SF715 (Revised)

Fertilizing Potato
in North Dakota

Photo: A. Robinson, NDSU

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Potato production has been a part of North Dakota agriculture since the earliest days of statehood. A state potato grade inspector position was created in North Dakota in 1929 to craft rules and regulations regarding seed potato production and promote the potato industry.

Today, about 12 percent of the total U.S. potato crop is grown in North Dakota/Minnesota. The potatoes grown in the region are destined for a combination of seed, fresh and processing markets. Storage of potato is an important part of the production process.

One of the critical management strategies in producing high-yield, high-quality potatoes is crop nutrient availability. A potato crop requires large amounts of nutrients. The total nutrients contained in vines and tubers of a potato crop are provided in Table 1.

Table 1. Nutrients contained in potato vines and total tuber yield. (From Rosen and Bierman, 2017)

		Total tuber yield, cwt/acre				
	Vines	200	300	400	500	600
Nutrient	Nutrient content, lb/acre					
Nitrogen (N)	90	86	128	171	214	252
Phosphorus (P)	11	12	17	23	28	35
Potassium (K)	75	96	144	192	240	288
Calcium (Ca)	43	3.0	4.4	5.9	7.4	8.9
Magnesium (Mg)	25	5.9	8.9	11.8	14.7	17.6
Sulfur (S)	9	8.8	13.2	17.6	22.0	26.4
Zinc (Zn)	0.11	0.07	0.11	0.14	0.18	0.21
Manganese (Mn)	0.17	0.03	0.04	0.06	0.07	0.08
Iron (Fe)	2.21	0.53	0.79	1.06	1.32	1.58
Copper (Cu)	0.03	0.04	0.06	0.08	0.10	0.12
Boron (B)	0.14	0.03	0.04	0.05	0.06	0.07

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Nitrogen

North Dakota nitrogen (N) recommendations are based partly on soil testing to a depth of 2 feet in the fall or spring prior to potato production. Potatoes are produced on a variety of soils in the state. Soil sampling on sandy loam or coarser soils would best be conducted in early spring because snowmelt or early spring rains could result in leaching of nitrate below the potato rooting zone.

Potato is a relatively shallow-rooted crop, with few roots below a depth of 2 feet. In loam- and finer-textured soils, fall soil sampling would be useful. In addition, previous crops should be considered. Annual legumes or sugar beet leaf color would contribute N to the potato crop directly or indirectly.

The N credit values in Table 2 should be considered when determining fertilizer N rates. The previous crop credit is necessary because the N expected to be available after these crops will not be seen in a fall or early spring soil test analysis.

Table 2. Previous crop N credits to subtract from recommended N rate.

Previous Crop	Credit, lb N/acre
Soybean	40
Dry edible bean	40
Other grain legume crops (field pea, lentil, chickpea, faba bean, lupin)	40
Sugar beet	
Yellow leaves	0
Yellow/green leaves	30
Dark green leaves	80

Elimination of Yield Goal-based Fertilizer Recommendations

Fertilizer recommendations used to be linked to yield goals. But during the past couple of decades, research has shown that no link exists between expected yield and N rate or any other nutrient rate. The same nutrient rate required to produce the greatest yield in a yield-limiting environment is the same nutrient rate required to produce the greatest yield in a yield-nonlimiting environment.

However, potato production is complicated due to the artificial vine kill to produce potato for various fresh markets and due to the unique nutrient requirements of different potato varieties commonly used in the region. The following recommendations (Table 3 and Table 4) are categorized into irrigated potato of different vine-killing dates and associated varieties, and dryland potato production.

Higher N rates will result in excessive vine growth at the expense of tuber production, and also will result in delayed maturity, increased brown center and incidence of knobby, misshapen and hollow tubers. Inadequate N can result in plants being more susceptible to early blight, verticillium and other diseases. Petiole analysis is a practice that will help make sure that N is adequate through the season so that “insurance N”' application is not necessary.

Table 4. Dryland full-season potato N requirements based on variety type.

Variety type	N, lb/acre*
Reds	140 ± 20
Russets and whites	170 ± 20

* Total of soil test N to 2 feet in depth; previous crop credits, if any, and fertilizer N applied.

Table 3. Irrigated potato N, P and K requirements based on variety and date of vine kill.

Vine-kill dates	Varieties	N, lb/a *
Early season fresh market – Vine kill before July 25 < 90 days after planting	Norland, Red Norland, Dark Red Norland, Yukon Gold	160 ± 10
Midseason fresh market – Vine kill between July 25 and Aug. 26, 90-120 days after planting	Midseason fresh market and processing varieties include Norkotah Russet, Gold Rush, Ranger Russet, Ivory Russet, Snowden, Atlantic, Dakota Pearl and Ivory Crisp. Also Alturas (N efficient variety)	200 ± 10
Late-season, fresh market and processing – Vine kill after Aug. 26, > 120 days after planting	Russet Burbank and Umatilla	240 ± 10

* Total of soil test N to 2 feet in depth; previous crop credits if any and fertilizer N applied.

Nitrogen Application Timing

Early season varieties

- Apply a band starter at planting.
- Apply one-third to one-half of recommended N near time of emergence.
- Apply remainder of N at final hilling.
- Apply additional N if fertigation is possible, based on petiole testing and harvest date.

Mid- to late-season varieties

- Apply a band starter at planting.
- Apply one-third to one-half of recommended N near time of emergence.

If fertigation is not available:

- Apply remainder of N at final hilling.

If fertigation is available:

- If final hilling is performed 10 to 14 days after emergence, apply one-third of recommended N at final hilling and fertigate the remainder based on petiole analysis.
- If final hilling is performed at emergence, begin fertigation 14 to 21 days later and apply the remainder of recommended N based on petiole analysis.

Notes on N Application

- Avoid use of nitrate-containing fertilizers in sandy soils at planting due to leaching hazard.
- Do not apply high amounts of ammonium-containing fertilizers close to the seed piece, especially in soils with a pH greater than 7, due to ammonia toxicity.
- N leaching may be reduced by using a poly-coated urea such as ESN.

Phosphorus

Potato has a high appetite for phosphate relative to what is taken up by the crop. Most potato is planted early in the spring, and a concentrated band of P, along with adequate P in the soil as indicated by soil testing, is important.

Much has been written about the influence of high pH and associated carbonates on the availability of P in our soils; however, in acid soils, P availability also is compromised. The conclusion is that P availability is a nearly universal problem in potato production. The rate of P recommended is based on soil test values (Olsen P extractant in North Dakota), the variety of potato to be grown and the date of vine kill (Table 5).

Phosphorus is best applied in a band at planting 2 to 3 inches to the side and 2 to 3 inches below the seed piece. A variety of alternative placements have been used; however, the banded treatment below and to the side of the seed piece provides consistent yields and flexibility in fertilizer rates for safety, and generally is accepted by potato fertility researchers as a superior placement to alternatives.

Success has been reported for liquid and dry fertilizer products. Within liquid choices, polyphosphate sources and ortho-phosphate sources are equally effective.

Table 5. Recommended P_2O_5 to apply for potato production in North Dakota.

	Olsen Soil Test P, ppm							
Vine-kill dates	**0-3**	**4-7**	**8-11**	**12-15**	**16-18**	**19-22**	**23-41**	**42+**
Irrigated	P_2O_5 to apply, lb/acre							
Before July 25 – < 90 days after planting*	125	100	75	50	50	50	50	50
July 25-Aug. 26 – 90-120 days after planting†	150	125	100	75	75	75	75	75
> 120 days after planting‡	175	150	125	100	100	100	100	100
Dryland Reds	125	100	50	50	25	25	25	25
Dryland Russets and Whites	150	125	100	100	75	25	25	25

*Early fresh market varieties include Norland, Red Norland, Dark Red Norland and Yukon Gold.

†Midseason fresh market and processing varieties include Norkotah Russet, Gold Rush, Ranger Russet, Ivory Russet, Snowden, Atlantic, Dakota Pearl and Ivory Crisp.

‡Late-season irrigated varieties include Russet Burbank, Umatilla and Alturas.

Potassium

Potassium (K) uptake by potato is greater than that of N (Table 1). Due to the recent corn and soybean production in this region, where fields previously were dominated by small grains and other crops with low K removal, the soil test K values have greatly decreased.

Recently, a K rate study in corn in North Dakota resulted in the conclusion that soils with a greater content of smectitic clay (shrinking and swelling clay) became K deficient at soil test values greater than the previous K soil test critical value would predict. For higher smectitic clays, the new K soil test critical level for corn is 200 parts per million (ppm), while the K soil test critical level for lower smectitic clays remains at 150 ppm.

Although this work has not been conducted for potato, a higher K critical value for corn suggests that a higher critical value for dryland potato production might also be important because K becomes less available in the growing season when soils are dry. The higher K soil test critical value is not necessary for irrigated land because the soil will be kept moist most of the growing season (Table 6). A map of clay species ratios in North Dakota is provided in Figure 1.

Potassium is important to prevent blackspot bruising and for storage quality. However, specific gravity may decrease with overapplication of K. In-season K applications contribute more to lower specific gravity than preplant or at-planting K applications. Apply half or more K preplant and the rest at planting. For lower K rates, all K can be applied with the starter band.

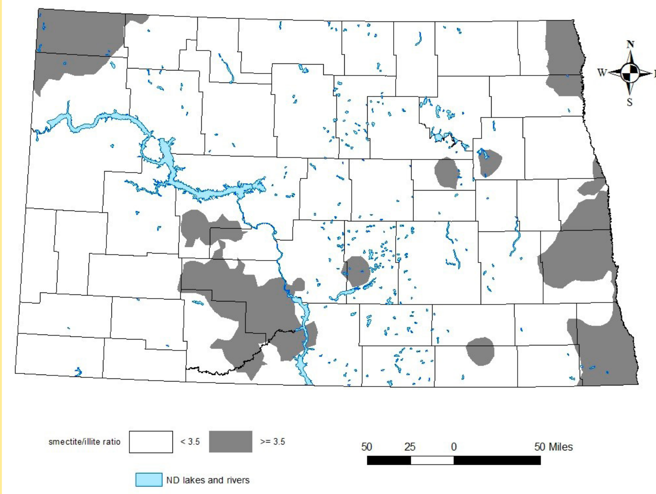

Figure 1. North Dakota smectite-to-illite ratio greater than or less than 3.5, based on 2017 soil sampling and clay species analysis.

The most common K fertilizer is 0-0-60, potassium chloride. It has a high salt index and may affect early growth more than other sources. In addition, in soils near Grand Forks, where soil chloride also may be high, choosing a sulfate form of K may result in better potato growth and less salt/chloride injury. Potassium sulfate or potassium-magnesium-sulfate are alternative sources of K.

Table 6. Recommended K_2O to apply for potato production in North Dakota.

Vine-kill dates, Production category		K Soil Test, ppm 0-40	41-80	81-120	121-150	151-200	200+
Irrigated		**K_2O to apply, lb/acre**					
Before July 25 – < 90 days after planting*		200	100	75	50	25	20
July 25-Aug. 26 –							
90-120 days after planting†		300	200	100	75	50	25
> 120 days after planting‡		400	300	200	100	75	50
Dryland	**Clay ¶Ratio**	**K_2O to apply, lb/acre**					
Reds	S/I Ratio > 3.5	400	300	200	100	75	50
	S/I Ratio < 3.5	300	200	100	75	50	25
Russets and Whites	S/I Ratio > 3.5	400	300	200	100	75	50
	S/I Ratio < 3.5	300	200	100	75	50	25

*Early fresh market varieties include Norland, Red Norland, Dark Red Norland and Yukon Gold.

†Midseason fresh market and processing varieties include Norkotah Russet, Ivory Russet, Snowden, Atlantic, Gold Rush, Ranger Russet, Dakota Pearl and Ivory Crisp.

‡Late-season irrigated varieties include Russet Burbank, Umatilla and Alturas.

¶Clay ratio is smectite-to-illite ratio that is greater than or less than 3.5

Sulfur

No soil test procedure that is diagnostic of a sulfur (S) deficiency is available. In potato production, given the sensitivity of the crop to S deficiency and greatly increased incidence and severity of S deficiencies in North Dakota in recent years, an S application would be prudent.

If the K fertilizer is potassium sulfate or potassium-magnesium-sulfate, the S requirement would be met. If the K fertilizer source is potassium chloride, then a sulfate or thiosulfate form of fertilizer would be needed.

Thiosulfate never should come in contact with the seed piece. Ammonium sulfate would be a preferred dry fertilizer, and ammonium or potassium thiosulfate could be applied as a liquid in a seed piece-separated band or through fertigation. The rate of S to apply would be from 15 to 25 pounds/acre.

Sulfate is leached easily if preplant S was applied. In sandy soil and if the field was subject to several inches of rain in one event, supplemental S might be necessary. Petiole analysis should provide guidance to in-season S application.

Calcium and Magnesium

Calcium (Ca) and magnesium (Mg) sources are a part of most North Dakota soils, unlike in Minnesota. Even sandier soils in North Dakota tend to have significant free lime (calcium/magnesium carbonates), and very acid soils are much less common and tend to be localized within fields.

To be more certain of field soil pH, Ca and Mg values, soil sampling by zone, even in relatively "flat" fields, is necessary. A number of tools can be used to construct soil management zones. These methods are detailed in www.ndsu.edu/fileadmin/soils/pdfs/SF-1176-2.pdf, "Soil Sampling and Variable-Rate Fertilizer Application."

If a field or areas within a field are acidic and contain lower Ca and Mg values, application of lime would amend all of these factors to satisfactory levels. The best local source of lime in the region is sugar beet waste lime, which is applied regularly in the Red River Valley for various purposes, including acid soil remediation.

Micronutrients

Zinc (Zn) is the most common micronutrient to be deficient in potato. Zinc deficiency in potato first was recognized in the state in the 1940s, and zinc application has been common for decades on potato.

Based on a zone soil test, Zn-DTPA extracted values greater than 1 ppm should not benefit from Zn application. From a soil test of 0.6 to 1 ppm, application of 0.25 pound of Zn a.i. (active ingredient) per acre as a banded zinc chelate or 15 pounds/acre of zinc sulfate 36 percent is recommended. For soils with less than 0.6 ppm, 0.5 pound of Zn a.i. per acre as banded zinc chelate or 30 pounds/acre of zinc sulfate 36 percent is recommended.

Although boron (B) deficiency has been found in Minnesota irrigated sands, it has not been diagnosed in North Dakota. In Minnesota, hot water-extracted B soil test values less than 0.4 ppm require 1 pound of B/acre. Most soils in potato-growing regions of North Dakota have soil test B levels greater than 0.4 ppm (www.ndsu.edu/fileadmin/soils/pdfs/Survey_of_soil_attributes.pdf).

Photo: A. Robinson, NDSU

Petiole Testing

The best method for monitoring in-season potato nutrient uptake and for directing any in-season application of fertilizer is through petiole testing. Whole leaves also can be analyzed, but the criteria developed for interpretation is different, so "leaves" as opposed to "petioles" needs to be indicated with the sample submission.

The petiole is the potato leaf stem and midrib of the fourth leaf from the shoot tip. Petioles from any other leaf obtained during sampling will lead to interpretation errors because the nutrient content of leaves and plant parts changes during their maturity.

A petiole sample consists of the petioles from 40 leaves taken from randomly selected plants within a field (or a part of a field if variable-rate capabilities are available for site-specific application). A leaf tissue analysis consists of 40 leaves taken in the same manner but submitted whole to the laboratory. After trimming to petiole status, petioles can be shipped or taken to a laboratory for analysis.

The best nutrient status determination will come from petioles taken at the tuber-bulking stage of growth. Generally, petiole analysis will begin about a week after final hilling, with a wait time of at least four days after a fertigation.

For N, petiole analysis is valid during the vegetative and tuber-maturation stages because sufficiency ranges also have been developed for these periods. For nutrients other than N, a whole-leaf analysis provides a better indication of total nutrient uptake because this is the sink for nutrients, whereas the petiole is more of a snapshot in time of nutrient transport.

Table 7. Sufficiency ranges in potato petioles and whole leaves obtained from the fourth leaf from the shoot tip during indicated growth stages.

Nutrient	Growth stage	Petiole	Whole leaf
Total N	Tuber bulking	—	3.5-4.5%
Nitrate N	Vegetative	1.7-2.2%	—
	Tuber bulking	1.1-1.5%	—
	Maturation	0.6-0.9%	—
Phosphorus	Tuber bulking	0.22-0.40	0.25-0.50%
Potassium	Tuber bulking	8.0-10.0%	4.0-6.0%
Calcium	Tuber bulking	0.6-1.0%	0.5-0.9%
Magnesium	Tuber bulking	0.30-0.55%	0.25-0.50%
Sulfur	Tuber bulking	0.20-0.35%	0.19-0.35%
Zinc	Tuber bulking	20-40 ppm	20-40 ppm
Boron	Tuber bulking	20-40 ppm	20-40 ppm
Manganese	Tuber bulking	30-300 ppm	20-450 ppm
Iron*	Tuber bulking	40-200 ppm	30-150 ppm
Copper	Tuber bulking	4-20 ppm	5-20 ppm

* If iron (Fe) is of particular interest, leaves/petioles should be cleaned using a clean, damp cloth prior to submission. Iron contamination from soil residue on leaves/petioles can affect analysis values greatly.

For N interpretation, the N analysis in whole leaves is best described as "total N," whereas in petioles, "nitrate-N" is the best indicator. Table 7 provides sufficiency ranges for nutrients from petiole and whole-leaf analysis at different growth stages.

A quicker, less expensive way to monitor potato N status is a small, portable nitrate meter through petiole sap analysis. The user should follow the manufacturer's instructions to obtain a proper, calibrated measurement. Table 8 provides sufficiency ranges for Russet Burbank potato sap nitrate values.

Table 8. Sufficiency values for nitrate from Russet Burbank potato petiole sap analysis.

Time of season	Growth stage	NO_3-N, ppm
Early	Vegetative/tuberization (June 15-30)	1,200-1,600
Mid	Tuber growth/bulking (July 1-15)	800-1,199
Late	Tuber bulking/maturation (July 15-Aug. 15)	400-799

Postharvest Considerations

Unless a high level of management of soil and nutrients occurs, potato production can result in serious consequences to future soil productivity and the local environment. No method is available to grow potato in a no-till environment outside of a small home garden; however, attention immediately after harvest can reduce soil loss significantly in most years.

A cover crop can be sown immediately following harvest, and an immediate, subsequent irrigation will result in adequate cover to protect soil. Avoid cereal rye if corn will be the next crop, opting instead for oat or barley. Forage radish also will help stabilize the soil and take up a portion of any residual N.

Following N rate guidelines in this publication, using split-N applications where recommended, and the judicious use of fertigation and in-season N application based on tissue/petiole/sap analysis will aid in reducing nitrate leaching and off-site contamination. Also, including a deep-rooted crop in the rotation will help "clean" the soil of deeply leached N and will result in continued viability of groundwater supplies to the farmer and general public.

Organic Potato Fertilization

The ability to manage N nutrition as precisely in organic production as in conventional production is limited by the rate of soil biology to recycle N in organic amendments. The most common approach to providing N is through the use of organic manures and composts.

A variety of products containing microorganisms claim to “help” the degradation of manures and composts and speed the release of N, but these have not been tested by unbiased third parties. Manures and composts contain significant populations of microorganisms that break down manure and composts, so the value of additives to already biologically rich materials is questionable.

Regardless, sampling the manure/compost source and analysis for total N will provide some idea of how much N might be released. In a dryland environment, the activity of microorganisms, amended or not, relies on moisture for decomposition and N release. If the field is irrigated, the release of N will be more constant through the season.

Fresh manure contains more readily available N than composted manure. However, a well-composted manure or compost that has achieved a high temperature during the composting process will result in a much lower weed bank to fight during the year.

Another N strategy is growing an annual legume the season before organic potato production. A substantial soybean/pea or other annual legume crop plowed under (not after harvesting the grain) will provide 100 to 200 pounds of N/acre to the subsequent crop.

Clipping several measured areas of the green manure crop just before termination/incorporation and sending the plant material to a laboratory for total N analysis will provide the total N in the material. Incorporated green manure usually will be able to supply about two-thirds of the total N it accumulated to the next crop.

Manure and compost also will provide significant P, K and micronutrients to the next crop. For supplemental K, surface-mined/skimmed salts of the Great Salt Lake Basin in the U.S. usually are listed as organic sources of potassium sulfate or potassium-magnesium-sulfate. Agricultural limestone to amend pH if necessary also is listed as an organic source, although sugar beet waste lime probably is not. Limestone quarries in southern Minnesota might be utilized to amend acid soils and provide Ca and Mg if needed.

Using NDSU-recommended soil testing methods always is of more value than relying on methods from other states because what NDSU bases its recommendations on was tested and verified in North Dakota.

Many organic growers use the “balanced cation approach” to their detriment. The approach is especially poor in this region due to the presence of soluble salts and carbonates in many of our soils that result in an inflated apparent (but not accurate) cation exchange capacity. As a result, this approach over-recommends the use of some nutrients.

Photo: A. Robinson, NDSU

One of the critical management strategies in producing high-yield, high-quality potatoes is crop nutrient availability.

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