Section 2: Fertilizer Rate Decisions and Soil Testing Methods

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Applying the appropriate rate of fertilizer is essential to optimize crop production while minimizing potential negative effects from excess nutrient applications. Farmers now have several avenues to obtain information to make fertilizer and application rate decisions including various soil and crop testing measurements, land grant university recommendations, private industry tools, and many more. It is important to understand what sources of information farmers utilize in making nutrient management decisions to assist extension and other government agencies in creating and promoting the use of nutrient management tools that are based on scientific evidence. South Dakota (SD) has varying moisture conditions with greater precipitation in the east and decreasing going west. Tillage systems and soil textures also vary across the state. In this chapter we will evaluate the results from the 2019 nutrient management survey to help us better understand the local factors that influence the use of different types of information to make fertilizer rate decisions and the use and methodology of soil testing. Local factors evaluated include geographic location within SD, tillage type, and farm size, as well as age and education of the responding farmer.

Information Used to Make Nutrient Rate Decisions

Nitrogen

To determine nitrogen (N) fertilizer rate guidelines in SD, an algorithm was developed using the factors of yield potential, preplant soil test N to a depth of 2 feet, previous crop credit, manure application credit, and tillage type (Clark et al., 2019). Among all respondents, yield potential and preplant soil test N were used the most frequently to determine fertilizer-N rates (68% and 74%, respectively) while the remaining three factors were used less than 48% of the time. (Figure 1). The use of soil test N is important as recent SD research and other regions of the US suggests it can reduce fertilizer-N needs by an average of 50 lbs N ac-1 without reducing yield. Following the use of yield potential and soil test N to determine fertilizer-N rate recommendations were the use of previous crop credit (48%), manure credit (25%), and tillage type (16%) (Figure 1).

Location and tillage factors were associated with the use of some factors used to make fertilizer-N rate decisions, but farm size was not (Table 1). Only the use of previous crop and manure credit factors varied by location and only previous crop credit by tillage. Farmers in eastern relative to central SD used both previous crop and manure credits approximately 10% more often to make fertilizer-N rate decisions. The main climate and management practice differences in eastern and central SD (precipitation and tillage type) did not seem likely to be related to the use of previous crop or manure credit. Another potential reason for the difference may be the greater number of farmers in eastern compared to central SD that grew legumes (73% vs. 59%) or applied manure (55% vs. 43%) who would be more likely to consider themselves as using these credits. Previous crop credit was utilized

more in N rate decisions among no-till and reduced-till farmers (56% and 71%, respectively) compared to conventional-till farmers (48%). These results indicate that geographic location and tillage system are related to recommended 4R practices for fertilizer-N and should be further studied to better understand how and why these factors affect adoption. The impact of the previous crop, manure, and tillage factors on the accuracy of fertilizer-N recommendations and reduced fertilizer costs needs to be emphasized in educational programming to help increase their usage.

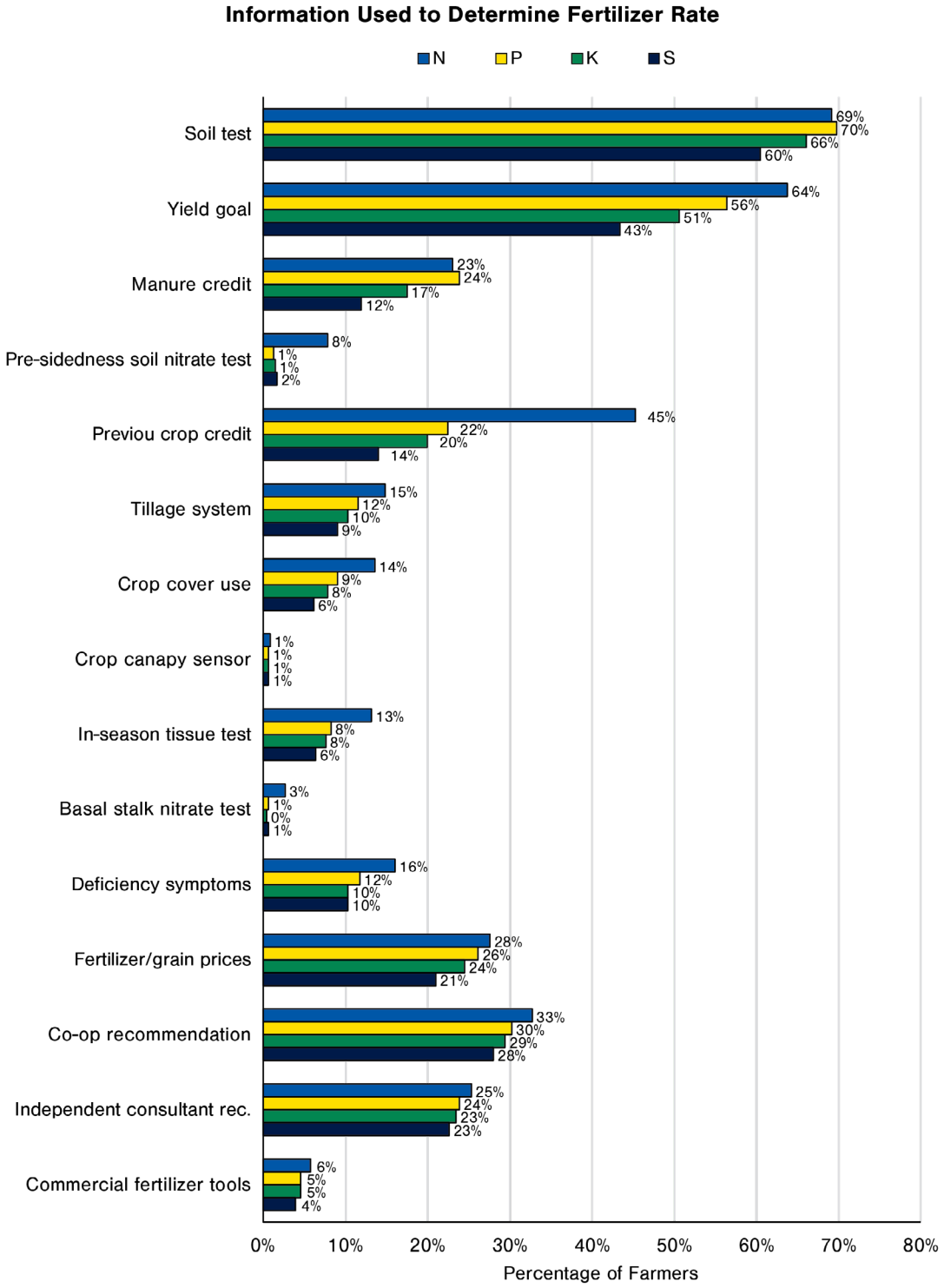

Figure 1. Percentage of responding farmers in central and eastern South Dakota using various parameters and information sources to make fertilizer rate decisions.

Table 1. Percentage of surveyed farmers who used the following university recommended factors to make fertilizer-N rate decisions as affected by location, tillage system, and farm size.

Variables	Entire survey	Location		Tillage			Farm size (ac)			
		Central	East	No-till	Reduced	Conventional	>1999	1000-1999	500-999	1-499
	%									
University recommended factors										
Yield goal	68	64	72	78	78	77	77	76	73	78
Soil test	74	70	76	85	86	80	84	81	82	81
Previous crop credit	48	43b[a]	53a	56ab	71a	48b	61	53	46	56
Manure credit	25	20b	30a	27	39	29	26	30	29	30
Tillage system	16	13	18	20	23	14	20	16	18	22
Other potential variables										
Use of cover crop	15	15	14	20	16	11	20	14	13	17
Presidedress soil nitrate test	8	4b	12a	8	14	10	12	8	7	7
In-season tissue test	14	12	16	14	18	18	22	16	13	10
Crop canopy sensor	1	1	1	1	2	2	0	1	0	5
Visual deficiency symptoms	17	14	19	17	27	19	24	20	16	15
Basal stalk nitrate test	3	1	4	3	4	2	1	6	2	2
Fertilizer and/or grain prices	29	24	33	35	35	34	36	37	29	37
Fertilizer-N rate recommendation help										
Commercial prediction tool	6	4	8	7	12	4	7	7	8	5
Independent consultant	27	26	29	30	33	26	22	21	32	37
Co-op recommendation	35	30	38	41	41	50	35	45	48	51
Percent of farms in each category		47	53	49	14	37	27	34	23	13

[a] Percentages with different letters within each row of each variable category (i.e., location, tillage, and farm size) are statistically different (P ≤ .05). If no letters are present, there are no significant differences.

Phosphorus and Potassium

For phosphorus (P) and potassium (K) fertilizer rate guidelines in SD, an algorithm was developed utilizing crop yield potential and soil test levels of P and K based on a 0 to 6 in. depth, and credits for manure application when applicable (Clark et al., 2019). Among all respondents, yield potential was used 51 to 56%, soil test level 66 to 70%, and manure credit 17 to 24% of the time (Figure 1 and Table 2). The use of yield potential and soil test levels were above 50%. This is significant as soil testing has been shown to be one of the most effective means in determining fertilizer P and K needs of crops. Therefore, educational programs need to focus on improving the use of soil testing, and therefore the effective use and accuracy of P and K fertilizer rates applied for SD corn.

Farm location within SD but not farm size or tillage type were found to be related to the use of university recommendations in determining P and K fertilizer rates. For both P and K, farms in eastern SD were on average 11% more likely to use crop yield potential, soil test levels, or manure credit to determine P and K rates. Farms in eastern SD were also on average 16% more likely to apply P and K fertilizer rates to build soil nutrient test levels. Similar to N fertilizer rate, the principle factors used by SD farmers to determine P and K fertilizer rates are location within SD and its associated weather and primary tillage and cropping systems. Therefore, education and research is needed to address these three factors across the state to improve the use of university crop P and K fertilizer rate recommendations.

Table 2. Percentage of surveyed farmers who used the various university recommended factors to make crop fertilizer-P and-K rate decisions, overall and by location. Tillage and farm size did not cause a significant effect on P and K rate decisions.

Variables	Phosphorus			Potassium		
	Overall	Central	East	Overall	Central	East
	%					
University recommended factors						
Yield goal	56	54b[a]	65a	51	45b	63a
Soil test	70	68b	79a	66	63b	77a
Manure credit	24	20b	30a	17	12b	15a
Other potential variables						
Tillage system	12	11	14	10	9	14
Use of cover crop	9	11	9	8	9	8
In-season tissue test	8	9	9	8	7	9
Crop canopy sensor	1	1	1	1	1	1
Visual deficiency symptoms	12	10	14	10	8	13
Fertilizer and/or grain prices	26	22b	33a	24	19	33
Fertilizer rate recommendation help						
Commercial prediction tool	5	3	6	5	3	6
Independent consultant	24	24	27	24	23	27
Co-op recommendation	30	27	36	29	26b	35a
Fertilizer rate application strategy						
Apply fertilizer rates that maintain soil nutrient levels	40	41	44	37	35	44
Apply fertilizer rates to build up soil nutrient levels	34	29b	42a	28	20b	39a

[a] Percentages with different letters between the central and east categories for phosphorus and Potassium are statistically different ($P \leq .05$). If no letters are present, there are no significant differences.

Sulfur

Sulfur (S) rate guidelines in SD utilize an algorithm based on soil test S to a depth of 2 feet, soil texture, and tillage type (Clark et al. 2019). Among all respondents, 43% used yield potential and 60% used soil test S (Figure 1). The lower use of yield potential and soil test S was lower than that for predicting N, P, or K and is likely due to the inconsistent relationship between soil test S and yield response found in previous studies (Sawyer and Barker, 2002; Kim et al., 2013). In addition, the lower use of S guidelines may be associated with typically higher soil organic matter and lack of consistent S deficiency symptoms observed by most producers. More work is needed to best identify the soil and environmental factors that influence S requirement of various crops. Location within SD, but not farm size or tillage type, were found to be related to the use of university recommendations in determining S fertilizer rates (Table 3). For S, farms in eastern SD were on average 10% more likely to use yield potential and manure credit compared to farms in the central part of the state, but farms in eastern and central SD were similarly likely to use soil test S level to determine fertilizer-S rates. Further research and demonstrations are needed to better determine the factors related to S fertilizer rate requirements for corn and to subsequently demonstrate the use and effectiveness of these factors to farmers.

Table 3. Percentage of surveyed farmers who used the various university recommended factors to make crop fertilizer-S rate decisions, overall and by location. Tillage and farm size did not cause a significant effect on S rate decisions.

Variables	Sulfur		
	Overall	Central	East
	---------- % ----------		
University recommended factors			
Yield goal	43	40b[a]	52a
Soil test	60	60	68
Manure credit	12	9b	17a
Other potential variables			
Tillage system	9	8	11
Use of cover crop	6	8	6
In-season tissue test	6	7	7
Crop canopy sensor	1	1	1
Visual deficiency symptoms	10	10	12
Fertilizer and/or grain prices	21	18b	27a
Fertilizer rate recommendation help			
Commercial prediction tool	4	3	5
Independent consultant	23	23	26
Co-op recommendation	28	26	33

[a] Percentages with different letters between the central and east categories for phosphorus and Potassium are statistically different (P ≤ .05). If no letters are present, there are no significant differences.

Other Information used for N, P, K, and S Fertilizer Rate Determination

We also included in our survey other plant and soil tests options that are not currently used in university recommendations for SD including visual nutrient deficiency symptoms, in-season tissue tests, crop canopy sensors, in-season soil nitrate-N tests, and the use of cover crops (Figure 1 and Tables 1, 2, and 3). However, only some farmers used these testing options (< 22% overall). This low adoption rate may be due to labor, time, money, and equipment required for in-season soil and plant tests. For example, crop canopy sensors require additional equipment and the use of algorithms to make fertilizer-N recommendations. Further, the algorithms used are routinely modified by industry and academic researchers to improve their accuracy. Most farmers would likely be more willing to adopt such technologies as research improves their consistency in providing an accurate fertilizer rate estimate (Bean et al., 2018; Ransom et al., 2020). Further, these technologies are primarily limited to N recommendations, making them currently unusable for other nutrient recommendations. In addition, these in-season testing methods can only be used to refine N recommendations when farmers allocate a substantial proportion of their N application from near planting to in the growing season after in-season tests occur. Currently, only 45% of SD farmers split up their N application that would allow them to use these in-season tests to refine their fertilizer-N rate. This percentage of farmers applying N in-season is likely lower than in other states in the eastern corn belt where greater amounts of precipitation are observed during the early part of the growing season. Additionally, fertilizer and grain prices were a factor used by only 21 to 28% of farmers when deciding on a fertilizer rate (Figure 1 and Tables 2, 3, and 4).

Another emerging field in nutrient recommendation systems especially for N are the development and use of models including: HybridMaize (Yang et al., 2004), Encirca (Corteva, Johnston, IA), Climate FieldView (The Climate Corp., St. Louis, MO), and Adapt-N (Yara International ASA Oslo, Norway). However, the use of these commercially available systems is limited in SD with only 4 to 6% of growers using a commercial proprietary fertilizer rate recommendation tool (Figure 1 and Tables 1, 2, and 3). Most growers who turn to people outside their farm for help in making fertilizer rate decisions turn to their co-op (28 to 33%) or an independent crop consultant (23 to 27%). Thus, working with individual farmers along with fertilizer dealers and crop consultants is likely the most effective means to expand farmer educational outreach. This process

could result greater adoption of emerging nutrient management technologies by individual farmers and improve fertilizer rate decisions.

Soil Testing

Use of Soil Testing

Farmers who use soil sampling to make fertilizer rate decisions were five times more likely to hire someone to sample their fields compared to sampling it themselves (Figure 2). This trend is likely due to farmers increased use of co-op agronomists or independent crop consultants to help them in making soil fertility and other farm management decisions opposed to researching and making their decisions on their own. Additionally, many agronomists are more experienced and have hydraulic soil sampling equipment to enable faster soil sampling of large fields compared to using a hand probe. Approximately, 18% of the farmers reporting did not currently use soil sampling to guide in their soil fertilizer rate recommendations. This low percentage is important as soil sampling is one of the most effective tools available in making accurate P and K fertilizer rate recommendations.

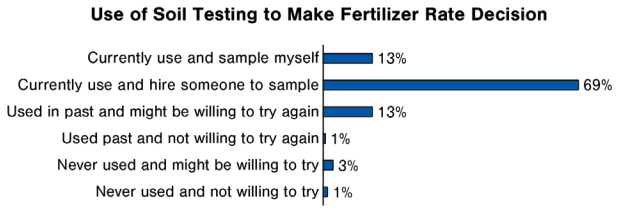

Figure 2. Percentage of surveyed farmers in central and eastern South Dakota regarding the use of soil testing to make fertilizer rate decisions.

Soil Testing Frequency

Within the same field, farmers most frequently obtained and tested soil samples annually (36%) or every two years (39%) while 25% tested in intervals of every three years or greater (Figure 3). These results indicate that most SD farmers follow university soil sampling frequency guidelines of every two to three years for P and K and every year before a N intensive crop such as corn and small grains. Sampling frequencies of every four or more years are likely due to longer cropping rotations and the cost of collecting and analyzing soil samples.

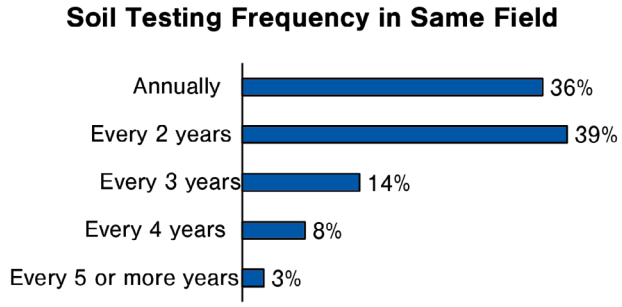

Figure 3. Percentage of surveyed farmers in central and eastern South Dakota regarding their use of different soil sampling intervals of the same fields.

Soil Sampling Collection Methodology

Farmers utilizing whole field composite soil sampling are nearly two times as common as those using a grid or zone methodology (Figure 4). Using a composite soil sample from at least 15 random cores from a field and mixing them together by depth increment is the traditional way SD producers sample fields. However, using grid or zone soil sampling provides spatial nutrient management information within a field and may reduce fertilizer cost and improve gran yields. Recommended soil sampling methodologies (grid, zone, or composite) currently vary among the states neighboring SD. North Dakota recommends zone sampling or grid sampling using one sample per acre (Franzen, 2018). Iowa recommendations vary by nutrient with grid sampling being more effective for managing P and both grid and zones working well for managing K and pH (Mallarino and Wittry, 2004). Nebraska takes a similar stance where both grid and zone are effective, depending on the individual field situation (Ferguson and Hergert, 2000). Further research in SD is needed to best determine what sampling methodology and density is most accurate and cost-effective depending on climate and soil geography.

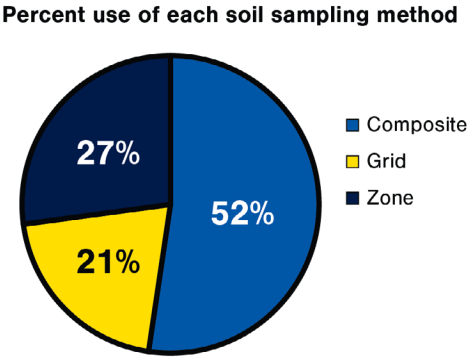

Figure 4. Percentage of surveyed farmers in central and eastern South Dakota using composite, grid, and zone soil sampling.

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