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Yield and Yield Components of Potato (*Solanum tuberosum*) as Affected by Rock Phosphate in Standoff Soil, Southern Alberta Canada

Adebusoye O. Onanuga[1], Roy Weasel Fat[1] & Roy M. Weasel Fat[1]

[1] Red Crow Community College, Standoff, Alberta, Canada

Correspondence: Adebusoye O. Onanuga, Indigenous Agriculture Program, Red Crow Community College, Standoff, P.O. Box 1258, Cardston, AB T0K0 0KO, Canada. Tel: 587-999-4250. E-mail: adebusoyeo@redcrowcollege.com

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Abstract

An experiment was conducted in Standoff, Southern Alberta in April, 2020. The object of the experiment was to investigate effect of rock phosphate organic fertilizer on growth and yield of potato crop grown in Standoff. The varying levels of rock phosphate were broadcasted into the soil at control (0 P Kg ha^{-1}), Low P level (50 P Kg ha^{-1}) and High P level (100 P Kg ha^{-1}). The basal application of urea inform of nitrogen fertilizer was applied at 280 N Kg ha^{-1}. Potato seeds were planted at a distance of 30 by 90 cm. The three treatments were replicated three times, resulting into nine plants. One plant was taken out of uniformly grown tallest plant in each of the treatment to measure yield parameters. The yield parameters collected were subjected to analysis of variance (ANOVA) using Duncan's Multiple Range Test (DMRT) for separation of means. Results of the experiment indicated that High P and Low P rock phosphate fertilizer levels positively influenced weight of potatoes at 76 and 112 Days after sowing (DAS), respectively while High P rock phosphate fertilizer level got highest number of potatoes than Low P and control at 76 DAS. Furthermore, High P rock phosphate fertilizer level and control plots supported marketable number of potatoes at 76 DAS while High P rock phosphate fertilizer level favoured unmarketable number of potatoes at 112 DAS. It was quite obvious from the results that marketable weight of potatoes was positively influenced by High P rock phosphate level and Low P rock phosphate level at 76 and 112 DAS, respectively whereas unmarketable weight of potatoes was affected by High P rock phosphate fertilizer level at 112 DAS. These results revealed the beneficial use of rock phosphate for potato crop production

Keywords: rock phosphate, marketable weight, unmarketable weight, marketable number, unmarketable number, standoff, soil, potatoes yield

1. Introduction

Potato (*Solanum tuberosum*) is a staple food crop for First nations, Kainai Blood Tribe in Southern, Alberta and Canada as a whole. It is a tuber vegetable crop, which can be boiled or fried and eat with leafy vegetable. It could also be processed by food industries as a snack. Potatoes accounted for 376,826,967 metric tonnes of world production (FAO, 2016). In Canada, it is accounted for 4,324,110 metric tonnes of production (FAO, 2016). The factors that support growth and yield of potatoes are fertile soils, water, nutrients especially nitrogen and phosphorus, light and temperature (Ensign, 1935; Mugo, et al., 2020). Potatoes production could be supported by adequate nutrient management (Koch, M. et al., 2020), but soil degradation caused essential nutrient to be deficient in western Canada soils (Oldeman, 1994; FAO, 1995; Lakshminarayan et al., 1996; UNEP, 2000). Southern Alberta soils have been affected by soil degradation, whereby most of the essential nutrients are deficient especially nitrogen, phosphorus and potassium. However, managing the soil phosphorus in this region is very important to increase production of potatoes.

Rock phosphate fertilizer is an organic fertilizer that increase phosphorus in soil deficient P (Chien & Menon, 1995; Rajan et al., 1996; Zapata, 2003). It is a resource cheap fertilizer that is mined from sedimentary rock (Chien, 1992; Chien & Friesen, 1992; Chien & Van Kauwenbergh, 1992). Application of rock phosphate increase other nutrients in the soil such as nitrogen, potassium, magnesium, sulphur, calcium and some micronutrients (Zapata, 2003). Furthermore, phosphorous in form of mono or di phosphate was released to the weakly acidic soil so as to increase crop yield and yield components (Jensen, 2010). However, the dissolved P in the soil can be taken up effectively by crops within the soil pH of 5.5 to 6.5 (Black, 1968; FAO, 1984; Jensen, 2010). Rock phosphate which contain lime materials is able to reduce the alkaline nature of soils for effectively P uptake by crops (Black, 1968; FAO, 1984; Zapata, 2003). Moreover, it has been discovered by Zapata and Roy (2004) that rock phosphate has residual effect, it builds up P for next cropping season. Nevertheless, many crops have been identified to use P from rock phosphate effectively (Flach et al., 1987; Kamh et al., 1999; Hocking, 2001; Montenegro & Zapata, 2002; Chien, 2003). However, most farmers in North America are still using water soluble fertilizer such as single supper phosphate, triple supper phosphate on their farms, not recognizing agronomical benefits of rock phosphate fertilizer. Therefore, the objective of this research effort was to evaluate effect of rock phosphate on the yield and yield components of potato planted in Standoff soil.

2. Materials and Methods

2.1 Site Description

The experimental trial was conducted in Standoff, Southern Alberta community garden. Standoff is a first nations, Kainai Blood Tribe (KBT) reserve community. It is located on latitude 49^o North and longitude 113^o West. Its location is on Hwy 2, 43 km South West of Lethbridge. Average temperature from April, 2020 to September, 2020 ranged between minimum of 7.6 ^{o}C to maximum of 20.7 ^{o}C while total daily rainfall was 261 mm from April, 2020 to September, 2020 (Agricultural Moisture Situation Update, 2021). Standoff is characterised by windy, dry and warm temperature in summer with little rainfall. Irrigation water was used to support little rainfall in the experimental site. Standoff soil is a Brown Chernozemic soils that are found in the Southern part of Alberta.

2.2 Physico-chemical Soil Composition

Soil samples from 0 to 15 cm layer were taken for physico-chemical analysis (Table 1). Nitrate-Nitrogen was extracted in the soil using 0.01M calcium chloride and N was detected by colorimetry. The phosphorus was extracted using modified Kelowna method and read by auto flow colorimeter while potassium was extracted from the soil using 1 N neutral ammonium acetate and K was detected by flame photometry. Micro nutrients were extracted from the soil using DTPA and measured by atomic absorption spectrophotometer (AAS). The soil texture was measured by hydromentry in soil samples dispersed in a water solutions of sodium hexametaphosphate. The major soil nutrients Nitrogen (N) was deficient, Phosphorus (P) was optimum and Potassium was in excess. Moreover. Secondary nutrients such as Calcium (Ca) and Magnesium (Mg) were at optimum levels whereas Sulphur (S) was deficient. Micro nutrients such as Zinc (Zn), Boron (B), Copper (Cu) and Sodium (Na) were at low levels while soil Iron (Fe) and Manganese (Mn) were in excess. The pH of the soil was 7.6 (1:1 soil:water). Soil textural class was silty clay loam. Southern Alberta soil is classified as Brown Chernozemic.

Table 1. Physico-chemical properties of potatoes field soil trial

Properties	Soil
N (Kg ha^{-1})	40.35
P (Kg ha^{-1})	97.50
K (Kg ha^{-1})	2006.32
S (Kg ha^{-1})	15.70
Ca (ppm)	4449.00
Mg (ppm)	510
Zn (ppm)	1.80
B (ppm)	0.90
Cu (ppm)	1.30
Fe (ppm)	23.00
Mn (ppm)	11.30
Na (ppm)	23.10
OM (%)	5.40
pH	7.6
EC	0.60
Saturated Bases (%)	
Ca	77.10
K	8.00
Mg	14.60
Na	0.30
ECEC	28.80
K/Mg	0.55
Sand %	19.9
Silt %	42.1
Clay %	38.0
Textural class	Silty clay loam

2.3 Experimental Design

The total area used in this trial plot was 450 m × 300 m = 135,000 m^2 The fertilizer was applied on April 30, 2020 at the rate of 100 P Kg ha^{-1} (High level), rate of 50 P kg ha^{-1} (Low level) and no application of fertilizer as control. The rock phosphate fertilizer was broadcasted to entire field according to P levels mentioned above. The basal application of nitrogen inform of urea was broadcasted at 280 N Kg ha^{-1} to entire experimental plot. The sangre potatoes variety were planted on May 8, 2020 at a space of 30 by 90 cm. Sangre is a new potato variety, dark red-skinned, white-fleshed oval potato recommended for boiling. Sangre potato variety is a mid to late season maturing with excellent tuber set and good yields. The treatments (Low P, High P and Control) were replicated three times, resulting into nine plants. One plant was taken from uniformly grown tallest plants in each of the treatment. The plant taken in each of the treatment was used to measure agronomic parameters: number of potatoes was measured by counting, weight of potatoes was measured by sensitive electronic weighing scale (Sartorius Lab. Instruments, GMBH & Co, Germany-ENTRIS 2202-1SUS), marketable number of potatoes was measured by counting harvested number of potatoes that weighed more than 33 g in each replicate and unmarketable number of potatoes was measured by counting harvested number of potatoes that weighed less than 33 g in each replicate, marketable and unmarketable weight of potatoes were measured by weighing potatoes that weighed more than 33 g and less than 33 g, respectively and residual phosphorus level in the soil after harvest was measured by using modified Kelowna method and read by auto flow colorimetry. The agronomic parameters were collected from May 8, 2020 when potato seeds were planted to September 15, 2020 when matured potatoes were harvested, resulting to total experimental period of 131 days after sowing.

2.4 Statistical Analysis

The agronomic parameters measured were subjected to analysis of variance (ANOVA) using IBM SPSS version 27 software, Duncan’s Multiple Range Test was used for separation of means.

3. Results

3.1 Effect of Rock Phosphate Fertilizer on Weight of Potatoes and Number of Potatoes

Table 2 shows effect of varying levels of rock phosphate fertilizer on weight of potatoes and number of potatoes. Weight of potatoes was significantly influenced by rock phosphate fertilizer. It was obvious from Table 2 that High P rock phosphate treated plot had higher potato weight (655.50 g) than either Low P rock phosphate treated plot or control at 76 DAS, whereas at 112 DAS, Low P rock phosphate treated plot gave higher weight of potatoes (2038.10 g) than either High P rock phosphate treated plot or control. There was a marked increase of 210.9% from 76 DAS to 112 DAS, when soil was treated with high and low rock phosphate fertilizer. There was no effect in the effort of the treatments to support weight of potatoes at 98 and 131 DAS. Furthermore, number of potatoes produced was significantly highest at 76 DAS, when high P rock phosphate treated plot produced highest number of potatoes (16.30) than Low P rock phosphate treated plot and control. Thereafter, there was no significant effect of the treatments to support number of potatoes.

Table 2. Effect of rock phosphate fertilizer on weight of potatoes and number of potatoes produced over time

Treatments	Days After Sowing							
	Potatoes Weight (g)				Number of Potatoes			
	76	98	112	131	76	98	112	131
Control	335.90b	252.02	268.90b	1243.10	9.30b	8.30	6.30	6.30
Low P	155.60b	1509.50	2038.10a	5497.70	6.00b	13.30	9.30	11.00
High P	655.50a	1610.40	1225.80b	2205.60	16.30a	10.70	10.30	12.00
SE	125.30	304.90	251.50	2439.20	3.70	4.50	2.50	3.50

Note. Means with different letters are significantly different according to Duncan Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.2 Effect of Rock Phosphate Fertilizer on Marketable and Unmarketable Number of Potatoes

Table 3 shows effect of varying levels of application of rock phosphate fertilizer on marketable and unmarketable number of potatoes. It was clearly seen from Table 3 that marketable number of potatoes at 76 DAS in High P rock phosphate treated plot and control plot jointly produced higher marketable number of potatoes than Low P rock phosphate treated plot, whereas High P rock phosphate treated plot gave higher unmarketable number of potatoes than either Low P rock phosphate treated plot or control at 112 DAS.

Table 3. Effect of rock phosphate fertilizer on marketable and unmarketable number of potatoes

Treatments	Days After Sowing							
	Marketable Number				Unmarketable Number			
	76	98	112	131	76	98	112	131
Control	6.30ab	7.30	6.00	5.70	3.0	1.0	0.30b	0.70
Low P	2.30b	8.70	9.30	9.70	3.7	1.0	0.00b	1.30
High P	11.00a	9.70	8.00	7.30	5.3	4.7	2.30a	5.00
SE	1.90	3.50	2.30	2.0	2.0	2.0	0.39	2.20

Note. Means with different letters are significantly different according to Duncan Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.3 Effect of Rock Phosphate Fertilizer on Marketable and Unmarketable Weight of Potatoes

Table 4 reveals that High P rock phosphate treatment significantly gave higher marketable weight of 585.30 g than either Low P rock phosphate treatment or control with marketable weight of 112 .60 g and 294.60 g for Low P rock phosphate treatment and control, respectively at 76 DAS. High P rock phosphate treatment gave marked increase of 98.70% over control at 76 DAS. Furthermore, Low P rock phosphate treatment produced higher marketable weight (2037.90 g) than either High P rock phosphate treatment or control plots with 1179.20 g and

965.5 g, respectively at 112 DAS. Low P rock phosphate treatment had an increase of 111.10% over control at 112 DAS. There was no significant effect in the effort of the treatments to support marketable weight of potatoes at 98 and 131 DAS. Moreover, unmarketable weight of potatoes was observed at 112 DAS only, where High P rock phosphate treatment gave higher weight of 44.50 g than either Low P treatment or control with unmarketable weight of 0 g for Low P rock phosphate treatment and 3.20 g for control.

Table 4. Effect of rock phosphate fertilizer on marketable and unmarketable weight of potatoes

Treatments	Days After Sowing							
	Marketable Weight (g)				Unmarketable Weight (g)			
	76	98	112	131	76	98	112	131
Control	294.60b	239.60	965.50b	1222.40	40.90	10.70	3.20b	20.70
Low P	122.60b	1412.20	2037.90a	2102.20	33.10	95.00	0.00b	28.60
High P	585.30a	1569.90	1179.20b	2106.20	62.80	38.60	44.50a	98.40
SE	106.13	287.60	248.00	498.20	26.40	36.00	10.40	53.50

Note. Means with different letters are significantly different according to Duncan Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

3.4 Residual Phosphorus Level in the Soil After Potato Harvest

Table 5 shows residual phosphorus levels in the soil after potato harvest. There was no significant difference in residual P level in the treated soil with rock phosphate fertilizer and control.

Table 5. Residual Phosphorus level after potatoes harvest

Treatments	Residual Phosphorus Level (Kg/ha)
	131 Days After Sowing
Control	38.50
Low P	46.30
High P	67.60
SE	23.20

Note. Means with different letters are significantly different Duncan Multiple Range Test (DMRT) $p < 0.05$.

SE: Standard Error.

4. Discussion

Potatoes gained weight at 76 DAS, when rock phosphate was applied at high rate of 100 P Kg ha^{-1}. It was also observed at 112 DAS that low rate of 50 P Kg ha^{-1} positively influenced weight of potatoes, thereafter, there was no significant effort of the applied rock phosphate fertilizer to support weight of potatoes. This outcome reveals that concentration of rock phosphate applied may not be enough to support yield of potato crop beyond 112 DAS. Incorporation of large applications of PR (500-1000 Kg ha^{-1}) followed by a regular maintenance application of P would increase availability of P in the soil, as well as maintain the P in the soil (Zapata & Roy, 2004). Furthermore, rainfall data collected in the experimental site revealed inconsistent of rainfall (261 mm) and shortage of irrigation water during hot Summer period which contributed to low solubility of rock phosphate to support effectiveness of phosphorus uptake by plant for increase in potato yield (Agricultural Moisture Situation Update, 2021). It was clearly seen in our results that rock phosphate has no effect at 98 DAS and 131 DAS due to inadequate of soil moisture to dissolve rock phosphate. It has been confirmed by Weil et al. (1994) that rainfall is the most important climate factor that influences PR dissolution and its agronomic effectiveness. It was also stated by Weil et al. (1994) that increased soil moisture brought about by rainfall or irrigation, increases PR dissolution. The highest number of potatoes were produced from the plot treated with high P (100 P Kg ha^{-1}) at 76 DAS which indicated that large application of rock phosphate above 100 P Kg ha^{-1} could influenced number of potatoes (Weil et al., 1994).

Our result observed that control experiment with no rock phosphate fertilizer application and high P rock phosphate treatment favoured marketable number, whereas high P rock phosphate treatment supported unmarketable number. This signifies that rock phosphate applied was not enough to support marketable number of potatoes (Perrott et al., 1996; Rajan et al., 1996).

Our result also revealed that application of high P rock phosphate treatment gave highest potato marketable weight than other treatments at 76 DAS while low P rock phosphate treatment significantly favoured highest marketable weight of potatoes than other treatments including control at 112 DAS. Moreover, unmarketable weight of potatoes was positively influenced by high P rock phosphate treatment at 112 DAS. High and Low rock phosphate applied to the soil able to support growth and yield of potato crop at 76 and 112 DAS due to favourable growing condition. However, inconsistent of rainfall (261 mm) and shortage of irrigation water at 98 and 131 DAS negatively influenced dissolution of rock phosphate. This was also confirmed by Perrott et al., (1993); Perrott and Wise (2000) that application of P would sustain P availability in the soil, as well as availability of moisture to dissolved rock phosphate.

After potatoes were harvested on the field, residual level of P was noticed in the soil that was treated with high P rock phosphate plot followed by low P treated rock phosphate plots while control gave the least, but there was no significant difference in the treated soils with rock phosphate and control, which indicated that rock phosphate applied at varying levels were not enough (Hedley & Bolan, 1997; Sale et al., 1997). However, Alberta Agriculture Food and Rural Development (2005) stated that the values of residual phosphorus obtained in this present study (38.50 P Kg ha^{-1} for control experiment and 46.30 P Kg ha^{-1} for Low P rock phosphate treated soil) were marginal P level in Alberta soils while 67.60 P Kg ha^{-1} for High P rock phosphate treated soil was adequate P level in Alberta soils. This confirmed that there was considerable amount of residual P in the soil after potatoes were harvested.

5. Conclusion

Direct application of rock phosphate is beneficial for potato crop production in Kainai Blood Tribe Southern Alberta soil. The rock phosphate organic fertilizer influenced potatoes yield, but we discovered that application of rock phosphate rates applied at 50 and 100 P Kg ha^{-1} were not enough to give real potatoes yield for the present study, as well as insufficient of soil moisture inform of rain fed or irrigation to dissolve P in rock phosphate for effective P uptake by potato crop. However, there was considerable quantity of P left in the soil after harvest. The P left in the soil could be used by plants in the next growing season. I would recommend that this trial should be repeated with higher rate of P than rate of P used in this experiment. Irrigation facilities must also be installed to supply water to soil for dissolution of rock phosphate for easy P uptake by potato crop, if there is no natural rainfall.

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