United States Soybean Quality

Annual Report 2016

Prepared for the US Soybean Export Council (USSEC) US Soy Outlook Conferences

November 2016

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SUMMARY

The US Soy Family, which includes the American Soybean Association, United Soybean Board, and US Soybean Export Council, has supported a survey of the quality of the US soybean crop since 1986. This survey is intended to provide new crop quality data to aid international customers with their purchasing decisions.

2016 ACREAGE, YIELDS, AND TOTAL PRODUCTION

According to the October 2016 United States Department of Agriculture, National Agricultural Statistics Service (USDA-NASS) Crop Production report, area harvested and yields will both increase from 2015. The total US soybean harvested area increased by 1.6% to 33.6 million hectares compared to 2015 (Table 1). Average yield increased 9% to 3.5 MT per hectare. Together, increased yields and area harvested will result in a US crop that is almost 8% higher than the record 2014 crop. The USDA expects the US crop to be 116.3 million MT. At the time of writing this report (November 1), we expect the November 9 Crop Production report to forecast even higher yields.

QUALITY OF THE 2016 US SOYBEAN CROP

Sample kits were mailed to 5,228 producers that were selected based on total land devoted to soybean production in each state, so that response distribution would closely match that of soybean production. By 24 October, 2016, 1,320 samples were received. These were analyzed for protein, oil, and amino acid concentration by near-infrared spectroscopy (NIRS) using a Perten DA7250 diode array instrument (Huddinge, Sweden) equipped with calibration equations developed by the University of Minnesota in cooperation with Perten. Regional and national average quality values were determined by computing weighted averages using state and regional soybean production data, so that average values best represent the crop as a whole. Results are in Tables 2 through 5.

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INTERPRETATION OF PROTEIN AND OIL RESULTS

Overall, when compared with the extraordinarily high quality 2015 crop, protein and oil concentrations noted in the 2016 crop were quite good (Table 2). Average protein concentration increased very slightly while oil concentrations were off by one half percentage point when compared with 2015. Although oil receded, the 2016 crop appears to produce on average oil concentration at the second highest level in the previous 10 years, and was one half percentage point higher than the average of the previous 10 years. Protein was 0.3 percentage points lower than the previous 10-year average. Compared with the long-term average (1986-2015), 2016 US soybeans were 0.7 of a point lower in protein, but 0.6 percentage points higher in oil.

The high oil levels noted again in 2016 should allow soybean processors to simultaneously achieve both good soybean oil yields and reasonable protein concentrations in the resulting soybean meal.

Protein and oil concentrations were unusually consistent across the US in 2015. The current year returns to a more normal variability in both protein and oil. Western Corn Belt states are expected to produce more than half of the total US soybean volume, and are therefore primary drivers of average US protein and oil values. Western Corn Belt states had average protein and oil concentrations that were 0.4 and 0.2 points lower, respectively, than the US average. Protein in Iowa and Missouri decreased by 0.3 points from 2015 to 2016, and oil concentrations in Minnesota and North Dakota decreased by 1.0 and 0.8 points respectively.

Protein and oil concentrations in the Eastern Corn Belt were both higher than the national average. Together, the Eastern Corn Belt states also fared a bit better with an increased protein concentration but an equal decrease (0.3 points) in oil compared to 2015. Protein increased in all states in the Eastern Corn Belt. Oil was reduced by 0.4 points in Michigan, Ohio, and Wisconsin compared to 2015.

As is often noted, Midsouth states had protein and oil concentrations that were higher than the national average; this year protein and oil were 0.8 and 0.4 points greater. Compared with 2015, the region saw protein increase by 0.6 and oil decrease by 0.5 points. These changes were fairly uniformly distributed across the region with Arkansas and Mississippi increasing protein by 0.5 points each and decreasing oil by 0.6 and 0.4 each, respectively.

Likely due to frequent rainfall through the early harvest period in the majority of soybean-producing states, the incoming moisture of 2016 samples (12.4%) was higher than the 2015 value at 11.6%. Although average incoming moisture was higher in 2016 than in the previous year, there was less variability in the data. Samples with moisture above 13% could be found in all major soybean-producing states.

INTERPRETATION OF SEED SIZE AND FOREIGN MATERIAL RESULTS

While seed size may not be important for most commodity soybean purchasers, seed size does provide some insight into the environmental conditions present during the production season. In general, environmental stresses such as drought in the early seed-filling period (late July and early August) tend to reduce the number of seeds on individual plants; if conditions return to normal, these remaining seeds can expand, resulting in larger than average seed size. Alternatively, stresses at the end of the seed-filling period (late August through September) reduce the energy available for each seed and seed size may be smaller than average. Average seed size increased from 15.8 grams per 100 seeds in 2015 to 16.3 in 2016 (Table 3). As is normally noted when there are hot conditions during the latter part of the growing season, seed size was smallest in the Midsouth and Southeast regions. States in the Eastern Corn Belt produced larger seeds, on average, as is the long-term trend. North and South Dakota had exceptionally large soybeans due to late season rainfall with above average temperatures. Missouri and Arkansas produced soybeans with relatively small seed size for their respective regions due to excess rainfall during the later stages of seed filling.

The distribution of rainfall is the single most important driver of soybean yields in the US. In northern ranges of US soybean production, yields can be constrained by excess early-season rainfall and/or limited rainfall during seed filling. However, in the south US, late summer rainfall can lead to greatly increased disease pressure that can reduce seed size and yields.

Foreign material (FM) found in 2016 US samples was, on average, very low at 0.1%, with regional averages ranging from 0.1 to 0.3%. Of the 1,320 samples, 98.3% of them (1,298 samples) had FM values below 1%, 1.3% (17 samples) had 1-2% FM, and only 0.4% of them (5 samples) had >2% FM.

AMINO ACIDS

Amino acids are the "building block" organic compounds linked in various combinations to form unique proteins. In human diets, amino acids are supplied by the variety of plant and animal proteins ingested. In animal feed, amino acids come from feed proteins such as soybean meal, and possibly from synthetic amino acid supplements. Soybean meal is the major feed protein source in poultry, swine, and cultured fish diets because of its high nutritional quality including its balanced amino acid profile. Optimal animal performance occurs when the feed protein contains an ideal amount and proportion of all essential amino acids (those amino acids which cannot be produced by animals) – this is an "ideal protein".

In a recent study, Ravindran et al. (2014) found crude protein to be a poor predictor of overall feed quality of soybean meal. In a comparison of soybean meal from US and other origins, US soybean meal had lower protein content than Brazilian soybean meal, but better quality of protein – higher concentrations of essential amino acids (Park and Hurburgh, 2002; Thakur and Hurburgh, 2007; Bootwalla, 2009). In whole soybeans, lower crude protein beans have a higher proportion of the five most critical essential amino acids (lysine, cysteine, methionine, threonine, and tryptophan), indicating that meal made from those soybeans will likely be of

higher feed quality for a given feed ration than meal made from higher crude protein soybeans (Thakur and Hurburgh, 2007; Medic et al., 2014; Naeve unpublished data).

In 2016, amino acid results varied a bit by state and region. Lysine (expressed as a percent of the 18 primary amino acids) (Table 4) tended to be highest in the Western Corn Belt and lowest in the Midsouth. There were similar regional differences in the sum of the five most limiting amino acids (also known as CAAV), cysteine, lysine, methionine, threonine, and tryptophan, with the WCB at 14.6; ECB, MDS, and EC at 14.4; and SE at 14.5. Regional differences alone do not fully explain amino acid concentration differences in the samples; when we evaluated the samples based on protein level rather than region, we found that **the protein in lower protein samples is more concentrated in the five critical amino acids than is the protein in higher protein samples**. Thus, protein concentration differences may account for much of the amino acid concentration differences across regions, rather than region *per se*. The higher concentration of critical limiting amino acids is a key differentiation of US soybeans over those from Brazil (Naeve, unpublished). We support complete and independent analysis of soybeans, soybean meal, and feeds throughout the value chain to ensure that the end user has access to the highest quality feed, not based on protein alone, but the full quality package that includes amino acid balance, energy, and more.

WEATHER AND CROP SUMMARY

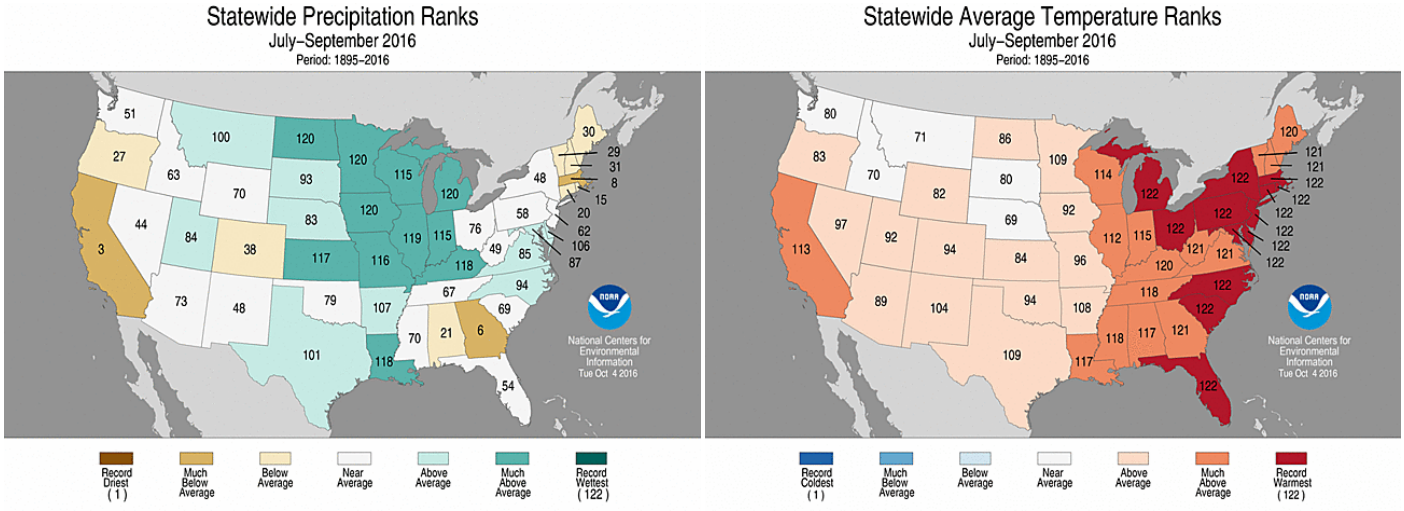
Planting: Average temperatures in the Midwest were above normal and precipitation varied, even within states. Areas in parts of MI, MO, the Ohio Valley (OH, IN, IL, WV, PA, and KY), and western IA experienced above normal precipitation, while parts of MN, eastern IA, MO, and IL were drier than normal early in the season. Higher than average rainfall erased the early-season drought in the central and southern Plains. In the Midwest overall, weather was generally favorable for planting; planting was mostly complete by early June and was ahead of the 5-year average in most soybean-producing states.

Mid-Season: The entire US experienced its warmest June on record. Average minimum temperatures were in the top 10 warmest for all Midwestern states except MN. Rainfall in early July broke records in MO, IL, IN, and KY. July rainfall in the Midwestern states of MN, WI, KY, IN, IL, and MI ranked in the top 10 wettest. Ohio rainfall was well below normal for July and August, and the Southeast experienced significant drought conditions all season. By the end of August, 94% of the US soybeans were at or beyond pod setting stage, well ahead of average.

Harvest: The Midwest experienced its 7th warmest September since 1895 and above average temperatures continued through October. Widespread flooding occurred in the first part of September in IA, MN, and WI, but some states in the region were below normal for rainfall. By the end of October, more than three-quarters of the nation's soybean crop was harvested, slower than last year but on par with the 5-year average.

Overall, weather during the 2016 growing season was generally wetter and warmer than normal in most primary soybean-producing states.

Weather Figure 1.



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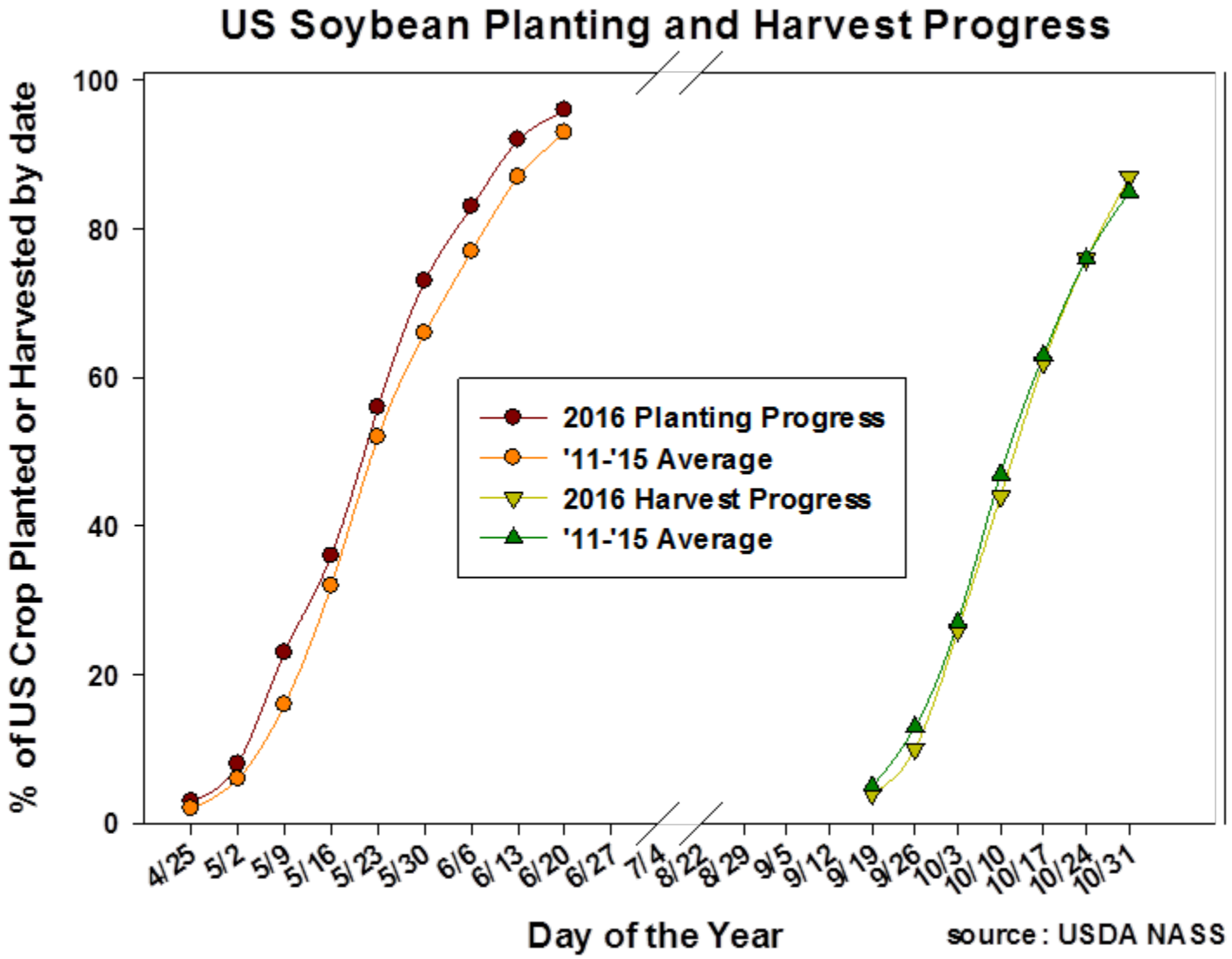

Figure 1

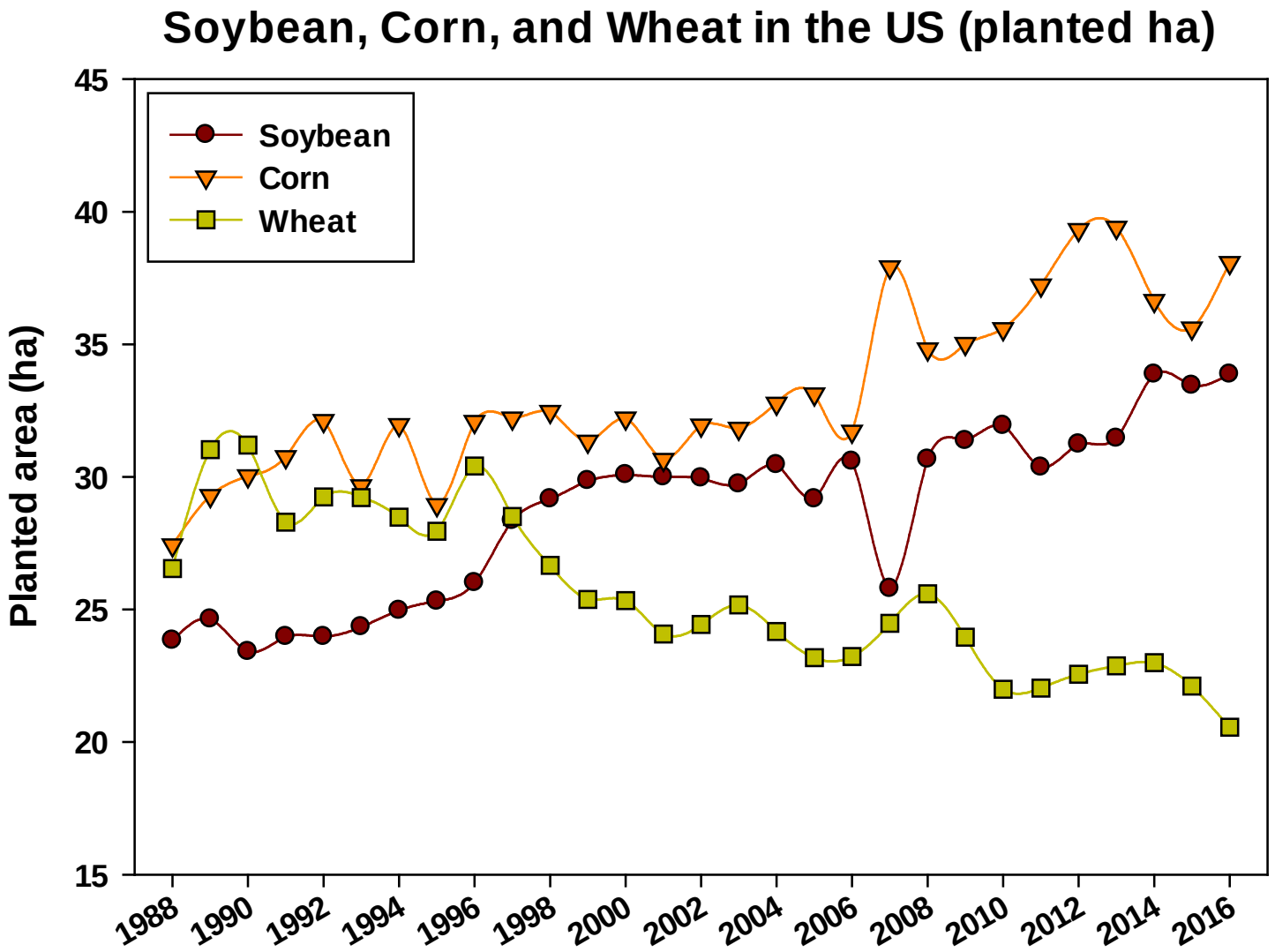
Soybean, Corn, and Wheat in the US (planted ha)
Planted area (ha)
45
40
35
30
25
20
15
Soybean
Corn
Wheat
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Figure 2

QUALITY REPORT: 2016

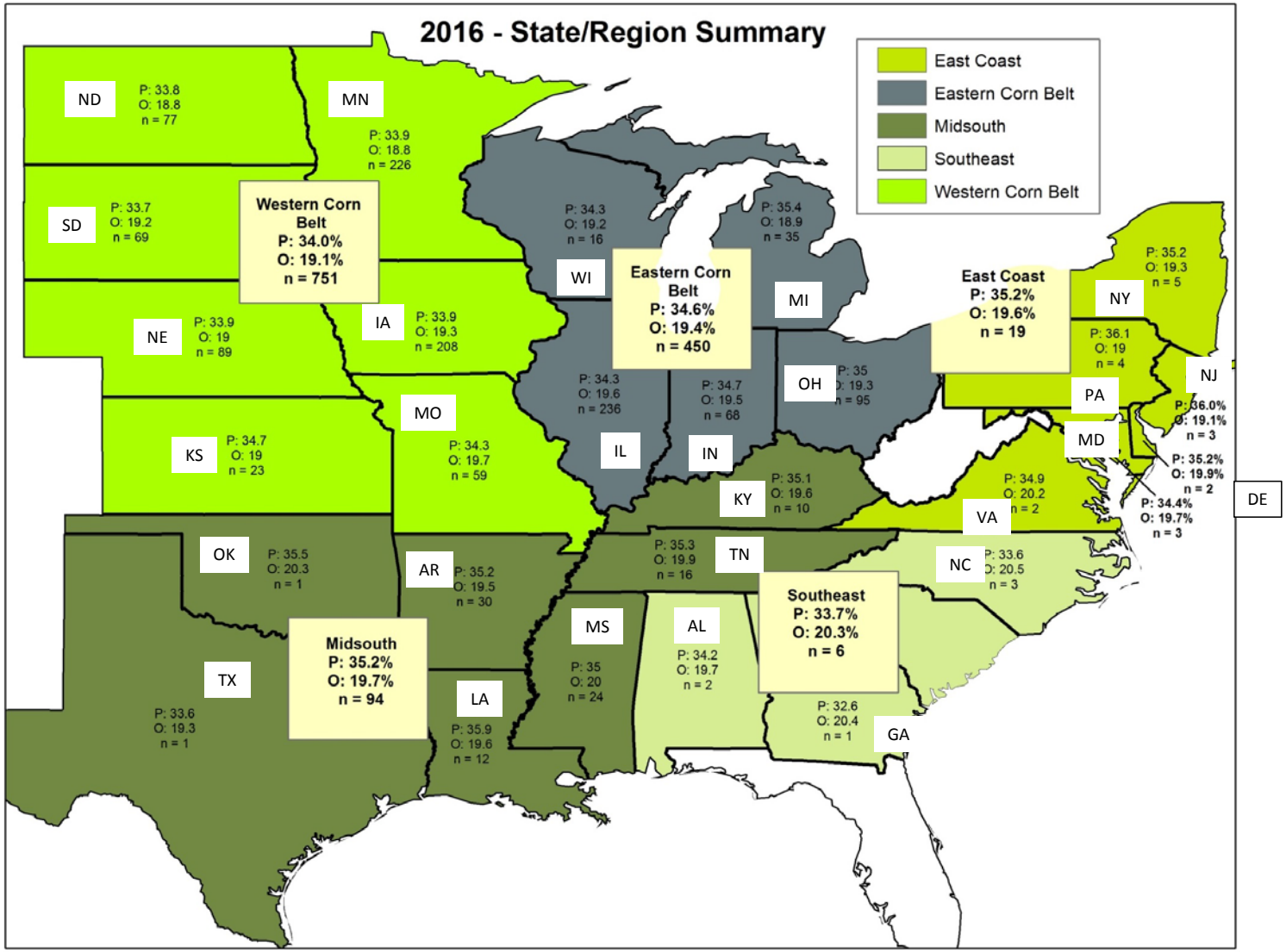

Figure 3

Table 1. Soybean production data for the United States, 2016 crop

Region	State	Yield (MT ha^{-1})	Area Harvested (1000 ha)	Production (M MT)
Western Corn Belt (WCB)	Iowa	3.9	3,848	15.0
	Kansas	3.0	1,624	4.9
	Minnesota	3.3	3,058	10.1
	Missouri	3.4	2,248	7.6
	Nebraska	4.1	2,086	8.6
	North Dakota	2.6	2,434	6.4
	South Dakota	3.1	2,094	6.5
	Western Corn Belt	3.3	17,391	59.0
				50.7%
Eastern Corn Belt (ECB)	Illinois	4.2	4,070	17.0
	Indiana	4.0	2,300	9.1
	Michigan	3.2	846	2.7
	Ohio	3.6	1,960	7.0
	Wisconsin	3.5	790	2.8
	Eastern Corn Belt	3.7	9,967	38.5
				33.1%
Midsouth (MDS)	Arkansas	3.2	1,264	4.1
	Kentucky	3.4	725	2.4
	Louisiana	3.3	490	1.6
	Mississippi	3.2	822	2.7
	Oklahoma	1.8	190	0.3
	Tennessee	3.1	664	2.1
	Texas	1.8	59	0.1
	Midsouth	2.8	4,214	13.3
				11.4%
Southeast (SE)	Alabama	2.3	166	0.4
	Georgia	2.7	103	0.3
	North Carolina	2.6	676	1.7
	South Carolina	2.3	166	0.4
	Southeast	2.5	1,112	2.8
				2.4%
East Coast (EC)	Delaware	2.8	68	0.2
	Maryland	3.0	209	0.6
	New Jersey	2.7	40	0.1
	New York	2.8	132	0.4
	Pennsylvania	3.0	237	0.7
	Virginia	2.6	243	0.6
	East Coast	2.8	928	2.6
				2.3%
US 2016		3.5	33,634	116.3
US 2015		3.2	33,101	107.0

Source: United States Department of Agriculture, NASS 2016 Crop Production Report (October 2016)

Table 2. USSEC 2016 Soybean Quality Survey Data

Region	State	Number of Samples	Protein (%)*	Std. Dev.	Oil (%)*	Std. Dev.
Western Corn Belt (WCB)	Iowa	208	33.9	1.0	19.3	0.6
	Kansas	23	34.7	1.0	19.0	0.7
	Minnesota	226	33.9	1.0	18.8	0.6
	Missouri	59	34.3	1.2	19.7	0.6
	Nebraska	89	33.9	1.1	19.0	0.8
	North Dakota	77	33.8	1.2	18.8	0.5
	South Dakota	69	33.7	1.1	19.2	0.8
Averages†	Western Corn Belt	751	34.0	1.1	19.1	0.6
Eastern Corn Belt (ECB)	Illinois	236	34.3	1.1	19.6	0.7
	Indiana	68	34.7	1.1	19.5	0.8
	Michigan	35	35.4	1.6	18.9	0.8
	Ohio	95	35.0	1.1	19.3	0.7
	Wisconsin	16	34.3	0.9	19.2	0.4
Averages†	Eastern Corn Belt	450	34.6	1.1	19.4	0.7
Midsouth (MDS)	Arkansas	30	35.2	1.7	19.5	0.8
	Kentucky	10	35.1	0.8	19.6	0.6
	Louisiana	12	35.9	1.0	19.6	0.7
	Mississippi	24	35.0	1.6	20.0	0.7
	Oklahoma	1	35.5		20.3	
	Tennessee	16	35.3	1.2	19.9	0.7
	Texas	1	33.6		19.3	
Averages†	Midsouth	94	35.2	1.3	19.7	0.7
Southeast (SE)	Alabama	2	34.2	1.3	19.7	0.4
	Georgia	1	32.6		20.4	
	North Carolina	3	33.6	2.5	20.5	1.0
	South Carolina	0				
Averages†	Southeast	6	33.7	2.3	20.3	0.9
East Coast (EC)	Delaware	2	35.2	0.8	19.9	0.8
	Maryland	3	34.4	0.1	19.7	0.5
	New Jersey	3	36.0	1.4	19.1	0.4
	New York	5	35.2	1.0	19.3	0.5
	Pennsylvania	4	36.1	1.6	19.0	0.9
	Virginia	2	34.9	0.6	20.2	0.6
Averages†	East Coast	19	35.2	0.8	19.6	0.6
US	Averages	1,320	34.3		19.3	
	Average of 2016 Crop†		**34.4**	**1.1**	**19.3**	**0.7**
	US 2006-2015 avg.†		34.7	1.4	18.8	1.0

* 13% moisture basis

† Regional, US, and 10-year average values weighted based on estimated production by state as estimated by USDA, NASS Crop Production Report (October 2016)

Table 3. USSEC 2016 Soybean Quality Survey Seed Data

Region	State	Number of Samples	Seed Weight g 100 seeds^{-1}	Std. Dev.	Foreign Material (%)	Std. Dev.
Western Corn Belt (WCB)	Iowa	208	16.0	1.5	0.1	0.2
	Kansas	23	16.4	1.7	0.1	0.1
	Minnesota	226	16.8	1.5	0.2	0.4
	Missouri	59	15.3	1.7	0.1	0.2
	Nebraska	89	16.4	1.5	0.1	0.2
	North Dakota	77	16.9	1.8	0.1	0.1
	South Dakota	69	17.4	1.4	0.1	0.2
Averages†	Western Corn Belt	751	16.4	1.6	0.1	0.2
Eastern Corn Belt (ECB)	Illinois	236	16.4	1.6	0.2	0.5
	Indiana	68	17.2	1.7	0.1	0.1
	Michigan	35	18.0	2.4	0.1	0.1
	Ohio	95	17.9	1.7	0.1	0.1
	Wisconsin	16	17.4	2.0	0.0	0.1
Averages†	Eastern Corn Belt	450	17.1	1.7	0.1	0.3
Midsouth (MDS)	Arkansas	30	13.8	1.4	0.4	0.5
	Kentucky	10	14.7	1.2	0.1	0.1
	Louisiana	12	16.2	2.1	0.5	0.7
	Mississippi	24	14.5	1.4	0.3	0.3
	Oklahoma	1	16.3		0.0	
	Tennessee	16	14.4	1.8	0.2	0.1
	Texas	1	13.3		0.0	
Averages†	Midsouth	94	14.5	1.5	0.3	0.3
Southeast (SE)	Alabama	2	13.5	0.5	0.1	0.1
	Georgia	1	14.9		0.0	
	North Carolina	3	14.9	2.2	0.2	0.3
	South Carolina	0				
Averages†	Southeast	6	14.6	1.9	0.2	0.3
East Coast (EC)	Delaware	2	16.0	0.7	0.0	0.0
	Maryland	3	14.1	0.6	0.2	0.2
	New Jersey	3	13.4	1.5	1.2	1.8
	New York	5	18.6	2.2	0.0	0.0
	Pennsylvania	4	16.1	0.9	0.1	0.1
	Virginia	2	12.7	0.8	0.0	0.0
Averages†	East Coast	19	15.0	1.0	0.1	0.1
USA	Averages	1,320	16.5		0.1	
	Average of 2016 Crop†		**16.3**	**1.6**	**0.1**	**0.2**

† Regional and US average values weighted based on estimated production by state as estimated by USDA, NASS Crop Production Report (October 2016)

Table 4. USSEC 2016 Soybean Quality Survey Amino Acid (AA) Data

Region	State	Number of Samples	Protein (%)*	Lysine (%18 AAs)	5 EAAs‡ (%18 AAs)
Western Corn Belt (WCB)	Iowa	208	33.9	6.8	14.6
	Kansas	23	34.7	6.8	14.5
	Minnesota	226	33.9	6.8	14.6
	Missouri	59	34.3	6.7	14.5
	Nebraska	89	33.9	6.8	14.6
	North Dakota	77	33.8	6.7	14.6
	South Dakota	69	33.7	6.8	14.7
Averages†	Western Corn Belt	751	34.0	6.8	14.6
Eastern Corn Belt (ECB)	Illinois	236	34.3	6.7	14.5
	Indiana	68	34.7	6.7	14.4
	Michigan	35	35.4	6.7	14.4
	Ohio	95	35.0	6.6	14.4
	Wisconsin	16	34.3	6.7	14.5
Averages†	Eastern Corn Belt	450	34.6	6.7	14.4
Midsouth (MDS)	Arkansas	30	35.2	6.6	14.4
	Kentucky	10	35.1	6.6	14.5
	Louisiana	12	35.9	6.4	14.1
	Mississippi	24	35.0	6.6	14.4
	Oklahoma	1	35.5	6.7	14.6
	Tennessee	16	35.3	6.6	14.4
	Texas	1	33.6	6.8	14.6
Averages†	Midsouth	94	35.2	6.6	14.4
Southeast (SE)	Alabama	2	34.2	6.7	14.5
	Georgia	1	32.6	6.9	14.9
	North Carolina	3	33.6	6.7	14.5
	South Carolina	0			
Averages†	Southeast	6	33.7	6.7	14.5
East Coast (EC)	Delaware	2	35.2	6.4	14.2
	Maryland	3	34.4	6.8	14.5
	New Jersey	3	36.0	6.4	14.1
	New York	5	35.2	6.5	14.3
	Pennsylvania	4	36.1	6.5	14.3
	Virginia	2	34.9	6.9	14.6
Averages†	East Coast	19	35.2	6.7	14.4
USA	Averages	1,320	34.3	6.7	14.5
	Average of 2016 Crop†		**34.4**	**6.7**	**14.5**

* 13% moisture basis

† Regional and US average values weighted based on estimated production by state as estimated by USDA, NASS Crop Production Report (October 2016)

‡ Five essential amino acids (also known as CAAV): cysteine, lysine, methionine, threonine, and tryptophan

Table 5. Historical Summary of Yield and Quality Data for U.S. Soybeans

Year	Yield (kg ha^{-1})	Protein* (%)	Oil* (%)	Sum† (%)	Harvested (M ha^{-1})	Production (M MT)	Protein Std. Dev.	Oil Std. Dev.
1986	2241	35.8	18.5	54.3	23.6	52.9	1.4	0.7
1987	2281	35.5	19.1	54.6	23.2	52.8	1.6	0.7
1988	1817	35.1	19.3	54.4	23.2	42.2	1.5	0.8
1989	2173	35.2	18.7	53.9	24.1	52.4	1.5	0.8
1990	2295	35.4	19.2	54.6	22.9	52.5	1.2	0.7
1991	2301	35.5	18.7	54.1	23.5	54.0	1.4	0.9
1992	2530	35.6	17.3	52.8	23.6	59.6	1.4	1.0
1993	2194	35.7	18.0	53.8	23.2	50.9	1.2	0.9
1994	2786	35.4	18.2	53.6	24.6	68.6	1.4	0.9
1995	2375	35.5	18.2	53.6	24.9	59.2	1.4	0.9
1996	2530	35.6	17.9	53.5	25.7	64.9	1.3	0.9
1997	2618	34.6	18.5	53.0	28.0	73.2	1.5	1.0
1998	2618	36.1	19.1	55.3	28.5	74.6	1.5	0.8
1999	2456	34.6	18.6	53.2	29.4	72.1	1.9	1.1
2000	2557	36.2	18.7	54.9	29.6	75.6	1.7	0.9
2001	2651	35.0	19.0	54.0	30.0	79.6	2.0	1.1
2002	2490	35.4	19.4	54.8	29.1	72.2	1.6	0.9
2003	2288	35.7	18.7	54.3	29.4	67.2	1.7	1.2
2004	2826	35.1	18.6	53.7	30.0	84.6	1.5	0.9
2005	2893	34.9	19.4	54.3	29.2	83.4	1.5	0.9
2006‡	2873	34.5	19.2	53.7	30.2	86.8	1.6	1.0
2007‡	2806	35.2	18.6	53.9	26.0	72.9	1.2	0.8
2008‡	2644	34.1	19.1	53.2	30.1	79.6	1.4	0.8
2009‡	2961	35.3	18.6	53.9	30.9	91.5	1.2	0.9
2010‡	2954	35.0	18.6	53.6	31.1	91.9	1.4	1.2
2011‡	2793	34.9	18.1	53.0	29.8	83.4	2.2	1.8
2012‡	2678	34.3	18.5	52.8	30.8	82.6	1.6	0.9
2013‡	2961	34.7	19.0	53.7	30.9	91.5	1.1	1.0
2014‡	3196	34.4	18.6	53.0	33.8	107.8	1.3	0.9
2015‡	3176	34.3	19.8	54.1	33.1	105.9	1.1	0.8
2016‡	3459	34.4	19.3	53.7	33.6	116.3	1.1	0.7
Averages (2006-2015)	**2904**	**34.7**	**18.8**	**53.5**	**30.7**	**89.4**	**1.4**	**1.0**
Averages (1986-2015)	**2599**	**35.1**	**18.7**	**53.8**	**27.7**	**72.9**	**1.5**	**0.9**

Sources: US Dept. of Agriculture, Iowa State University, and University of Minnesota

*Protein and oil concentrations expressed on a 13% moisture basis

†Sum represents sum of protein and oil concentrations

‡2006 - 2016 quality estimates are weighted by yearly production estimates by state

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