corn production for each state. Also included is an indication of the relative changes in harvested acres and yield between 2013 and projected 2014. The green bar indicates a relative increase and the red bar indicates a relative decrease from 2013 to projected 2014. This illustrates that harvested acres were largely unchanged to slightly lower, with the exception of North Dakota, which experienced a 24% reduction in harvested acres. Yield changes were largely unchanged to slightly higher, with the exception of significantly higher yields in Kansas and Missouri and slightly lower yields in Kentucky.

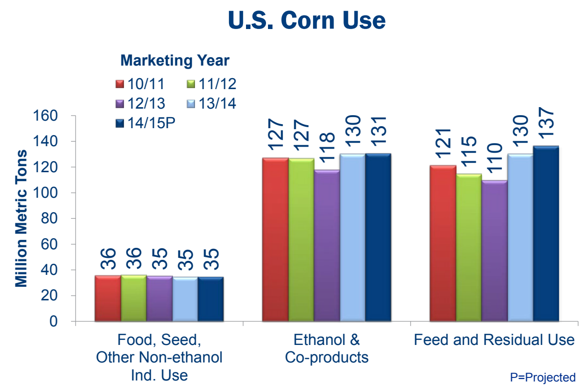
**U.S. Corn Production**

| | | | Difference | | Relative % Change* | |
|---|---|---|---|---|---|---|
| **State** | **2013** | **2014P** | **MMT** | **Percent** | **Acres** | **Yield** |
| Illinois | 53 | 59 | 6 | 11% | | |
| Indiana | 26 | 27 | 1 | 3% | | |
| Iowa | 55 | 61 | 6 | 12% | | |
| Kansas | 13 | 15 | 2 | 14% | | |
| Kentucky | 6 | 6 | (1) | -9% | | |
| Minnesota | 33 | 33 | (0) | -1% | | |
| Missouri | 11 | 15 | 4 | 38% | | |
| Nebraska | 41 | 40 | (1) | -2% | | |
| North Dakota | 10 | 9 | (1) | -11% | | |
| Ohio | 17 | 16 | (1) | -7% | | |
| South Dakota | 21 | 21 | 0 | 1% | | |
| Wisconsin | 11 | 13 | 1 | 12% | | |
| Total | 354 | 366 | 12 | 3% | | |

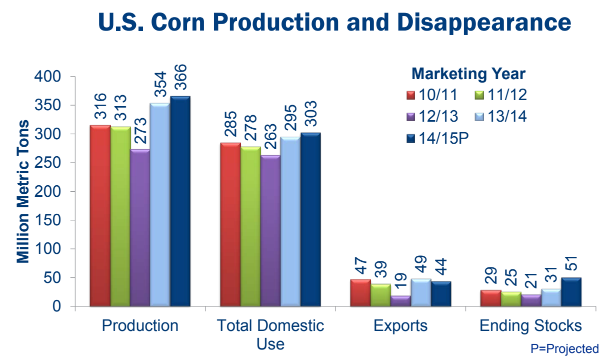
***Green indicates 2014 is higher than 2013 and red indicates 2014 is lower than 2013; bar height indicates the relative amount.***
***P=Projected***
*Source: USDA NASS*

# B. U.S. Corn Use and Ending Stocks

- U.S. corn use for food, seed and other non-ethanol industrial purposes has remained fairly constant since the 2010/2011 marketing year (MY10/11).
- While the amount of corn used for ethanol production was lower in MY12/13 relative to MY10/11, MY11/12 and MY13/14, the proportion of corn used for ethanol production to overall use has not changed greatly the past four completed marketing years.
- Direct consumption of corn as a feed ingredient in domestic livestock and poultry rations rebounded in MY13/14 due to ample corn supplies and lower corn prices relative to other feed ingredients.
- U.S. corn exports during MY13/14 were more than double the previous marketing year, mostly due to record U.S. corn production and lower prices.
- The 2012 drought resulting in lower production greatly drew down the MY12/13 ending stocks, the lowest in many years. However, the large 2013 crop helped rebuild ending stocks in MY13/14.




Source: USDA WASDE and ERS




Source: USDA WASDE and ERS

## C. Outlook

### 1. U.S. Outlook

- The record-setting 2014 U.S. corn crop is creating an abundant supply of corn for MY14/15. The ample corn supply has put a downward pressure on corn prices, which has helped support corn use in the domestic market. As a result, domestic use is projected to increase 2.4% from MY13/14 to MY14/15.
- Corn use for food, seed and non-ethanol industrial (FSI) purposes is expected to remain largely unchanged in MY14/15 compared to MY13/14, continuing the pattern of the previous four marketing years.
- Projected MY14/15 corn use for ethanol is about the same as the previous marketing year, with corn expected to represent a larger share of the ethanol feedstock. U.S. ethanol disappearance will be impacted by lower crude oil and gasoline prices, possibly weakening domestic ethanol demand and net ethanol exports.
- Domestic corn use for livestock and poultry feeding and for residual use is expected to be about 4.5% higher in MY14/15 than in MY13/14 and at the highest level since MY07/08. Factors driving this demand include the continued decline in the relative price of corn to other feedstuffs and increasing demand due to feeding livestock longer and/or the rebuilding of livestock herds.
- U.S. corn exports during MY14/15 are projected to be about 9.5% lower than last year, yet higher than in MY11/12 and MY12/13. Lower corn prices and ample supply will help support U.S. exports.
- MY14/15 corn ending stocks are projected to be 38.4% higher than the previous marketing year primarily because of the large corn crop. This will increase the stocks-to-use ratio for the second year in a row.

### 2. International Outlook

***Global Supply***

- Global corn production during MY14/15 is expected to be a record-setting year, primarily due to the large U.S. corn crop.
- Greater production for MY14/15 in the EU, Russia, Serbia and the Philippines will offset lower production in China, Brazil, Ukraine, India, Canada and Argentina.
- In addition to slightly lower U.S. exports, total non-U.S. exports are expected to be 11% lower in MY14/15 than in MY13/14.
- Increases in exports are expected in Serbia, South Africa and the EU.

***Global Demand***

- Global corn use is expected to increase around 2% in MY14/15 from MY13/14.
- Corn use is anticipated to be higher in MY14/15 in China, Mexico, Brazil and Russia, but lower in Canada compared to MY13/14.
- An 11% decrease in year-over-year imports is expected globally in MY14/15, with decreases in the EU (64% decrease), Indonesia, Egypt and China.

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

| Metric Units | 10/11 | 11/12 | 12/13 | 13/14 | 14/15P |
|---|---|---|---|---|---|
| Acreage (million hectares) | | | | | |
| Planted | 35.7 | 37.2 | 39.4 | 38.6 | 36.8 |
| Harvested | 33.0 | 34.0 | 35.4 | 35.5 | 33.6 |
| Yield (mt/ha) | 9.6 | 9.2 | 7.7 | 10.0 | 10.9 |
| Supply (million metric tons) | | | | | |
| Beginning stocks | 43.4 | 28.6 | 25.1 | 20.9 | 31.4 |
| Production | 315.6 | 312.8 | 273.2 | 353.7 | 366.0 |
| Imports | 0.7 | 0.7 | 4.1 | 0.9 | 0.6 |
| Total Supply | 359.7 | 342.2 | 302.4 | 375.5 | 398.0 |
| Usage (million metric tons) | | | | | |
| Food, seed, other non-ethanol ind. use | 35.7 | 36.1 | 35.5 | 34.6 | 35.2 |
| Ethanol and co-products | 127.5 | 127.0 | 117.9 | 130.4 | 130.8 |
| Feed and residual | 121.3 | 114.8 | 109.6 | 130.4 | 136.5 |
| Exports | 46.5 | 39.1 | 18.5 | 48.7 | 44.5 |
| Total Use | 331.1 | 317.1 | 281.5 | 344.1 | 347.0 |
| Ending Stocks | 28.6 | 25.1 | 20.9 | 31.4 | 51.0 |
| Average Farm Price ($/mt*) | 203.93 | 244.87 | 271.25 | 175.58 | 122.04-145.66 |

| English Units | 10/11 | 11/12 | 12/13 | 13/14 | 14/15P |
|---|---|---|---|---|---|
| Acreage (million acres) | | | | | |
| Planted | 88.2 | 91.9 | 97.3 | 95.4 | 90.9 |
| Harvested | 81.4 | 83.9 | 87.4 | 87.7 | 83.1 |
| Yield (bu/ac) | 152.6 | 146.8 | 123.1 | 158.8 | 173.4 |
| Supply (million bushels) | | | | | |
| Beginning stocks | 1,708 | 1,128 | 989 | 821 | 1,236 |
| Production | 12,425 | 12,314 | 10,755 | 13,925 | 14,407 |
| Imports | 28 | 29 | 160 | 36 | 25 |
| Total Supply | 14,161 | 13,471 | 11,904 | 14,782 | 15,668 |
| Usage (million bushels) | | | | | |
| Food, seed, other non-ethanol ind. use | 1,407 | 1,421 | 1,397 | 1,363 | 1,385 |
| Ethanol and co-products | 5,019 | 5,000 | 4,641 | 5,134 | 5,150 |
| Feed and residual | 4,777 | 4,520 | 4,315 | 5,132 | 5,375 |
| Exports | 1,831 | 1,541 | 730 | 1,917 | 1,750 |
| Total Use | 13,033 | 12,482 | 11,083 | 13,546 | 13,660 |
| Ending Stocks | 1,128 | 989 | 821 | 1,236 | 2,008 |
| Average Farm Price ($/bu*) | 5.18 | 6.22 | 6.89 | 4.46 | 3.10-3.70 |

*P-Projected*
** Farm prices are weighted averages based on volume of farm shipment.*
*Average farm price for 14/15P based on WASDE November projected price.*

***Source: USDA WASDE and ERS***

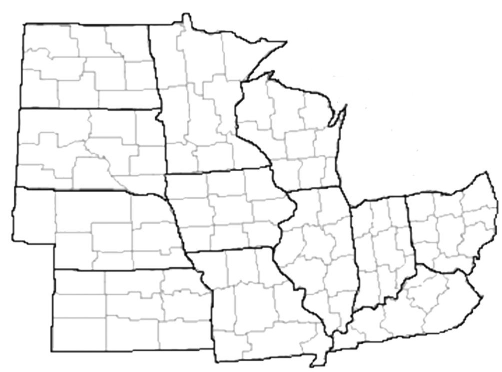
# VI. SURVEY AND STATISTICAL ANALYSIS METHODS

## A. Overview

The key points for the survey design and sampling and statistical analysis for this *Harvest Report 2014/15* are as follows:

- Following the methodology developed for the previous three Harvest Reports, the samples were proportionately stratified according to Agricultural Statistical Districts (ASDs) across 12 key corn-producing states representing 98.5% of U.S. corn exports.
- A total of 600 samples collected from the 12 states were targeted to achieve a maximum ±10% relative margin of error (Relative ME) at the 95% confidence level.
- A total of 629 unblended corn samples pulled from inbound farm-originated trucks were received from local elevators from September 20 through December 5, 2014, 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 182 samples being tested for aflatoxins and DON.
- 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 the quality factor results was less than ±10% except for three attributes – total damage, stress cracks and stress crack index (SCI). 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 2014 and 2013 and the 2014 and 2012 quality factor averages.

**Agricultural Statistical Districts (ASDs)**



## B. Survey Design and Sampling

### 1. Survey Design

For this *Harvest Report 2014/15*, the target population was yellow commodity corn from the 12 key U.S. corn-producing states representing about 98.5% of U.S. corn exports. 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 marketing 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 12 key corn-producing states representing 98.5% of U.S. corn exports (Source: USDA/GIPSA). 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 *Harvest Report 2014/15* differed from ASD to ASD because of the 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 *Harvest Report 2014/15* was a relative margin of error (Relative ME) no greater than ±10%, estimated with 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 17 quality factors evaluated for this year's corn crop were not known, the variance estimates from the *Harvest Report 2013/14* were used as proxies. The variances and ultimately the estimated number of samples needed for the Relative ME of ±10% for 14 quality factors were calculated using the 2013 results of 610 samples. Broken corn, foreign material, and heat damage were not examined. Stress crack index (SCI), with a Relative ME of 12%, was the only quality factor for which the Relative ME exceeded ±10% for the U.S. Aggregate. Based on these data, a total 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 SCI.

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 with a 95% level of confidence, was desired. Testing at least 25% of the total number of targeted 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 FDA action level of 20 parts per billion (ppb) would have a Relative ME less than or equal to ±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 less than or equal to ±10%, estimated with 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 total number of targeted samples (600) and at least one sample from each ASD, the targeted number of samples to test for mycotoxins was 181 samples.

## 2. Sampling

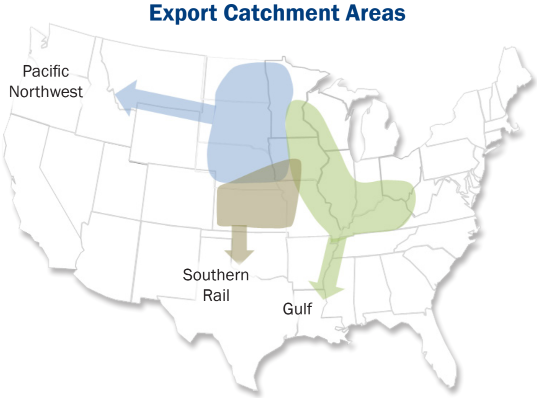
The ***random selection*** process was implemented by soliciting local grain elevators in the 12 states by mail, fax, e-mail and phone. Postage-paid sample kits were mailed to elevators agreeing to provide the 2050 to 2250-gram corn samples requested. Samples were collected from the elevators when at least 30% of the corn in their area had been harvested. The 30% harvest threshold was established to avoid receiving old crop corn samples as farmers cleaned out their bins for the current crop or new crop harvested earlier than normal for reasons such as elevator premium incentives. 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. A maximum of four samples from each physical location was collected. A total of 629 unblended corn samples pulled from inbound farm-originated trucks was received from local elevators from September 20 through December 5, 2014, 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 (PNW) ECA includes areas that export corn through Pacific Northwest and California ports; and
- The Southern Rail ECA comprises areas generally exporting corn to Mexico.

**Export Catchment Areas**




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.

New to this *Harvest Report 2014/15* is a simple average of the quality factors' averages and standard deviations of the previous three *Harvest Reports (2011/12, 2012/13 and 2013/14)*. These simple averages are calculated for the U.S. Aggregate and each of the three ECAs and are referred to as "3YA" in the text and summary tables of the report.

The Relative ME was calculated for each of the quality factors for the U.S. Aggregate and each of the ECAs. The Relative ME was less than ±10% for all the quality attributes except for SCI for the U.S. Aggregate and the Gulf and Southern Rail ECAs, and total damage, stress cracks and SCI for the Pacific Northwest ECA. The Relative ME for total damage, stress cracks and SCI was as follows:

| | Relative ME | | |
|---|---|---|---|
| | Total Damage | Stress Cracks | SCI |
| U.S. Aggregate | | | 11% |
| Gulf ECA | | | 11% |
| Pacific Northwest ECA | 11% | 12% | 16% |
| Southern Rail ECA | | | 14% |

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 "Grade Factors and Moisture" and "Physical 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 2014 and 2013 and 2014 and 2012 test results were validated by two-tailed t-tests at the 95% confidence level. The t-tests were calculated between results in the *Harvest Report 2012/13* and the *Harvest Report 2014/15* and the *Harvest Report 2013/14* and the *Harvest Report 2014/15.*

# VII. TESTING ANALYSIS METHODS

The corn 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 sample was split into two 1100-gram subsamples using a Boerner divider. The divider splits the complete sample into two 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) for grading. CDGI is the official grain inspection service provider for east-central Illinois as designated by USDA's 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.

## A. Corn Grading Factors

### 1. Test Weight

Test weight is a measure of the quantity of grain required to fill a specific volume (Winchester bushel). 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).

### 2. Broken Corn and Foreign Material (BCFM)

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

This test determines the amount of matter that passes through a 12/64th-inch round-hole sieve and all matter other than corn that remains on the top of the sieve. Broken corn is defined as all material passing through a 12/64th-inch round-hole sieve and retained on a 6/64th-inch round-hole sieve. Foreign material is defined as all material passing through the 6/64th-inch round-hole sieve and the coarse non-corn material retained on top of the 12/64th sieve. BCFM is reported as a percentage of the initial sample by weight.

### 3. Total Damage/Heat Damage

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

A representative working sample of 250 grams of BCFM-free corn is visually examined by a properly trained individual 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), surface mold, 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 properly trained individual 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 rises.

# C. Chemical Composition

## 1. NIR Proximate Analysis – Corn

Proximates are the major components of the grain. For corn, the NIR Proximate Analysis includes oil content, protein content, and starch content (or total starch). This procedure is nondestructive to the corn.

Chemical composition tests for protein, oil, and starch were conducted using a 400- to 450-gram sample in a whole-kernel Foss Infratec 1229 Near-Infrared Transmittance (NIT) instrument. The NIT was calibrated to chemical tests, and the standard error of predictions for protein, oil, and starch were about 0.2%, 0.3%, and 0.5%, respectively. Results are reported on a dry matter basis (percent of non-water material).

# D. Physical Factors

## 1. 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 $cm^3$/kernel. Kernel volumes usually range from 0.18-0.30 $cm^3$ 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 1.16 to 1.35 $g/cm^3$ at "as is" moistures of about 12 to 15%.

## 2. 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) 1 crack; (3) 2 cracks; and (4) more than 2 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 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.

### 3. 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 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%.

### 4. Horneous Endosperm

The horneous (or hard) endosperm test is performed by visually rating 20 externally sound kernels, placed germ facing up, on a light table. 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 70-100%, though most individual kernels fall in the 70-95% range.

## E. Mycotoxin Testing

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 rail car.

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 *Harvest Report 2013/14* assessment of mycotoxins is only to report the frequency of occurrences of the mycotoxin in the current crop, but not specific levels of the mycotoxin in corn exports.

To report the frequency of occurrences of aflatoxins and DON for the *Harvest Report 2013/14*, 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 109 BG and AQ 254 BG quantitative test kits were used for the aflatoxin and DON analysis, respectively. The DON was extracted with water (5:1), while the aflatoxins were extracted with 50% ethanol (2:1). 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 analytical methods developed for different types of mycotoxins and commodity combinations. The LOD for the EnviroLogix AQ 109 BG and AQ 254 BG are 2.5 parts per billion (ppb) for aflatoxins and 0.3 parts per million (ppm) for DON.

A letter of performance has been issued by FGIS for the quantification of aflatoxins and DON using the Envirologix AQ 109 BG and AQ 254 BG kits, respectively.

# VIII. U.S. CORN GRADES AND CONVERSIONS

## 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 |

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 |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