# ANDEAN GRAIN CROP INTRODUCTION TO THE BRAZILIAN SAVANNAH

Carlos Roberto Spehar[1], Roberto Lorena de Barros Santos[1] & Sven-Erik Jacobsen[2]

[1]Embrapa Cerrados
Caixa Postal 08223
CEP 73301-970 Planaltina, DF
Brazil

[2]Centro Internacional de la Papa (CIP)
Apartado 1558
Lima 12
Peru

## Abstract

Agricultural history of the Brazilian savannah dates back 150 years, beginning with extensive cattle ranching on native grassland, eventually developing into a rice-pasture system, followed by today's modern grain production on 10 million ha. For the past 20 years the cropping system has been soybean and maize in the rainy season, with little agricultural activity during the long dry season. A recent trend toward growing crops as a source of mulch has been limited to a few species of two botanical families: *Gramineae* such as maize, millet, and sorghum; and *Leguminosae* such as soybean. Such highly specialized monocrop systems, which are becoming common in Brazil, threaten the sustainability of the region, because of increased pests, diseases and weeds problems, loss of soil organic matter content due to excessive soil preparation, nutrient loss, soil compaction and erosion, increased production cost due to excessive/unbalanced use of fertilizers and pesticides, yield reduction, and negative environmental impacts.

Introduction of new crops is essential to improve the sustainability of the system, serving as break-crops to increase soil fertility and provide additional income to farmers. The selection criteria for new species are drought resistance, rapid growth, nutrient improvement, and diversified uses. Two species that meet these characteristics are the Andean grain crops quinoa (*Chenopodium quinoa* Willd.) and amaranth (*Amaranthus* spp.). They are characterized by a high quality protein and a high vitamin and mineral content.

In the low-altitude tropical savannah, locally selected genotypes of quinoa, originating from hybrid populations in Cambridge, England, have been evaluated in Brazil in Planaltina, DF (1000 masl; 15$^o$ S latitude) and in Rio Verde, GO (700 masl; 18$^o$ S latitude) in the winter dry season from May to September, following the main crop. Yields were nearly 7.0 t dry matter/ha and 3.0 t seed/ha, with a growth period varying between 90 and 130 days. In preliminary yield trials amaranth accessions gave similar results. Further research to determine improved production practices for optimal, sustainable cultivation of quinoa and amaranth, and to evaluate their market potential, is needed. It is expected that these novel crops can contribute to the development of the

Brazilian savannah to benefit farmers and the environment, making this important ecological region less prone to degradation.

## Introduction

The Brazilian savannah is facing increasing problems with erosion and nutritional imbalance caused by inappropriate crop and soil management after 20 years of modern production of soybean and maize in the rainy season, with little agricultural activity during the long dry season (Spehar, 1996). Similar monocrop systems have been a threat in other parts of the world (Matson et al., 1997). These problems have increased the interest for a no-tillage system, dependent on mulch production (Spehar and Landers, 1997).

Experiments with quinoa have been conducted in Brazil since 1987, with locally selected genotypes originating from hybrid populations (Spehar and Souza, 1993; Santos, 1996). More recent work has included species of grain amaranth (*Amaranthus caudatus, A. hypocondriacus, A. cruentus*, and A. *hybridus*). A remarkable characteristic of these crops is the nutrient value of the protein in the seed (Cardozo and Bateman, 1961; Negron et al., 1976), which may be of particular importance for the savannah grain production system, relying partly on processing raw material at the community level and on an industrial scale in the region (Spehar, 1996).

An undesirable character of quinoa is its saponine content. Saponins are bitter-tasting substances associated with the seed hull, which may be eliminated by washing and cooking. In nature they act as nonspecific protective agents against pests and diseases (Risi, 1986).

Amaranth is photoperiod sensitive and is classified as a short daylength plant, whereas quinoa may be short daylength sensitive or daylength insensitive. There are less sensitive species of amaranth *(A. hypocondriacus* and *A. cruentus*) that perform well under the short days of autumn sowing in the savannah region (Spehar, unpublished data). Varietal response has been detected for flowering and maturity under different temperature and daylength regimes. The onset of flowering, however, did not vary between early and late maturity types (Santos, 1996) as it did in European experiments (Jacobsen, 1997).

Quinoa is yet not cultivated in Brazil, although preliminary data on its agronomic performance conducted in the savannahs of the Central Plateaux show its potential (Spehar and Souza, 1993), so this study was undertaken to identify quinoa and amaranth genotypes less sensitive to daylength and temperature, and to adapt the crop to various sowing dates in a double-cropping system in the low altitude savannah. Germplasm selection and evaluation has been done to identify saponin-free varieties with high grain and biomass yield, and other suitable agronomic characters for crop adaptating to modern grain production systems.

## Materials and methods

*Quinoa*

Breeding Procedure

Progenies originating from seeds of Bolivian, Chilean and Peruvian material in Cambridge, England, were grown in the dry season (winter), in Planaltina, DF, Brazil, the core area of the savannah region (1000 masl; 15$^{o}$ S latitude). Late individuals with reduced branching and compact panicles were selected from the varieties Amarilla de Marangani, Chewecca, Kancolla, Real, Salares-roja, and Blanca de Junín. Their respective progenies were grown in individual plots. Selection was carried out during five growth cycles within plots to select breeding lines, which were given the identification Q1, Q2, etc. The method used was a modified pedigree, allowing some variability among lines of the same cycle, without attempting to generate more uniform lines with undesirable effects of inbreeding, except for plant height (PH), days to maturity or growth period (GP), stem diameter (SD), plant color, and inflorescence type. Almost all selected lines had amarantiform inflorescences, either lax or compact, although the glomerulate type also exists. Dry matter yield (DM) and grain yield (GY) were determined.

Additional germplasm introduction has taken place more recently from the USA, Europe, and the Andean region. The same procedure of selecting panicles within populations has been used and new breeders lines have been generated. The new lines underwent preliminary tests in Planaltina, DF.

Agronomic Evaluation

The selected lines were tested in a randomized complete block design. The same genotypes were sown in Planaltina and in Rio Verde (700 masl; 18$^{o}$ S latitude) in the summer (wet season, October-February), autumn (with and without supplemental irrigation, February-April), and winter (dry season under irrigation, May-September). The lines were characterized for days to first flower, days to maturity, plant height, inflorescence type and size, stem and peduncle color, seed production, seed size, seed quality, and saponin content. Data reported here are from lines further selected from available germplasm (Spehar and Souza, 1993). This paper presents data primarily on winter cultivation, from sowing on 26 June, 1995.

*Amaranth*

The experiments with amaranth began in 1996 with germplasm introduced from the USA. Accessions of *A. cruentus*, *A. hypocondriacus*, *A. hybridus*, and *A. caudatus* have been selected and tested. They were evaluated for days to maturity, plant height, inflorescence length and diameter, stem diameter, dry matter production, and grain yield. The experimental design was similar to the one used for quinoa. Variability within accessions has been observed, and segregants have been individually selected for progeny tests.

## Results and discussion

Mean values for grain yield, plant height and dry matter production are presented in Table 1. Highest grain yield was 2.4 t/ha and maximum biomass production 6.4 t/ha. The total growth cycle for the genotypes varied between 112 and 143 days, shorter than that normally observed in the Andes. When sown in autumn the same genotypes had a shorter growth period of only 85-130 days.

The data indicated that the quinoa genotypes selected at the savannah responded to daylength and temperature. Plants were smaller and had a longer growth period when temperature decreased and days became shorter in winter, which is consistent with results from the Andean region (Espíndola and Gandarillas, 1986). The large day-night temperature range in the winter dry season may have contributed to extending the growth period. The mean temperature in the Andes is much lower than on the savannah, which explains the slower plant development there.

Days from flowering to maturity differed between genotypes and for all sowing dates. No significant differences between lines were found for days to flowering, which differed with results from the temperate zone (Risi, 1986, Jacobsen, 1997). Although the selected lines were uniform in plant color, height, and inflorescence type, variability for other characters, such as saponin content, was noticed.

Correlation coefficients for a number of characters showed that the length of the growth period was positively correlated to GY and PH (Table 2). Late genotypes grew taller and were superior in grain yield. GY was positively correlated to GP, PH and DM, which was not true for HI, where late varieties with low HI and early varieties with higher HI could be found (Table 1, Fig.1). Usually in specialized crops produced commercially (e.g. soybean), HI is high in comparison to less specialized, multipurpose crops, used for forage, grain, and mulch, bred for low-input systems, as seen for at least some of the quinoa cultivars (Spehar et al., 1997). Thus, it is possible to develop crops such as quinoa to high grain, high biomass or both grain and biomass production to satisfy different production systems.

Grain yield for the best quinoa lines across experiments was 1.8 t/ha for summer, 1.3 t/ha for nonirrigated autumn sowings, 2.6 t/ha for irrigated autumn sowings, and 3.0 t/ha for winter sowings. Dry matter production reached nearly 7.0 t/ha. These results confirmed previously results at the Brazilian savannah, and are higher than the yield at the Altiplano of the Andes. High yields, however, have been obtained in other environments with selected genotypes (Risi, 1986; Jacobsen and Stølen, 1993; Jacobsen et al., 1994), and the yield potential has been shown to be between 4 and 11 t/ha (Wahli, 1990; Rivero, 1994). In addition, stability of various quantitative traits is encouraging for crop improvement (Jacobsen et al., 1996). This evidence for crop adaptation increases the prospects for including quinoa in rotation/double-cropping systems on the savannah. The preliminary experiments with grain amaranth accessions have shown promising GY of 3.5 t/ha and DM yield of 7.0 t/ha for the best performer.

Saponin content, which varies from medium to high, is limiting for improving quinoa. Selections are based on the method described by Alvarez and von Rutte (1990), to isolate and identify saponin-free individuals in the population, in addition to introducing saponin-free lines from Latinreco, Quito, Ecuador. All are being evaluated for GY and other agronomic characters. Recurrent selection using saponin-free, high yielding varieties, as described by Spehar & Souza (1993), will be employed in the breeding programme.

The integration of quinoa and amaranth into the production system of the savannah will result in crop diversification. That will help to break pest cycles and reduce pathogens in bean, pea, and other crops in the dry season, and in soybean and maize in summer-rainfed cultivation (Spehar et al., 1997). The most serious diseases in the region are caused by *Fusarium solani*, *Sclerotinia sclerotiorum* and *Heterodera glycines*, affecting soybean and bean, increasing production costs and contributing to environmental degradation. They are soilborne organisms with a complex genetic inheritance, which are difficult to eliminate, except by crop rotation.

Quinoa and amaranth, however, need further studies on their drought resistance, as drought is frequent at the end of the second crop growth period in a double-cropping system. Also of interest are their tolerance of low pH and high soil Al content. Other characters of interest are new sowing techniques, such as relay or oversowing which will allow saving of moisture and time. Quinoa and amaranth have small seeds, a favorable character for such sowing, although their slow growth in early stages may lead to weed competition (Spehar, 1996). The feasibility of quinoa and amaranth with the specific purpose of soil cover during the dry period and crop residue incorporation for mulching after grain harvest, should be studied in the future.

Quinoa and amaranth cultivation in the summer, where high temperatures lower yields and intense rain at the end of the growth period lowers seed quality, need also to be studied. If the crops can be considered as sources of mulch and forage in addition to seed use, grown on residual moisture or in irrigated systems in different periods of the year, their prospects for cultivation are strengthened.

## Conclusion

1. Quinoa and amaranth have an exceptionally high nutritive value, and in addition quinoa has high drought resistance.
2. Quinoa and amaranth may contribute to improving the diet of low income populations, and raise their standard of living.
3. The high quality protein may be a key factor for the agroindustry in the cattle, cow and chicken production.
4. Preliminary seed yields are encouraging, and selection will be continued to attain saponin-free quinoa.

## References


Alvarez, M. and Rutte, S. von 1990. Genética. In Wahli, C. (Ed.). Quínua - Hacia su cultivo comercial. Quito, Ecuador: Latinreco. p. 33-60.

Cardozo, A. and Bateman, J.V. 1961. La quínua en la alimentación animal. Turrialba, 11:72-77.

Espíndola, G. and Gandarillas, H. 1986. Estúdio de caracteres correlacionados y sus efeectos sobre el rendimiento en quínua. In Gandarillas, H. (Ed.) Estructura anatómica de los organos de la planta de quínua/Estúdio de caracteres correlacionados y sus efectos sobre el rendimiento en quínua/Hibridaciones entre espécies de la subsección cellulata del genero *Chenopodium*. Ministério de Asuntos Campesinos y Agropecuários/Instituto Boliviano de Tecnologia Agropecuária/Centro Internacional de Investigaciones para el Desarollo. p.19-22.

Jacobsen, S.-E. 1997. Adaptation of quinoa (*Chenopodium quinoa* Willd.) to Northern European agriculture: Studies on the developmental pattern. Euphytica 96, 41-48.

Jacobsen, S.-E. and Stρlen, O. 1993. Quinoa - Morphology and phenology and prospects for its production as a new crop in Europe. European Journal of Agronomy 2, 19-29.

Jacobsen, S.-E., Jρrgensen, I. and Stρlen, O. 1994. Cultivation of quinoa (*Chenopodium quinoa*) under temperate climatic conditions in Denmark. Journal of Agricicultural Sciences, Cambridge, 122, 47-52.

Jacobsen, S.E., Hill, J. and Stølen, O. 1996. Stability of quantitative traits in quinoa (Chenopodium quinoa). Theoretical and Appplied Genetics, 93:110-116.

Matson, P.A., Parton, W.J., Power, A.G. and Swift, M.J. 1997. Agricultural intensification and ecosystem properties. Science, 277:504-509.

Negron, A.A., Alvares, G.E. and Calmet, U.E. 1976. La quínua y la cañihua en raciones de pollos parrilleros en Puno, Perú. In: Convención Internacional de Quenopodiáceas, 2. Actas. Potosí. Universidad de Bolivia "Tomas Frías", p.170-176.

Risi, J. 1986. Adaptation of the Andean grain crop quinoa for cultivation in Britain. Cambridge: University of Cambridge, 1986. 338p. Ph.D. Thesis.

Rivero, J.L.L. Genética y Mejoramiento de cultivos altoandinos. PIWA, Puno, Peru. 459 p. 1994.

Santos, R.L.B. Estudos iniciais para o cultivo de quinoa (*Chenopodium quinoa* Willd.) nos Cerrados. 1996. Brasília: Universidade de Brasilia, 129p. M.Sc. Thesis.

Spehar, C.R. 1996. Prospects for sustainable grain production systems in the cerrados (Brazilian Savannas). In: Simpósio sobre o cerrado, 8, 1996, Brasília, Anais do 8o Simpósio Sobre o Cerrado: biodiversidade e produção sustentável de alimentos e fibras nos Cerrados e proceedings do 1st International Symposium on Tropical Savannas: biodiversity and sustainable production of food and fibers in the Tropical Savannas. Planaltina: EMBRAPA-CPAC, p.139-151.

Spehar, C.R. and Souza, P.I.M. 1993. Adaptação da quinoa (*Chenopodium quinoa* Willd.) ao cultivo nos cerrados do Planalto Central: Resultados preliminares. Pesquisa Agropecuária Brasileira, Brasília, 28:635-639.

Spehar, C.R., Santos, R.L.B. and Souza, P.I.M. 1997. Novas espécies de plantas de cobertura para o plantio direto. In: Seminario Internacional do Sistema Plantio Direto, 2, 1997, Brasília. Anais. Passo Fundo, RS, Brazil: Embrapa-trigo. p.169-172.

Spehar, C.R. and Landers, J.N. 1997. Características, limitações e futuro do plantio direto nos cerrados. In: Seminario Internacional do Sistema Plantio Direto, 2, 1997, Brasília. Anais. Passo Fundo, RS, Brazil: Embrapa-trigo. p.127-131.

Wahli, C. Quínua - Hacia su cultivo comercial. Quito, Ecuador : Latinreco S.A. 206 p. 1990.