Improving Skin Color & Quality in Red Potato Varieties

Effects of Nutrients & Bio-Compounds with 2,4-D Applications

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Introduction

Although it has been suspected since early 1900's that the red pigment necessary for improved skin color was a result of the accumulation of anthocyanins in the outer cells, this was not verified until 1997. This indicates the complex chemistry involved in these compounds.

It is now understood that anthocyanins are made up of 120 different organic chemicals! Color intensity is related to the variation in content of these compounds, which is effected by environmental conditions throughout the growing season.

"Anthocyanins" are a group of compounds that are red to blue, whereas "carotenoids" (carrots) are yellow to red-orange compounds.

Applications of 2,4-D (2,4 dichlorophenoxy acetic acid) have been made since the early 1950's to improve the level or intensity of the "red" color.

Although this is a common practice, it is not without drawbacks such as distorted top growth, earlier vine lodging (increases chance of disease) and a reduction of tonnage due to its effect on set and tuber size.

The purpose of this information is to clarify the effect of 2,4-D applications and suggest methods of negating the negative effects.

Recommended rates are 1.5 to 2.0 fluid ounces per acre at 7-14 inches of potato growth followed by a second application 10-14 days later with the last application at least 45 days prior to harvest.

Mode of Action of 2,4-D

The primary effect of 2,4-D is to stimulate cell growth in the phloem vascular tissue of higher plants. This clogs the phloem, pinches the phloem shut and blocks translocation. The mode of lethality of these herbicides appears to be by plant starvation resulting from this blockage.

NOTE: If the effect of 2,4-D is phloem (the transportation system to tubers) blockage, then this is negative for the translocation of carbohydrates (starch) to the tuber.

2,4-D is an effective herbicide in dicots (potatoes included) because of the location and structure of the phloem of these plants. Dicot species are more capable of 2,4-D translocation in the phloem.

In monocots, the phloem is scattered in bundles and often protected by a layer of tissue (schlerenchyma tissue), whereas in dicots have selective tissue components (cambial and pericycle tissue) that may even help the activation of the 2,4-D effect.

Monocots are resistant to 2,4-D not only due to poor translocation, but also do not have an adequate level of *esterase*, an enzyme that "activates" the chemical. 2,4-D resistant plants do not readily metabolize 2,4-D to the free acid active form.

Low rates of 2,4-D on potatoes have a positive effect on tuber color, but only in soils already naturally produce good color (high organic matter).

The mode of action on potatoes is not clearly explained in any known literature, except for a "ripening" effect when the plant is subjected to a compound that triggers ripening and fruit maturity because it "thinks" it will die. A "***STRESS***" response! However, the rate is low enough that the plant grows through it.

It is known that an application of 2,4-D stimulates the production of ethylene (the "maturity" plant hormone). Applications of calcium are known to suppress the ethylene effect and reduce plant stress. This will be shown in the data presented later.

2,4-D and Auxins

As an auxin, 2,4-D applications can be related to the known functions of auxins in potato production. Auxins are plant growth hormones produced in the newly growing leaves of plants. An important concept to understand in relation to auxin "balance" between lower and upper parts of a plant is that the highest level of auxin "attracts" the photosynthates (energy – sugar). This is one of the effects of excess nitrogen on vine growth. High N stimulates new vine growth, which produces more auxins resulting in a higher level of auxins in the upper part of the plant and a shift of photosynthates to the vine, resulting in more stem growth and poor tuber development.

On the other hand, calcium is known to counteract this effect. This is due to the effect of calcium uptake and mobility in a plant. As calcium moves up the plant (xylem), it is thought that it "interchanges" with IAA, an auxin. Therefore, CALCIUM causes the downward translocation of auxins and switches the flow of photosynthates to the tubers, resulting in tuber bulking and the necessary "chemistry" for tuber compounds (remember red color is 120 different organic compounds).

2,4-D & Nutrient Applications

The following data needs to be credited to the work of Jiwan Palta & associates at the University of Wisconsin. The paper is titled "Effects of 2,4-D and Supplemental Calcium Application of Skin Color of Dark Red Norland Potatoes". The work of Dr. Jiwan Palta in relation to calcium and potato quality in recent years deserves high recognition!

In this study, Norland reds were planted in "muck" (high peat) soils near Endeavor, WI with a rate of 30 units of N at planting and no other additional nutrients other than the nutrient treatments in Table One.

The calcium/nitrogen fertilizers were applied by dissolving them in water and applying them over top the row, with care not to allow it to run into the furrows and then irrigated in.

At total of 150 units of calcium was applied using calcium nitrate $Ca(NO_3)_2$ with ammonium nitrate (NH_4NO_3) and calcium chloride ($CaCl_2$) with urea. The ratios of ammonium nitrate to calcium nitrate and the urea to calcium chloride were balanced to give equal units of nitrogen per acre. Applying ammonium nitrate only made an additional nitrogen treatment, without calcium.

The 2,4-D was applied in three timings (early, middle & late) and combinations thereof at a rate of 2 ounces/acre.

The timings of nutrient applications and 2,4-D applications are summarized in Table One.

TABLE ONE

Application Timing	2,4-D Spray Date		Nutrient Timing	
	1997	1998	1997	1998
Early	22-Jul	30-Jun	26-Jul	6-Jul
Middle	1-Aug	13-Jul	19-Aug	10-Aug
Late	7-Aug	23-Jul	26-Aug	18-Aug

Tuber periderm quality can be rated several ways:

1. Skin Color Quantification – A method in which the entire peel is ground, extracted and quantified with a spectrophotometer. This rating gives an indication of the intensity of color without the need for human evaluation. A setback is that characteristics such as scab and harvest damage detract from the rating.

2. Visual Rating – This method involves visually rating the tuber from 1 to 5 by various individuals (3 in this study) under both dry and wet conditions.

In the following table (Table Two), the rating method used was "skin color quantification"

TABLE TWO

Application Timing	Control	NH_4NO_3	$CaNO_3$ + NH_4NO_3	$CaCl_2$ + Urea
Control	606	593	590	581
Early (E)	629	663	632	612
Middle (M)	764	885	727	654
Late (L)	786	705	756	671
E & M	793	817	705	712
E, M & L	883	876	810	818

This shows that increasing applications of 2,4-D did the best in improving the intensity of red color, whereas nutrient applications suppressed the effect somewhat. This is due to the effect a nutrition relieving the stress effect of the 2,4-D application.

To look at the data in a different way, the table below shows the reduction of color quantification as a percentage of 100% - Each 2,4-D treatment and the control being 100%.

Application Timing	Control	NH4NO3	CaNO3 + NH4NO3	CaCl2 + Urea
Control	100%	98%	97%	96%
Early (E)	100%	105%	100%	97%
Middle (M)	100%	116%	95%	86%
Late (L)	100%	90%	96%	85%
E & M	100%	103%	89%	90%
E, M & L	100%	99%	92%	93%

It is important to visualize the difference in this way; 883 vs 818 seems to some as a considerable change, however, noticing a 7% change in the field is quite unlikely.

In contrast, when all treatments are compared to the control only (no 2,4-D and no additional nutrients) the difference (control only – 100%) is more visible.

Application Timing	Control	NH4NO3	CaNO3 + NH4NO3	CaCl2 + Urea
Control	100%	98%	97%	96%
Early (E)	104%	109%	104%	101%
Middle (M)	126%	146%	120%	108%
Late (L)	130%	116%	125%	111%
E & M	131%	135%	116%	117%
E, M & L	146%	145%	134%	135%

2,4-D & Scab???

It was noted that the **middle** and **late** applications of 2,4-D were impacted by scab to the point that "determining visual quality independent of the effect of scab was not possible." No further comments are made on this effect in the paper. Note that the plots were 692 feet by four rows wide and randomized, so it is not known if this is a field condition or has a relation to the application of 2,4-D.

According to the visual rating, the two calcium treatments had a slight effect on scab, as demonstrated in the following table in a rating to 1 to 5, 5 being least affected with scab.

Application Timing	Control	NH4NO3	CaNO3 + NH4NO3	CaCl2 + Urea
Control	3.8	4.1	3.7	4.2
Early (E)	3.2	3.9	2.6	3.9
Middle (M)	2	1.1	2.3	2.1
Late (L)	1.2	1.3	1.5	1.1
E & M	4.1	3.6	3.7	3.6
E, M & L	4.4	4.6	4.3	4.8

Again, it is useful to visualize the numbers in percentage compared to the control only (3.8 = 100%). The late application was 68% MORE affected by scab.

Application Timing	Control	NH4NO3	CaNO3 + NH4NO3	CaCl2 + Urea
Control	1	108%	97%	111%
Early (E)	84%	103%	68%	103%
Middle (M)	53%	29%	61%	55%
Late (L)	32%	34%	39%	29%
E & M	108%	95%	97%	95%
E, M & L	116%	121%	113%	126%

As with most data, many different conclusions and evaluations can be made, however, it is important to summarize some of the important results;

1. All applications of 2,4-D improved the intensity of red color
2. All nutrient applications, especially calcium, had a slightly negative effect on the color intensity of 2,4-D
3. This effect though was neutralized by the visual observation, which showed that nutrients alone with no 2,4-D did improve color and quality.
4. 2,4-D timing MAY have an effect on scab.

Furthermore, consider that from experience, 2,4-D effects tuber color differently from variety to variety, as follows.

Genetics of Red Potato Varieties

Accumulation of anthocyanins in petals, leaves, and kernels require exposure to light. However, potatoes make anthocyanins in tubers, which are underground tissues, so without direct exposure to light.

'Desiree' is a potato variety that makes pink tubers. It has been found that tissue-cultured plantlets of 'Desiree' need to be exposed to light in order to make red tubers. If the plantlets are put into tuber-inducing media, and then kept in darkness, they produce white tubers.

However, 'Norland' is a potato variety that makes red tubers, even if its plantlets are kept in the dark after transfer into tuber-inducing media.

It has been discovered that 'Norland' tubers make anthocyanins very early, when they are basically swollen stolon tips. After that, accumulation per given surface area decreases as the tuber grows.

This could have had very important implications on the effect of 2,4-D application in the preceding data. Therefore, it is important to know this basic difference for each variety in order to plan the best possible application timing of nutrients and 2,4-D.

Amino & Organic Acids + 2,4-D

In the search for information on the effect of 2,4-D on potatoes, an interesting document was found showing the effect of 2,4-D application with and without varying levels of amino acids (methionine & glutamic) and organic acids (citric).

What is most likely one of the most interesting parts of this work is the discovery of the effect of methionine many years before it was fully understood that this amino acid is a precursor to ethylene. Note that it is now known that the triggering agent (2,4-D) stimulates the production of ethylene (made from methionine), which in turn gives the "stress" signal in the plant.

The same is the case for glutamic acid, which is a known precursor to GABA (gamma amino-butyric acid), a plant stimulant and activator of SAR.

From this work there are some interesting results and comments.

The test was performed on Pontiacs in ND and the number indicates the average tuber set of four replicated plots. What's interesting is the comment in evaluating the test results.

Treatment-2 (2,4-D + Citric + Methionine + .33% glutamic) was found to be superior in all commercial aspects "except red color on red varieties". However, treatment-2 lead to more #1's, shallower eyes, tougher skins, less scurf, scab and rhizoctonia.

Treatment-3 (2,4-D + Citric + Methionine + .83% glutamic) not only increases tuber set, but also yield by 17%. Observations included;

a) Heavier top growth of a deeper green, broader leaves and more secondary stems.
b) Evened out tuber size, in Pontiacs it is important to have a rounder potato than an oblong tuber (even today).

c) Shorter stolons, less sun scalding and frost damage.
d) Skins "tougher" leading to less disease.
e) Increased tonnage of #1's, regardless of effect on set.
f) Better "dormancy" – Storage for 3-4 weeks.

	1% 2,4-D	w/Citric, Meth & Glu (.33)	w/Citric, Meth & Glu (.83)
Replication 1	46	39	53
Replication 2	35	63	63
Replication 3	54	66	84
Replication 4	58	61	69
Replication 5	49	66	76
Average	48.4	59	69

In other demonstrations, increasing the amounts of methionine and glutamic acids showed less "herbicidal" activity (twisting or damaging of terminal bud). HOWEVER, the interesting comment was that this caused excess vine growth and was not conducive to extra tuber set and tuber sizing. This demonstrates that an excess amount of material could neutralize the effect of 2,4-D.

In same these tests, increased amounts of 2,4-D where used (2%), resulting in the rapid aborting of flowers, twisting of terminal bud growth and an increase in set and size.

In a further demonstration using the above combinations with other amino acids including; glutaric acid, glycine, alanine, tryptophan (precursor to cytokine), aspartic acid and lysine, various additional positive effects were noticed.

Treatment	Avg Set	Treatment	Avg Set
Control (no 2,4-D)	69.8	Alanine	89.7
2,4-D + Base	**82.3**	Tryptophan	85.8
Casein Complex	93.6	Aspartic Acid	80.7
Glutaric Acid	95.5	Lysine	78
Glycine	91.1		

The "casein" complex had some of the most desirable observations; tops heavier, greener and stayed greener in fall, tubers set quickly and sized early, heaviest yield weight, evenness and uniformity of tubers, high average set and significantly increased storage. This could indicate that all amino acids play some type of a role in the enhancement of the 2,4-D effect.

Ironically, the same has been learned by Bio-Gro, individual amino acids all have good, positive effects, but a solution of hydrolyzed protein often has the better effect.

2,4-D Management Strategies

Based on data demonstrated in these and many other reports, the following materials and methods are recommended.

A TOTAL NUTRITION SYSTEM – This is still first and foremost. The effect of a 2,4-D application is to trigger a "maturity" response. The healthier and stronger the plant is going into this "stress" mode, be better the yield and quality will be. That simple.

Calcium & Magnesium – Calcium is especially important in the process not only due to the quality issue, but also for the transport of auxins to the tubers. Magnesium is so overlooked, because it plays in important role in the translocation of photosynthates and the conversion of these compounds in the tuber. Remember, everyone knows the importance of calcium for tuber quality – Magnesium is found in **2 X's** the level in the tuber in comparison to calcium. There is a reason for this.

Organic Matter – The complex chemistry of the red pigment (anthocyanins) is derived from various phenolic compounds, which originate from the humic/fulvic acids found in organic matter. Although it has been known that humic acids may have little effect in high organic matter soils on overall yield, they may play a role in tuber color formation, especially in the lower organic matter soils. It would be suggested to utilize a significant volume (3-5 gallons) of low molecular weight humic acids on a test basis.

Organic Acids – NUE Chelate is 26% citric acid. Based on a target of 1% of spray solution, a 10 gpa foliar should contain about 42 oz/acre of NUE Chelate. Although not mentioned, NUE Chelate is also formulated with other organic acids, which include lactic, succinic and others.

Amino Acids – Higher rates of amino acids seem to show the potential of negating the positive effect of 2,4-D. Therefore higher rates should be used on an experimental basis. However, a 32-oz/acre dose of NUE Stimulate results in a total amino acid concentration of 0.10% amino acid by weight in 10 gpa foliar. This is 1/10 of the amount used in the study. Additional amino acid can be used but it would not be recommended to exceed 64-oz/acre on a large scale. Special blends of NUE Stimulate contain higher rates of amino acid and higher ratios of desired amino acids can be made available to experimentation.

Multiple Applications – Obviously, multiple applications of 2,4-D seem to be better than just one. This may be somewhat debatable, due to the fact that some varieties (Norland), may determine color potential early in growth cycle. This is definitely a subject of study. Furthermore, other plant stress inducers such as CHB 0-0-30 that do not negatively effect phloem development (cutting off the supply line to the tuber) many result in the color effect with less negative effect on yield. This would be especially true with varieties that determine color early in the growth cycle.