



Carbon Footprint Study

Topline Information

December 2023



Carbon Footprint Study

Study Background

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Study Background & Purpose



- In 2012, The United Sorghum Checkoff Program developed a model to analyze the carbon footprint of sorghum used for ethanol production based on information obtained from sorghum growers. This information was collected in an extensive study over time and included the following:
 - Sorghum acres – including both irrigated and non-irrigated acres in the past five years; seeding rate; crop acres preceding 2012 sorghum.
 - Sorghum inputs (brands and acres treated) - including fertilizer, herbicide, insecticides, fungicides, and seed treatments.
 - Sorghum outputs - including yields, sorghum stubble for grazing, and bale.
 - Field operations (type of operation and sorghum acres covered) – including specific tillage practices; fertilizer, herbicide, insecticide and fungicide application methods; planting methods, cultivation methods, and harvest methods.
 - Energy use (type and quantity) – including energy for drying; energy for irrigation; residual energy; energy for delivery.

- In 2020, the United Sorghum Checkoff Program confirmed the model estimates using some of the primary predictors from the 2012 Sorghum Carbon Footprint Study. Figures were updated in May of 2022. Now the United Sorghum Checkoff Program is interested in obtaining updated information for 2023. Thus, the current study will gather information from growers, to confirm estimates and verify near-future estimates of sorghum’s carbon footprint.

- Specifically, this study will gather the following information about sorghum production for both non-irrigated and irrigated acres for the years 2021, 2022, and 2023:
 - Sorghum production acres (seeding rates and crop acres)
 - Yields
 - Tillage practices (no-till, minimum/strip-till, and conventional till acres)
 - Crop inputs (nitrogen fertilizers, phosphate potash, etc., application rates and acres treated)
 - Soil test frequency
 - Crop rotation
 - Soil type

- To gather information used in this study, phone interviews were conducted with 104 sorghum growers in Kansas in December 2023. Kansas was selected due to its high concentration of sorghum growers and high sorghum output. Kansas produces half of all sorghum acres grown in the U.S. (50% or 3.6 million out of 7.2 million). To participate in this study, growers had to meet the following criteria:
 - Have input into decisions about sorghum for their farming operation.
 - Not employed by or affiliated with advertising, sales promotion, market research or public relations organizations/companies.
 - Planted at minimum of 50 sorghum acres in 2023.

- To get a representative sample of sorghum growers across Kansas, counties were divided into three regions: Central, East and West (see appendix for a list of counties in each region). Soft quotas were imposed on each region. Below is the number of interviews completed in each region versus the quota.

- Two growers reported the county as the USA. Also, two growers reported acres over 5,000. Some results in this report exclude these growers from the analysis due to their disproportionate influence on stated results.

	Sampled Growers		Acres Represented		
	Desired	Completed	# of Acres Represented*	% of Acres Represented	% of Acres Irrigated
Central	63	64	28,465	36%	3%
East/Others*	2	7	4,220	5%	18%
West	36	33	46,450	59%	7%
Total	101	104	79,135	100%	6%

* Two sorghum growers listed USA as the county.



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Sorghum Production

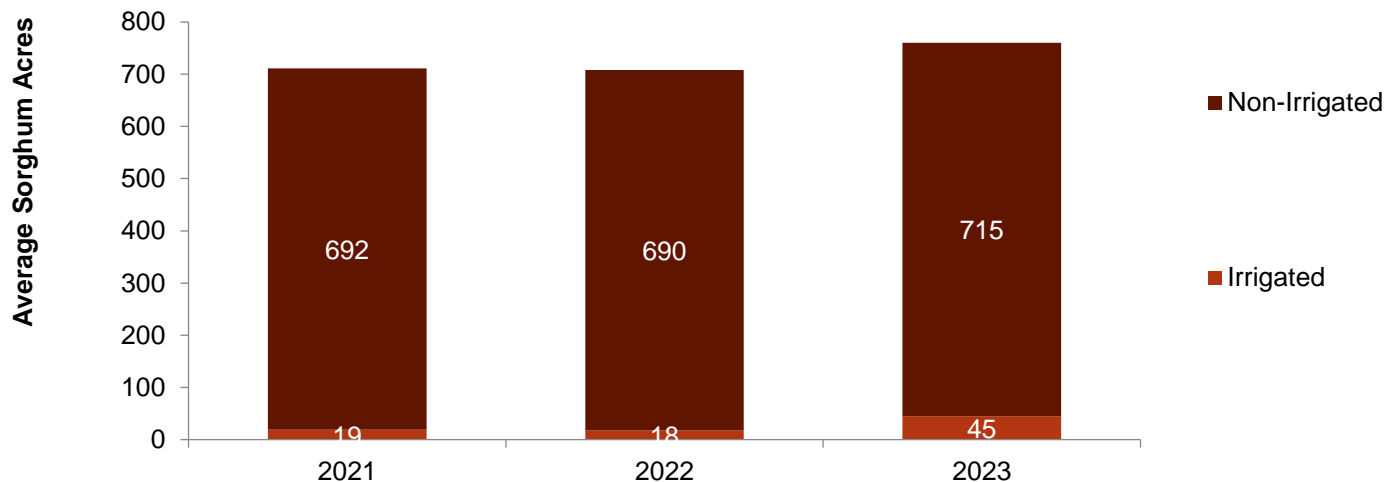
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Sorghum Acres Planted



- Growers in this study planted on average 762 sorghum acres in 2023, including two growers who planted 5,500 and 7,500 sorghum acres (see Appendix for results excluding these growers). The average number of irrigated sorghum acres increased in 2023 from the previous two years among growers who planted sorghum in the respective years. Historically, irrigated sorghum has accounted for about 5% of sorghum all acres, however, results below show in 2021 and 2022, irrigated sorghum accounted for only 3% of planted sorghum acres.

Average Irrigated and Non-irrigated Sorghum Acres*



Average Sorghum Acres*	656	662	762
% of All Sorghum Acres that are Irrigated	3%	3%	6%
Base	104	104	104

Source: How many [irrigated/non-irrigated] sorghum acres did you plant in the following years?

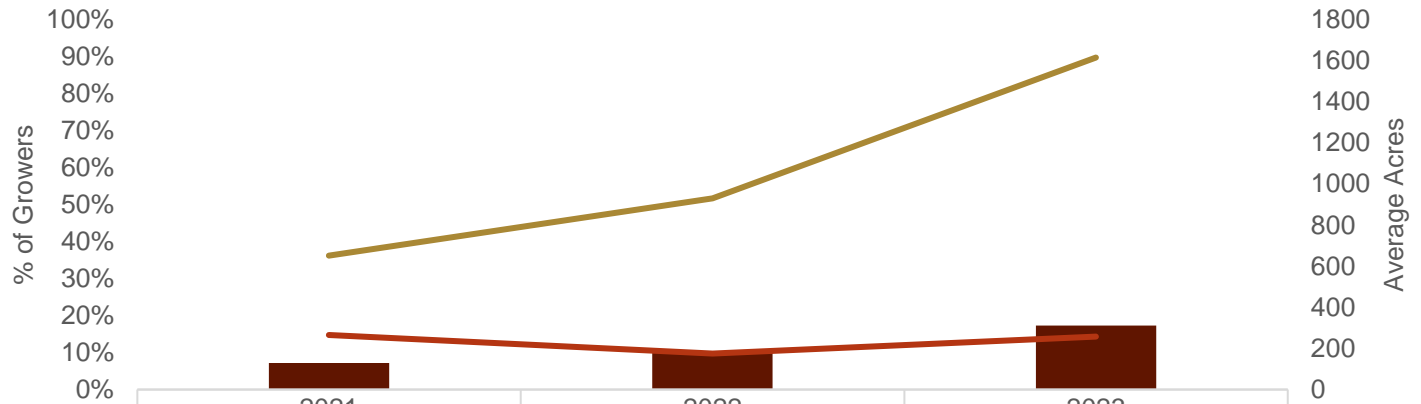
*Includes 0

Irrigation in Sorghum



- About 17% of growers had irrigated sorghum in 2023, a significant increase over the previous two years.

Average Acres Among Growers with Irrigated Sorghum Acres *



	2021	2022	2023
% Growers With Irrigated Sorghum	7%	10%	17%
Average Acres Irrigated	266	175	258
Average Acres Non-Irrigated	651	930	1613
<i>% of Growers</i>	100	100	100
<i>Average Irrigated</i>	6	6	7
<i>Average non-irrigated</i>	97	96	100

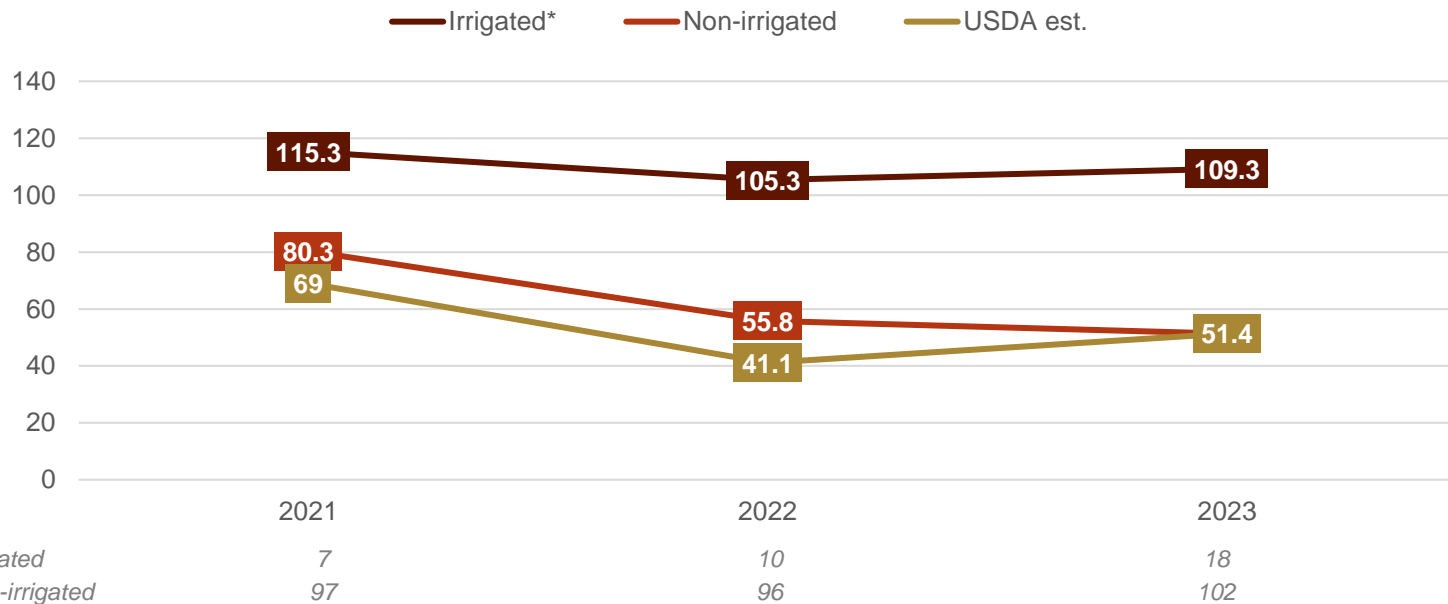
Source: Were any of your sorghum acres irrigated in [insert year]? How many [irrigated/non-irrigated] sorghum acres did you plant in the following years?
 *Caution due to small sample sizes. Excludes 0's.

Sorghum Yields



- Non-irrigated sorghum yields dropped in 2022 by about 30% fewer bushels from 80 bu/acre in 2021 to 56 bu/acre in 2022. In 2023, non-irrigated sorghum yields declined by about 8%, compared to 2022. USDA shows a similar trend between 2021 and 2022 but shows sorghum growers produced 25% more bushels per acre in 2023 than in 2022.

Average Sorghum Yields (Bushels per Acre) by Year
Among All Sorghum Growers



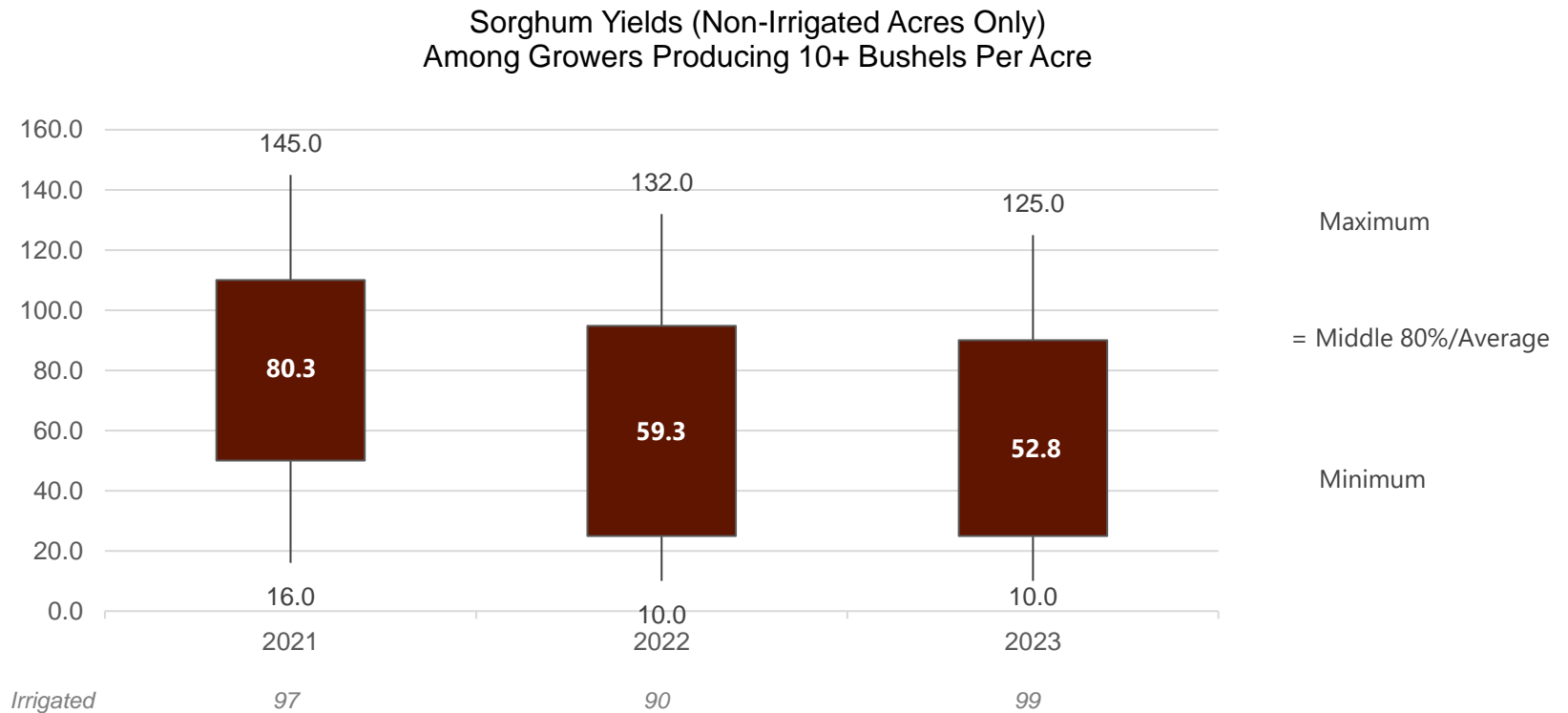
Source: What was your average sorghum/milo yield for your [irrigated/non-irrigated] sorghum in the following years?
Sorghum yields include 0's (i.e., growers who reported planting sorghum, but said they had 0 yields.)

* Caution due to small sample size.

Sorghum Yields (Non-Irrigated Acres Only)



- Growers over the past two years have produced on average about 56 bushels per acre of sorghum on non-irrigated land. However, yields vary widely with most growers (80%) reporting yields between 25 and 95 bushels per acre.



Source: What was your average sorghum yield in bushels per acre or pounds per acre for your [non-irrigated] sorghum in the following years?



Carbon Footprint Study

Planting & Tillage Practices

December 2023

Average Seeding Rates

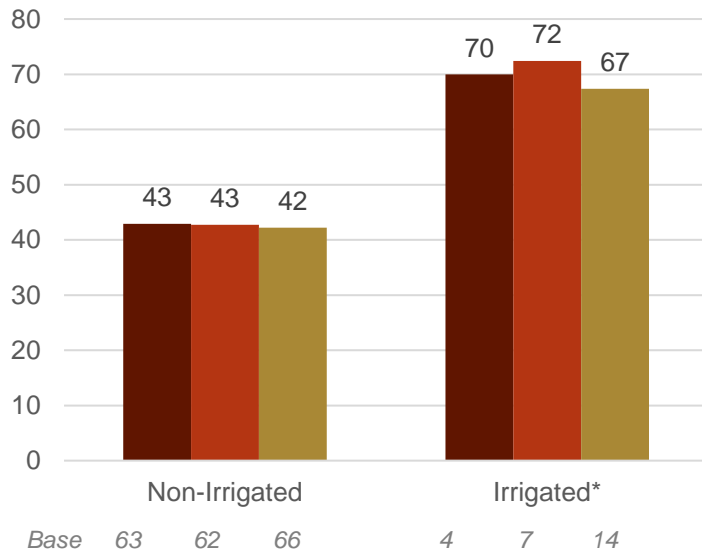


- On average, sorghum growers planted about 42,000 seeds per acre on their non-irrigated acres or about 5 to 6 pounds of sorghum seed per acre. This amount has been consistent over the past three years.

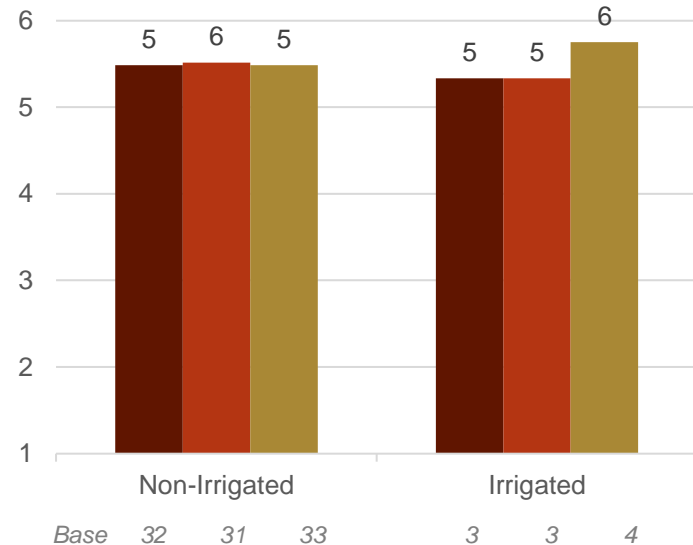
Average Sorghum Seeding Rate by Year

■ 2021 ■ 2022 ■ 2023

Seeds Per Acre (Thousands)



Pounds of Seed Per Acre*



Source: Do you plant your sorghum/milo in seeds per acre or pounds per acre? What was the seeding rate in for your [irrigated/non-irrigated] sorghum/milo in the following years?

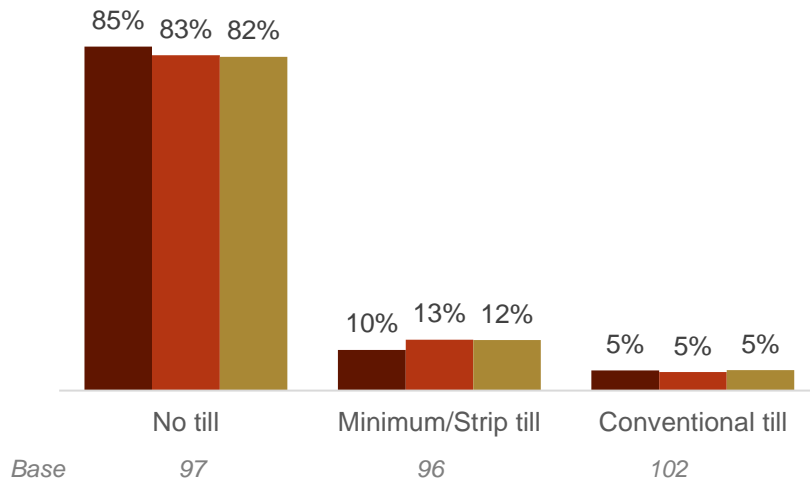
* Caution due to small sample.

Tillage Practices

- Consistently year over year, roughly 80% of non-irrigated sorghum acres are no-till. Strip-till accounts for 10% to 12% of non-irrigated sorghum acres and conventional till accounts for 5% of non-irrigated sorghum acres.

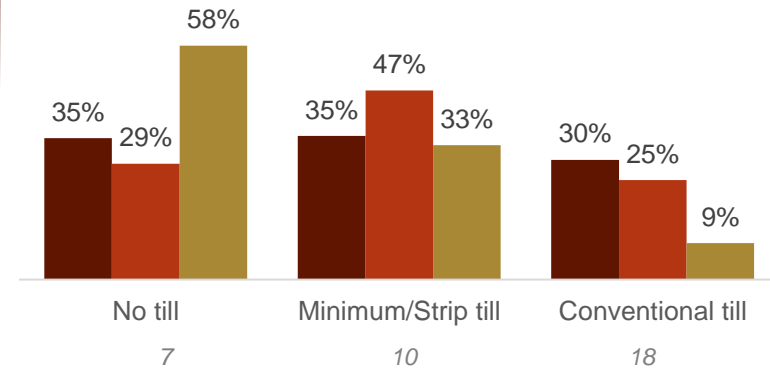
Percent of **Non-Irrigated** Sorghum Acres On Which Tillage Practice is Used by Year

■ 2021 ■ 2022 ■ 2023



Percent of **Irrigated** Sorghum Acres On Which Tillage Practice is Used by Year*

■ 2021 ■ 2022 ■ 2023



Source: How many of your sorghum acres were no till, minimum/strip till or conventional tillage in [year]?

* Caution due to small sample.



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Nutrient/Nitrogen Use

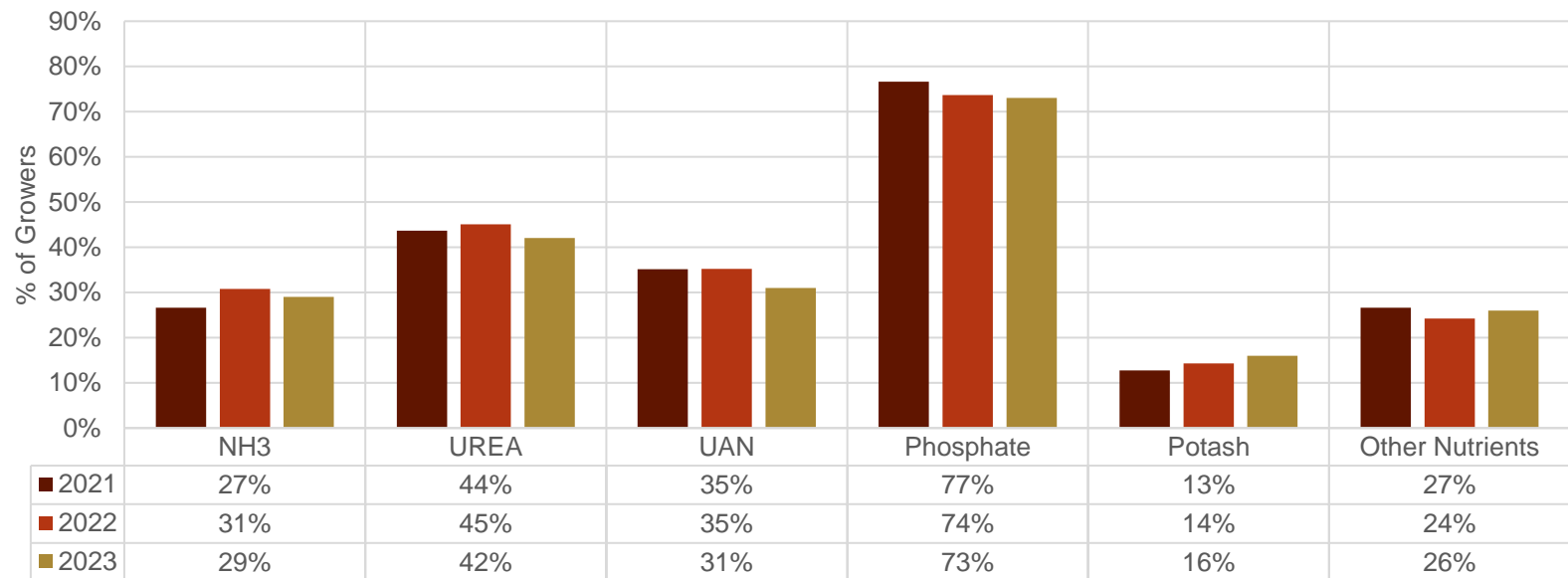
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Nutrient Use on Non-Irrigated Sorghum



- The chart below shows the percent of growers who use nutrients on their *non-irrigated* sorghum acres.
 - UREA was used by 42% of sorghum growers in 2023, followed by UAN (31% of growers) and NH3 (29% of growers). This hierarchy has been fairly consistent over the past three years.
 - Results suggest phosphate use may be declining while potash use is increasing slightly.
 - Other nutrients include sulfur, zinc, phosphorus, potassium, etc.

Nutrient Use on Growers **Non-Irrigated** Sorghum in Indicated Years



Bases: 2021=94, 2022=91, 2023=100.

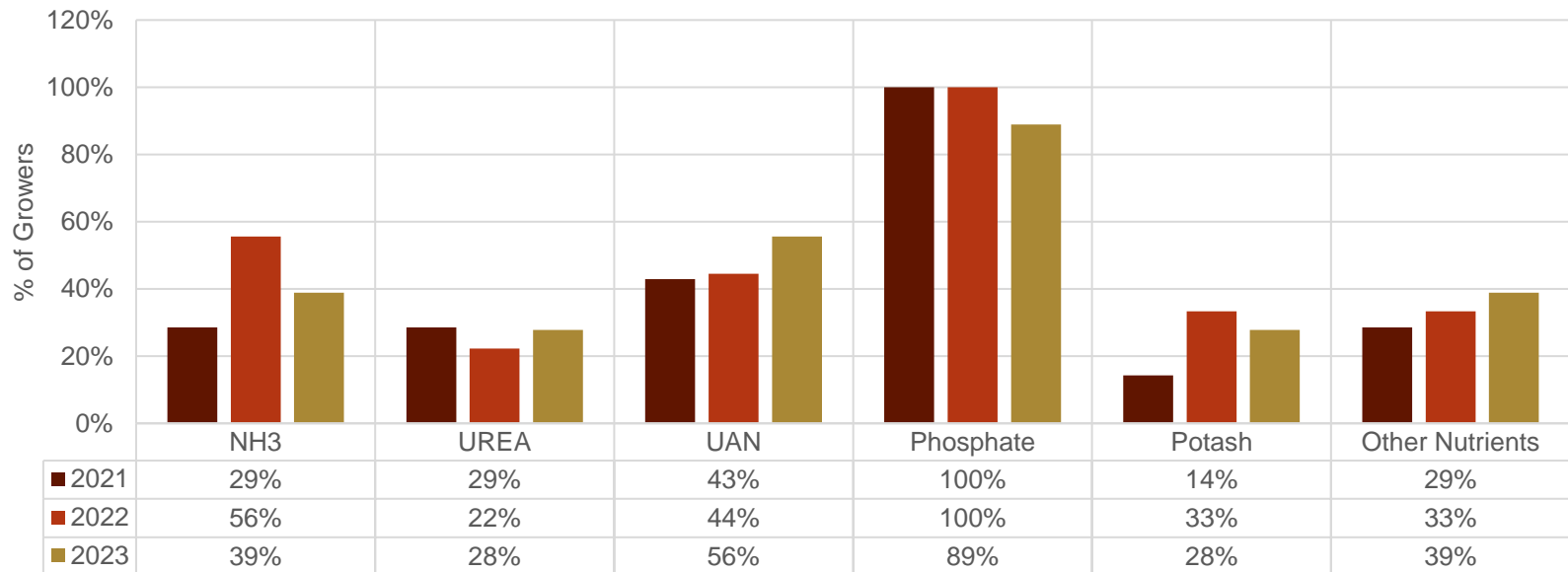
Source: Which, if any, of the following nutrients were applied to your NON-IRRIGATED (DRYLAND) sorghum/milo acres in the following years?

Nutrient Use on Irrigated Sorghum



- The chart below shows the percent of growers who use nutrients on their irrigated sorghum acres. The sample size for growers with irrigated sorghum acres is low so the reader should exercise caution in projecting results.
 - UAN is the second most used nutrient behind phosphate on *irrigated* sorghum acres.

Nutrient Use on Growers **Irrigated** Sorghum in Indicated Years*



Bases: 2021=7, 2022=9, 2023=18.

Source: Which, if any, of the following nutrients were applied to your IRRIGATED sorghum/milo acres in the following years?

*Caution due to small sample sizes.

Units of Application Rate Used by Nutrient



- Most growers apply nutrients in pounds per acre. Growers who apply UAN also use gallons per acre (34% of growers with non-irrigated sorghum and 40% of growers with irrigated sorghum).

Unit of Application Rates Used*

Non-Irrigated	Gallons/ Acre	Tons/ Acre	Pounds/ Acre	Pounds of elemental nitrogen /bushel	Other/ Can'	Base
NH3	0%	3%	90%	0%	7%	30
UREA	6%	0%	73%	19%	2%	48
UAN	34%	0%	57%	9%	0%	35
Phosphate	20%	0%	71%	8%	1%	79
Potash	6%	0%	89%	6%	0%	18
Irrigated	Gallons/ Acre	Tons/ Acre	Pounds/ Acre	Pounds of elemental nitrogen /bushel	Other	
NH3	0%	0%	78%	0%	22%	9
UREA	0%	0%	86%	14%	0%	7
UAN	40%	0%	40%	10%	10%	10
Phosphate	17%	0%	78%	0%	6%	18
Potash	0%	0%	80%	0%	20%	5

Source: What unit do you use to quantify the application rate for the following nutrients on your [irrigated/non-irrigated] sorghum
 *Caution due to small sample sizes.

Nitrogen Fertilizer Types by Usage



- The table below shows the share of nitrogen applied attributable to three different nitrogen fertilizer types. Given the acres treated with each nutrient, UREA and UAN account for most of nitrogen applied to sorghum (83%).

% Attributable to Nutrient**

Non-Irrigated	2021	2022	2023	<i>Min. Base</i>
NH3	17%	20%	21%	24,27,28
UREA	42%	40%	43%	41,41,42
UAN	41%	40%	36%	32,31,30
Irrigated*	2021	2022	2023	
NH3	23%	37%	26%	2,5,5
UREA	41%	23%	18%	2,2,4
UAN	36%	40%	56%	4,4,7

Source: At what rate did you apply the following nutrients to your [irrigated/non-irrigated] sorghum/milo acres in the following years? How many of your [irrigated/non-irrigated] sorghum/milo acres were treated with the following nutrients at the rate specified in the following years?

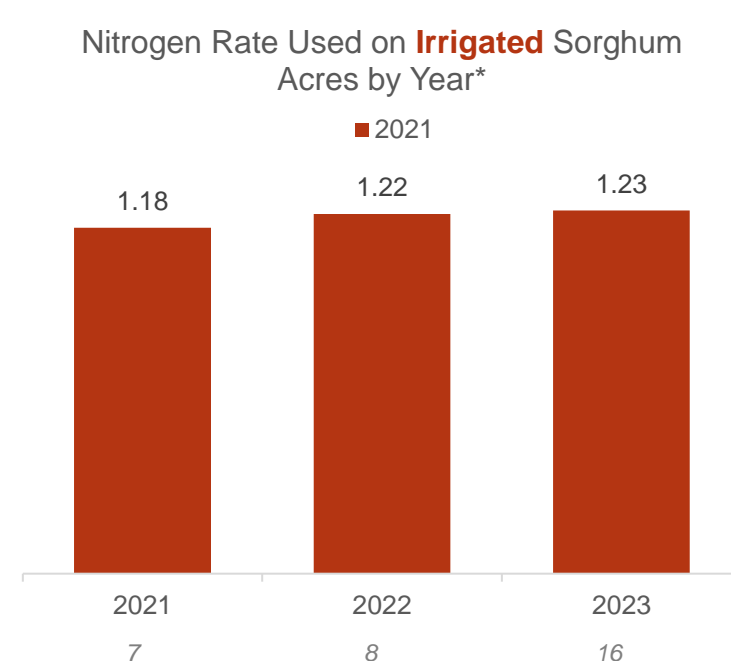
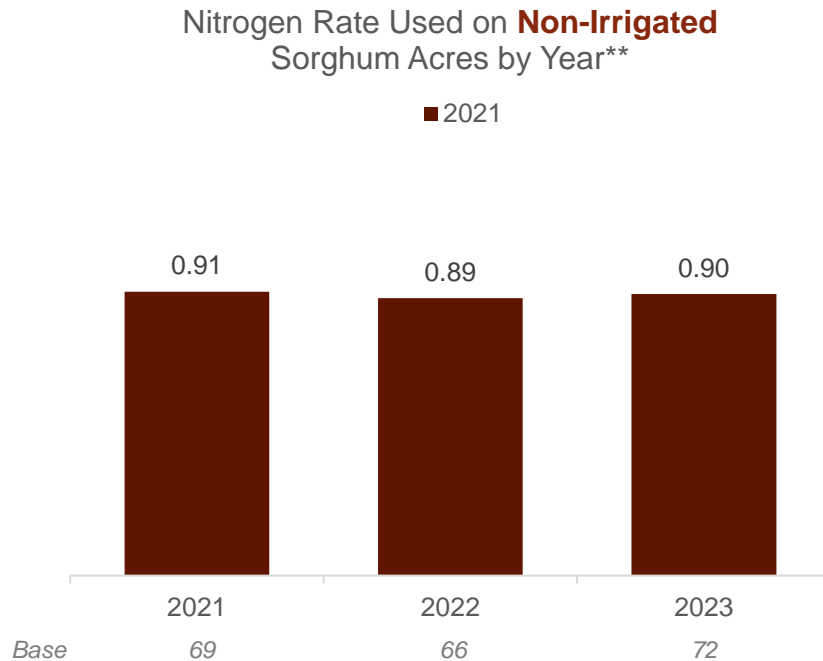
*Caution due to small sample sizes.

**Two growers with 5,500 and 7,500 sorghum acres were excluded from acres information due to skew potential.

Average Nitrogen Rates Used



- Sorghum growers apply a higher rate of nitrogen to their irrigated sorghum than their non-irrigated sorghum. In general, growers apply roughly .90 pounds per bushel to their non-irrigated sorghum and 1.2 pounds per bushel to their irrigated sorghum.



Source: What is your rate for nitrogen minus soil residual nitrogen on your [irrigated/non-irrigated] sorghum/milo acres? For context, a recent study found a target rate of 0.91 pounds per bushel minus any soil residual nitrogen (N).

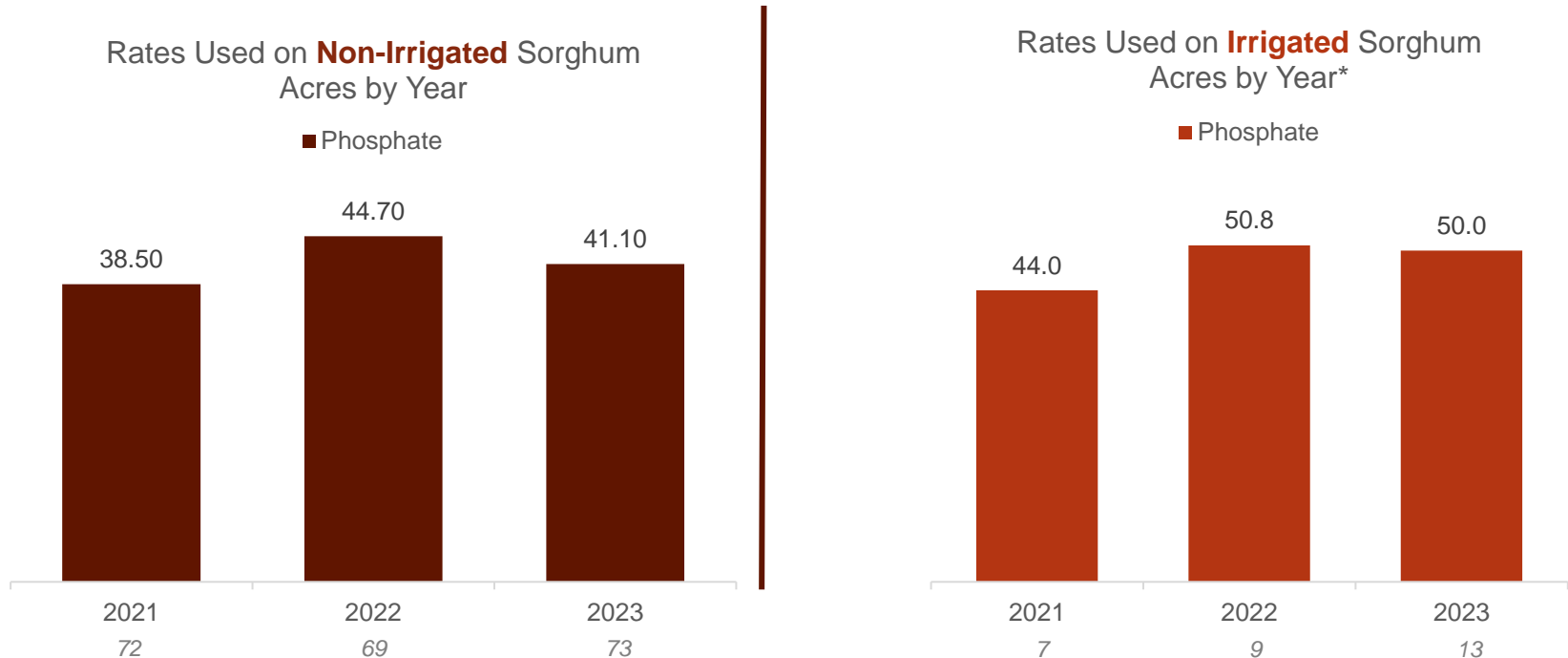
*Caution due to small sample sizes.

**One grower who reported a rate of 4.0 on non-irrigated acres was removed from results in the chart above.

Phosphate Rates Used



- On average, phosphate has been applied to about 70% of users' non-irrigated sorghum acres over the past few years at an average rate of about 41 lbs./acres, with slight fluctuations from year to year. Few sorghum growers apply potash to their sorghum acres, and the few that did were excluded to mitigate skew.



Source: At what rate did you apply the following nutrients to your [irrigated/non-irrigated] sorghum/milo acres in the following years? How many of your [irrigated/non-irrigated] sorghum/milo acres were treated with the following nutrients at the rate specified in the following years?

*Caution due to small sample sizes.

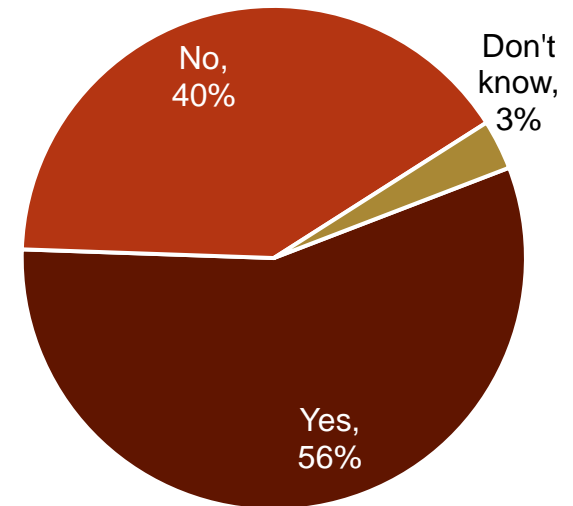
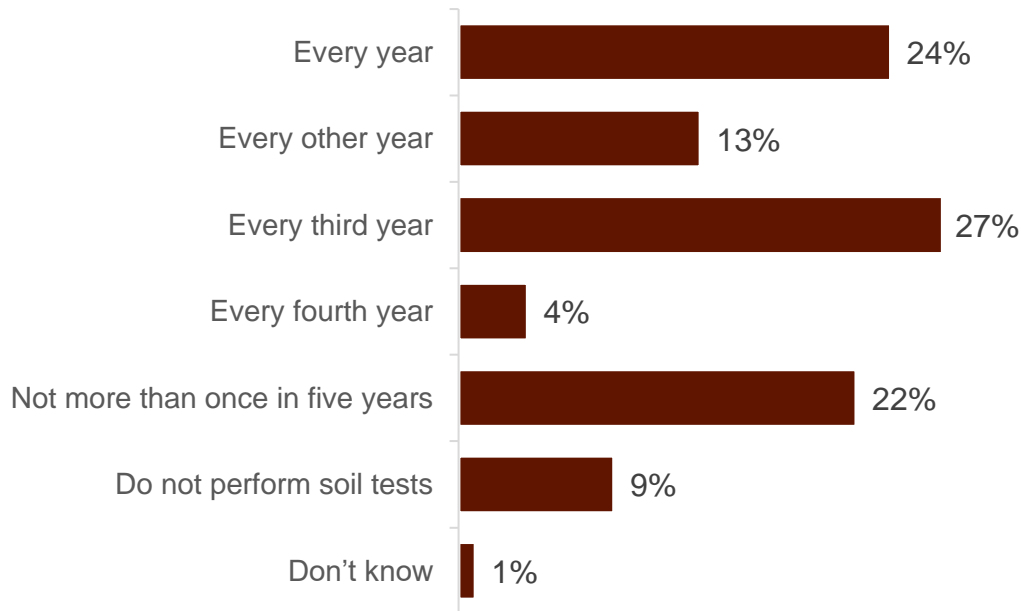


Other Farm Information

Soil Tests



- About 37% of growers perform soil tests at least every other year, mostly annually (24%), 73% of growers perform soil tests at least once every three years, and less than 10% of growers report they do not perform soil tests.
- Among growers who report performing soil tests, most growers (56%) subtract residual nitrogen from their nitrogen application rate.



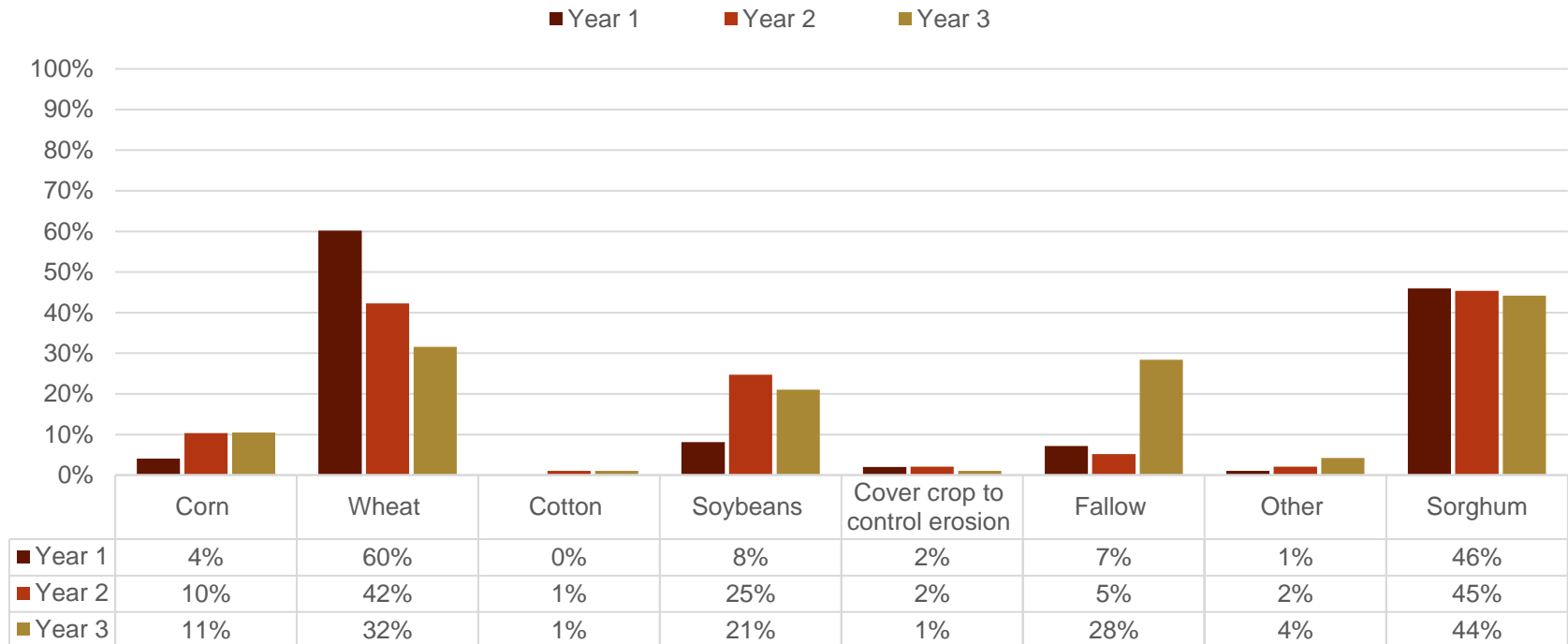
Source: (Left) How often do you perform soil tests? (Right) Based on soil test results, do you subtract residual nitrogen from your nitrogen application rate?

Crop Rotation



- Wheat is the crop that typically follows sorghum for the single largest portion of growers. Similar results were observed in the 2022 study.

Rotational Crops

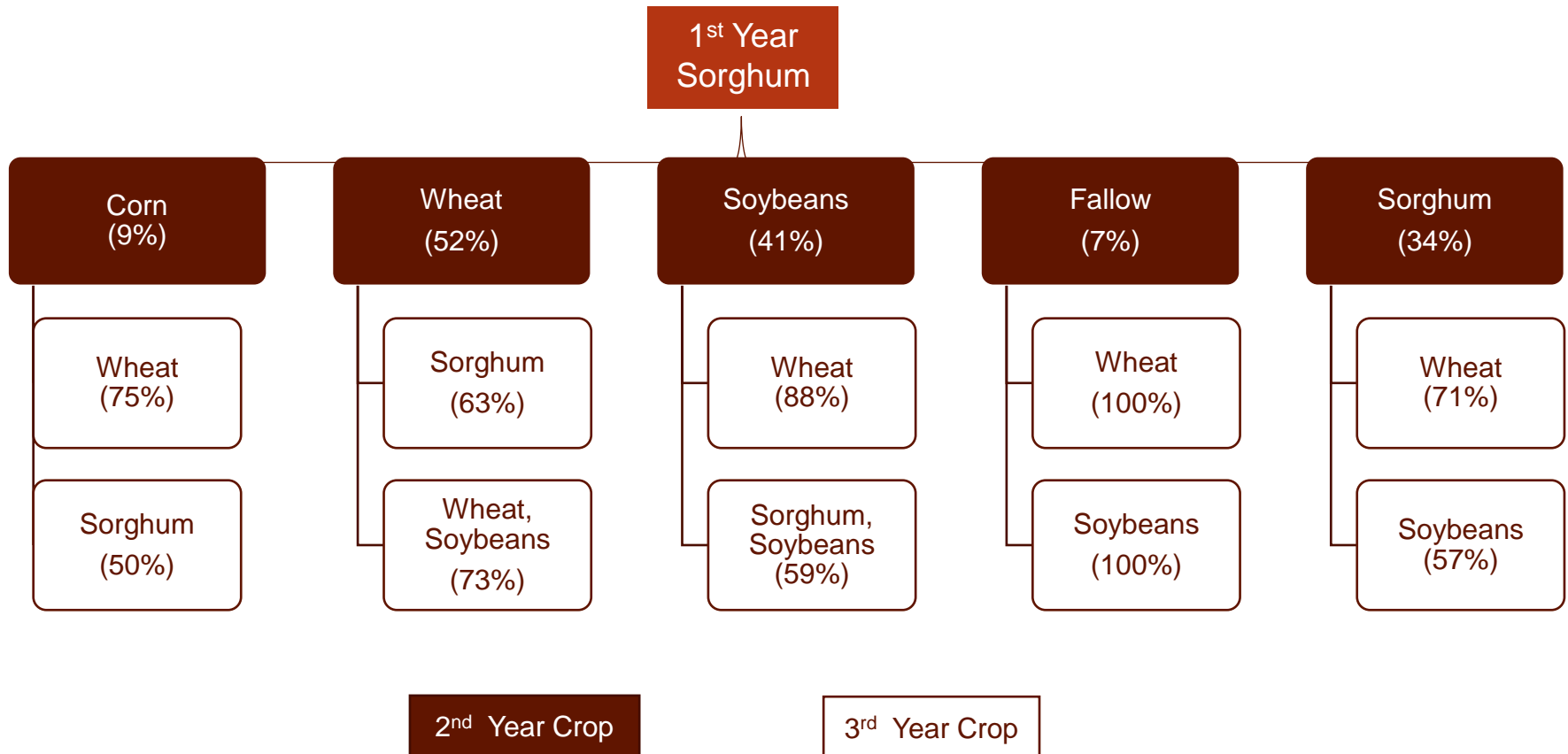


Minimum Base =98.

Source: Common Kansas rotational systems include sorghum-wheat and sorghum-soybeans. What is your typical sorghum rotation?

1st and 2nd Year Crop Rotations

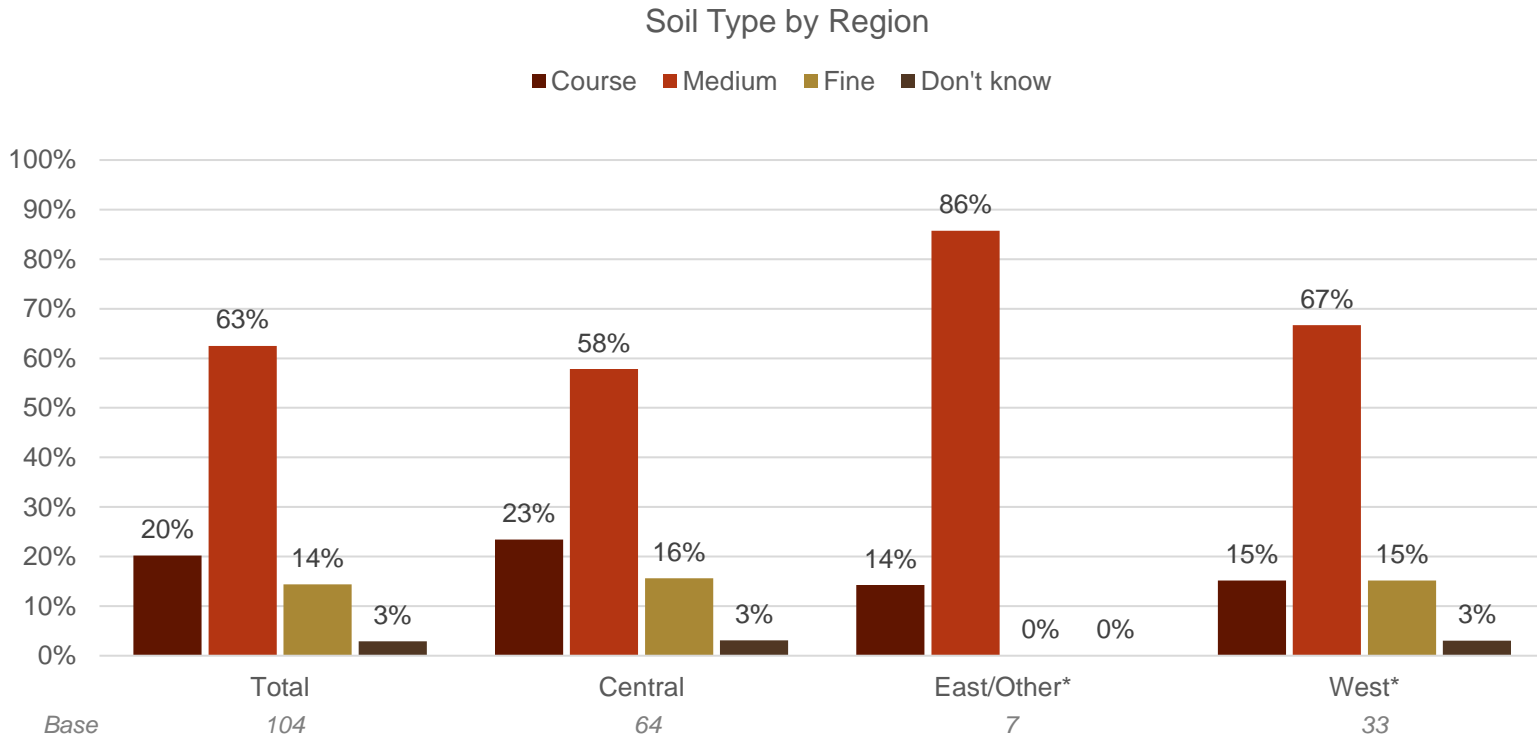
- The diagram below shows crops following sorghum in the first year followed by the two most mentioned second year crops. The highest portion of growers plant wheat (52%) or soybeans (41%) following sorghum in the first year. Half of growers who plant soybeans following sorghum plant wheat in the second year following sorghum.



Source: Common Kansas rotational systems include sorghum-wheat and sorghum-soybeans. What is your typical sorghum rotation?

Soil Type

- Most growers describe their soil type as medium. This is especially true in the Western counties.



Source: How would you define your typical soil type---course, medium or fine?

*Caution due to small bases.



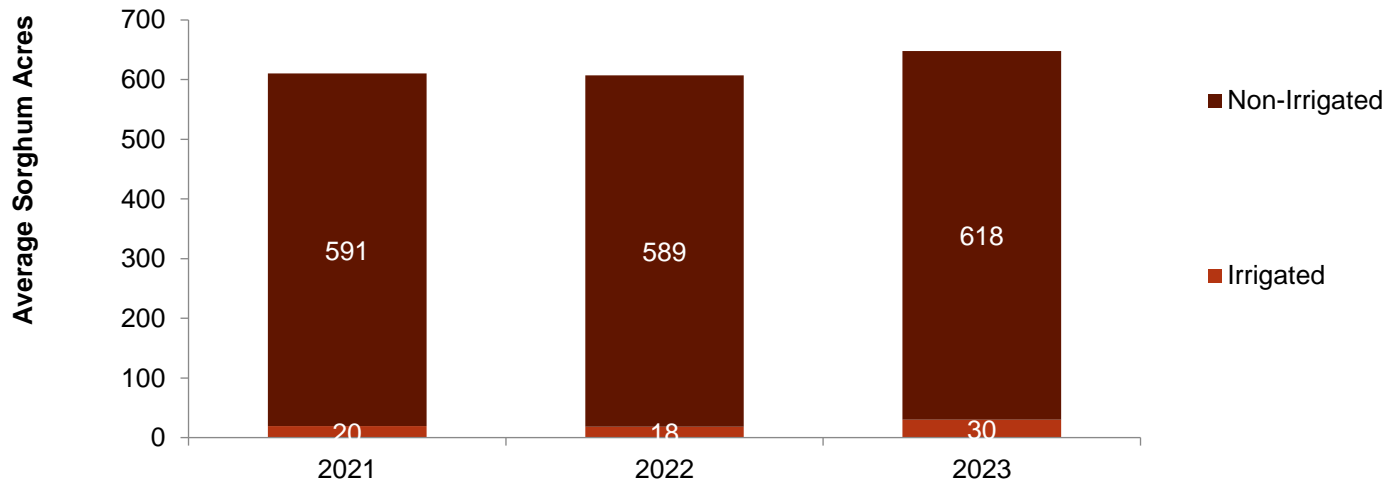
Appendix

Sorghum Acres Planted



- The figures in the chart below exclude two growers each of whom planted over 5,000 sorghum acres. Growers in this study planted on average 618 sorghum acres in 2023, excluding two growers who planted 5,500 and 7,500 sorghum acres. The average number of irrigated sorghum acres increased in 2023 from the previous two years among growers who planted sorghum in the respective years. Historically, irrigated sorghum has accounted for about 5% of all sorghum acres and results show this remains true in 2023.

Average Irrigated and Non-irrigated Sorghum Acres*



Average Sorghum Acres*	561	567	650
% of All Sorghum Acres that are Irrigated	3%	3%	5%
Base	102	102	102

Source: How many [irrigated/non-irrigated] sorghum acres did you plant in the following years?

*Includes 0