International Quinoa Conference 2016:
Quinoa for Future Food and Nutrition Security in Marginal Environments
Dubai, 6-8 December 2016
www.quinoaconference.com

Optimization of Quinoa Nitrogen Nutrition Under Mediterranean Climatic Conditions

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Introduction

Quinoa was introduced to Morocco in 2000 in Khenifra region

1. Characterization of the most suitable genotypes for Moroccan conditions,
2. Development of sustainable production systems for quinoa for consumption and food security

- Suitable crop management techniques need to be developed to assist in sustainable cultivation of quinoa and in the perspective of crop dissemination

Introduction

- Nutrient management is one of the main factors that affect the quinoa production besides the choice of cultivars and optimal sowing date.

Developing productive and respectful of the environment fertilization practices for quinoa sustainable production and management.

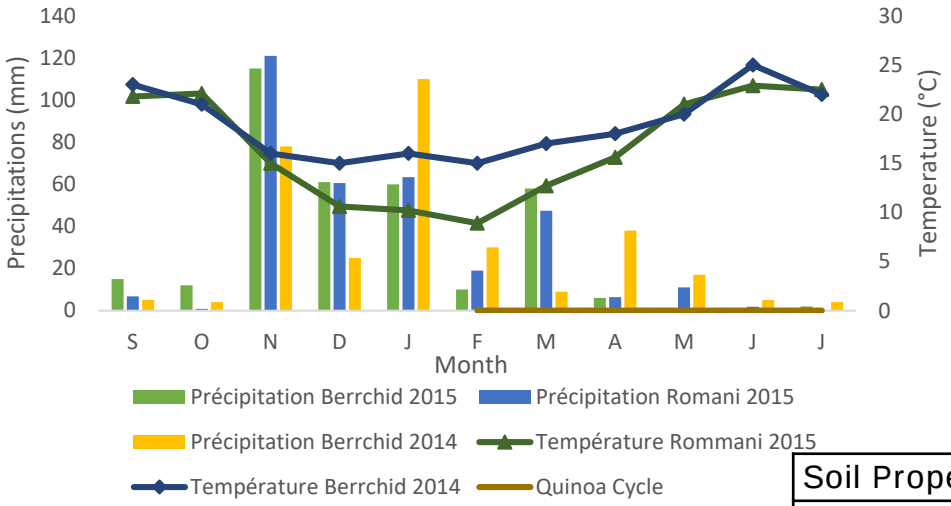
Introduction

3 years of studies with two main objectives :

1. Defining the quinoa crop nitrogen needs and response, and
2. Establishing regional technical references for sustainable quinoa production.

Materials and Methods

Experimental sites



Precipitations and means temperatures during the 2014 and 2015 growing seasons at the Berrechid and Rommani experimentation sites.

Soil Property		Rommani	Berrechid
Mineral nitrogen (ppm)	Nitrate	4.4	9.3
	Ammonium	20.2	23.9
Phosphorus (ppm)		40.0	11.8
Potassium (ppm)		178	229
Organic Matter (%)		0.96	1.10
Electrical Conductivity (mmhos /cm)		0.69	2.40
Soil texture	Sand (%)	10.5	33.5
	Silt (%)	28.0	32.5
	Clay (%)	**61.5**	**45.0**
CaCO3(%)		0.0	0.2
pH		6,6	7.7

Materials and Methods

Trials characterization and management

	Rommani 2013	**Berrechid 2014**	**Berrechid 2015**	**Rommani 2015**
Previous crop	Wheat	Oat	Wheat	Wheat
Initial mineral N (mg/kg sol)	19.5	33.2	16.5	24.6
Sowing (varieties, mode, date & rate)	**L11** Hand sowing in lines **15/03/2015** 2kg/ha	**Titicaca et Puno /** Drill **26/02/2014** 4 kg/ha	**Titicaca** Drill **15/02/2015** 4 kg/ha	**Titicaca et Puno** Hand sowing in lines **06/03/2015** 2kg/ha
Fertilization	**sowing and onset of active growth: (0 ,0) ; (60, 0) ; (0,60) ; (60, 60) ; (60,120) kg N / ha**	**Onset of active growth: 0, 60, 120 or 180 kg N/ha**	**Onset of active growth: 0, 60, 120 or 180 kg N/ha**	**sowing and onset of active growth: (0 ,0) ; (60, 0) ; (0,60) ; (60, 60) ; (60,120) kg N / ha**
Maturity	**07/06/2013**	**19/06/2014**	**10/06/2015**	**06/07/2015**
Residual mineral N (mg/kg sol)	22.8	29.7 (Puno) 19.5 (Titicaca)	20.9 (Titicaca)	18.3 (Puno) 15.1 (Titicaca)

Results

Dry matter Production

DM increased significantly in response to N supply, due to a higher branching and an increase in the stems diameters.
N supply at the onset of active growth is essential for increasing DM.
Maximum TDM at maturity was recorded for 180 kg N / ha;

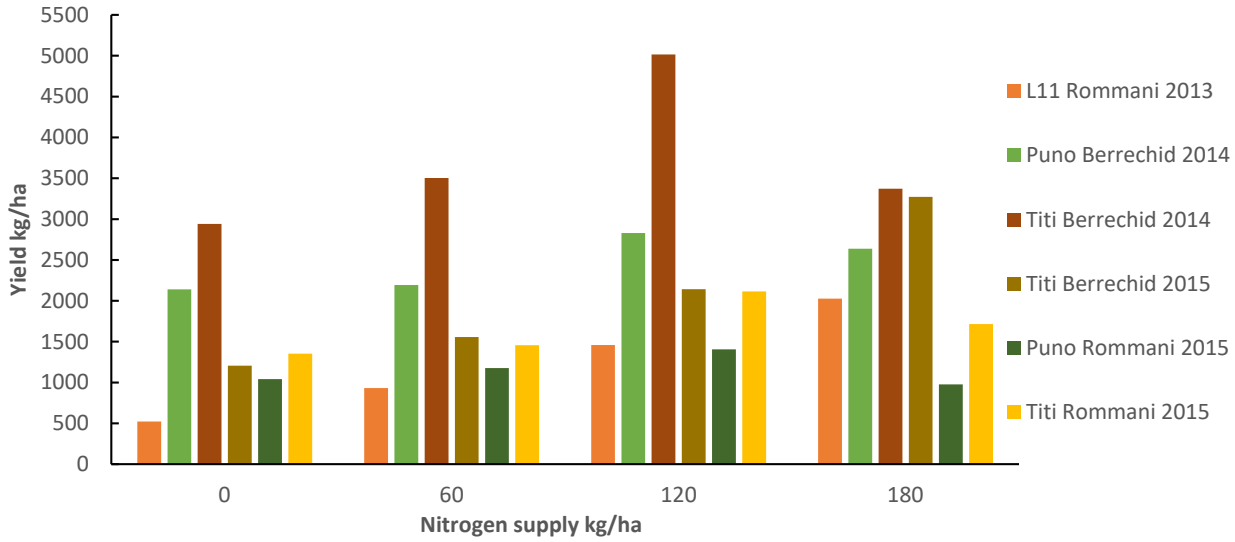
Increases of 33 to 65% over the control (No N application)

	Maximum DM (Mg / ha)
L11 2013	5.1
Titicaca Berrechid	10.5
Puno Berrechid	8.0
Titicaca Rommani	4.3
Puno Rommani	3.9

Rommani : shortening of the growing season (late sowing), less favorable water conditions and also drastic reduction in plant stand due to cracking of a dried clay soil.

Results

Grain yield



Grain yields of the quinoa crop for the tested N rates at Rommani and Berrechid during the 2013, 2014 and 2015 growing seasons.

	R^2 (grain yield - N rate)
L11 in 2013	0.92
Titicaca 2014	0.65
Puno 2014	0.71

Results

Performance development Analysis
Average grain yield and main yield components.

		Berrechid 2014	ANOVA	Rommani 2015	ANOVA
NP/m²	Titicaca	17.20		8.00	
	Puno	16.10		9.60	
NG/P (x 10³)*	Titicaca	11.22	S	8.00	NS
	Puno	10.62	NS	13.40	S
Kernel weight (mg)	Titicaca	2.34	NS	3.20	NS
	Puno	1.98	NS	2.10	NS
Grain yield (Mg/ha)	Titicaca	3.71	S	1.62	S
	Puno	2.45	NS	1.15	NS

*Calculated by the formula: NG/P = [(grain weight/m²/NP/m²)/kernel weight]

Results

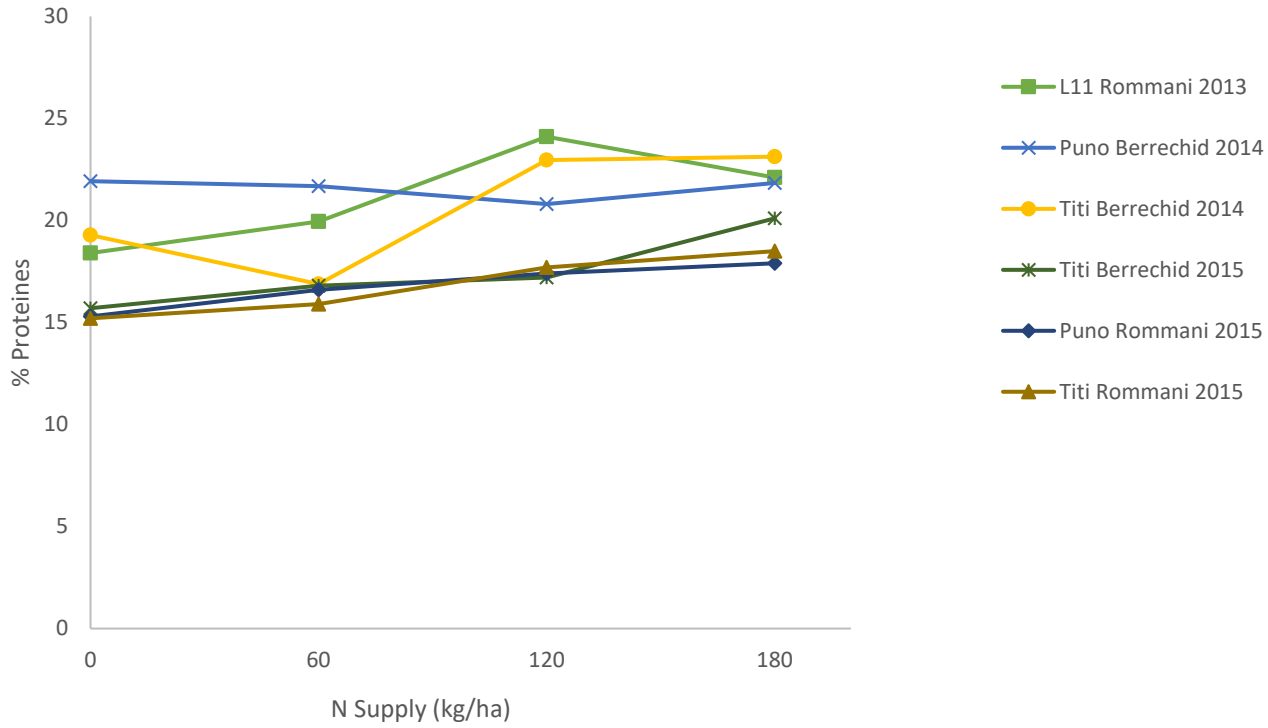
Nitrogen use efficiency (NUE)

N use efficiency (NUE) is expressed as the amount of grain produced per unit of nitrogen absorbed.

	Maximum NUE (kg grain kg N^{-1})	**Treatment**
L11 in 2013	20.3	Control (no N)
2014	17.1 / Titi and 14.5 / Puno	120 kg N / ha
Rommani 2015	15.1 / Titi and 12.5 / Puno	180 kg N / ha
Berrechid 2015	20.7	180 kg N / ha

Results

Grain protein content (GPC)



Grain protein concentration (GPC) of the quinoa crop for the tested N rates at Rommani and Berrechid during the 2013, 2014 and 2015 growing seasons.

Results

Optimum N rate

The optimum rate corresponds to N supply for which the profit is maximum for the quadratic and/or square root model, that provided the best fit of the profit function.

Square root model: $\textbf{Profit (MAD)} = b_0 + b_1 N^{0,5} + b_2 N$;

Quadratic model: $\textbf{Profit (MAD)} = b_0 + b_2 N^2 + B_1 N$;

$N_{Optimal} = (-b_1 / 2\,b_2)^2$

$N_{Optimal} = -b_1 / 2b_2$

MAD = Moroccan dirham

	Variety	Model with the best fit	R^2	Optimal Rate	Maximum Profit MAD*
Berrechid 2014	Titi	Quadratic $Y = -21.9N^2 + 5200.6N - 60170$	0.79	118.7	248377
		Root square $Y = -997208.3 + 239040.4\ N^{0.5} - 11332.9\ N$	0.74	111.2	248377
Rommani 2015	Puno	Quadratic $Y = -1.6N^2 + 285.4N + 49438.7$	0.65	90.43	88152
	Titi	Quadratic $Y = -1.2N^2 + 365.2N + 62407.5$	0.59	151.4	145341
Berrechid 2015	Titi	Linear	0.93	_	

Conclusions

- Dry Matter production and N uptake at maturity responded positively to N inputs ; maximum values observed for (60.120).
- High grain yields, 3.0 to 5.0 Mg / ha achieved in the favorable conditions of Berrechid 2014 were recorded for 120 to 180 kg N/ha.
- Yields were lower in the difficult conditions of Rommani with an average of 1.8 Mg / ha.
- Quinoa grain yield seems to be more dependent upon early growth and development of the quinoa crop (NG/m^2)

Understanding of this relationship will allow control of crop management, nutrient utilization, carbohydrate production, utilization and plant yield.

- NUE (Max around 20 kg grain kg N^{-1}) remain low

strategies for manipulating plant metabolism for greater efficiency may be formulated in the perspective of improving the sustainability of crop quality and yield.

Conclusions

- N supply improves significantly the nutritional quality of quinoa (GPC of 20.9 for L11 in Rommani in 2013, around 18% in Rommani 2015, and over 20% at Berrechid) and maximum values recorded for (60-120 kg N/ha).

- Good productions at Berrechid due to early and proper plant stand establishment, **a critical step for achieving good plant density and yields of quinoa,** while in Rommani trials, a shortening of the growing season, limited DM accumulation and grain yield.

High yields and DM productions for 120 to 180 kg N / ha indicate a promising adaptation and large opportunities for extension of quinoa production to a larger scale:

- **as an alternative crop to diversify and improve the sustainability of the Moroccan cropping systems**
- **as an export-cash crop to increase producers returns.**

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Questions?