



THE UNIVERSITY *of* EDINBURGH

THE INTRODUCTION AND ADAPTABILITY OF QUINOA  
(*CHENOPODIUM QUINOA*) TO COASTAL REGIONS IN NORTHERN  
PERU TO MEET FOOD DEMAND AS INTRODUCED SPECIE

By

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## I. ABSTRACT

In a world where population is increasing, available land is decreasing and food shortage is becoming a critical issue worldwide, new ecosystems will need to be exploited with foreign crop in order to ensure food security. Quinoa arises as the perfect food in order to deal with the demand for food. Since quinoa is originally from the highlands, where there is not enough land for the crop, it is being introduced as foreign specie to new ecosystems. One of these new ecosystems is the northern coastal area of Peru, where companies are looking for possibilities to increase quinoa production. Having it as an introduced species, its adaptability is important, as well as the effect on local species. Three varieties were tested (Altiplano, Salcedo and Arequipeña) with two different fertilisation treatments corresponding to traditional and new nutritional treatments in order to assess adaptability through biometrics and yield. Qualitative assay of species affected by the introduction of quinoa was also reported. All three varieties produced grain, being the Altiplano and Salcedo variety the most productive with 905 kg/ha and 691 kg/ha respectively. All varieties adapted well as they all reached height of more than 115 cm, yet the Salcedo and Altiplano had longer panicles than the Arequipeña variety. Furthermore, the quinoa was affected by pests like *E.melanocampta*, which had an increased on its impact zone by being found in this region of Peru. Quinoa had an effect on the local ecosystem shown by the presence of local species feeding and sheltering within the crop. Quinoa has a huge potential to be introduced in new environments as it adapts to even the hostile environments, thus being an important crop to cope with increasing population growth and could be the key to ensure food security.

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### III. ABBREVIATIONS

Cm - centimetre

cm<sup>2</sup> – centimetre squared

dS/m – electrical conductivity in deciSiemens per metre

F1 – fertilisation formula 1

F2 – fertilisation formula 2

FAO - The Food and Agriculture Organization of the United Nations

Fig - figure

G – grams units of weight

Ha – hectare, units of area

IESAC - Innovación y Ecología Aplicada S.A.C

INIA – Instituto Nacional de Innovación Agraria

Kg – kilogram, unit of weight

M – metre, unit of length

m.a.s.l – metre above sea level

m<sup>2</sup> – squared metre, unit of area

mm – millimetre, unit of length

NPK – Nitrogen, Phosphorus and Potassium

S - South

SPAD – unit of chlorophyll

Spp – species

T – ton, unit of weight

W – West

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## VI. INTRODUCTION

### 1. Setting the scene

In the face of current global problems such as population growth, climate change, water and food security, ecosystems are put under pressure to be able to meet the rise in demand of services. As problems continue to increase, we have to look at other areas never thought as solutions. Agriculture methods and technology will need to increase to satisfy a growing population expected to reach 9.1 billion by 2050 (Geerts *et al*, 2008; Panta *et al*, 2014) and to ensure global food security. Since the time of Thomas Malthus, food availability and security has been a recurring theme (Cuffaro, 1997), as well as the pessimistic views on how population growth and agricultural productivity impact the sustainability of natural resources (Pender, 1998).

Humans have been known to influence ecological processes and food security has become a challenge to maximize crop yields with minimum impacts (Schramski *et al*, 2011). Agriculture provides us with our daily resources (Goodland, 1992) and accounts for 40% of land cover (1.7 billion ha) with 2.5 billion ha of potential agricultural areas in order to increase production to achieve food security (Hanjra & Qureshi, 2010; Panta *et al*, 2014; Smith, 2013). Demand for food has increased and to achieve food security grain production need to increase by 44 million tones with a smaller amount of available fresh water (Geerts *et al*, 2008; Panta *et al*, 2014). In order to achieve this goal, we face decreasing arable land, soil degradation (Jolly, 1994), such as salinity, desertification and global climate change (Ingram *et al*, 2008).

Agriculture is heavily dependent on weather and climate (Bandara & Cai, 2014) and it is the changing patterns in weather such as excessive heat, insufficient water or floods can have negative impacts on crop growth and yields which mostly have become visible year after year (Bandara & Cai, 2014; Geerts *et al*, 2008; Rutten *et al*, 2014). In the last 50 years, according to FAO, agriculture has been reduced by 13% and is expected to fall by 1.5% per year by 2030 (Hanjra & Qureshi, 2010).

## 1.1 The problems we will have to face

The challenges to meet food demands will accelerate in the coming decades (Editorial, 2009). We need to frame the on-going debates of Malthusian philosophies of the need to double food production by 2050 to meet the exponential population growth (Sage, 2013). The total land area varies yearly according to climatic changes and the adaptability of crop yields and favourable environments, which leads to the survival of crops (Lee & Tuljapurkar, 2008). However, there are still problems like population growth, climate change and food insecurity that puts pressure on agriculture.

### 1.1.1 the exponential increase in population

One of the current problems is facing the exponential population growth, and these demographic forces are important determinants for food security and ensure decrease in population hunger (Tirado *et al*, 2010). World population is expected to increase by 37% by 2050, which puts pressure in the agriculture sector to be able to secure food. Furthermore, the increase in population means an increase of hunger related problems (Lal, 2013), especially in children if food production does not meet the increasing demand.

Land and water are essential for the production of food and therefore are fundamental resources (Schneider *et al*, 2011), yet they are under pressure from population growth, economic development and environmental change. This cycle of problems puts further pressure on food security, as although agricultural intensification can be done by employing fertilizers, pesticides or machinery (Schneider *et al*, 2011), food security cannot be achieved if land use is changed from agricultural land to urbanize areas as population increases.

Two of the fast growing countries, China and India show rapid economic growth rates of 12% (Gandhi & Zhou, 2014), represented by their large contributing population and a rapidly increasing food demand. China especially, with only 9% of world arable land, has to feed about 20% of the world's population (Gandhi & Zhou, 2014). As Harris & Kennedy (1999) discuss, many areas are reaching carrying capacity and thus, agricultural productivity needs to switch to a more intense agriculture (Krautkraemer, 1994) and a change in consumption composition of crops that can produce higher yields, higher nutritional values with low resources of land and water.

Population growth perhaps may not be detrimental for agriculture, as in Krautkraemer's (1994) classical model of agriculture and population growth, the increase in population is the result of better agricultural productivity and better wage rates. Due to the rising population and rising incomes, then people are able to buy agricultural commodities that they were not able to do before. The demand for cereals and meat for example, are projected to increase by 65% (Hanjra & Qureshi, 2010) for instance. So while the environmental impacts of cattle rearing are high like deforestation for wider extension of land for grazing and methane production from the cows, the environmental impacts of having crops like cereals are minimum. This is especially true when crops are introduced to desert areas and it perhaps improve the environment.

### 1.1.2 the impact of climate change

Another major threat to food production is of climate change as it affects, agricultural production, especially water supply through changes in the spatial and temporal distribution of heat and precipitation (Hanjra & Qureshi, 2010; Lennox & Gowdy, 2014). Global temperatures are predicted to increase by 1.8°C to 4°C, (Rutten *et al*, 2014) by 2050, as a result of the 35% increase of greenhouse gas concentration in the atmosphere. Furthermore, changes in climate change means that heat waves, droughts and heavy precipitation are expected to persist and be more frequent (Tirado *et al*, 2010). This can affect agricultural yield production; seasonal production can also change or even make some areas infertile for production. As a result, new areas have to be introduced with crops that can adapt to the changing conditions.

Facing food security with climate change is one of the challenges of the 21st century; especially as agriculture is the principal livelihood of the world's poor (Lee *et al*, 2014) and thus is vulnerable to climate change. Thus, by affecting agriculture through changes in precipitation and declining productivity, the livelihoods of people will be significantly affected, especially in Latin America, where climate changes are expected to intensify natural phenomenon like El Niño effect, as well as having impacts on the quantity and quality of water resources (Misra, 2014).

Changes will vary depending on the location and the adaptive capacity and there will be places where livelihood strategies will need to drastically change (Vermeulen *et al*, 2012). These changes will have influence on regional production within a country and alter crop production. Since yield is sensitive to precipitation and temperature (Kang *et*

*al*, 2009), changes in climate will have major influences. The majority of countries in arid areas are total dependent on water sources (Misra, 2014) and climate changes is leading to changes in cultivation patterns of tubers, cereals and pseudocereals (Lennox & Gowdy, 2014). To maintain production yields, farmers of different regions will have to change planting dates or crop varieties according to climatic changes (Lee *et al*, 2014). For tubers, cereals and pseudocereals, which are of important economic value, climate change will affect their distribution pattern and they will perhaps have to be introduced to new areas that match each crop's climatic requirement.

### 1.1.3 Food insecurity

Climate change and population growth is not the only threat to secure food production, but there is also land degradation, competition for land and water, the slowing of agricultural technologies and ongoing uncertainties of regional conflicts and socio economic transitions (Chen & Kates, 1994), which pose a challenge and make food production vulnerable. Currently the definition of food security does not match the current situation worldwide (Kang *et al*, 2009). Not all people have physical, social and economic access to food that meets dietary needs and are able to have a healthy life.

Globally, the potential for food production is very high and it is projected to increase in most areas worldwide as a result of climate change (Tirado *et al*, 2010). Yet, having more food production, does not guarantee that each individual has enough access to food or even less a nutritious and healthy diet (Cuffaro, 1997). This means, that agriculture needs to grow crops that meets people nutritional requirements, that are widely accessible, inexpensive, and that can be stored for months to ensure transportation to the people in most need.

In order for this to be accomplished, international food trade is vital (Kang *et al*, 2009). Since global food security can be threatened by weather, it is of interest for countries with wide areas of available land to be able to manage climatic risk (Wei *et al*, 2014) and be specific growers of crops that match their climatic conditions. With food trade, access to food becomes inexpensive and enables a global exchange of surplus of food. The concept of country crop specificity can be considered as a solution to deal with current global problems, which allows for the global exchange to happen and this depends on how adaptable crops are to worldwide change.

## 1.2 Some solutions to face the current problems

Even before the current challenges, the world posed several obstacles to solve. (Lennox & Gowdy, 2014). However, with better technologies, new strategies have been developed to ensure food security and minimize the risks of crop loss. Populations can benefit from crops due to the increase in relative prices as a result of the increasing demand, thus it helps overcome trade barriers (Parry *et al*, 1999). Furthermore, globalization has helped increase knowledge in agriculture and thus be able to develop strategies, such as the introduction of new crops to new areas and the use of specific type of crops like pseudocereals.

### 1.2.1 Introduction of new crops

Agriculture as it has been described is highly vulnerable to the predictions of global mean temperatures, posing major impacts for rural and urban food security (Vermeulen *et al*, 2012). Crop yields are not increasing fast enough either so a possibility can be to increase food production for the areas currently cultivated (Kang *et al*, 2009) through the increase in water, fertilizers and energy. This puts further pressure on water resources and land fertility, as well as environmental concerns arising from the overuse of fertilizers and pesticides.

Another possibility is through extensification. Expanding crops to other areas can contribute to the increase in production (Ingram *et al*, 2008). Certainly this method can generate trade-offs or environmental impacts if the land is degraded. According to Ingram *et al* (2008), there are 3 billion ha of the world's land suitable for agriculture, from which 50% is still available. Perhaps with the increase in agricultural technologies, food production can expand to areas where it wasn't suitable at first and where the introduction of new crops has allowed their adaptability and yield increase. The use of stress resistant plants could hold the key to ensure food security.

### 1.2.2 The use of pseudocereals

Cereals are grasses that produce grains. Their production has decline since 1961 (Harris & Kennedy, 1999) as a result of decreasing agricultural land and in combination with climate change (Lennox & Gowdy, 2014). Land use has changed to favour urbanization

as population grow, yet as population increases, the demand for nutritional crops like pseudocereals will increase. Pseudocereals are non-grasses that can produce grains in the similar way as cereals. The introduction of crops to new areas that can adapt to very harsh conditions is a possibility to increase yields.

Quinoa is a pseudocereal from the Andean regions of Peru, Bolivia, Chile, Ecuador and Colombia with high nutritional and functional values, highly adapted to different environments (Curti *et al*, 2014; Pasko *et al*, 2009; Fischer *et al*, 2013). Quinoa's composition resembles that of fruits and vegetables with the potential to be a protein substitute in food with its 16 amino acids and fatty acids (Lamothe *et al*, 2015; Escuredo *et al*, 2014; Peiretti *et al*, 2013) Quinoa is considered as an strategic food security crop for its nutritional and functionality and thus it has been considered as a 'perfect food' (Razzaghi *et al*, 2012).

Using salt tolerant and drought resistant crops is of vital importance to mitigate the abiotic factors that limit crop productivity (Ruiz Carrasco *et al*, 2011; Geerts *et al*, 2006; Geerts *et al*, 2008) Quinoa arises as the 'perfect food' for its flexible growth cycle, high nutritional value, and salt and drought tolerance and is therefore a suitable option for hostile environments. In addition to its high level of tolerance to salinity and drought, it is also tolerant to frost, diseases and pests (Garcia *et al*, 2003).

### 1.3 Why quinoa?

The combined impact of population increase and the increase in consumption, together with the insufficient supply to meet nutritional demands have led to look at quinoa for food supply (Garcia *et al*, 2003; Harris, 1996). It has a great potential for different parts of the developing world and international markets (Jacobsen *et al*, 2012). Quinoa (*Chenopodium quinoa*) is an Andean seed, from the family of the pseudocereal that has been cultivated for thousands of years by ancient cultures (Bhargava *et al*, 2006; Garcia *et al*, 2003; Mackinen *et al*, 2014). In recent years, it has attracted interest for its nutritional values and for its adaptability.

Quinoa is a dicotyledonous seed 1.4-1.6mm in diameter. The plant reaches 1-2 m tall after 6 months from germination with leaves growing at rate of 5.5 mm per day terminating in a panicle with small flowers (Bhargava *et al*, 2006; Bois *et al*, 2006; Geerts *et al*, 2008; Mackinen *et al*, 2014). Its deep penetrating roots and seed coat and

endosperm are high resistant to adverse factors like drought, salinity and frost, which allows yield levels of 1439 kg/ha (Bhargava *et al*, 2006; Mackinen *et al*, 2014), while crops like rice, wheat and maize are more sensitive and produce 50%-65% less during adverse effects. Quinoa is also highly versatile and can be consumed in bread, soups, and drinks, due to its high protein content and thus its demand is increasing (Garcia *et al*, 2003; Geerts *et al*, 2008).

Quinoa is highly affected by climate, even in its native location where frosts tend to cause severe impacts in production (Geerts *et al*, 2006; Jacobsen *et al*, 2007). Evaluating different types of quinoa could be an agronomic solution (Bendevis *et al* 2014; Folke *et al*, 2004; Gely & Santalla, 2007; Shabala *et al*, 2013) that can help facing food security (Curti *et al*, 2014).

The introduction of crops into areas outside their native location can alter the environment and the stability of natural populations and communities (Ruokolainen *et al*, 2009). Furthermore, plant species can adapt differently and thus produce different yields. With the increasing globalization we can grow required crops for food security such as quinoa in hostile environment where we could not grow at all, as a result of better agricultural technologies and the pressure to solve the current challenges described (Lambin & Meyfroidt, 2011).

Previous studies have shown how quinoa has adapted in two different environments like highlands and valleys (Curti *et al*, 2014) with different temperatures (Bois *et al*, 2006), different nitrogen fertilization (Schulte *et al*, 2005) and different photoperiod (Bertero *et al*, 1999), all of which have affected quinoa's development and adaptation. Depending on these factors, there can be an increase in crop biomass and seed number (Bertero & Ruiz, 2008).

### 1.3.1 Grows under saline conditions

Quinoa is a halophyte crop, which can grow in saline conditions and withstand soil and water with electrical conductivity of 52 dS/m (Jacobsen *et al*, 2012). This makes quinoa quite efficient when irrigated with any quality of water. Because of its high tolerance, saline conditions will not affect yield, the number of seeds produced or the water use efficiency. Fertilization, which is based on salts, can also work without affecting yield production.



This characteristic is also ideal so that quinoa can be introduced to other areas. Normally, in the Andean regions, water is pristine, however with the current problems of increasing population and climate change, quinoa needs to be grown in other areas. With its ability to grow under saline conditions, quinoa can be introduced to coastal areas, which are subjected to high salinity.

### 1.3.2 Growing in drought conditions

Quinoa not only tolerates high saline conditions, but tolerates drought through its plasticity and low osmotic potential (Jacobsen *et al*, 2012). This tolerance is attributed to morphological characteristics like a very deep and ramified root system, its small leaf area and the presence of vesicles containing calcium oxalate (Bhargava *et al*, 2006, Jacobsen *et al*, 2012). These characteristics help reduce transpiration and prevent water loss

During severe water stress, quinoa maintains positive turgor down to zero turgor (Jensen *et al*, 2000) as a result of the sensitive stomatal closure, which allows the plant to maintain its photosynthetic levels and results in an increase of water use efficiency (Jacobsen *et al*, 2012). Despite this adaptation, which makes quinoa a better option than most other crops, some water application is still needed to obtain more yields (Garcia *et al*, 2003).

### 1.3.3 A high nutritional content

The pseudocereal quinoa can be a solution to food security because of its high nutritional content that resembles that of fruits and vegetables with the potential to be a protein substitute in food with its 16 amino acids and fatty acids (Lamothe *et al*, 2015; Escuredo *et al*, 2014; Peiretti *et al*, 2013) that makes quinoa to be considered as a super food. It has an exceptional balance between oil, protein and fats, which are found, stored in the seed (Bhargava *et al*, 2006). These values are known to be superior to cereals with protein contents ranging from 7.47 to 22.08%, which are composed of high levels of amino acids, especially lysine, methionine and threonine (Jacobsen *et al*, 2012).

Furthermore, it has quite a range of minerals like iron, calcium and folic acid (Jacobsen *et al*, 2012) and a vitamin like A, B2 and is an exceptional source of vitamin E (Garcia *et al*, 2003; Vilche *et al*, 2003). All of this makes quinoa a good source of energy and

essentials people need. By increasing the production of quinoa, plus its versatility in cuisine, it can be considered one of the main ingredients for food security and reducing hunger worldwide.

## 2. Objective of the research

According to Razzaghi *et al* (2012), quinoa is well adapted to arid environments with poor soil conditions, and that is why the objective of the research was to evaluate the area of northern coastal areas of Peru as new agricultural land to grow quinoa for food security. Yields and growth rates of three varieties under different fertilization treatments were evaluated. Quinoa grown in coastal areas is considered as an introduction to a new environment and therefore, the research also evaluated how quinoa affects the local environment by trying to answer two main hypotheses: How might quinoa add to and interact with the local ecosystem? And, how adaptable is quinoa in coastal areas to produce yields to ensure food security?

### 2.1 Adaptability of quinoa

As a result of the current problems our world is facing long term planned adaptive crops like quinoa, will become important to anticipate and minimize adverse changes (Curti *et al*, 2014; Lee *et al*, 2014). The different combinations in solar irradiance, temperature, humidity and even light hours can be found in tropical areas and can have an effect on the growth and metabolism of plant. Different quinoa cultivars can adapt differently depending on the thermal responses in relation to their site of origin (Bois *et al*, 2006) and this can lead to the different strategies of dispersal and of regional food diversification in an attempt for food security.

Furthermore, quinoa can be grown in various types of soils with various pH and salinity, as well as its photoperiod sensitivity. As a result, cultivars from Peru, Bolivia and Chile can be grown in India, with plant reaching 1.5 metres with good nitrogen fertilization (Bhargava *et al*, 2006). Naturally, quinoa is grown in the Andean regions, and sea level quinoa has been grown in Chile (Bertero & Ruiz, 2010). In places, where light hours and temperatures are high, there can be a higher biomass and yield, with greater panicle biomass giving sustainable intensification opportunities (Lal, 2013). Its great adaptability to different geographies allows for a smooth transition from other regions, something that cannot be done with common crops (Bleaney & Dimico, 2011).

That is why it is important to evaluate the adaptability of Peruvian quinoa to the most extreme conditions, like deserts, high temperatures and dry climates. This would evaluate the effectiveness of the crop, even in poorest of soils. Since quinoa is considered as a super food, then it could adapt to different areas as a way to reduce poverty, hunger and improve the quality of life of farmers by giving them opportunities with this new crop and overall, ensure food security

## 2.2 Quinoa in its new environment

As the demand for food continues to increase as a result of the increasing population, the fight for land for urbanization and food crops will intensive. New areas for agricultural development will be exploited with new species being introduced beyond their natural range. Quinoa, which is commonly grown in the Andean highlands, could be grown in coastal areas through human activity and therefore have a degree of impact on the ecosystem. Additionally, by introducing quinoa, it can be affected by the natural species of that area as a new source of food or new niche for living.

Quinoa in its natural range of the Andean region is infected by different pathogens like damping off and blight, and Downy mildew caused by *Peronospora farinose*, endemic to quinoa's natural region and being the most severe pathogen, (Bhargava *et al*, 2006; Danielsen & Munk, 2004). This pathogen is known to reduce the photosynthetic area of the plant resulting in yield reduction of 33-58% (Danielsen & Munk, 2004). Additionally, quinoa can be attacked by insect pests like *Eurysacca melanocampta* that can cause damage from 8 to 40%, and similarly be affected by birds (Bhargava *et al*, 2006).

Being introduced into a new area, quinoa is subjected to different temperatures. Climate change and global warming can have serious consequences for the diversity and abundance of insects and pests that can impact production, and thus food security (Sharma & Prabhakar, 2014). It is known that Downy mildew can have an accelerated maturity in Huancayo, even more so, on the Peruvian coast, which creates perfect conditions for growth and easy reproduction of Downy mildew (Danielsen & Munk, 2004).

Consequently it is important to assess what affects quinoa in their new areas in terms of pests or viral infections and correlate it with species in the natural environment.

Furthermore, it will allow us to determine how the introduction of this new species has benefitted or negatively affected species in their natural environment by being a new source of food, habitat or source of disease.

## VII. MATERIALS AND METHODS

The study proposed to evaluate how quinoa (*Chenopodium quinoa*) adapts to the newly introduced area, which is the coastal region of Peru. With this evaluation, I compared how quinoa grows in the coastal region compared to the highlands. The only site of study is in the coastal area, which prevented a direct comparison with quinoa being grown in the highlands. That is why; the data has been compared with the fact sheets created by the National Institute of Agrarian Innovation (INIA) for the varieties being evaluated. There were three varieties evaluated. Two of them with comparable fact sheets since they are more commercially grown (INIA Salcedo and INIA Altiplano are the name of the two varieties). While the other quinoa variety is a non-commercial, more local highland variety.

### 1. The varieties of quinoa used

The following describe the two commercial varieties being used and the characteristics being compared with biometric readings. For the non-commercial variety, there is no similar comparable data.

#### 1.1 INIA Salcedo

It is a hybrid between the variety Real Boliviana and Sajama. It has been through a whole program of selection by INIA PERU in Puno and now it has been introduced in coastal regions.

Some characteristics:

- Days for emergence: 8
- Days for first flowering: 70
- Days for total maturity: 150
- Height at total maturity: 164 cm
- Colour of stem: Green
- Colour of panicle: White
- Form of panicle: Glomerulate



Figure 1. Salcedo Quinoa

- Density of panicle: Intermediate
- Uniformity of grain colour: Uniform
- Size of grain: 2,0 mm
- Seed used: 10 kg/ha
- Potential production: 4 t/ha
- On the field: 2,5 t/ha

## 1.2 INIA Altiplano

It is also a hybrid, which origin is also the highlands of Peru, especially Puno where research is conducted on this variety.

Some characteristics:

- Days for emergence: 8
- Days for first flowering: 70
- Days for total maturity: 150
- Height at total maturity: 164 cm
- Colour of stem: Green
- Colour of panicle: White
- Form of panicle: Glomerulate
- Density of panicle: Intermediate
- Uniformity of grain colour: Uniform
- Size of grain: 2,0 mm
- Seed used: 8 kg/ha
- Potential production: 4 t/ha
- On the field: 2,11 t/ha



Figure 2. Altiplano quinoa

As quinoa is introduced to a new areas, it will grow differently compared to its native location, that is why biometric readings will be measured throughout the growth period of the plant up to its point of maturity. Both of these varieties have potential for coastal areas, and they will be evaluated. Furthermore, the third variety has been brought from Arequipa city, located in the highlands of Peru in order to compare more native and rustic grown quinoa compared with commercial varieties, such as Salcedo and Altiplano.

## 2. Area of study

### 2.1 Location

The experiment took place on an agricultural experimental area of the privately owned company IESAC, located at 38.06 km northeast of Piura City in Piura Province ( $4^{\circ}57'48.94''S$   $80^{\circ}29'23.03''W$ )



Figure 3. Experimental area in the coastal Piura region (blue), Northern Peru at 140 m.a.s.l, while quinoa is traditionally grown in the highlands of Peru (red)

### 2.2 Weather

Climate variability is an important factor that affects production of any crop as it affects directly the availability of water, changes in humidity and temperature. The weather in Piura is sub tropical, characterized by light rainfall and high temperatures and sometimes leading to more extreme weather as a result of the El Niño phenomenon. This is because both Humboldt and Equatorial sea currents affect the area.

Temperature can be a factor that can affect the production for the introduced quinoa. Despite having more sunlight hours (6 hours), which can increase the photosynthetic metabolism, high temperatures can affect production by making stomata in leaves close, reducing production. Relative humidity is also an important factor as it has a direct and indirect relationship with the consumption of water, plant transpiration and the development of pests and diseases. Precipitation is another factor, since rainfall is very irregular in the area of study, and mostly related by events of the El Niño, which can bring rainfall up to 20 times the normal. All of these factors are different of the area of study and the highlands areas where quinoa is usually produced, which could have an impact on adaptability of the crop to new areas.

Table 1. Comparison of climatic conditions in the area of study (Piura) to traditional highlands areas (Arequipa) where Quinoa is grown locally, Senamhi (2015)

|                       | Piura    | Arequipa |
|-----------------------|----------|----------|
| Temperature (°C)      | 16 to 35 | 7 to 22  |
| Relative humidity (%) | 55 to 73 | 27 to 70 |
| Precipitation (mm)    | 10 to 80 | 100      |

### 3. Measurements taken

Biometric readings were conducted for 30 plants of each variety. On site, there were two fertilization programs being tested and therefore evaluations were conducted with both treatments. Fertilisation programs also help determine the adaptability of the quinoa in coast since the first fertilisation (Table 2) correspond to hot climates like the one where the experiment is being run in order to reduce the impact of stress, while the second fertilisation program (Table 3) correspond to the normal nutrient requirement of quinoa in its native environment. The differences in the programs are the nutrient concentration used for quinoa, having fertilisation 1 be double in concentration than fertilisation 2.



Table 2. Fertilization program (1) with high nutrient content for extreme conditions

| Phenology                    | WEEKS | N      | P <sub>2</sub> O <sub>5</sub> | K <sub>2</sub> O | CaO    | MgO   | S      |
|------------------------------|-------|--------|-------------------------------|------------------|--------|-------|--------|
| Germination                  | 1     |        |                               |                  |        |       |        |
| Growth                       | 2     | 8.00   |                               |                  |        |       |        |
|                              | 3     | 10.00  | 8.0                           | 0.00             | 0.0    | 0.00  |        |
|                              | 4     | 13.00  | 10.0                          | 4.26             | 3.4    | 8.33  |        |
| Branching                    | 5     | 12.00  | 12.0                          | 5.3              | 4.6    | 8.33  |        |
| Panicle                      | 6     | 12.00  | 14.0                          | 5.3              | 5.7    | 8.33  |        |
| Flowering                    | 7     | 10.00  | 14.0                          | 6.5              | 11.5   | 12.50 |        |
| Grain growth and development | 8     | 8.00   | 12.0                          | 7.7              | 11.5   | 12.50 |        |
|                              | 9     | 8.00   | 10.0                          | 8.7              | 11.5   | 12.50 |        |
|                              | 10    | 7.00   | 8.0                           | 10.7             | 9.2    | 8.33  |        |
|                              | 11    | 6.00   | 6.0                           | 12.9             | 10.3   | 8.33  |        |
|                              | 12    | 6.00   | 4.0                           | 12.9             | 11.49  | 12.50 |        |
|                              | 13    | 0.00   | 0.0                           | 12.9             | 9.20   | 8.33  |        |
|                              | 14    | 0.00   | 0.00                          | 12.87            | 0.00   | 0.00  |        |
|                              | %     |        | 100.00                        | 98.00            | 100.04 | 88.51 | 100.00 |
| UNITS                        |       | 300.00 | 120.00                        | 300.00           | 40.00  | 20.00 | 50.00  |

Table 3. Fertilization program (2) with low nutrients used for quinoa in its native environment.

| Phenology                    | WEEKS | N      | P <sub>2</sub> O <sub>5</sub> | K <sub>2</sub> O | CaO   | MgO    | S    |
|------------------------------|-------|--------|-------------------------------|------------------|-------|--------|------|
| Germination                  | 1     |        |                               |                  |       |        |      |
| Growth                       | 2     | 8.00   |                               |                  |       |        |      |
|                              | 3     | 10.00  | 8.0                           | 0.00             | 0.0   | 0.00   |      |
|                              | 4     | 13.00  | 10.0                          | 4.26             | 3.4   | 8.33   |      |
| Branching                    | 5     | 12.00  | 12.0                          | 5.3              | 4.6   | 8.33   |      |
| Panicle                      | 6     | 12.00  | 14.0                          | 5.3              | 5.7   | 8.33   |      |
| Flowering                    | 7     | 10.00  | 14.0                          | 6.5              | 11.5  | 12.50  |      |
| Grain growth and development | 8     | 8.00   | 12.0                          | 7.7              | 11.5  | 12.50  |      |
|                              | 9     | 8.00   | 10.0                          | 8.7              | 11.5  | 12.50  |      |
|                              | 10    | 7.00   | 8.0                           | 10.7             | 9.2   | 8.33   |      |
|                              | 11    | 6.00   | 6.0                           | 12.9             | 10.3  | 8.33   |      |
|                              | 12    | 6.00   | 4.0                           | 12.9             | 11.49 | 12.50  |      |
|                              | 13    | 0.00   | 0.0                           | 12.9             | 9.20  | 8.33   |      |
|                              | 14    | 0.00   | 0.00                          | 12.87            | 0.00  | 0.00   |      |
| %                            |       | 100.00 | 98.00                         | 100.04           | 88.51 | 100.00 | 0.00 |
| UNIDADES                     |       | 170.00 | 60.00                         | 200.00           | 20.00 | 15.00  |      |

As the plant was under new climatic conditions, as well as soil conditions compare to its native location, biometric readings were measured to assess the adaptability and yield production of quinoa in the coastal region. Measurements were taken in 1m transects, 10 plants will be evaluated by measuring the height of the plant and the number of leaves. When the plants are developing a panicle, the length and number will be also measured. Total grain production was weigh as well as 100 grains of each variety per treatment to determine the quality of the grain.

Having several transects ensured good randomization of the individuals being evaluated as well as having a good procedure to have a representative population of the varieties and treatments there were. Readings will carry out using measuring tapes once a week for a period of 3 months.

The comparability between quinoa grown in coastal regions and highlands is important and with the biometric data as well as grain yield, we can establish a comparison using the factsheet of the variety. However, from a commercial point of view it is important to establish which of the varieties is best suited for coastal regions, being the one with the highest yield and better behaviour and adaptation to its new ecosystem.

One way to do this is to measure the amount of chlorophyll within their leaves. Chlorophyll is an important pigment for photosynthesis, enabling plants to produce their source of energy (Yu *et al*, 2014). The amount of chlorophyll in the leaves is a good indicator on how well plant is absorbing nutrients and thus, how well the plant has adapted by developing a good root and leaves systems. This also relates to plant stresses and senescence that involve nutrient deficiencies as Yu *et al* (2014) describes. By comparing the amount of chlorophyll between varieties, it will determine how well quinoa has adapted by using it as a fact how well it has assimilated nitrogen (Baglieria *et al*, 2014) with both of the fertilisation treatments.

Chlorophyll was measured using a chlorophyll meter SPAD502, Spectrum Technologies that enables, quick, easy measurements of the chlorophyll content of plant leaves without damaging the leaf. Chlorophyll was measured from the 4th leaf from the top. This allowed us to take several measures and getting an average to compare it with. It will be measured weekly 3 weeks from sowing. The reason that the 4th leaf is chosen to evaluate for each variety is the maturity of the leaves as they growth. It will be difficult to measure the previous leaves as they are still in development as the plant continues to grow and reach its maximum height. It will also help measuring with the chlorophyll meter without damaging the leaf.

Quinoa, being native from the highlands of Peru, by introducing it into coastal environments, it will act as a foreign species and may affect the local ecosystem balance. In other to be a successful crop, it will need to have better adaptability than other local plants and thus be rarely affected by native wildlife species. In order to survive, as Rukolainen *et al* (2009) mentions, depends on how quinoa interacts with its predators and competitors that is why; it is imperative to monitor the species affecting the crops, such as insects, birds, and mammals.

The evaluation will occur for each variety in two different methods. The first one is evaluation per zones within each variety, where 40 individuals will be evaluated for larvae and eggs of insects. Furthermore, 2 transects of 100m for tossing pieces of cloth in order to capture adult species of the insects affecting the crop will do each variety. The number of adults will be counted for 10 cm<sup>2</sup> of the cloak and then projected to the total area. In the sighting of other species hard to collect like birds, their presence will be noted to evaluate qualitatively.

The species identified will be compared with the list of local fauna obtained after an Environmental Impact Assessment study carried out in 2014. Locally one mammalian species, for example is the Sechura fox, *Lycalopex sechurae*. This will allow to infer possible effects on the native ecosystem.

In terms of invertebrates the lists range of different orders such as orthoptera, lepidotera, coleopteran, odonata, diptera and hymenoptera. One of the main problems of quinoa in Peru is *Eurysacca melanocampta*, as Povolny, 1990 describes. This main plague of quinoa has been registered in Junin, Cerro de Pasco, Puno y the valley of the Huallaga River, located 1,200 km from the area of study. The plague has not been registered for Piura, where the experiment is located, however the problem arises when the increasing areas of quinoa being developed along the coastal regions of Peru, may affect the distribution of *E. melanocampta* and thus, if its persistence increases, it becomes difficult to eradicate. By introducing quinoa in Piura, it perhaps shifts wild populations and thus the propensity of new crops being affected. During the evaluation, *E.melanocampta* will be evaluated for by methods described by counting the number of adults as well as the presence of other common pests and invertebrates. This way, the adaptability and the effects of quinoa's introduction to Piura can be assessed. Agricultural cultural practices such as the use of pesticides were performed when pests were encountered in order to obtain a good yield production. This was done through counting the insects present in trapping cloaks (Fig.4) within 10cm<sup>2</sup> and then projecting the value for the 2m<sup>2</sup> cloak trap.



Figure 4. Cloak trap with insects for processing [Taken November 2014]

Furthermore, the reason why companies are switching to grow quinoa in coastal regions is to ensure more and better quality yields. This will be evaluated for each variety and fertilization treatment. After harvesting, quinoa is left to dry for a week and then threshed in order to obtain the grain. The grains are weighed by rows and then for each

variety under each treatment and an average obtained from which the total yield value per ha can be extrapolated and compared to the expected values for each variety on their factsheet. Furthermore, quinoa is not only about volume, but quality as well and thus in order to compare which quinoa has adapted best to the local environment of Piura, 100 grains will be evaluated through weight. To ensure food security, the biggest yields are wanted with the less amount of input in terms of water and fertilizers and thus, it will help evaluate its potential to cope with the rising demand of food.

## VIII. RESULTS

The different varieties of quinoa within the different fertilisation management were evaluated in biometrics from November 7<sup>th</sup> 2014 to February 13<sup>th</sup> 2015, while chlorophyll levels were measured from December 3<sup>rd</sup> to March 4<sup>th</sup>, when the leaves of the plants were of a size suitable for the chlorophyll meter, thus preventing damage. The varieties Altiplano and Salcedo were harvested by March 18<sup>th</sup> 2015, while the Arequipeña variety needed more time on the field to mature, harvested by March 30<sup>th</sup> 2015. Threshing of the panicles happened between March 18<sup>th</sup> and April 17<sup>th</sup> because of the persistent rainfall. Quinoa panicles need dry and hot days to dry in order to obtain the grains. Grains were then weighted and evaluated.

### 1. Chlorophyll levels

Chlorophyll in the leaves is a good indicator on the adaptability of the plant to its new environment, as it represents how well it can absorb its nutrients, which lead to prosperous growth. Using both fertilisations, there is an increase in chlorophyll levels from the end of November to beginning of January, which later drops as a result of the maturation of the plant, indicating the time for harvest.

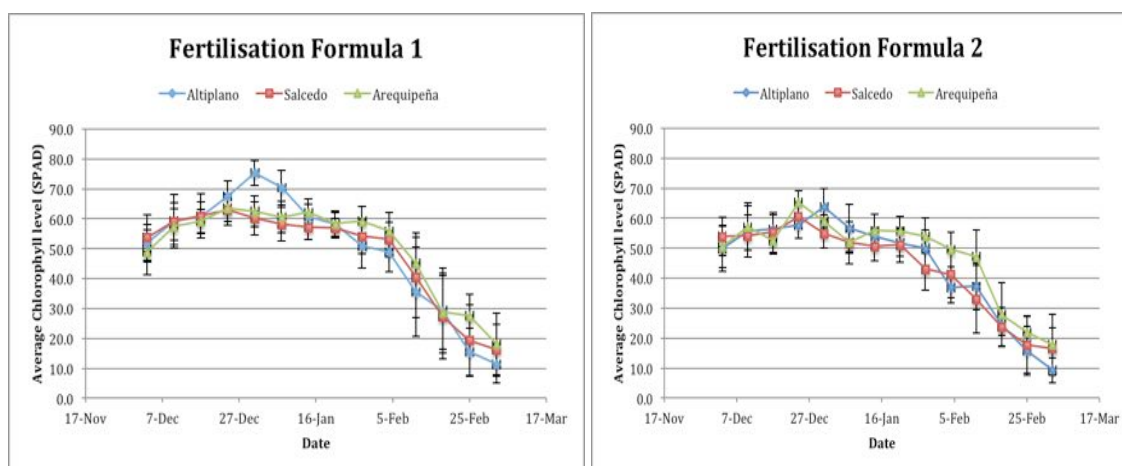


Figure 5. Average chlorophyll levels of quinoa leaves through growth and maturation stages for both fertilization treatments and their standard deviations from Table I-VI in the Appendix

Fertilisation formula 1 of 300-120-300 NPK shows that all three varieties (Fig.5), reached a maximum of 63 SPAD during a month and then decrease at a rate of 1.4 SPAD/day. The Altiplano variety does have a bigger concentration compared the other

varieties during a period of 21 days between December 24<sup>th</sup> 2014 and January 14<sup>th</sup> 2015. During this period, the chlorophyll level increased at a rate of 1.8 SPAD/day to a maximum of 75 SPAD. It then decreased at a rate of 1.1 SPAD/day.

Fertilisation formula 2 of 170-60-200 NPK shows that chlorophyll levels were very different for each transects done. For the month of December, there was an average increase of 0.4 SPAD/day for the three varieties (Fig.5). Salcedo and Arequipeña varieties reach their average maximum peak on December 24<sup>th</sup> 2014, while for Altiplano variety it is on December 31<sup>st</sup> 2014. This time, it is Arequipeña variety that has the highest average SPAD level of 65.2 compared to the Altiplano of 63.7 SPAD. From January 14<sup>th</sup> 2015, there was a drop of 0.8 SPAD/day for the Altiplano and Salcedo variety. The Arequipeña variety remains with average 50 SPAD for one more month and then drops for the next 21 days at a rate of 1.4 SPAD/day.

In terms of type of varieties, they all show similar pattern of the concentration of chlorophyll in the leaves as it matures. Comparing fertilisation is also important as this determines how well the plant has adapted to its new environment. Fertilisation 2 represents fertilisation usually used in its local environment, while fertilisation 1 is one formulated to satisfy the plant in these harsh conditions. Quinoa will have to deal with hot weather as well as poor sandy soils, making it important to give the plant more nutrients for growth.

The amount of chlorophyll can be seen from the results to have been affected by the amount of nutrients. For the Altiplano variety, the quinoa subjected to fertilisation 1 and fertilisation 2 follow similar pattern, however, the one being given more nutrients increase at a rate of 0.9 SPAD/day, compared to F2, where the rate of chlorophyll levels increase at a rate of 0.5 SPAD/day. Quinoa fertilised with more nutrient reached a peak of 75 SPAD, while fertilisation 2, a peak of 63 SPAD. As the quinoa matures, chlorophyll levels decrease at similar rates of 1.1 SPAD/day.

In a similar way, the Salcedo variety (Fig.5) shows differences in chlorophyll levels with the two-fertilisation treatments. Quinoa fertilised with more nutrients increased during December at a rate of 0.4 SPAD/day, while the other fertilisation treatment, chlorophyll levels increased at a slightly lower rate of 0.3 SPAD/day. Compared the Altiplano variety, which showed difference of fertilisation treatment until January 21<sup>st</sup> 2015, the chlorophyll of Salcedo variety with fertilisation 1, remains with a higher

concentration of chlorophyll and decreasing at a rate of 0.2 SPAD/day. With fertilisation 2, the decrease in chlorophyll levels is of 0.8 SPAD/day. Both varieties from the February 18<sup>th</sup> 2015, decrease at a similar rate e

For the Arequipa (Fig.5), there seems to be no relationship by adding more nutrients. Both show a similar pattern with both treatments. Fertilisation 1 has a more constant and bigger chlorophyll level of 60 SPAD for a month, while with fertilisation 2, its is mostly around 55 SPAD, with a peak 65 SPAD on December 24<sup>th</sup> 2014. As quinoa matures, the fertilisation treatment becomes minor since, from February 11<sup>th</sup> 2015, there was a decrease in chlorophyll levels of 1.5 SPAD/day for both fertilisation treatments. Despite these differences, for all three varieties, their standard deviations would suggest that there is no difference among the varieties and that all follow a similar pattern of remaining above 50 SPAD for at least 2 months, and then decreasing as a result of the maturity.

## 2. Mean of height of plants

The height of the plants was recorded weekly in order to assess its adaptation as an introduced species and compare the records of height of the varieties of quinoa used. Both fertilisation treatments produced interesting results as shown by the growth of the varieties with fertilisation treatment 1 (Fig.6).

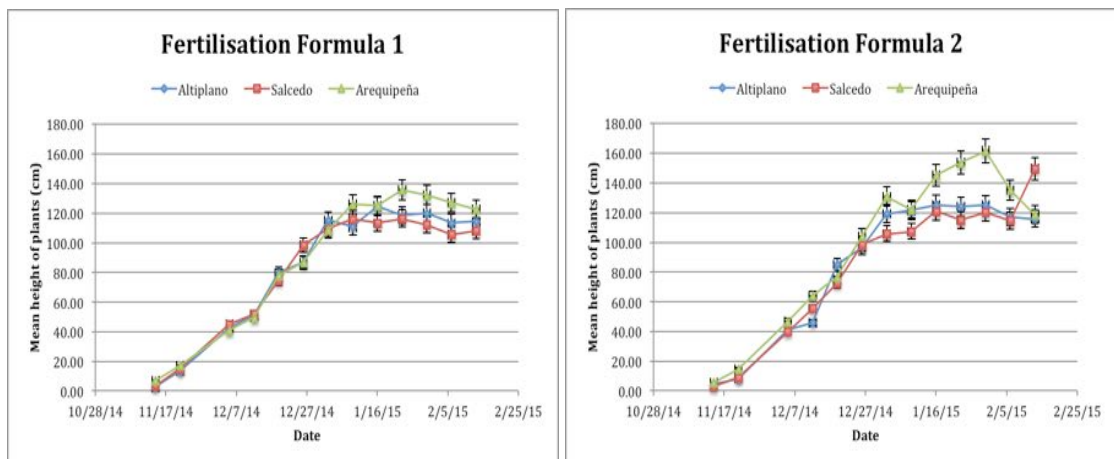


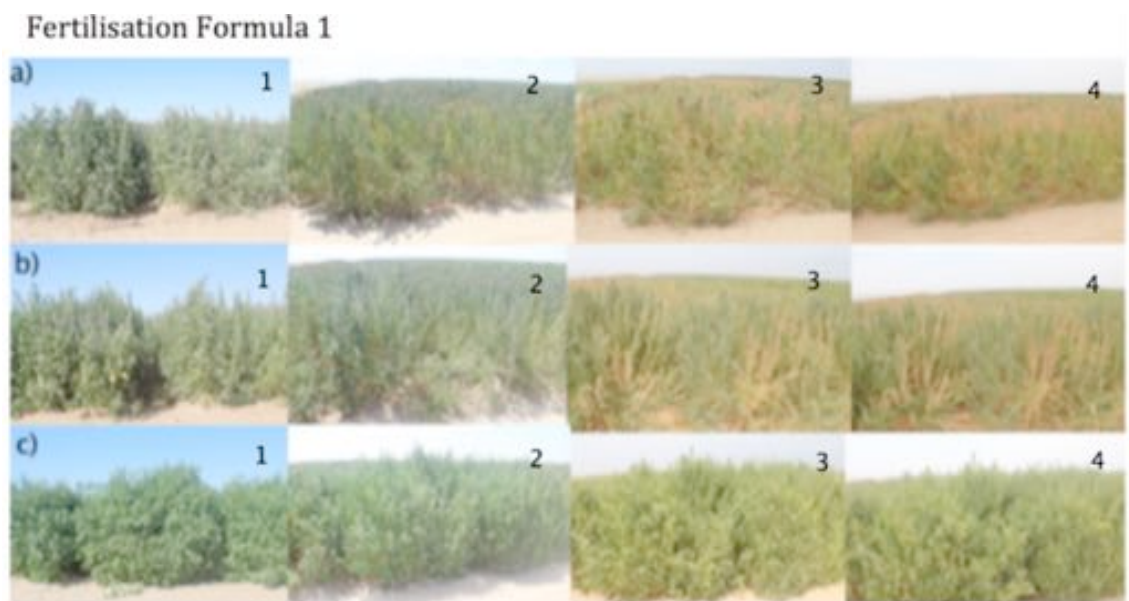
Figure 6. Average height of plants of quinoa for both fertilisation treatments during the growing stages and their standard deviations from Table VII in the Appendix

Using more nutrients so that it can adapt to the new environment, all of the three varieties increased linearly at a rate of 1.9 cm/day for a period of 62 days, reaching an



average height of 120 cm. From this point on, both the Altiplano variety and the Salcedo variety remain at that height, which implies the formation of the panicle from January 9<sup>th</sup> 2015. The Altiplano variety reached an average maximum height of 124.9 cm. The Salcedo variety reached an average maximum of 116.1 cm. The Arequipeña variety, which comes directly from the highlands, continues to grow at a lower rate of 1.0 cm/day for 14 days following January 9<sup>th</sup> 2015 reaching an average maximum height of 135.6 cm.

For fertilisation formula 2 170-60-200 (NPK), all three varieties increased during the first 49 days at a rate of 2.0 cm/day, reaching to an average height of 100 cm. From that point on, December 26<sup>th</sup> 2014, the varieties behave differently. To start, the Altiplano variety, reaches an average height of 120 cm on January 2<sup>nd</sup> 2015, which is one week before than with fertilisation formula 1. For the Salcedo variety on the other hand, an average maximum height of 120 cm, on January 16<sup>th</sup> 2015, which is one week after compared to fertilisation formula 1. The Arequipeña variety after December 26<sup>th</sup> 2014, stays with an average 126 cm for a week before increasing to 161.3 cm for 21 days at a rate of 1.8 cm/day. The Altiplano variety shows less variability and a more uniform average mean height of plants, showing that as a commercial crop in the coast, it could have potential for being uniform. All of the varieties were recorded in growth and maturity as shown by Fig.7, where both Altiplano and Salcedo start to dry both panicles and leaves as a result of maturation earlier than the Arequipeña variety.



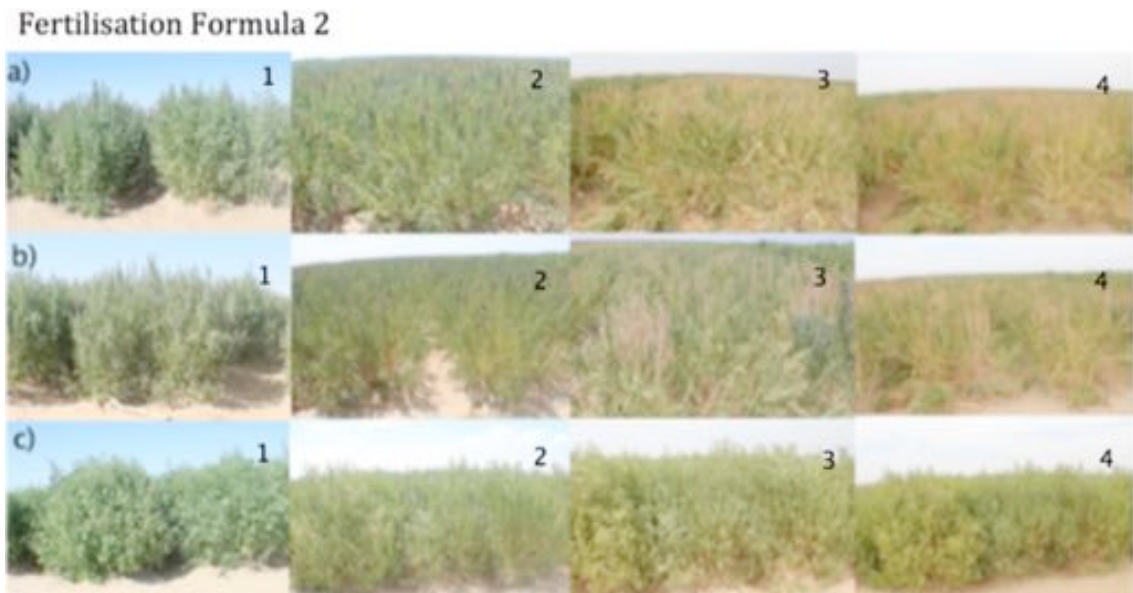


Figure 7. Growth and maturation of quinoa from January 8<sup>th</sup> to February 25<sup>th</sup> 2015 for Altiplano (a), Salcedo (b) and Arequipeña (c) varieties showing the height difference between varieties as well as the precocity of the Altiplano and Salcedo by showing an early maturation (4) than Arequipeña

In addition, by comparing the nutrient formula for each of the varieties, both the Altiplano and Salcedo varieties show that the fertilisation formulas did not have effect on the height of the plant. In the case of the Altiplano, through both treatments, the plant reached an average maximum height of 120 cm at the same time, showing that there was no difference in adding more nutrients. In a similar way, the Salcedo variety, through both treatments, reaches a maximum of 120 cm but with fertilisation formula 2, it does after one week of the fertilisation formula 1 as previously described. Fertilisation formula 2 does make the third variety of quinoa, Arequipeña to grow on average 30 cm more than with fertilisation formula 1, except for the last two average measurements that a decrease in height as a result of the high variability of the seeds of the Arequipeña variety, having an effect on the random measurement recording.

### 3. Mean Length of Panicle

Together with the height of plant, the length of the panicle formed was also assessed weekly. The panicles are where the flower forms and is where the grain can be found. The longer the panicle, the more grains there are and therefore the bigger the yield. Fertilisation formulas do have an effect on the mean length of the panicle. For fertilisation formula 1 (300-120-300) (Fig.8), the panicle shows to be forming from

November 21<sup>st</sup> 2014 for all three varieties at 0.24 cm/day. From December 12<sup>th</sup> 2014, there starts to be a difference on the growth of the panicle for each variety.

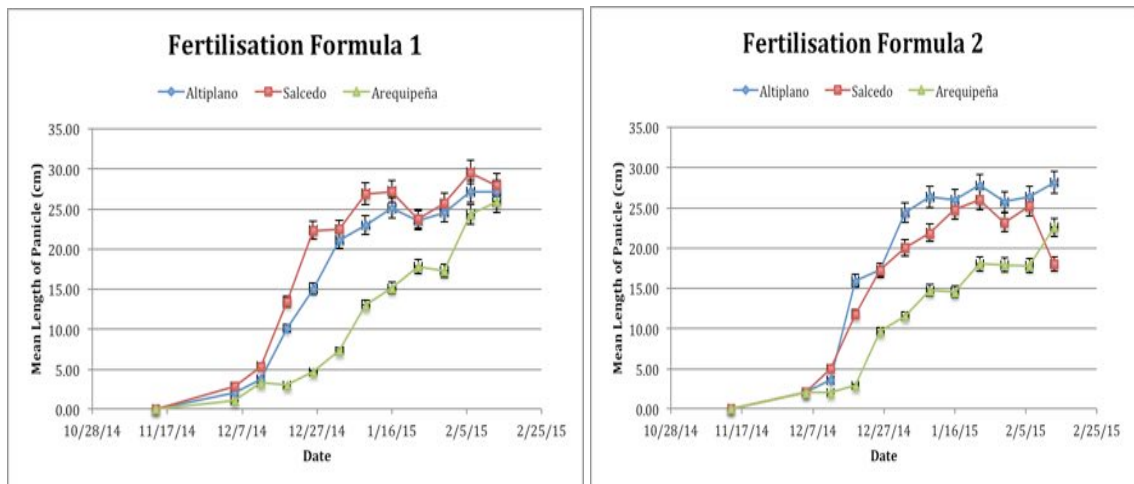


Figure 8. Average length of panicles of quinoa for both fertilisation treatments for its growing stages and maturation and standard deviations from Table VII in the Appendix

The Salcedo variety shows the greatest panicle growth of 1.21 cm/day and also the slowest by then increasing at 0.10 cm/day December 26<sup>th</sup> 2014 to reach a maximum average of 29 cm. The rapid panicle growth is also seen in the Altiplano variety by increasing 0.86 cm/day and then at 0.12 cm/day from January 2<sup>nd</sup> 2015 reaching a maximum average length of 27 cm. The Arequipeña variety shows a more constant growth rate reaching a maximum average of 25 cm. The maturation of the panicles and the formation of grains occur early for the Altiplano and Salcedo varieties (Fig.9)

For fertilisation formula 2 (Fig.8), all varieties increase in panicle length until December 5<sup>th</sup> 2014, where the average length panicle was of average 3 cm. From this point both the Salcedo and Altiplano increase at a rapid rate (1.50 cm/day and 0.95 cm/day respectively). Salcedo increases in a period of 14 days, while the Altiplano variety has this rapid growth rate for three weeks. Afterwards, the average increase in length follows the same pattern as the rate decreases for the Salcedo and Altiplano (0.10 cm/day and 0.07 cm/day respectively). Altiplano variety reaches a maximum average length of 28 cm, while Arequipeña of 22 cm. The Arequipeña increases at a constant 0.35 cm/day. On the last week, the mean length of panicle decreases for the Salcedo variety.

Fertilization 2 shows less uniformity. It also depends on the variety, how much it adapts to its environment, and of course on the length of the panicle, which produces the quinoa grains. In the case of the Altiplano variety (Fig.8), for both fertilisation treatments, the panicle starts to gain length from December 12<sup>th</sup> 2014. Fertilisation formula 2 gives a longer panicle for a period of 7 weeks, where the length differs by no more than 5 cm to fertilisation formula 1. During the last two weeks, however, the length of the panicles becomes similar and with both fertilisation treatments, it achieves a panicle of average 28 cm.

In the case of the Salcedo variety (Fig.8), both treatments increase similarly up to a length of average 5 cm by December 12<sup>th</sup> 2014. Afterward, both increase to 25 cm by January 16<sup>th</sup> 2015. Fertilisation formula 1 in this case, shows a faster growth rate as the panicle reaches the average length of 25 cm in two weeks before quinoa with fertilisation formula 2 treatment. There is a high variation from January 30<sup>th</sup> 2015 and by the end of treatments, formula 1 produced a 28 cm panicle, while formula 2 a length of 18 to 20 cm.

The Arequipeña variety (Fig.8) with both fertilisation treatments follows similar patterns. During the first 6 weeks, in both cases, the growth rate of the panicle was of 0.06 cm/day. From December 19<sup>th</sup> 2014, the panicle grew at a slighter faster rate with fertilisation formula 1 than formula 2 (0.40 cm /day and 0.35 cm/day respectively). With formula 1, the panicle grew to average 25 cm, while with formula 2, it grew to average 22 cm.

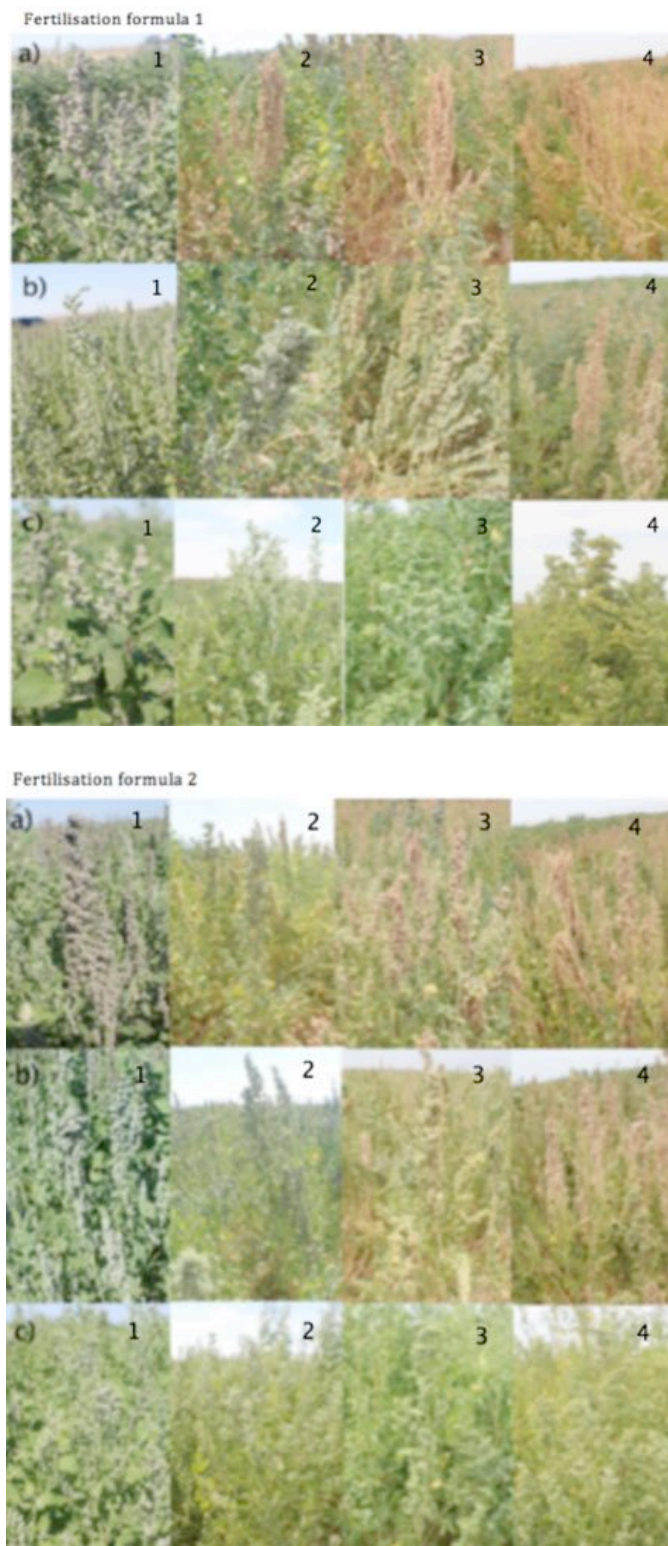


Figure 9. Growth and maturation of quinoa from January 8<sup>th</sup> to February 25<sup>th</sup> 2015 for Altiplano (a), Salcedo (b) and Arequipeña (c) varieties showing the panicle formation, showing the bigger size and precocity (4) of the Altiplano and Salcedo varieties compared to Arequipeña

#### 4. Mean Number of panicles

Quinoa produces the grains in the panicles and the number of panicles per linear metre means that the total production increases by having more grain producing plant organs. Using formula 1, all three varieties start to produce panicles at different times.

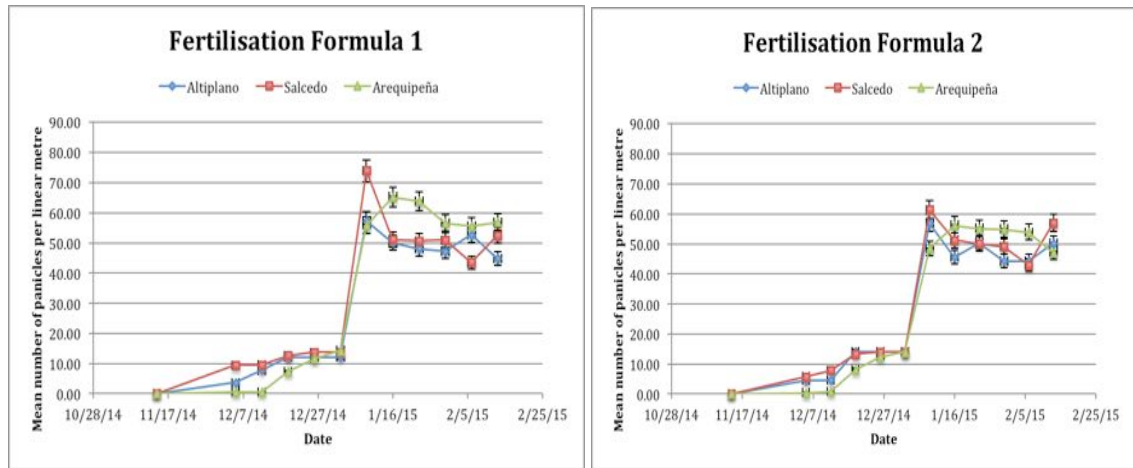


Figure 10. Average number of panicles of quinoa for both fertilisation treatments for its growing stages and maturation and standard deviations from Table VII in the Appendix

The Salcedo variety (Fig.10) starts to increase in the number of panicles on November 21<sup>st</sup> 2014 at a rate of 0.33 panicles per day, the Altiplano variety (Fig.10), one week later at a rate of 0.41 panicles per day and the Arequipeña variety (Fig.10), one week later of the Altiplano at a rate of 0.68 panicles per day. The number of panicles increased very rapidly for the three varieties on January 2<sup>nd</sup> 2015 at an average rate of 7.14 panicles per day. The number of panicles per linear metre increased by 45 for both the Altiplano and Arequipeña variety, while Salcedo increase by 60 panicles per linear metre. The Arequipeña variety also shows a greater number of panicles per linear metre, being an average of 60 for the last 6 weeks, while for the Altiplano and Salcedo, they has on average 50 panicles per linear metre.

With lower fertilisation, the average number panicles also increase for the first 8 weeks for the Altiplano, Salcedo and Arequipeña (0.28, 0.30 and 0.33 respectively) and then rise at an average rate of 5.78 panicles per day. The Altiplano variety shows and average number of panicles of 49 panicles per linear metre, the Salcedo variety of 50 and the Arequipeña variety of 54 panicles per linear metre.

The different nutrient formula, gave interesting results for each of the three-quinoa varieties. For the Altiplano variety (Fig.10), having two nutrient formulas does not affect the number of panicles per linear metre, as for both; the rate of growth is the same at each stage, resulting in a maximum of 56 panicles per metre. The average mean number of panicles for the last 5 weeks for fertilisation formula 1 is of 50 panicles, while for fertilisation formula 2 is of 49 panicles.

Similarly, the Salcedo variety (Fig.10) does not show a difference when using different nutrient formula. The rate of growth is similar at each stage. Fertilisation formula 1 does produce a higher maximum mean number of panicles of 73 panicles, while fertilisation formula 2 of 61 panicles. For the last 5 weeks however, the Salcedo variety had an average of 50 panicles per linear metre for both fertilisation treatment.

In contrast, the Arequipeña (Fig.10) responds slightly different to the nutrient formulas. For the first 9 weeks, quinoa grows at the same rate, however after the rapid increase of number of panicles on January 2nd 2015, the quinoa with fertilisation formula 1 has an average number of panicles per linear of 60, while with fertilisation formula 2, of 52 panicles.

## 5. Yield production

For each fertilisation treatment, there were 5000 plants of each variety. The quinoa was harvested; left to dry under the sun and then threshed in order to obtain the grain (Table 3).

Table 3. Yield (kg) of 5 lines (806 m<sup>2</sup>) and projected for 1 ha (by multiplying by 12.4 since there are 62 lines per ha) of quinoa for each fertilisation treatment

| Quinoa Variety | Fertilisation 1 | Projected F1 | Fertilisation 2 | Projected F2 |
|----------------|-----------------|--------------|-----------------|--------------|
| Altiplano      | 71.60           | 887.84       | 73.00           | 905.20       |
| Salcedo        | 55.80           | 691.92       | 44.40           | 550.56       |
| Arequipeña     | 4.50            | 56.40        | 10.00           | 124.3        |

The Altiplano variety with fertilisation 2 produced the highest yield (905.20 kg/ha) while the Salcedo was second, producing more with fertilisation 1 (691.92 kg/ha). The Arequipeña had the lowest yield of 56.40 kg/ha. This means that the Altiplano and Salcedo varieties produced 14.01 times more in combination than the variety that came from the highlands of Peru, showing potential for coastal areas.

## 6. Grain quality

The other factor regarding its adaptability is the quality of the grain. The quality of the grain refers to the size and therefore weight of the grain. A plant that adapts better to the environment will produce grains with more weight and be efficient by producing more yields with lower nutrients. This will show that the plant is able to absorb nutrients easily in the new environment. Table 4 shows how each variety and fertilisation treatment produced different quality quinoa. Comparison was done once by selecting the grains randomly from the full yield produced.

Table 4. Weight (g) of 100 grains of the different varieties of quinoa

| Quinoa Variety | Weight (g) of 100 grains |                 |
|----------------|--------------------------|-----------------|
|                | Fertilisation 1          | Fertilisation 2 |
| Altiplano      | 0.1416                   | 0.1096          |
| Salcedo        | 0.1633                   | 0.1703          |
| Arequipeña     | 0.1343                   | 0.0447          |

The Altiplano variety produces a bigger grain when using more nutrients according to fertilisation 1. The 100 grains weight 30% more than when using fertilisation 2, which has fewer nutrients. In contrast, for the Salcedo variety, the grain with fertilisation treatment 2 showed a better quality grain than with fertilisation 1. It produced 5% more using the second fertilisation, yet this difference was not significant. In case of the Arequipeña variety, fertilisation 1 weights three times the grains of fertilisation 2. Yet, overall, the Arequipeña variety produces the lowest quality grain. The T-test performed on the results, argues that there is no relation on the type of fertilisation and the grain quality ( $p > 0.05$ ).



Furthermore, from Figure 11 the colour of quinoa grains for all three varieties is a light beige colour. For the Arequipeña variety, it seems darker because of the residues of the flower and parts of the panicle, which are difficult to separate due to this variety having low quality grain.



Figure 11. Grain quality of both fertilisation treatments; fertilisation 1 (above), fertilisation 2 (below) showing that Altiplano and Salcedo varieties produce cleaner and better quality grains than the Arequipeña variety which has more debris within the grains, despite all grains gone through a cleaning and thrilling process

#### 7. Presence of common pests

Being an introduced species, quinoa grown in this area will generate a new niche to local species to feed, and this could affect positively the new ecosystem. Furthermore, the introduction of quinoa in Piura can bring pests that normally affect this crop. The presence of traditional quinoa pests would mean the increase in range of the pest, widely expanding its distribution. This geographic expansion of pests can be prejudicial to the yield production and the increase in sanitary costs of the crop.

Seedling feeding insects such as *Nysius raphanus* and *Eurysacca melanocampta* are common quinoa pests and their distribution depends on the presence of quinoa. The presence of common pests such as this, were evaluated in order to understand the impact of introducing quinoa to new areas.

The presence of the Lepidoptera *E. melanocampta* was recorded for the three varieties regardless on the fertilisation treatment. It was recorded from November 22<sup>nd</sup> 2014 to December 9<sup>th</sup> 2014 (Fig.12). For the first 7 days, there is a clear difference between varieties. Both the Salcedo and Arequipeña variety show a very high projected presence of *E. melanocampta* individuals of more than 10,000 present. In the Salcedo, the drop with the cloaking was of 3,000 individuals per day up to November 25<sup>th</sup> 2014, where the population starts to increase by November 28<sup>th</sup> 2014. In the case of the Arequipeña variety, there is a constant decrease of 740 individuals per day, with a light outbreak on December 5<sup>th</sup> 2014. The *E. melanocampta* shows preference towards the Salcedo and Arequipeña variety since the presence in the Altiplano variety is half of what can be seen in other varieties for the first 5 days. There is a second outbreak on December 4-5<sup>th</sup> 2014 in all of the varieties.

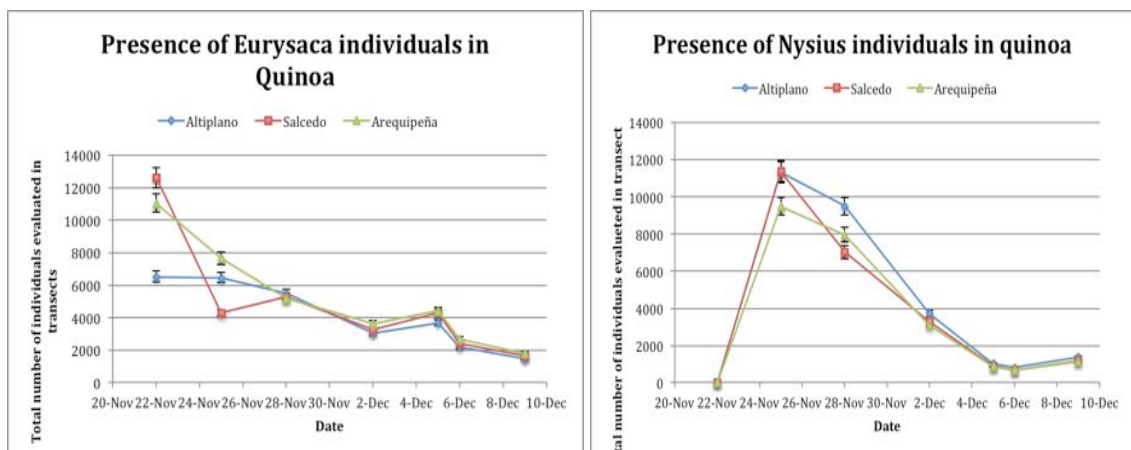


Figure 12. Quantitative presence of two of the most important pests for quinoa from Table VIII in the Appendix

Other pest such as the presence of *Nysius spp* (Fig.12) was recorded from November 22<sup>nd</sup> to December 9<sup>th</sup> 2014. Similarly with *E. melanocampta*, it affected all three varieties in a similar pattern. There is an increase in individuals with rates of 2,273 per day for Altiplano, 2,262 for Salcedo and 1,899 for Arequipeña for the first days of the evaluation, reaching peaks on November 25<sup>th</sup> and November 26<sup>th</sup>. After reaching an average peaks, there is a constant decrease for all three varieties after agricultural controls were performed. The Altiplano and Salcedo variety showed propensity of being affect with *Nysius*, by having peaks of 11,367 individuals (Altiplano) and 11,313 individuals (Salcedo). The Arequipeña variety was slightly less susceptible by having 9,495 individuals.

Pest can also be synergistic or compete among them (Fig.13). The mean number of individuals for all three varieties was obtained for both *E. melanocampta* and *Nysius spp.* The pattern shows that when *E. melanocampta* starts to decrease from November 22<sup>nd</sup>, its competitor begins to increase reaching a peak of 32,175 individuals. On December 2<sup>nd</sup>, the population of both pests were equal at 10,089 individuals creating a balance in the quinoa ecosystem. The competitiveness of both pests, affecting the seedling, generates a control having both populations at relative low numbers. Once the population of *Nysius spp.*, decreases even more, the population of *E. melanocampta* starts to increase but having a peak at a much lower value showing that the competition is also a good control of crops.

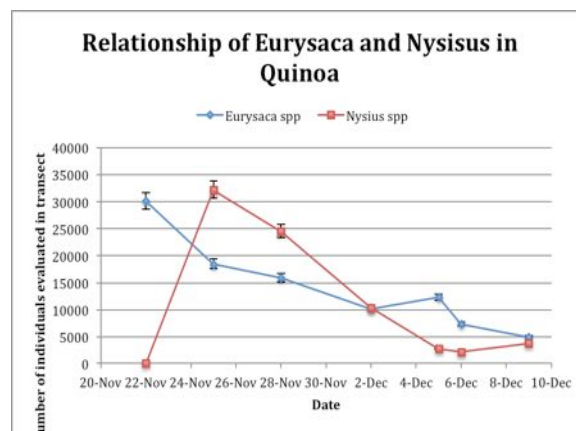


Figure 13. The interaction of the number of individuals of two most important pest for quinoa, *E. melanocampta* and *Nysius spp* from Table VIII in the Appendix

Among other pests that were present in quinoa were of Lepidoptera such as *Spodoptera spp.* and *Spoladea spp.*, Hemiptera such as *Liorhyssus spp.* and Coleoptera such as *Diabrotica spp.* Cloak trapping was stopped less than a month into the evaluation as the number of *Apanteles* started to increase in the cloaks. This specie found locally started to parasitize *E. malanocampta*, acting as a local biocontrol. Furthermore, other local fauna present were of crysopas (both larvae and adults), spiders and coccinelids in lower numbers. All these contributed to the natural biocontrol of introduced pests to the ecosystem.

## 8. Qualitative Presence of vertebrae wildlife in quinoa

During the stages of growth of the quinoa there was presence of local wildlife, which was recorded qualitatively rather than quantitative, especially from the vertebrate family. One of the species found during the early stages of growth was the local fox, *Lycalopex sechurae* (Fig.14), probably searching for sources of water like the irrigation drip lines.



Figure 14. *Lycalopex sechurae* individual (AJMC 2015)

Birds were the most common vertebrates seen in the quinoa field. Not only was the quinoa a good habitat as it provided shelter from predators as well as shade during hot days, but it also was a good source of food when grains were available. Based on my perception, the number of birds increased as quinoa grew. As the quinoa gained height and covered the field, the number of West Peruvian doves, *Zenaida meloda* (Fig.15) and the long-tailed mockingbird, *Mimus longicaudatus* (Fig.16) seems to increase, especially looking for shelter.

As the panicle starts to form, the presence of new species seem to appear. The number of Ash-breasted sierra finch, *Phrygilus plebejus* (Fig.17), Sulphur-throated finch, *Sicalis taczanowskii* (Fig.18) and Cinereous finch, *Piezorhina cinerea* (Fig.19) increases as food availability increases from the panicles. Furthermore, shelter is apparent in the quinoa, protecting them from the high temperatures of the day and from predators. Lastly, Collared warbling finch, *Poospiza hispaniolensis* (Fig.20) was seen in ready to harvest quinoa. This last species was seen mainly on the panicles feeding on the grain.



Figure 15. *Zenaida meloda* (AJMC 2015)



Figure 16. *Mimus longicaudatus* (AJMC 2015)



Figure 17. *Phrygilus plebejus* (AJMC 2015)



Figure 18. *Sicalis taczanowskii* (AJMC 2015)



Figure 19. *Piezorhina cinerea* (AJMC 2015)



Figure 20. *Poospiza hispaniolensis* (AJMC 2015)

Reptiles were another species that benefit from the introduction of quinoa in the Piura region of Peru. From the 9 local species in the area, three were found in quinoa. It is the perfect habitat for reptiles such as the knobbed pacific iguana, *Microlophus occipitalis* (Fig.21), the Peruvian desert tegu, *Dicrodon Guttulatum* (Fig.22) and Galapagos Gecko, *Phyllodactylus reissi* (Fig.23) as they have shade and protection from predators. Their presence could be rarely seen, but rather heard as one passed. Because of this, it is not

certain whether the population varies throughout the quinoa growth. The individuals were recorded going into the quinoa plantation, revealing the presence of local reptiles.



Figure 21. *Microlophus occipitalis* (AJMC 2015)



Figure 22. Juvenile *Dicrdom Guttulatum* (AJMC 2015)



Figure 23. *Phyllodactylus reissi* (AJMC 2015)

## IX. DISCUSSION

Quinoa is a very important perfect crop and its production needs to increase in order to meet the demands. As a result, new areas need to be prepared for such cultivar. This in turn makes quinoa become an introduced specie so it is important to assess its adaptability and interaction with the local ecosystem. Having different varieties of quinoa can allow us to compare quinoa from different origins adept to new areas. Furthermore, the different fertilizations allow us to conclude on the adaptability of quinoa, and discuss if traditional ways of fertilization for quinoa in their native areas can work as well in the new areas. Fertilization 2 (170N-60P-200K) represents the fertilization use traditionally in the highlands were soils maintain humidity and thus low fertilization is needed compare to sandy soils. Fertilization 1 (300N-120P-300K) is traditionally use for various crops in sandy soils and high temperatures.

### 1. Quinoa varieties

All three varieties grew and produced quinoa grains. In terms of height, there was no difference among varieties as well as the chlorophyll level in the leaves. All quinoa varieties adapted well to the new areas and all reached heights of more than 115 cm. In terms of the height of the panicle, however, there was a significant difference between varieties. The Salcedo and Altiplano varieties have longer panicles than the Arequipeña variety, and the number of panicles of this variety is significantly higher ( $p < 0.05$ ) producing more than the Altiplano and Salcedo varieties, with both fertilization treatments. However, the Arequipeña variety, despite having more panicles cannot compete in production with the other two varieties as it produced a much lower seed yield.

Furthermore, there was no effect of the variety in the relationship with the local environment. All the varieties were affected by the presence of *Nysius* and *Eurysacca* suggesting a non-specificity of the pests. *Nysius spp* affected Altiplano and Salcedo the most compared to Arequipeña variety, but this is not significant following a t-test. The Arequipeña variety was affected the least because there were less and shorter number of panicles compared to the other varieties and thus, the presence of pests is as a result lower. Similarly, *Eurysacca melanocampta* can be found in all three varieties, less in the Altiplano variety, which could suggest that it was this variety, the least affected by



the pest. The individuals of *E. melanocampta* decrease for all three varieties as a result of cultural methods and of netting.

The presence of both pests in quinoa in the coastal areas of Peru, where the study was carried out is of huge importance, since it determines the expansion of pests from its natural habitats. These pests have been registered in Junin, Cerro Pasco (central Peru) and Puno (southern Peru). All of these located in the highlands where quinoa is traditionally grown. By being present in this experiment confirms that by having introduced species, their pests will follow and can have serious problems with the local environment. Since coastal areas are very harsh environments, food availability is low and without quinoa, both *E. melanocampta* and *Nysius spp* will have to establish in other local species or start affect other crops in the area. With this experiment, the species can be registered as being present in Piura and it requires prevention measures if new areas of quinoa are grown.

## 2. Fertilization treatments

Agricultural management is different in each region as a result of the different soils, different climate and different interaction with other species. As an introduced species, its adaptability also depends on the nutrient composition given to the plant. The comparison of the two treatments allow us to determine the adaptability of the quinoa under coastal conditions with nutrition used locally and with higher nutrition to cope with the harsher environment compare to its native area.

The chlorophyll level shows that it responds to the fertilization applied. The effect was more significant on the Salcedo variety ( $p < 0.001$ ) than for the Arequipeña and Altiplano varieties ( $p < 0.01$ ). Having more fertilization, especially of magnesium, which is a key component of chlorophyll, means that the plant will be able to absorb more and therefore this is represented by having more chlorophyll concentration within the leaves as shown with the SPAD chlorophyll meter. Furthermore, having more chlorophyll level suggests that the quinoa plant has adapted well to the new environment, to the soil conditions and that the roots are healthy and there is ion exchange between roots and soil. This could however, be confirmed by an analysis of roots or even biometric readings on the growth of roots through the crop's lifespan. This could have improved our observation and also correlate to the levels of chlorophyll in the leaves.

In addition, the fertilisation treatment shows a significant comparison in height in all three varieties ( $p < 0.01$ ). The difference achieved in height is significant ( $p < 0.05$ ) for both Altiplano and Arequipeña variety but interestingly not for the Salcedo variety ( $p > 0.05$ ). Furthermore, it is the quinoa with the lower fertilization treatment that is taller. This shows that despite fertilization 1 increases the concentration of chlorophyll and thus on the metabolic rates of the plant, it is the quinoa with fertilization 2 (lower nutrients) that produces a taller plant. This shows the incredible adaptability of quinoa to a different soil and a different climate, as well as altitude. For the Salcedo variety, both fertilization treatments produced tall plants; yet, it shows that the concentration of chlorophyll in the leaves of this variety does not have influence in growth of the quinoa. An analysis of metabolism through photosynthesis rate could give us a clearer understanding why despite having more chlorophyll content for Salcedo with fertilization 1, there was no difference in height of quinoa.

Fertilisation also had an effect on the panicles. The length of the panicle was significant in Altiplano and Salcedo ( $p < 0.05$ ) but not in the Arequipeña. Furthermore, for Altiplano, longer panicles were found with fertilisation treatment 2 and for Salcedo with fertilization 1. More nutrients provide the Salcedo variety with the ability to produce longer panicles having more chlorophyll levels as shown before. In comparison, Altiplano shows its adept and adaptability capabilities as with lower nutrient levels supplied to it, it can produce a taller plant and also with longer panicles. In addition, the only effect that fertilisation has in the number of panicles is in the Arequipeña variety. With more nutrient levels, the variety compensates its shorter panicles with numbers.

Production overall was not affected by fertilization treatments but both Altiplano and Arequipeña varieties produced more with F2 (low nutrient) while Salcedo with the higher fertilization. This shows that with longer panicles and taller plants, the Altiplano will produce more and in the case of the Arequipeña, more panicles will mean more production, which is the result of a higher supply of nutrients.

In general, all three varieties were able to grow and produce grain at different levels, in this region of Peru showing its good adaptability as an introduced species. Furthermore, it shows great adaptability since the fertilization with lower nutrient composition can also produce healthy plants with producing panicles. Biometric readings for the rooting

system would have helped why nutrient absorption is good, even at low nutrient concentration resembling quinoa's native area.

But how well adapted was quinoa? The Salcedo variety and Altiplano variety, both that come from the highland region of Puno can have heights of 164 cm in their native environment. This experiments has shown that coastal quinoa of those varieties mentioned, can reach heights of 120 cm. This is 73% of the height that reach in the coastal area. In contrast, with production levels, the quinoa underperformed of what it can give locally. Quinoa introduced to coastal areas just produce an average projected production of 900 kg/ha (Altiplano) and for Salcedo, 620 kg/ha. This represent 42.6% and 24.8% respectively of production levels in the highland regions as stated by the INIA factsheet (2.5 Tn/ha Salcedo and 2.11 Tn/ha Altiplano). For the Arequipeña, there is no data in its local region in order to make a comparison on how well it has adapted as an introduced species. Certainly climatic, soil and biological conditions of the highlands will have an effect so it would be interesting to have a similar experiment in the highland regions.

Despite showing growth and production, the yield of the quinoa varieties is very low compared to native areas. It can be considered that the varieties do adapt to Piura, to its high temperatures and sandy soils but more information perhaps could be needed. The methodology carried out dealt more with biometrics above ground and the chlorophyll levels as an indicator of good root absorbance, however, there was no measuring of roots which is important to relate to the amount of chlorophyll or determine why in some varieties, the different fertilization treatments produce different traits in panicle length or number of panicles. In addition measuring photosynthetic rates allow us to understand adaptability using metabolism as an indicator.

Apart of needing new measurements and indicators, the current methodology can be improved. First of all, a way to measure absorption and adaptability, is to analyse soil water content below 60 cm. in this way, we can determine the fertilization that is lost and the amount of fertilizer absorbed by quinoa. As an introduced species, an indicator to determine its adaptation to the new harsh conditions is to evaluate how efficient is root absorption and correlate it with the concentration of magnesium in the leaves. Furthermore, reducing the density of the cultivar and thus allowing a greater range for data collection can improve biometric readings. It proved difficult to collect data as the

plant grew as its height plus the panicle formation, resulted in foliage closing the path between lines of quinoa.

Quinoa grains are formed from pollinated flowers. This could be interesting to evaluate as the number of flowers with the different variety and fertilisation treatments can estimate yield and grain quality. Without any doubt, there are various parameters that can be evaluated, from roots, to number of leaves to photosynthesis rates in order to assess adaptability. However one of the main weak points of this investigation is the comparability with quinoa's native location. The best way to compare the adaptability and yield is to have had two areas with quinoa, one in the coastal areas and the other in the highlands. That way, we could answer with more certainty if quinoa can be expanded from its native areas since abiotic factors, like rainfall, temperature and soil conditions can affect the growth and formation of quinoa grains. Biotic factors can also influence quinoa production, such as the interactions of quinoa with its local ecosystems compared to its interaction with foreign ecosystems.

### 3. Effect on local fauna

Quinoa is an introduced species and as such will have an effect. Since the area was the experiment is a desert, a vigorous irrigated plant is a good niche for habitat and food source for different species. As we have seen, there was presence of species of different taxon, from reptiles, birds, mammals and insects. Some species like different birds and reptiles used the quinoa as a source of habitat, as sunshade and protection from the high radiation and also protection from predators. As the quinoa grew and started closing the paths between lines, it became difficult to assess the species in the crop, except for some birds that could be flying in and out of the quinoa. Furthermore, when quinoa started to form grains, the number of species of birds increased, while looking a source of food.

In terms of the insect taxa, many Lepidoptera and Coleopteran were present. Their population could have been monitored more thoroughly but two main species were evaluated: *Eurysacca melanocampta* and *Nysius spp.* They are both pest for quinoa and their presence in Piura had not previously been documented. By being present, it shows the dangers and the effects of introduced species. Not only will local species benefit of the new niche, but it can also bring other species from foreign areas. By introducing new species, can bring forth other insect taxa that can become other pest for other types

of crop if not managed properly. It is important to evaluate whether that introduced species, in the case of quinoa, the grain is pathogen free in order to prevent viruses and fungi to infect other plants.

In fact, one of the reasons that trapping was stopped as a cultural measure to reduce the pest was because the presence of the Hymenoptera *Apanteles spp* started to increase. This native parasitoid controlled the increase in population of *E. melanocampta*. This shows the effects that the local environment can have on quinoa. Perhaps a new evaluation of this relationship could be assessed and find out more, whether this would happen again or if it was just a special occasion given the right conditions. Not only there is an effect on quinoa towards the local environment, but also the local environment benefits from the crop and the pests that come with it. It would be interesting to evaluate the number of individuals found in quinoa of those species found in the native environment and assess how it changes through the growth stages of quinoa.

One of the difficulties about evaluating the relationship of pests with the native species is that there should not be any chemical or cultural control of pests, thus putting in risk yield production. But perhaps this could evaluate species interaction and how it can have an effect on grain production. These relationships are crucial to evaluate the impact of the introduced species into this new environment. As a contrast, the same should be done in the highlands, quinoa's native location in assess how it interacts normally with the native ecosystem. As naturally it could also serve as a habitat, or a food source but to what level, it is similar or differs when it is an introduced species.

#### 4. Improving the methodology

In order to have a better evaluation of the effects caused by the introduction of quinoa in the Piura region, and how it adapts, the current methodology can be improved to get more and more accurate results. Firstly, the effect of quinoa as an introduced species can be better evaluated through more quantitative analysis. Before growing quinoa, a quantitative evaluation of native populations can be performed so that when quinoa is introduced evaluate whether those populations increase or decrease as a result of quinoa and establish an influence zone.

With the invertebrates' population, the quantification through traps and similar methods to the cloaks can be done. With the quantification of the vertebrate population, counting the number of species seen, or even use indicators such as footprints, faeces or burrows can do the evaluation. That way we can identify what species are permanent in quinoa or if their presence increases with grain production throughout all stages of growth.

The biometrics is important and these have been evaluated weekly. This is important to assess the growth rates and how the plant adapts to the new environment. Certainly a comparison with a similar experimental area in the highlands could give light to a more accurate results and conclusion on adaptability. On top of that the chlorophyll and perhaps photosynthetic values could be measured twice a week at least in order to evaluate the quality of the growing plant, through evaluating its metabolism. Nutrient compositions have been evaluated and we have seen that for some varieties more nutrients have an effect, but in some, as with height, more or less nutrients don't have an effect. In order to evaluate how much of those nutrients are actually absorbed and consequently determine the actual nutrients that the plant needs is through measuring the water content at 30 cm and 60cm underground. Since the roots are located between 30 cm and 60 cm, water below wouldn't have been absorbed. By measuring nutrient concentration in those samples, we can determine absorption levels in order to give more highlights on quinoa's adaptability.

## X. CONCLUSION

Quinoa is an important crop and could be the answer to food security as it is described as a perfect crop due to its nutritional content and high storage characteristics. That is why, the idea of trying to introduce it to non-native areas in order to supply grains worldwide.

Concerning the adaptability of quinoa to this region, three different varieties were evaluated, having its origins from the highlands of Peru, showed that they can be grown and some yield can be obtained. In terms of the quinoa's metabolism, there was not difference among varieties, but by giving more nutrients; there was more concentration of chlorophyll in the leaves. Fertilization did not affect biometrics of the crop, since all of them grew similarly to 120 cm in height, and produced panicles. In the case of the Altiplano and Salcedo varieties, produced less but longer panicles, while the Arequipeña variety compensate the short panicles by having more in number.

With yield and grain quality, the Altiplano variety showed the best adaptation since it produced more of three varieties despite fertilization, and bigger grains with less nutrients, making it efficient at absorption and nutrient use. Then comes the Salcedo variety which gives a higher yield with less nutrients, but when talking about quality, the more you give this variety, the bigger the grains. The Arequipeña variety needs more fertilization to give bigger grains but can give a greater yield of smaller grains with less nutrients. Overall, the Arequipeña was the variety that preformed the worst, giving insights that perhaps another management can be given particularly to this variety. In conclusion, quinoa can adapt to its new area as is able to grow and produce some grains, however production did not reach the one desired or comparable to that of its native area, which can reach more than 2 Tn/ha. In order to reach greater yields, more fertilization can be done or genetically modified varieties that can adapt to the new conditions and create a generation that best adapt to the new environment.

Wildlife was also evaluated and it was seen that there are various interactions between quinoa and the environment from which more follow up investigations can arise. Quinoa is a good niche for local fauna of different taxa as quinoa is a good habitat for diverse birds and reptiles and it is also a good source of food for birds. Pests are also a problem in quinoa. Traditional pests such as *Eurysacca melanocampta* have not been recorded in Piura before and with the introduction of quinoa its presence was recorded

and was high during the growth stages of quinoa. Yet, the introduction of pests through quinoa has also effect on local wildlife since *E. melanocampta* became a food source for the native parasitoid *Apanteles spp*, but more investigation needs to be carried out on this level.

Quinoa has a huge potential to become the food for the future, its adaptability as it has been seen is good as it can grow in the coastal region of Peru with temperatures reaching more than 30°C. Its optimization and yield production as well as yield quality can increase with better management and changing the fertilization program. Quinoa in this respect could adapt everywhere and as a ‘perfect food’ by having more yields to support the increasing demand that comes with population growth it can be an answer for food security by its introduction to new regions where quinoa has not been grown before.



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