Response of Quinoa to Emergence Test and Row Spacing in Chiang Mai – Lumphun Valley Lowland Area

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ABSTRACT: Quinoa is a pseudo-cereal crop with high potential and is considered as an alternative cash crop in lowland area of Chiang Mai-Lumphun valley. However, no existing understanding of how a selected variety responds to management at the field level. Five quinoa varieties were planted in the plants nursery to test emergence percentage. Temuco has shown the maximum percentage of emergence at 59.8% among another four varieties, namely; Cherry Vanilla (48.5%), Rainbow (27.7%), Brilliant Bright Rainbow (22.3%) and Black quinoa (3.5%). Temuco variety was selected for further testing of its responses to plant spacings. A randomized complete block design having three spacing treatments with four replications was used in the study. The spacings included 30x10, 40x10, and 50x10 cm (row x between plants). The three-week old seedlings were transplanted to the plot to investigate dry weights of different plant parts namely leaves, stems, seeds, inflorescences and total plant dry weights. Plant total dry weights were 15,267 kg ha-1; 9,938 kg ha-1; and 10,560 kg ha-1 for the 30, 40 and 50 cm plant spacing treatments, respectively. Seed dry weight also showed that the 30 cm plant spacing treatments produced the highest seed dry weight of 7,067 kg ha-1, whereas the 40 and 50 row spacing treatments produced 4,400 and 5,520 kg ha-1, respectively.
Keywords: Emergence test, row spacing, quinoa, lowland Thailand, dry weight

Introduction

Quinoa (Chenopodium quinoa), a pseudo-cereal crop, is an important food crop in the highland Andean region. It has been cultivated in Bolivia, Peru, Chile and others Andean countries for 7000 years (FAO, 2013). It has high protein content with abundance of essential amino acids and gluten free (FAO, 2013). Quinoa is mainly used for cooking, baking, and various products for people allergic from gluten; animal feed, green fodder, and pellets (Jacobson, 2003). The plant is well adapted to various environmental stress factors like drought, soil salinity and frost (Bhargava, 2006). Seeds are coated with saponin which offers some protection from diseases and pest such as birds or insects (Bhargava, 2006). The United Nations Food and Agriculture Organization has declared the year of 2013 as "The International Year of Quinoa"(IYQ). This statement implies that quinoa is recognized around the world as a natural food resource with high nutritive value, which especially contributes for present and future generations (FAO, 2013). Various cultivars of quinoa are known for their adaptability to agro-ecological zones, ranging from sea level to an altitude to over 4000 m and relative humidity from 40% to 88% in temperature from -8 to 38 °C (FAO, 2013). Quinoa has been introduced to Europe, North America, Asia, and Africa. Many European countries are members of the project entitled 'Quinoa—A multipurpose crop for EC's agricultural diversification' which was approved in 1993 (Bhrgava, 2006). The American and European tests of quinoa have yielded good results and demonstrated the potential of quinoa as a grain and fodder crop (Bhargava, 2006). In Asia quinoa has been tested at National Botanical

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Research Institute, a research institute of Council Scientific and Industrial Research in Lucknow India, located at an altitude of 120 meter above sea level since 2002. The result has shown the possibilities of introducing quinoa as the alternative food crop in subtropical, hot summer and monsoon ecological conditions (Bharagava, 2007). So far there is no experimental data set of understanding the quinoa responses to different planting spacings in lowland zone of northern Thailand. In addition, discovering the suitable variety with high emergence percentage is vital to gain better understanding of quinoa as a new crop in Thailand. The objective of this paper is to report the results of field trial on emergence percentage and responses of quinoa to plant spacings in Chiang Mai – Lumphun valley.

Materials and Methods

Two separate field experiments were conducted to test emergence percentage of five quinoa varieties and response of a selected quinoa variety to plant spacings. The emergence percentage test was carried out during November 6-30, 2013 at the Agricultural Resource System Research Station of the Center for Agricultural Resource System Research, Faculty of Agriculture, Chiang Mai University, Chiang Mai, Thailand (18°47'45.8226" N; 98°57' 42.9336" E), with an average elevation of at 310 above sea level. The second experiment was performed during November 30, 2013 to February 27, 2014 to test the responses of Temuco variety to row spacing and density treatments under field conditions. This experiment was conducted at Mae Hia Agricultural Research and Training Center, Chiang Mai, Thailand (18°45'48.2" N and 98°55'51.2" E), situated at 350 meter above sea level. The details of materials and methods used in each experiment are as follows;

Emergence percentage test

Seeds of five quinoa varieties namely; Temuco, Black, Rainbow, Brilliant Briant Rainbow, and Cherry Vanilla were tested for seed emergence percentage under the plants nursery Condition at Mulyiple cropping centre, Chiang Mai, Thailand. Seed sowing was performed on November 6, 2013. Five Quinoa varieties were sowed each variety in 12 seedling trays which were growing material made from plastic, each tray has 110 slots to place a seed. The numbers of trays were quantity of replications. The soil was the mixture of peat soil, steamed soil and cow manure at the ratio 50:40:10, respectively. Steamed soil was a method the soil was steamed for three hours in metal tank to control germ, bacteria and fungi. The seedlings were kept in a nursery under plastic sheet to prevent direct sun and off-season rains. Water was applied twice a week to keep soil moisture at the field capacity level to support germination and full emergence. Seedlings were allowed to germinate and emerge for three weeks and the final numbers of emerged seedlings were counted, and analysis of variance (ANOVA) was carried out using the Statistix software package version 8.0.

Response to plant spacing

The quinoa variety with the highest emergence percentage from the emergence plants nursery test was selected for further study to gain better understanding of its responses to row spacings. The row spacing experiment was conducted in a Mae Rim soil series (loamy-skeletal, mixed, isohyperthemic Typic (Kandic) Paleustults) at Mae Hia Agriculture Research and Training Center, Chiang Mai University. Temuco variety had the lowest mortality rate among all five tested varieties in the emergence percentage experiment and was selected for further study at the Station. Its seedlings were transplanted to 2x2 m plots using a randomized completed block design with four replications. The treatments were three different spacings, i.e., 30×10, 40×10, and 50×10 cm. The number of plant in a plot of 30×10, 40×10, and 50×10 cm was 36, 30, 24 plants respectively. Composite soil samples were taken at two depths, i.e. 0-15 and 15-30 cm and were analyzed for soil pH, soil moisture, amount of organic matter, amount of ammonium-nitrogen, concentration of exchangeable phosphorus and extractable potassium. To control pests, neem oil extract was mixed with water at the ratio of 5 litres water: 15 ml neem oil extract. The mixture was sprayed twice a week throughout the growing season. Hand picking of butterfly larvae and other pests were regular carried out to control pests. At final harvest, plants were cut and sun-dried for one week. Ten plants from each plot of different spacing treatments were sampled and separated to different plant parts, i.e., leaves, stems, spikes, seeds, and total plant dry weights, and weighed.. The dry weights were converted to kg ha1. Finally, the Statistix software package version 8.0 was used to conduct the analysis of variance (ANOVA). Significant differences were considered at p-value < 0.05.

Results

Emergence Test

The emergence data was recorded three weeks after sowing. Temuco variety showed the highest emergence percentage(59.8%). Meanwhile, those of quinoa varieties Cherry Vanilla, Rainbow, Brilliant Bright Rainbow and Black were 48.5%, 27.7%, 22.3%, and 3.5%, respectively. The results have shown significant difference at p-value < 0.01 (**Table 1**).

Table 1 Emergence percentage of five quinoa varieties studied on 6th to 30th November 2013 at Multiple Cropping Centre, Chiang Mai, Thailand

Varieties	Temuco	Cherry Vanilla	Rainbow	Brilliant Bright Rainbow	Black
Emergence rate %	59.8a	48.5b	27.7c	22.3c	3.5d
F-test[1]			**		
CV%		34.9			

[1/ **] = significant different at p-value < 0.01

Means in the same row followed by the same letter are not significantly different by DMRT

Soil properties

Soil properties at 0-15 cm depth indicated 7.06 soil pH , 20.64% soil moisture and 2.584 g/100g organic matter (**Table 2**). The amount of ammonium-nitrogen was 9.13 mg/kg and the exchangeable phosphorus and extractable potassium in the soil were 4.17 and 12.21 mg/kg, respectively. Soil properties at 15-30 cm depth were slightly different from those of 0-15 cm depth , i.e., 7.32 soil pH; 18.63% soil moisture and 1.335g/100g organic matter . Ammonium-nitrogen concentration at 15- 30 cm depths was 10.81 mg/kg. The exchangeable phosphorus at 15-30 cm depth (2.35 mg/kg) was lower than that of 0-15 cm depth (4.17 mg/kg). On the other hand, extractable potassium concentration at 15 to 30 cm depth (91.09 mg/kg) was dramatically higher that of 0-15 cm depth (12.21 mg/kg) (**Table 2**).

Table 2 The result of soil test of the response to row spacing on 0-15 cm and 15-30 cm depths. Composite soil was collected on 5th December 2013 at Mae Hia Agriculture Research and Training Center, Chiang Mai University.

Soil depth	pH	Moisture %	Organic matter g/100g	NH_4^+-N mg/kg	Phosphorus mg/kg	Potassium mg/kg
0 to 15 cm	7.06	20.64	2.584	9.13	4.17	12.21
15 to 30 cm	7.32	18.63	1.335	10.81	2.35	91.09

Response of Temuco variety to row spacing

At final harvest on February 27, 2014, statistic tests of quinoa variety Temuco leaves, stems, seeds, and total plant dry weights were highly significant at $p < 0.01$, whereas spike dry weights was statistically significant at $p < 0.05$ (**Table 3**). Leaf dry weights of 30, 40 and 50 cm row spacing treatments were 1,033; 613; and 630 kg DM ha-1, respectively. Stem dry weight of the 30, 40, and 50 cm row spacing treatments were 3,800, 2,763 kg DMha-1; 2,762.5 kg DMha-1 on 40 cm row spacing 2,400 kg ha-1 on 50 row spacing. Seed dry weights of 30, 40 and 50 cm plant spacing treatments were 7,067; 4,400; and 5,520 kg ha-1, respectively. The total dry weight of plants followed the same trend as the results of seed dry weight, that of the 30 row spacing treatment was the highest (5,267 kg DMha-1), followed by 50 and 40 cm row spacing treatments(10,560 and 9,938 kg DMha-1, respectively). The spike dry weights of 30 cm row spacing treatment (3,367 kg DM ha-1) was higher than those of the 40 (2,163 kg DMha-1) and 50 (2,090 kg DM ha-1) row spacing treatments.

Pests and Diseases

Seedlings had rotten stem with increased humidity or under excess water condition. Aphids started to attack young quinoa when they were transplanted to the field. Regularly, butterflies laid eggs on the plants throughout the growing season. Hand picking were required to remove the butterfly caterpillars. Powdery mildew was a common disease when the weather was hot and humid or cool at night and hot in the daytime. Another main pest that lived on plants when quinoa started to develop from flowers to seeds was Cletus tregonus (Thungberg). This pest sucked plant sap from the flowers until they dried out. In addition, when there was dew at night and the temperature increased in the daytime this allowed mold to grow on top of the flowers. They started from small area and expanded in bigger scale. Birds also could cause yield loss when they landed on plants. Some plants were not strong enough, so broken stem occurred and plant died.

Table 3 Dry weights of the quinoa variety (Temuco) as affected by the three row spacing treatments at Mae Hia Agricultural Research and Training Center, Chiang Mai, Thailand. Growing duration 92 days from 30th November 2013 to 6 February 2014.

	Dry weight (kg DM.ha$^{-1)}$				
Planting space	Leaves	Stem	Spike	Seeds	Total plant
30 x 10 cm	1,033 a	3,800 a	3,367 a	7,068 a	15,267 a
40 x 10 cm	613 b	2,763 b	2,163 b	4,400 b	9,938 b
50 x 10 cm	630 b	2,400 c	2,090 b	5,520 b	10,560 b
F-test	**	**	*	**	**
CV%	34.8	11.5	42.2	22.1	18.8

*, **= significantly different at p<0.05 and <0.01, respectively

Means in the same column followed by the same letter are not significantly different by DMRT

Discussion

Temuco is the chosen variety due to its highest rate of seed emergence and was used in experiment field. Temuco is a quinoa variety that has been reported to be well-adapted to the coastal and lowland in Chili's diverse ecosystems. People have been cultivating quinoa at the altitude of 360 m in Chile (Bhargava and Srivastava, 2013). This variety has been reported to be successfully grown in other coastal areas of Peru using drip and sprinkler irrigations, and produced dry seed yield of 7,500 kg ha-1 (Bhargava and Srivastava, 2013). This could be the indicator that sea level and coastal varieties could be grown in different parts of the world with similar climatic and edaphic conditions. It has also been reported that the cultivars from Southern Chile, Peru, and Bolivia were very sensitive to temperature and photoperiod (Bhargava and Srivastava, 2013). However, the growth and seeds yields might not be the same because ecological conditions, and treatments are vital factors. In addition, there was an experiment conducted on quinoa (Amarilla de Marangani and Buer) (Risi and Galwey, 1991) at Cambridge in England with row spacing of 40 cm and 20 cm and sowing rates of 15, 20 and 30 kg seed ha-1 were examined The higher sowing rate, the plants were shorter, stunned branching and matured earlier than lower sowing seed rates. The result has shown increasing of competition effects when they increase in within row density and this effect was greater than reduction of row width, except for the effect of the proportion of the branched plant. The highest seed yield on this experiment was 6,960 kg ha-1 in row spacing of 20 cm with a sowing density of 20 kg seed ha-1 (Risi and Galwey, 1991). The grain yield was similar to our finding that Temuco variety was grown in 30 cm row spacing in lowland Chiang Mai, Thailand. Additionally, there are several factors that affect the emergence percentage such as photoperiod and temperature (Bertero et al., 2001). The rate of leaf appearance is controlled by temperature and photoperiod. This also associates with the origin of seed. For example, the variety that originates from cold or dry climate has the highest temperature sensitivity, whereas variety originating in humid or warm climate has the lowest temperature sensitivity (Bertero et al., 2001). Temuco quinoa originates from lowland/coastal areas in Chile where the average humidity is 79.6%, and the average cold and warm temperatures are between 6.6°C to 17.4 °C. According to the emergence percentage test carried out between the end of rainy season and beginning of winter in northern Thailand which was the time that had high humidity and cool weather in the morning. This might be the reason why emergence percentage of Temuco was highest.

Conclusions and Suggestions

Growing quinoa in Chiang Mai lowland with three row spacing treatments has shown high potential for introduction and domestication. Quinoa variety Temuco was the best variety with respect to emergence test in the plants nursery condition. Seed dry weight of the 30 cm row spacing was approximately 7,000 kg DM ha-1, which is close to that was obtained in Peru (7,500 kg DMha-1). Therefore, Temuco quinoa variety and the 30 cm row spacing could be used to conduct field experiments in Chiang Mai-Lumphun valley to get better understandings of other agronomic practices. The obtained data set could be useful for commercial purpose or subsistence for small-scale farmers. However, growing quinoa on new ecological zone, the location needs to be ensured for consistency of yields and other aspects. For example, growing quinoa all year around would help to fulfill the data for different growing seasons. This would help growers to know exactly when the best to sow quinoa in Thailand. Importantly, the post-harvest techniques are very important due to quinoa seeds have high saponin content that must be removed before consumption and required further studies. According to this experiment its result suggested that 30 cm row spacing and 10 cm between plants was the best growing design for quinoa in lowland, Chiang Mai, Thailand. This might be an idea for commercial growing Temuco variety in the future. However, growing in the seedling trays process might not need anymore because it was high labor intensive and high investments. In addition, when roots system was broken from transplant process this tremendously affect plant growth and yield. Therefore, sowing seeds directly to the soil would be an alternative method to maximize yield, plant growth and this could minimize labor cost for commercial or substantial purpose.

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