2016 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Fertility Requirements for Quinoa

Project Number: 20150386

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location: AAFC Scott Research Farm, R.M. #380, NE 17-39-21 W3

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Objectives and Rationale

Project Objective

The objectives of this demonstration were**: 1)** to expose producers to quinoa production **2)** to fine tune our understanding of quinoa's macronutrient requirements and **3)** to determine if quinoa respond to micronutrients.

Project Rationale

There is market-driven opportunity to significantly expand quinoa production in western Canada from the 2014 projected production of 1200-1800 MT to 35,000-45,000 MT by 2020. The 2014 projected production was expected to supply about 2 % of the 2014 North American consumption with imports from South America providing the remaining production shortfall of 98 %. Although Bolivia and Peru provide 90-95 % of the North American demand, domestic consumption in both countries is also rising, limiting their ability to meet the increasing demand for quinoa in North America and Europe. Also, quinoa production in South America is on a small scale with limited ability to employ mechanical equipment and organic production is also dependent on manual weeding and animal manure as fertilizer sources.

Quinoa is considered as a healthy grain and acts as a substitute for rice as a gluten-free alternative. It is finding its way into many products such as pasta and breakfast cereals (www.Quinoa.com). Quinoa is a crop that is best grown around highway 16 and north, from Winnipeg to Edmonton but it is recently getting attention from producers around other parts of Saskatchewan and the prairies as a whole. There is a small acreage grown on the Canadian prairies, especially in Saskatchewan and Manitoba. Approximately 1,600 acres of quinoa is currently grown in Saskatchewan, primarily to supply the Northern Quinoa Company (NQC). Because of the variability in production, NQC also still imports product from South America to augment domestic supplies (AARD, 2005).

It is grown under production contract with acres continuing to increase. Its price varies between the conventional and organically grown sources. For example, in 2013 producers received $ 0.60/lb and $ 0.90/lb for conventional and organically grown quinoa, respectively. Yields range from 300 to 2000 lbs per acre. Anything under 1000 lbs/acre is considered disappointing for conventional producers. In Saskatchewan, the average yield over the past five years (2000-2004) ranged between 750-1250 lbs/ac. Despite the increasing acreages and the potential for higher yields in Saskatchewan and the prairies, there is little research regarding the agronomy of quinoa despite its fertility requirements being similar to canola.

Therefore, the intent of this study was to demonstrate the response of quinoa to both macro and micronutrients in NW Saskatchewan. Information on the adaptability of quinoa to NW environment and its yield potential and response to fertility will provide producers with the necessary information to help make informed decisions on the inclusion of quinoa in their rotation.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in spring 2016. A randomized complete block design with four replications was used. There were 12 treatments in total (Table 1). Plots were seeded using a cone seeder with six rows spaced 10 inches apart. Plot sizes were be 2 m by 5 m and the entire plot was harvested using a Wintersteiger plot combine. The plot size was kept small due to manual hand-weeding as the only in-crop weed management option. Phosphorous, potassium and sulphur were mid-rowed at seeding. All the micronutrients were applied through broadcast and plots seeded immediately afterwards. No pesticides were applied as they are no registered products for use in quinoa (see Appendix A for complete agronomic details). Soil analysis was done prior to seeding to get the residual nutrient (Table 3). Following visible rows, spring plant densities were assessed for both crops to determine if there is a response on different nutrient rates on plant establishment. This was assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants m^{-2} based on 10 inch row spacing. All crops were straight-combined using a wintersteiger plot combine. The grain was cleaned and corrected to 10 % moisture content; this was used to determine whether different nutrient rates and combinations had any significant effects on yield.

Table 1: Demonstration treatment list for 2016 growing season

Treatment	**N** (lbs/ac)	**P_2O_5** (lbs/ac)	**K_2O** (lbs/ac)	**S** (lbs/ac)	**Micronutrient** (lbs/ac)
1	0	0	0	0	0
2	0	30	20	15	0
3	30	30	20	15	0
4	60	30	20	15	0
5	90	30	20	15	0
6	120	30	20	15	0
7	150	30	20	15	0
8	120	15	20	15	0
9	120	0	20	15	0
10	120	30	0	15	0
11	120	30	20	0	0
12	120	30	20	15	Cu, Mn, Zn and B; Crop Max II @ 7 lbs/ac

Statistical Analysis

An analysis of variance (ANOVA) was conducted on plants emergence and grain yield using the Mixed Procedure in SAS 9.4. Treatments were considered as a fixed effect factor and replication was considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using a Levene's test, and Shapiro-Wilks. The data was normally distributed; therefore, no data transformation was necessary. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) and considered significant at $P < 0.05$. Weather data was estimated from the nearest Environment Canada weather station (Table 2).

Results

Growing season weather conditions

In Scott, the 2016 growing season started out very dry in April with only 1.9 mm of precipitation. May, July, and August were far above the long-term average, with 40 %, 21 %, and 50 % increase, respectively. Overall, when looking at the accumulated amount of precipitation in 2016 from April to October, there was 38.5 mm more than the long-term total. Throughout the growing season, the temperature was very similar to the long-term average. Growing degree days were higher than the long-term average for the months of April – July, and lower for the remaining months (Table 2).

Table 2. Mean monthly temperature, precipitation and accumulated growing degree days from April to October for the 2016 growing season at Scott, SK

Year	April	May	June	July	August	Sept.	Oct.	Average /Total
				Temperature (°C)				
2016	5.9	12.4	15.8	17.8	16.2	10.9	1.6	11.5
Long-term[z]	3.8	10.8	14.8	17.3	16.3	11.2	3.4	11.1
				Precipitation (mm)				
2016	1.9	64.8	20.8	88.1	98.2	22.2	33.1	329.1
Long-term[z]	24.4	38.9	69.7	69.4	48.7	26.5	13.0	290.6
				Growing Degree Days				
2016	58.9	224.9	303.0	398.7	343.8	176.2	12.5	1518.0
Long-term[z]	44.0	170.6	294.5	380.7	350.3	192.3	42.5	1474.9

[z]Long-term average (1985-2014)

Table 3: Residual soil nutrients prior to seeding for the 2016 growing season at Scott, SK.

Depths	NO_3^--N	PO_4-P	K	SO_4-S	Cu	Mn	Zn	B
				Residual nutrients (lbs/ac)				
0-15 cm	20	29	267	>24	1.6	44.2	2.2	1.2
15-30 cm	14	-	-	24	-	-	-	-
30-60 cm	16	-	-	24	-	-	-	-
Total	50	29	267	>72	1.6	44.4	2.2	1.2

Effects of different nutrients combination on plant density and grain yield

Analysis of variance showed that different nutrient combinations had no significant effects on plant density (P = 0.2575) and grain yield (P = 0.8206). Plant density in this study range from 19 to 39 plants/m^2. The highest application of N (150 lbs/ac), P_2O_5 (30 lbs/ac), K_2O (20 lbs/ac) and S (15 lbs/ac) resulted in the highest plant density of 39 plants/m^2 (Figure 1). However, this highest plant stands did not translate into the highest yield. This can be explained by the fact that, the large standard error of the mean may be an indication that, apparently a rather wide range of plant densities would provide similar yields (Figures 1 and 2). It may also be because there is no correlation between plant density and yield, which shows the compensatory capability of quinoa (Jacobsen et al., 1994). This is because if there are few plants, they will be large and each have high yield. However, a relatively high density is preferred in order to secure uniform plants and maturity, therefore, 100 plants/m^2 is recommended, obtained with a sowing rate of approximately 10 kg/ha. In this study, the recommended plant stands was not attained.

The highest grain yield relative to the control was recorded in treatments with N (60 or 120 lbs/ac), P_2O_5 (15 or 30 lbs/ac), K_2O (20 lbs/ac) and S (15 lbs/ac) (Figure 2). The increment was 5 bu/ac relative to the control (Figure 2). The general trend in yield in this study (49 to 58 bu/ac or 2739 to 3230 kg/ha) compares well with typical quinoa yield in other studies, with yields in this study higher than most of the reported values, except for a study in Kenya where seed yield of up to 4000 kg/ha was reported.

For example, field studies conducted in Colorado indicated that depending upon variety, seed yields of quinoa ranged from 1351 to 1948 kg/ha (Robinson, 1986). An Alberta producer reported, depending on weather conditions, quinoa seed yield ranged from 672 to 1790 kg/ha (ADF News, 1991). In Saskatchewan, yields are said to be highly variable, and can range from zero to in excess of 2000 lbs/ac. The average yield over the past five years (2000-2004) is said to range between 750 to 1250 lbs/ac. The measured yield in this study is higher than the five year average in Saskatchewan (3185 to 3770 lbs/ac vs. 750 to 1250 lbs/ac).

The lack of significant effects of increased N rate on quinoa yield in this study runs contrary to results from other studies. For example, in the first year of trials in Colorado, the variety Linares and others responded favorably to application of N fertilizer. The study indicated that maximum seed yields are possible with 168 to 200 kg N/ ha and at higher rates of N levels decrease seed yields as a result of late maturity and severe lodging incidences (Johnson, 1990). Nitrogen applications also have significant impact on protein content of quinoa seed (Johnson, 1990). Despite the non-significant effects of different N rates on yield, yields in this study were higher than those in Johnson (1990). Finally, N level of 150 kg ha^{-1} was proven to be the best level for N supplementation of soil for grain yield (2.95 t ha^{-1}) and crude protein (CP) content (16 %) of quinoa under Mediterranean ecological conditions of Bornova (Geren, 2015).

The lack of significant effects of increased N rate on yield in this study can further be explained by the fact that, because quinoa may be adapted to poor soils, the N application did not make a huge difference. This can be confirmed by a study in Denmark which concluded that, although there was a significant yield increase when the amount of N fertilizer was increased from 40 to 160 kg N/ha, quinoa seems to be well adapted to poor soils (Jacobsen et al., 1994). However, the lack of significant effects of increased P and K rate agrees with other studies. For example, there was no effect on yield when 30 lbs. of P (as phosphate acid) per acre was applied, in comparison to an untreated field plot (Johnson, 1990). Again, Gandarillas (1982) reported that quinoa responds only to N with no measurable response being observed for either P or K. Gandarrillas (1982) concluded that on average, every kg of ammonium nitrate applied per ha, would increase the seed protein content by 0.1%.

The application of micronutrients in combination with the macronutrients: N (120 lbs/ac), P_2O_5 (30 lbs/ac), K_2O (20 lbs/ac) and S (15 lbs/ac), did not offer any advantage relative to other treatments on both plant density and grain yield (Figures 1 and 2). This may be due to the fact that none of the applied micronutrient had a deficient level from the residual soil levels (Table 3). They had the following levels from the soil test: Cu (sufficient), Mn (Sufficient to Excess), Zn (Sufficient) and B (Marginal to Sufficient). Another possible explanation may be due to the nature of micronutrient interaction with macronutrients to affect yield and yield components. The non-significance of micronutrients in this study may also be due to their interactive effects with other nutrients. For example, Fageria (2002) reported that, interactions of Zn, Mn, and Cu with macro and micronutrients can either be synergistic, antagonistic or have no effects, depending on crop species and nutrients under investigation).

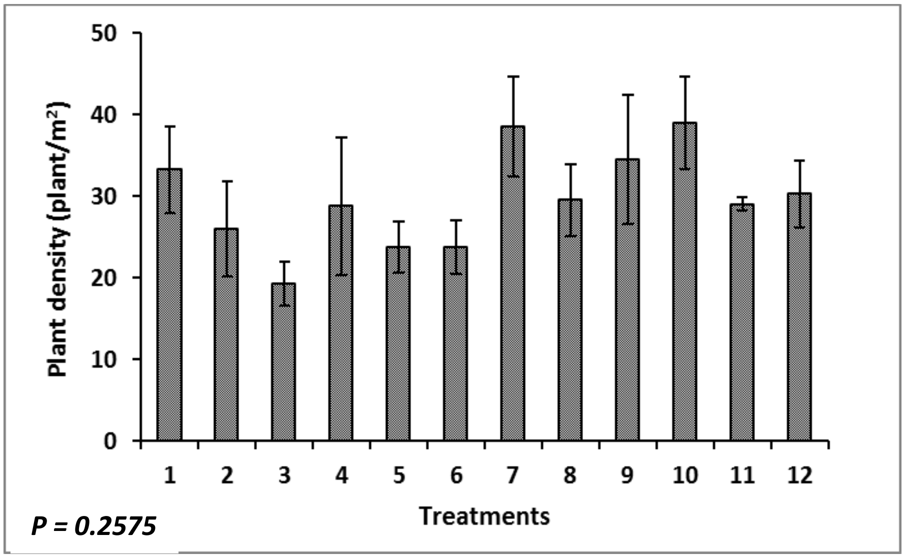

Figure 1: Effects of nutrient combinations on plant density (plants/m^2) in quinoa in 2016 growing season at Scott, SK.

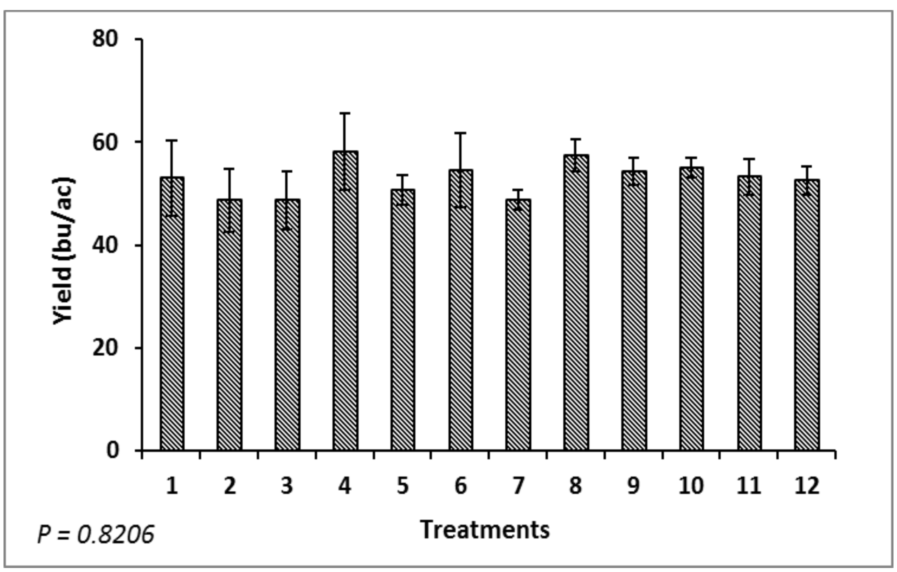

Figure 2: Effects of nutrient combinations on grain yield (bu/ac) in quinoa in 2016 growing season at Scott, SK.

Conclusions and Recommendations

Results from the study have shown that, quinoa plant stands were lower than the recommended plant population; however, yield was higher than most of reported values around the world and specifically in Saskatchewan and /or the prairies. This may be because the large standard error of the mean may be an indication that, wide range of plant densities would provide similar yields. It may also be because there is no correlation between plant density and yield, which shows the compensatory capability of quinoa. There were no significant effects of both the macro and micronutrients on plant density and yield. This may be because quinoa can perform well even on poor soils in terms of macronutrients as per previous studies. Also the lack of response due to the micronutrient may be because the initial residual micro levels were at or close to sufficient levels. In short, from the yield obtained, the production of quinoa is feasible under northwestern Saskatchewan conditions, if appropriate early-maturing cultivars and agronomic practices to control weed and diseases are adapted. However, further agronomic work on variety selection, weed control, disease control, and fertilization requirements (macro and micro) is needed to stabilize yields, enhance quality, and further enhance adaptation to northwestern Saskatchewan environment.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for funding this project through the ADOPT program. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation. This report will be distributed through WARC's website and included in WARC's annual report.

Appendices

Appendix A – Agronomic information for the demonstration in the 2016 growing season

Abstract

Abstract/Summary

Quinoa is considered as a healthy grain and acts as a substitute for rice as a gluten-free alternative. It is finding its way into many products such as pasta and breakfast cereals and is a crop that is best grown around highway 16 and north, from Winnipeg to Edmonton but it is recently getting attention from producers around other parts of Saskatchewan and the prairies as a whole. Despite the increasing acreages and the potential for higher yields in Saskatchewan and the prairies, there is little research regarding the agronomy of quinoa despite its fertility requirements being similar to canola. Therefore, the demonstration was conducted at the AAFC Scott Research Farm in spring 2016 in randomized complete block design with four replications. Results from this study showed that, range of quinoa yield were higher than any yield obtained in Saskatchewan and across the prairies (3185 to 3770 lbs/ac vs. 750 to 1250 lbs/ac). From the yield obtained, the production of quinoa is feasible under northwestern Saskatchewan conditions, however, further agronomic work is needed to stabilize yields, enhance quality, and further enhance adaptation to northwestern Saskatchewan environment.

Appendix A
Agronomic information for 2016 demonstration

Table A.1. Selected agronomic information for the 'Fertility requirements for quinoa' trial at Scott, SK.

Seeding Information	2016
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 19, 2016
Cultivar	Quinoa (NQ94PT)
Seeding Rate	10 lbs/ac
Stubble Type	Chemfallow
Fertilizer applied	Applied based on treatment list
<u>Plot Maintenance Information</u>	
Pre-plant herbicide	Glyphosate @ 1.5L/ac + Bromoxynil @ 0.48L/ac (May 1, 2016)
In-crop herbicide	N/A- Hand-weeding
Fungicide	N/A
Insecticide	N/A
Desiccation	N/A
<u>Data Collection</u>	
Emergence Counts	June 7, 2016
Harvest Date	November 6, 2016

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