BAND PLACEMENT FOR POTATOES IN CALCAREOUS SOIL

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ABSTRACT

Potato is one of six crops responsible for 80% of worldwide human caloric intake. Other than grain, bean, and cotton row crops, the relatively high value potato (*Solanum tuberosum*) has the greatest acreage and crop value in the US. This crop is unique in that it has a very high nutrient requirement relative to most other crop plants, but it has a very shallow, limited root system. As a result, potato growers commonly apply high rates of broadcast, band, and water injected fertilizers in an attempt to maintain superior tuber bulking rates throughout the season. Although there is recent research on fertilizer rates for modern potato production, very little replicated research is available regarding band placement. Work with many other crops shows an advantage for applying a concentrated band of fertilizer in close proximity to the seed, avoiding high rates in direct seed contact. Many potato growers apply a concentrated band of fertilizer, but most do so before planting and at a shallow depth, resulting in the band likely being disturbed with the planting process. The objective of this study is to investigate optimal placement of concentrated fertilizer bands for potato production. A greenhouse trial was conducted in 2005 with fertilizer band placements at various locations on and around the seed piece. The results of this trial show no differences with regard to early season plant growth and nutrition for any treatment. This may suggest that the relatively large and nutrient rich seed piece has ample nutrition for early season growth. A similar field study was also conducted from 2005-2007, but with fewer treatments and with the potatoes being grown to maturity. Fertilizer bands were placed three inches to the side and either three inches above or below the potato seed piece at row formation or at planting. These treatments were compared to a check that did not receive any banded fertilizer. The results of these trials show that the fertilizer band applied high in the hill at row formation was substantially disturbed with the planting process, resulting in no improvement in tuber yield and quality over the check in any year. In contrast, the fertilizer band placed low in the hill at row formation remained intact and resulted in significantly more US No. 1 yield (45-50 cwt/A) than all other treatments in 2005 and than the grower's standard practice treatment of shallow placement at row formation in 2007. The shallow placement treatments did not have significantly increased yields over the untreated check in any year. In addition, significant increases in percentage of US No. 1 tubers and gross crop value were measured for the deep placement treatment. It is recommended that potato growers applying banded fertilizer place it to the side of the seed piece and low enough in the hill to avoid disturbance by the planter.

INTRODUCTION

Potatoes (*Solanum tuberosum*) are a crop of major economic importance, especially in the irrigated Western US. Much of the most productive, intensively cultivated areas in this region (e.g. Snake River Plain, Columbia Basin, San Luis Valley, San Joaquin Valley, etc.) are dominated by potato cropping systems. From a national (US) perspective, only grain, bean, and cotton crops exceed potatoes in terms of row crop production value and acreage.

Potatoes have a relatively high nutrient requirement and small root system (Stark and Love, 2003). As a result, producers commonly apply significantly more fertilizer materials to their potato crops as compared to grain and other rotational crops that tend to be more nutrient efficient. Growers are also more willing to apply high rates of fertilizer to potatoes due to the high value of this crop, with cost of production typically ranging from $1500 to $2500 per acre. Therefore, it is common for growers to apply the vast majority of the fertilizer for the entire cropping system to the potato crop. Much of the fertilizer is broadcast applied, but it is also common to apply a liquid band in the hill either at planting or, more routinely, when the rows are formed (known as “mark-out”).

Research shows that, in most situations, a combination of broadcast and banding is beneficial (Hopkins and Ellsworth, 2005a, 2005b). However, many potato growers and agronomists have begun to question whether or not they are getting a benefit to application of concentrated liquid fertilizer bands due to on-farm evaluations. It is possible that these observations are due to problems with the fertilizer band placement. It is common practice for the liquid fertilizer band to be applied with the row formation process and at a depth at or above where the seed piece is planted. The advantage of shallow placement is that it takes less fuel to pull an implement as compared to a deep placement. Although this mark-out application is considered by many to be a “starter” fertilizer, the potato planting operation results in dramatic soil disturbance and a significant mixing of the banded fertilizer with the bulk soil. It is likely that much of the expected benefit of concentrated banding of mark-out fertilizer is minimized as a result of this practice.

Surprisingly, there is very little published research on the placement of starter fertilizers in potato production after the 1960’s. Yield potential and production systems have changed dramatically since the initial work was reported. Furthermore, very little unpublished research could be found after several personal communications with researchers and others considered as experts in potato nutrition.

The benefits of starter fertilizer have been shown repeatedly in most other major crops. Research establishing the effects of concentrated liquid fertilizer bands is badly needed for potato production. This work is needed particularly in the western United States, where soils tend to be calcareous and have an alkaline pH. High pH, calcareous soil results in reduced solubility of phosphorus and micronutrient metals and, as a result, an increased potential benefit of concentrating these fertilizers in a band near the roots. Furthermore, it is common for potatoes to be grown in sandy, low organic matter soil in this region. Crops grown in sandy, low organic matter soils have been shown to be relatively more responsive to starter fertilizer applications. However, greenhouse work done by Hopkins and Ellsworth (2006) suggests that the nutrient-rich, large potato seed piece (in comparison to true seeds) may have adequate nutrition to allow it to get by without a starter fertilizer benefit for the first few weeks of growth. Although the concentrated fertilizer bands may not be improving early season nutrition and growth, final tuber quality does seem to be impacted favorably (Hopkins and Ellsworth, 2006), suggesting that the mid to late season contribution may be important.

The objective of this study is to determine the effects of complete starter fertilizer bands at various placements in the hill applied to calcareous soil as either mark-out or starter application on potato growth, nutrient uptake, grade, and yield.

MATERIALS & METHODS

Field trials were conducted in southeastern Idaho in 2005 (Blackfoot), 2006 (Aberdeen), and 2007 (Aberdeen) on irrigated *Russet Burbank* potatoes grown in a calcareous soil with relatively low soil test values (sandy loam to loam soil with pH 7.8-8.2, 1.1-1.5% OM, 2-12% $CaCO_3$, 4-8 ppm nitrate-N, 8-19 ppm bicarbonate phosphorus, 120-180 ppm ammonium bicarbonate potassium, 10-20 ppm sulfate-S, 0.7-1.0 ppm DTPA zinc, 6.2-10.9 ppm DTPA manganese, and 0.6-0.9 ppm hot water extractable boron).

The experimental design was a randomized complete block (RCBD) replicated six times. The plots were established as four rows (12 ft width) by 40 ft length. Treatments are identified as: 1) untreated check (UTC), 2) row mark-out shallow (MS), 3) row mark-out deep (MD), and 4) planter shallow (PS). The row mark-out treatments (2 & 3) were applied pre-plant by dribbling the fertilizer through injection tubes attached to shanks when the potato hills were formed (mark-out). The planter treatment (4) was applied at planting with a concentrated band sprayed on the soil as the closing shoes covered the seed piece. The placement for treatment 3 (deep) was three inches to the side and three inches below the seed piece. The placement for treatments 2 and 4 (shallow) was approximately three inches to the side and three inches above the seed piece. The seed piece was planted at approximately five to six inches below the top surface of the pre-formed hill.

The UTC did not receive any banded fertilizer at mark-out or at planting as a starter. The planter and mark-out treatments received identical concentrations of nitrogen (N), phosphorus (P as P_2O_5), potassium (K as K_2O), sulfur (S), zinc (Zn), manganese (Mn), and boron (B). These nutrients were applied at rates of 24 N, 80 P_2O_5, 15 K_2O, 11 S, 1 Zn, 1 Mn, 0.2 B (lb-nutrient/A) applied as 20 gallons of ammonium polyphosphate (10-34-0), 5 gallons of potassium thiosulfate (0-0-25-17S), and 1 gallon of a custom blended micronutrient mixture (0-0-0-10Zn-10Mn-2B) per acre. These rates were based on soil test values and University of Idaho fertilizer recommendations.

The mark-out fertilizer application was done in conjunction with row formation on May 23, 2005, May 19, 2006, and April 26, 2007. The planter fertilizer application was done in conjunction with planting on May 27, 2005, May 20, 2006, and April 28, 2007. In 2005, planting occurred approximately three weeks later than normal due to several inches of rain in May.

All plots, including the check, received a complete regime of pre-plant incorporated broadcast fertilizer (~ 60-150-100-50S) based on soil test concentrations and University of Idaho fertilizer recommendations, applied as urea, monoammonium phosphate, potassium chloride, and elemental sulfur. Multiple split applications of additional nitrogen (N) fertilizer was applied in-season (~ 100-0-0) based on petiole tissue analysis, University of Idaho fertilizer recommendations, and a N credit from the previous crop, applied as urea ammonium nitrate injected into the irrigation water.

Soil samples were taken shortly after planting to ascertain the extent of disruption of the fertilizer bands due to the planting operation. The fertilizer band disruption evaluation was accomplished by cutting a trench across a hill in each plot and then removing a six inch long by three inch diameter core horizontal to the soil surface in a three inch vertical and horizontal grid pattern. Each soil sample was analyzed for all of the applied nutrients. Petiole samples were taken from each plot at 21 days after emergence to ascertain differences in early season nutrient uptake. Soil and plant analysis was performed with official/standard methods (MDS Harris

Laboratory; Lincoln, Nebraska). Best management practices were followed in growing the potato crop with regard to crop, soil, water, pest, and nutrient management.

Vines were desiccated with Reglone on September 16, 2005, September 11, 2006, and September 10, 2007 and then harvested on October 26, 2005, October 2, 2006, and September 28, 2007. Twenty feet from the center two rows of each plot was harvested, with all tubers weighed and graded for size, shape, specific gravity, and internal/external defects. Gross crop value was estimated by applying five year average grower contract returns. Statistical analysis was done by ANOVA (*P*=0.10) and means separated by LSD (alpha=0.10).

RESULTS AND DISCUSSION

Fertilizer Band Disruption - The results of the soil sampling and analysis show that the nutrients from the 3 X 3 mark-out shallow (MS) fertilizer band were disturbed significantly, whereas the other fertilized treatments tended to stay concentrated in the band. The MS fertilizer band was essentially spread evenly in the side of the hill in which it was applied. There were essentially no significant differences observed between sampling points in the side of the hill in which the fertilizer was applied, although the other side of the hill had significantly lower nutrient concentrations (data not shown). Not surprisingly, there were significant differences between the nutrient concentrations in the soil samples immediately surrounding the fertilizer band and those farther away for both the 3 X 3 mark-out deep (MD) and the 3 X 3 planting-starter shallow (PS), with the greatest differences for MD. Results were essentially the same in all three years. Not surprisingly, these results show that growers that apply bands of fertilizer in the zone where soil is disturbed by the planting process lose the concentration effect and that they should instead apply the fertilizer more deeply or apply it immediately before the closing shoes at planting if their goal is to maintain fertilizer concentration in the band and, thus, improved plant availability of nutrients.

Yield - In 2005 the MD treatment for the 4-6 ounce US No. 1 category had significantly greater yield than all other treatments, as well as significantly greater yield for the 6-10 ounce category than the check and the MS treatments (Hopkins and Ellsworth, 2006). There were no statistically significant differences for individual size grades in 2006 and 2007.

The sum of all grade categories into total yield showed no significant differences for any treatment in any year (Fig. 1). However, differences for US No. 1 (addition of all size categories) yields were significant in 2005 and 2007 and differences for marketable (US No. 1 plus US No. 2) yield were significant in 2006 and 2007 (Fig. 1).

The MD treatment had significantly more US No. 1 yield (45-50 cwt/A) than all other treatments in 2005. Although not significant in 2006, a similar trend was observed for this same treatment over the untreated check. In 2007, this same treatment had significantly greater US No. 1 yield than the grower's standard practice treatment (MS). The MS and PS treatments did not have significantly increased yields over the untreated check in any year. When adding the US No. 2 tubers, the fertilizer bands did not increase marketable yield for any category in any year except for a slight increase in 2006 for the PS treatment. Combining the yield data across years for orthogonal comparisons resulted in significant increases in both US No. 1 and marketable yield for the MD treatment over the grower's standard practice (MS) (Fig. 2).

In addition, many fresh market contracts pay the premium based on the percent (as opposed to total weight) of US No. 1 tubers. In 2005, the percent of US No. 1 tubers for the MD treatment in this trial was 72%, which was a substantially higher (9-10%) than the other treatments (Hopkins and Ellsworth, 2006). In 2006, both the treatments with undisturbed bands (MD and PS) resulted in significant increases in percentage (5-6%) of US No. 1 tubers over the untreated check (Hopkins and Stephens, 2007). No increases in US No. 1 percentage over the check were measured in 2007 (data not shown). The treatment with the disturbed band (MS) did not have an increase in US No. 1 percentages over the check in any year.

Other tuber quality parameters measured did not seem to be impacted by treatment. Tuber specific gravity (solids) was high for all treatments (1.084 to 1.092) and not impacted by treatment. Internal and external defects were minimal (<7%) for all treatments in all years (data not shown). Petiole tissue analysis also showed no significant differences for any nutrient measured in any year of the trial (data not shown). Significant increases in tuber numbers were significantly impacted in 2005, especially for the MD treatment (Hopkins and Ellsworth, 2006).

Applying five year average grower's fresh market contract pricing to these results showed a significant increase in gross crop value. In 2005, the MD treatment had a $136-$160/A increase in gross crop value over the other treatments, which was due to the increase in US No. 1 yield. In 2006, both treatments with undisturbed bands had a significant increase in gross crop value, with increases of $97/a (MD) and $127/a (PS) over the untreated check. Gross crop value for the fertilized band treatments were not significantly increased over the check in 2007. The crop value increases in 2005 and 2006 would likely increase if incentives were paid for the increase in US No. 1 percentage (not included in the scenario used for this analysis). It should be noted that the cost of the fertilizer band application was not subtracted from these values. It should also be noted that applying pricing to yield results is highly speculative, with each grower's contract being different from another. For example, a grower that is being paid on straight yield, with no premiums, would not have experienced an increase in gross crop value for any of the treatments. However, tuber quality premiums are the rule, rather than the exception with potato marketing.

CONCLUSIONS

These results suggest that concentrated fertilizer bands tend to improve the potato tuber quality, as evidenced by increases in both the weight and percentage of US No. 1 potatoes when band treatments are compared to an untreated check or the grower's standard practice of shallow application of the fertilizer band at row formation. The deep placement of the band at row formation prevents it from being disrupted during the planting operation. Shallow placement of the band at row formation results in the band being disrupted, which seems to negate the effectiveness of the application. Shallow placement with planter allows the band to remain mostly intact, but only had minor positive impacts on yield in one of the three locations tested. This apparent discrepancy may be due to random variation, but it is possible that the shallow placement is less effective due to roots located close to the surface being less efficient due to relatively greater fluctuations in soil moisture and temperature, as compared to soil in which deep roots grow. It is recommended that the best management practice of applying liquid fertilizer bands to potatoes should be done by placing the band to the side of the seed piece and low enough in the hill to avoid disruption with the planter.

LITERATURE CITED

Hopkins, B.G. and J.W. Ellsworth. 2005a. Phosphorus Availability with Alkaline/Calcareous Soil. p. 9-18. *In* K. Copeland et. al. (eds.) Proceedings of the Winter Commodity Schools – 2005. Vol. 37. University of Idaho-Cooperative Extension System, Moscow, Idaho.

Hopkins, B.G. and J.W. Ellsworth. 2005b. Phosphorus Availability with Alkaline/Calcareous Soil. *In* W.B. Stevens (ed.) Western Nutrient Management Conference Proceedings. 6:88-93. Potash and Phosphate Institute. Norcross Georgia.

Hopkins, B.G. and J.W. Ellsworth. 2006. Starter Band Placement for Potatoes in Calcareous Soil. p. 88-95 . *In* L. Murphy (ed.) 2006 Fluid Forum Proceedings. Vol. 23. Fluid Fertilizer Foundation, Manhattan, Kansas.

Hopkins, B.G. and S.C. Stephens. 2007. Starter Band Placement for Potatoes in Calcareous Soil. p. 47-54 . *In* L. Murphy (ed.) 2007 Fluid Forum Proceedings. Vol. 24. Fluid Fertilizer Foundation, Manhattan, Kansas.

Stark, J.C. and S.L. Love (*eds*.). 2003. Potato Production Systems. University of Idaho Agricultural Communications. Moscow, ID.

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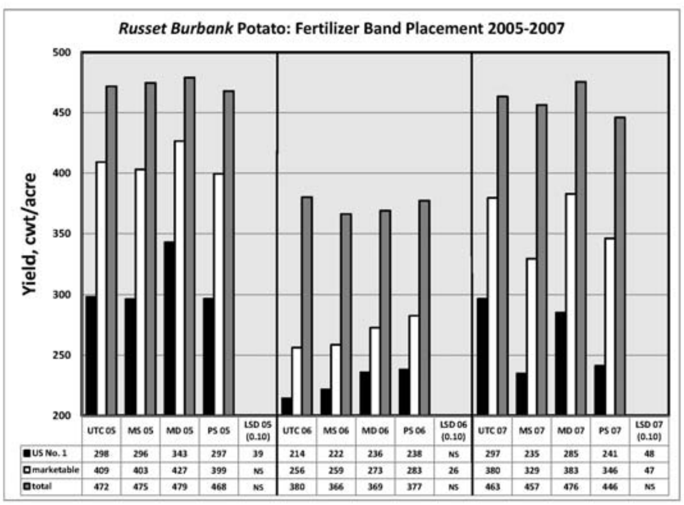

	UTC 05	MS 05	MD 05	PS 05	LSD 05 (0.10)	UTC 06	MS 06	MD 06	PS 06	LSD 06 (0.10)	UTC 07	MS 07	MD 07	PS 07	LSD 07 (0.10)
US No. 1	298	296	343	297	39	214	222	236	238	NS	297	235	285	241	48
marketable	409	403	427	399	NS	256	259	273	283	26	380	329	383	346	47
total	472	475	479	468	NS	380	366	369	377	NS	463	457	476	446	NS

Fig. 1. US No. 1, marketable (US No. 1 & 2), and total (marketable + cull) potato tuber yields for three banded fertilizer placement trials in southeastern Idaho from 2005-2007. An untreated check (UTC) was compared to complete liquid fertilizer band treatments applied at row mark-out at shallow depth (MS), at mark-out at deep depth (MD), or at planting at shallow depth (PS). All bands were applied three inches to the side of the seed piece; and either three inches above (shallow) or three inches below (deep) seed piece depth. Yield differences greater than the value found in the “LSD” column to the right of each site year of data are significant at the *P*=0.10 level. Yield data with “NS” indicates that the values are statistically equivalent.

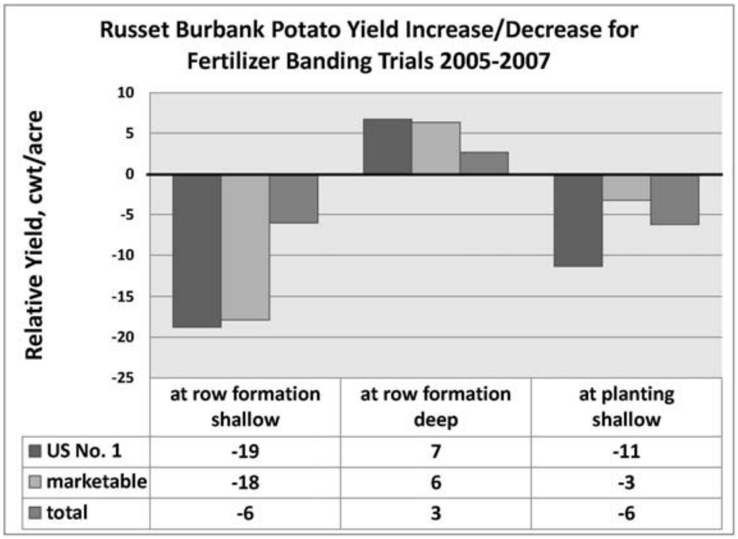

Fig. 2. Average potato tuber yields for three banded fertilizer placement trials in southeastern Idaho from 2005-2007. Three banded fertilizer treatments were compared to an untreated check. The bands were applied either at row formation or at planting. The “at planting” and one of the “at row formation” treatments were applied at a “shallow” depth (three inches above and three inches to the side of the seed piece. The other “at row formation” treatment was applied “deep” at three inches below and three inches to the side of the seed piece. The fertilizer band applied “at row formation deep” had significantly greater US No. 1 and marketable yield than the “at row formation shallow” treatment. No other differences were significantly different. (P=0.10)