

# TNS - Potato Fertility

## Understanding Nutrient Accumulation & Potato Development

The objective of this publication is to understand the basic development and accumulation of nutrients and compounds for the potato plant. Much of this publication is based on the information gathered from two outstanding publications on this issue:

*"Development, growth and chemical composition of the potato crop (Solanum tuberosum). Part I - Leaf & Stem, by Kolbe & Beckmann, in Potato Research, Volume 40, 1997, pages 111-129*

*"Development, growth and chemical composition of the potato crop (Solanum tuberosum). Part II - Tuber & Whole Plant, by Kolbe & Beckmann, in Potato Research, Volume 40, 1997, pages 135-153*

Copies of these papers, along with an MS Excel spreadsheet, can be obtained by calling Peter Aleman @ (509) 894-4110. In the spreadsheet, the data presented in these papers are sorted and summarized in such a way that one can input seed spacing and adjust yield to equal anticipated yield for a specific area.

### *Disclaimer:*

It is not meant that these papers & this publication be construed as being the final answer for every area, soil, growing season and potato variety. However, it does give some interesting insight into how a potato develops.

The objective of this publication is to illustrate that plant nutrients (although essential) are only a small part of the total picture. The concept that can be developed from this information is a different view of plant nutrition, which can be summarized as follows;

- Firstly, nutrients are definitely part of a plants structure, but do they only need to be supplied to become part of the plants structure, or do they also play a role in regulating plant growth?
- Secondly, supplying these nutrients in a raw "chemical" form is important, but what role does biology play? This relates to the known fact that "virgin" ground can produce 5-10 tons/acre more quite consistently. Why then, do we limit ourselves to only evaluating and utilizing nutrients in "pure" chemical form?

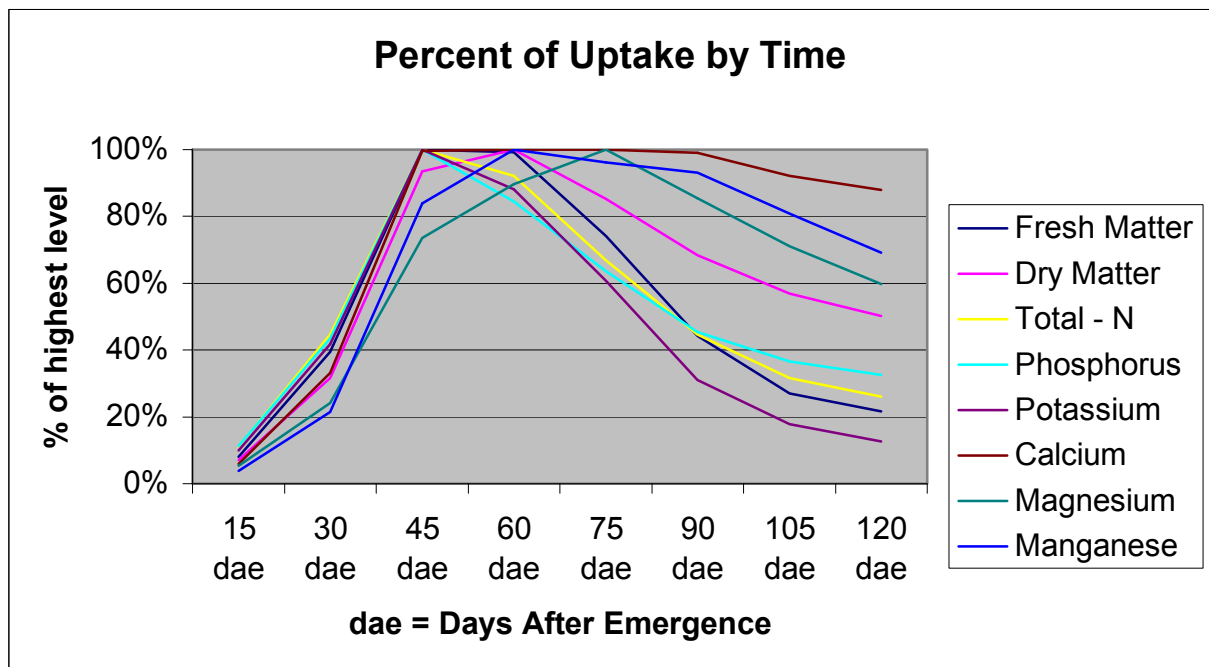


In the table below, we have taken the information based on the two papers referred to earlier, place it in a spreadsheet so that it is converted to "lbs/acre" and so that one can change seed spacing to arrive at average tonnage for a particular cropping area. What remains to be done in this work are two things:

- 1) Make the spreadsheet adjustable in days from emergence to harvest. This will produce the optimum nutrient uptake timings for shorter and longer growing varieties.
- 2) The second thing that needs to be done is to compile numbers based on in field testing for various soils and varieties, to "fine tune" the program

The spreadsheet was "set" to a yield of 33.7 tons per acre (674 sacks/acre). In this table, we will illustrate the percentage of the **highest** level of nutrients obtained throughout the growing season.

Potato Leaves	15 dae	30 dae	45 dae	60 dae	75 dae	90 dae	105 dae	120 dae
Fresh Matter	8.1%	39.5%	100.0%	99.3%	74.1%	44.2%	27.1%	21.7%
Dry Matter	7.1%	31.7%	93.4%	100.0%	85.2%	68.3%	56.8%	50.3%
Total - N	11.2%	44.6%	100.0%	92.1%	66.9%	44.6%	31.6%	26.0%
Phosphorus	11.3%	43.5%	100.0%	84.6%	63.6%	45.5%	36.6%	32.5%
Potassium	10.0%	41.9%	100.0%	88.1%	60.7%	31.1%	17.8%	12.6%
Calcium	6.0%	33.2%	99.5%	100.0%	100.0%	99.1%	92.2%	88.0%
Magnesium	5.3%	24.1%	73.6%	89.7%	100.0%	85.4%	71.1%	59.7%
Manganese	3.8%	21.5%	83.8%	100.0%	96.2%	93.1%	80.8%	69.2%



This information demonstrates the importance of soil fertility in the first 60 dae. However, remember that in the first 15 dae, the plant is likely still received appreciable quantities of nutrients from the seed tuber. Furthermore, the largest "jump" in nutrient levels occurs in the growth period of 30-45 dae.

Examples: Fresh matter - 60.5%, NPK - 55-58%, Ca - 66.3%, Mn - 62.3%!  
The table also illustrates which elements are translocated from the leaves to other plants parts (i.e. - tubers).

Did you know? – Of nutrients accumulated in the vines, approximately 67% of N, 85% of P, 62% of K is translocated to the tubers. However, only 17% of Ca, 32% of Mg and 50% of Zn is translocated to the tubers.

### Nutrients in the Stems

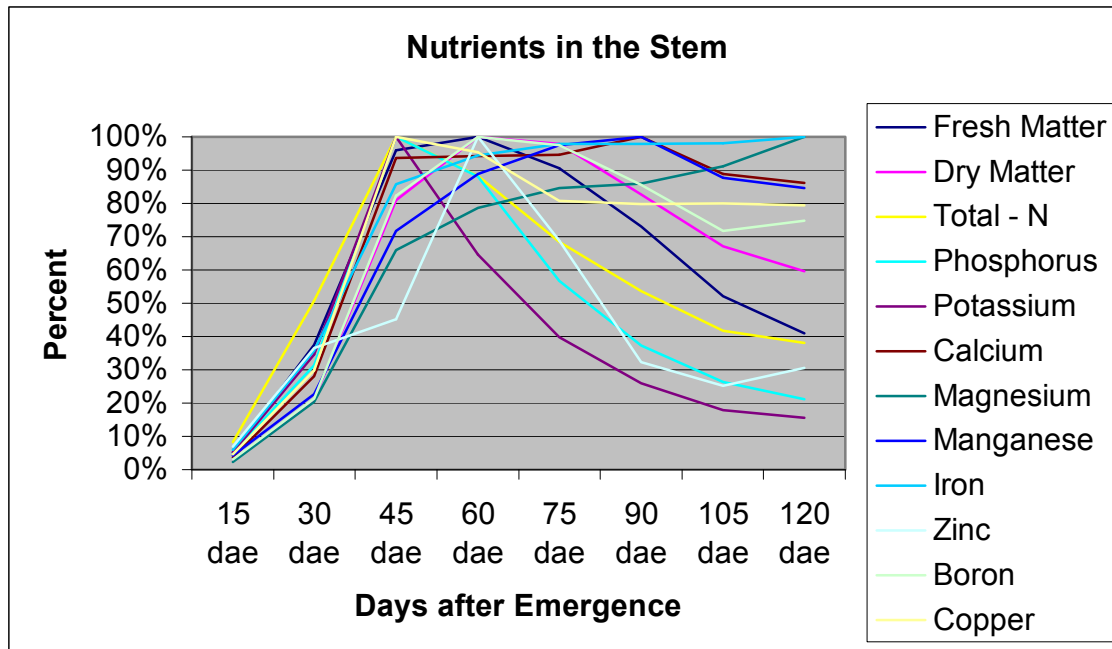
The nutrient content of the stems exhibits a similar pattern to that of the leaves, however somewhat delayed. Contents of NPK are like that of the leaves, but some of the minerals such as Mg, Mn, Fe and Zn are somewhat slower in accumulation.

All minerals, (except Zn), show higher levels well after maturity because they do not translocated to the tubers like NPK. Notice especially P & K.

Potato Stems	15 dae	30 dae	45 dae	60 dae	75 dae	90 dae	105 dae	120 dae
Fresh Matter	5.2%	37.4%	95.9%	100.0%	90.5%	73.0%	52.1%	41.0%
Dry Matter	3.1%	21.1%	81.0%	100.0%	97.8%	82.6%	67.0%	59.7%
Total - N	8.3%	50.7%	100.0%	88.3%	68.4%	53.6%	41.7%	38.1%
Phosphorus	5.1%	31.3%	100.0%	88.0%	56.7%	37.3%	26.3%	21.2%
Potassium	5.2%	34.7%	100.0%	64.5%	39.8%	25.9%	17.9%	15.5%
Calcium	3.7%	28.0%	93.7%	94.2%	94.7%	100.0%	88.9%	86.2%
Magnesium	2.3%	20.5%	66.0%	78.6%	84.7%	86.0%	91.2%	100.0%
Manganese	4.3%	22.6%	71.8%	88.9%	97.4%	100.0%	87.6%	84.6%
Iron	6.0%	35.8%	85.7%	94.4%	97.9%	97.9%	98.1%	100.0%
Zinc	7.0%	36.6%	45.2%	100.0%	68.8%	32.3%	25.3%	30.6%
Boron	3.1%	21.4%	82.4%	100.0%	97.5%	85.5%	71.7%	74.8%
Copper	4.5%	29.8%	100.0%	95.5%	80.8%	79.8%	80.0%	79.5%

Much emphasis in potato nutrition is put in nitrogen. Petiole samples are taken regularly to monitor nitrogen content. P & K are also monitored, but minerals such as Ca, Mg, Zn, Mn, Fe, Cu and B are not monitored as closely. Furthermore, monitoring petiole levels of these minerals is questionable in the first place.

The leaf and stem data exemplifies the need for available minerals in a two-week period, which is 30-45 dae. Zn, Mn and Mg can be extended into the 30-60 day range.



This brings up the question of when to put on minerals; pre-plant or water-run during the 30-45 day period. Pre-plant minerals (soil levels) need to be maintained, however, their availability is related to soil chemistry and biology. Without rotation and a biological program, minerals should be water-run in the period of 25 days to 45 days after emergence.

Potato Tubers	Unit	30	45	60	75	90	105	120	135
Nitrate - N	lbs	0.09	0.32	0.43	0.55	0.61	0.67	0.77	0.84
Total N	lbs	6.82	41.79	110.87	189.76	226.01	237.52	240.93	240.93
Phosphorus	lbs	1.28	9.38	24.31	40.51	49.04	52.88	52.88	52.45
Potassium	lbs	8.10	55.44	147.12	238.38	280.17	291.68	293.39	293.81
Calcium	lbs	0.55	2.56	4.09	5.42	5.93	6.27	6.99	6.99
Magnesium	lbs	0.34	2.09	6.23	11.68	15.01	16.42	16.29	15.78
Manganese	lbs	0.00	0.02	0.05	0.09	0.11	0.12	0.14	0.14
Whole Plant	Unit	15	30	45	60	75	90	105	120
Nitrate - N	lbs	3.87	19.16	24.90	9.26	2.66	1.71	1.49	1.84
Total - N	lbs	19.19	103.20	231.13	277.61	316.41	315.56	302.34	293.39
Phosphorus	lbs	0.00	0.01	0.03	0.05	0.06	0.06	0.06	0.06
Potassium	lbs	17.06	92.96	277.61	317.69	350.95	343.70	331.34	324.51
Calcium	lbs	0.01	0.03	0.10	0.10	0.11	0.11	0.10	0.10
Magnesium	lbs	1.45	7.08	23.03	31.56	39.62	39.96	39.15	37.57
Manganese	lbs	0.02	0.14	0.56	0.70	0.72	0.73	0.66	0.61

### Nutrients & Carbohydrates in the Tuber

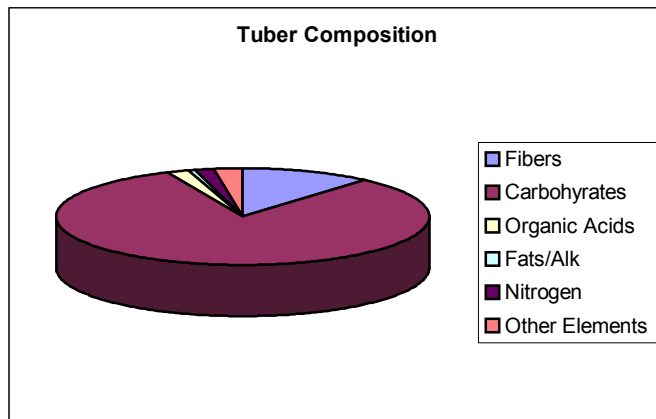
Nutrient levels in leaves and stems are basically the "catalyst" and "structure" of the "solar collectors" that take free energy from the sun and product carbohydrates which is what potato tubers are (a collection of starch)

The following table illustrates the various compounds that are likely to be found in lbs/acre of our 33.7-ton crop at 135 dae.

	lbs/acre	% of total		lbs/acre	% of total
Fresh Matter	67,461		Crude Protein - N	240	
Dry Matter	15,181	22.50%	Pure Protein - N	133	
			Non-Protein - N	106	
Crude Fiber	255	1.68%	Amid - N	14	
Cell Wall	1,156	7.61%	Nitrate - N	1	
Cellulose	307	2.02%	Total N	241	1.59%
Starch	11,727	77.25%	Phosphorus	52	0.35%
Sucrose	106	0.70%	Potassium	294	1.94%
Glucose	292	1.92%	Calcium	7	0.05%
Fructose	337	2.22%	Magnesium	16	0.10%
Ascorbic Acid	41	0.27%	Manganese	0	0.00%
Citric Acid	232	1.53%	Sodium	2	0.02%
Malic Acid	31	0.21%	Ash	1	0.01%
			Total Lipids	81	0.53%

As the following table and chart illustrate, most of the tuber solids is starch, complex carbohydrates.

Summary	Lbs	%
Fibers	1,718	11.31%
Carbohydrates	12,462	82.09%
Organic Acids	305	2.01%
Fats/Alk	84	0.55%
Nitrogen	241	1.59%
Other Elements	372	2.45%



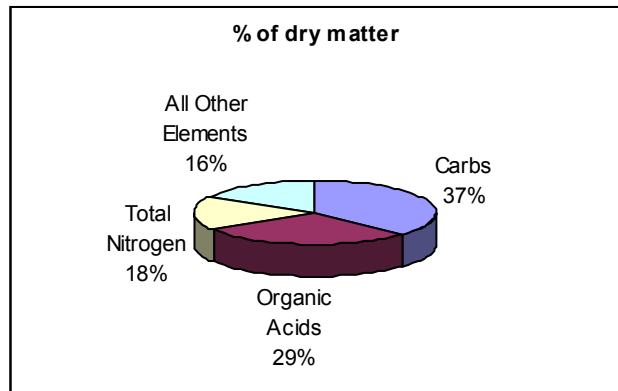
Notice, of the total dry matter, only 4.04% is NPK and all the other elements of which, N (1.59%) & K (1.94%) make up the bulk. All other elements consist of a paltry 0.51%. The question that arises is why so much attention on the 4.04% and not on the remaining 96% that is made up of carbon based compounds, ALL manufactured through photosynthesis!

Potato leaves at maximum dry matter accumulation point of 60 dae, is also highly driven by biological compounds as the table below illustrates.

Potato Leaves - lbs/acre of compounds/elements at 60 dae					
Fresh Matter	29722.3		Crude Protein - N	122.8	3.93%
Dry Matter	3121.5	10.5%	Pure Protein - N	106.6	3.42%
			Non-Protein - N	11.5	0.37%
Starch	275.5	8.83%	Nitrate - N	2.3	0.07%
Sucrose	87.4	2.80%	Total - N	243.2	7.79%
Glucose	59.3	1.90%			
Fructose	91.3	2.92%	Phosphorus	13.1	0.42%
			Potassium	101.5	3.25%
Malic Acid	191.9	6.15%	Calcium	92.5	2.96%
Citric Acid	178.7	5.72%	Magnesium	18.1	0.58%
Ascorbic Acid	29.2	0.94%	Manganese	0.6	0.02%
Glycoalkaloids	6.7	0.21%	Sodium	2.3	0.08%

The summary of important compounds in percentage of leave dry matter also illustrates the overall significance of nutrient elements;

Summary	lbs/acre	% of DM
Carbohydrates	513.4	16.4%
Organic Acids	399.8	12.8%
Total Nitrogen	243.2	7.8%
All Other Elements	228.1	7.3%



*Although it is impossible to relate it's significance to our petiole data, based on this information the question arises on the measure of petiole nitrates based on the following observation.*

*Of the nitrogen compounds, which make up 7.79% of dry matter only 0.07% (0.9% of total N) is in the nitrate form. Petiole nitrate?*

## Potato Tuber "Solids"

While on the topic of tuber solids, let's further examine the issue of solids in relation to plant nutrition and plant function.

In the previous page we relate % of nutrient content to % of organic compounds of which carbohydrates is a major part. This comparison is somewhat misleading because the whole objective of potato production is based on the leaves converting the sun's energy to sugars (carbohydrates) and the ability of the plants to translocate these compounds to storage, the tuber. Therefore, the levels of carbohydrates in the leaves should vary from low in the morning, the highest possible levels towards evening.

*What causes low solids?*

During the day the level of starch located in the chloroplasts can reach up to 5-7% of the total leaf dry matter. During the night, translocation of assimilates (starch, sugars & others) occurs. Under the best growing conditions (hot days and cool nights), shortly before sunrise, the starch content should only be less than 1% of leaf dry matter.

Over the growing season, the total concentrations of starch steadily increase until tuberization (60 dae) when it decreases continuously thereafter. However, during periods of high temperatures (especially warm nights) tuber starch synthesis is inhibited and the starch content of the leaves will remain the same, or even increase, during the later stages of vegetative growth.

However, based on cropping experience, it can be demonstrated that fields with equal soil and plant nutrition can have both high and low solids. Therefore, simple chemical nutrition does not play a role in the ability of potatoes to continue translocating starch to the tubers during periods of warm weather.

This brings up a possible method of testing biological compounds (plant growth regulators) that exhibit properties of plant drought and heat stress resistance. Such compounds are now being developed and will be available soon. Their performance could possibly be measured by testing sugar levels just before dark and again in early morning.

Conclusion - Most potato growers are paid for one thing only - Yield/acre = Starch.