CHAPTER 6.3.1

Assessment and adaptation of quinoa (*Chenopodium quinoa* Willd) to the agroclimatic conditions in Mali, West Africa: an example of South-North-South cooperation

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Abstract

Quinoa's adaptation was tested in Mali, West Africa, where the difficult agroclimatic conditions are similar to those in central northern Chile. The traditional varieties used were predominantly from Chile ('A64', 'BO25', 'BO78', 'PRP', 'PRJ', 'UDeC9', 'R49', 'VI-1', 'Regalona', 'Mix'), plus two crop cultivars from Argentina ('Roja Tastina' and 'Sajama') and one varietyfrom Bolivia. Trials began in 2007 and continue today. They tested sowing in the rainy season (June–Oct.) and in the dry season (Nov.–Mar.). Pests, diseases and yields were assessed, taking into account also the grain storage conditions and more sustainable soil management (compost). Some Altiplano cultivars were recalcitrant ('A64', 'R49' and 'MIX'), while the traditional varieties from central southern Chile gave satisfactory yields (1–2 tonnes/ha). Ideally, seeds should be sown each season to avoid a reduction in germination vigour which is caused by the ambient humidity and high temperatures characteristic of *in situ* storage in tropical zones. The crop cycle is 90–100 days for the accessions from Chile and up to 108–119 days for the accessions from Argentina. The panicles can be attacked by fungal diseases that reduce productivity in the rainy season. The presence of phytophagous insects (*Bemisia*, *Aphis* and *Aspavia* genera) was observed, as well as Coccinellidae, which are their natural predators in biological control. Quinoa has the potential to improve the supply of high quality protein in Africa. Pests in the rainy season and insect infestation can be controlled by adopting ecological management practices, using saponins from the same quinoa varieties. The limiting factor is the energy requirement for using water (not readily available in the dry season) and for mechanized threshing. The population's use and acceptance of quinoa can be expected to be high, on the basis of past experience introducing other crops from America (potato, maize and tomato) to this continent and given the culinary similarity with millet and rice.

Context and problems of introducing quinoa to this part of the world

Africa is a region characterized by serious nutritional problems. In most African countries, over 20% of the population is malnourished and infant mortality exceeds 75% for children under five. In 2012, across the Sahel, an estimated 1.1 million children under the age of five were at risk from severe acute malnutrition. Therefore, in April, UNICEF launched SahelNOW, a campaign to raise global awareness of the imminent crisis. For the first time in history, UNICEF's offices and national committees came together to join social networks that were used as the principal means of communication for advocacy and fundraising. The campaign mobilized Goodwill Ambassadors from UNICEF at national and global level to alert the world about the convergence of a series of conditions threatening the nutritional status of children in nine countries: Burkina Faso, Cameroon, Chad, the Gambia, Mali, Mauritania, the Niger, Nigeria and Senegal. SahelNOW boosted the conventional media coverage and was described as innovative by CNN. In 2012, UNICEF's national committees raised USD29.8 million to help provide treatment to save the lives of over 920 000 severely malnourished children under five (UNICEF, 2013). In addition, the chronic lack of rain in the entire sub-Saharan region has worsened according to studies conducted by the Intergovernmental Panel on Climate Change (Figure 1).

In this region, agriculture's main objective is food security for the population. Thus, subsistence farming is the principal activity in the region, although cotton, maize, peanut and other crops are sold on a regular basis to generate family income. In the case of Mali (West Africa) around 90% of the population depend on cereal production (predominantly sorghum, millet, maize and rice), yielding about 1 tonne/ha (Soumaré *et al.*, 2008). In addition to drought, the duration of the rainy season is very varied. Soils are very poor and some elements in the soil (Al, Fe) constitute a limiting factor (Gigou, 1987; Gigou *et al.*, 1998; Traoré *et al.*, 2004).

These difficult conditions generate tremendous fluctuations in annual production, while there is a need to secure production for the fast-growing population. In this context, agricultural diversification and soil improvement are useful tools for facing these challenges. Agro-ecological farming (Altieri, 1995) offers

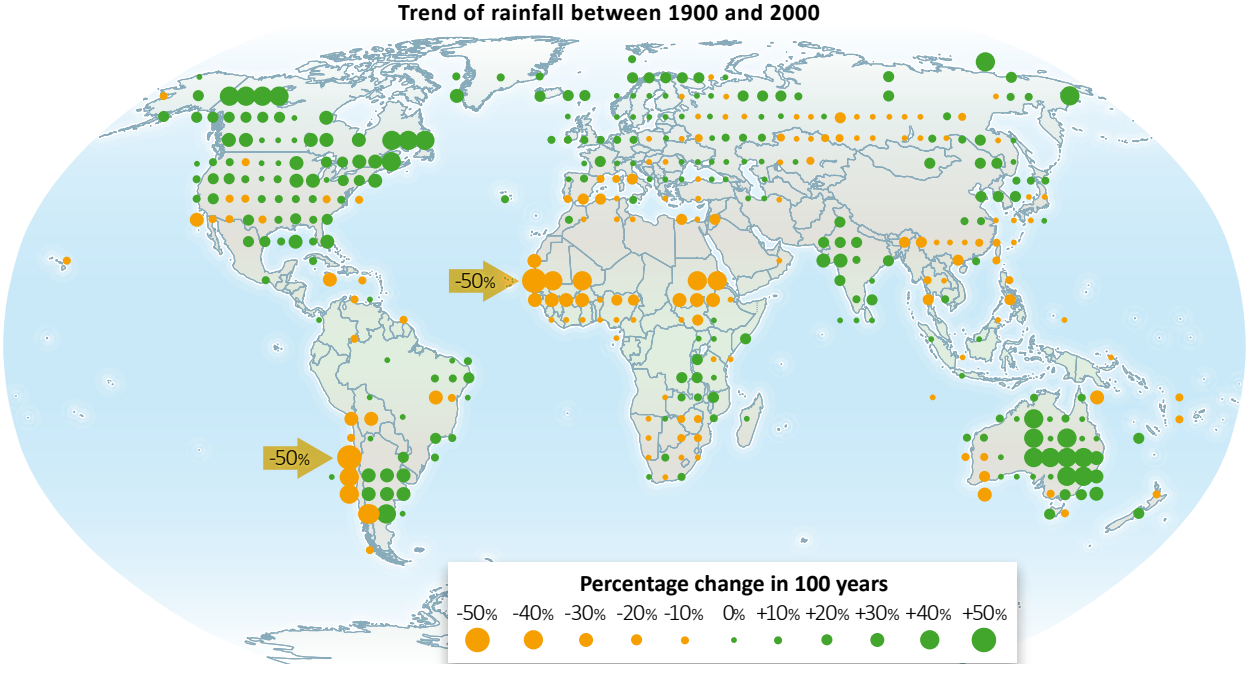

Figure 1. Map of the world's rainfall balance (deficit/excess in 100 years). The deficit of over 50% (arrows) in some parts of sub-Saharan Africa is comparable to central northern Chile (Coquimbo region). Source IPCC 2001.

a solution for populations whose limited financial resources are insufficient for other more technological alternatives, such as chemical fertilizers or genetic modification. Furthermore, technological solutions increase the effect of greenhouse gases and are unsustainable or beyond the economic reach of developing countries (Anon., 2010).

It is in this context that the potential of quinoa emerges. It is a highly nutritious plant, tolerant to various types of abiotic stress, capable of diversifying the crop production systems in many countries (Glass and Johnson, 1974; Jacobsen, 2003; Jacobsen *et al*., 2003) with problems of drought, food insecurity and poverty, such as Mali. For this reason, FAO declared 2013 the International Year of Quinoa (IYQ), just one year before 2014, the International Year of Family Farming.

Historically, farmers in Africa have always been open to experimenting with new varieties or crops in order to improve their living conditions (Chevassus-au-Louis and Bazile, 2008; Louafi *et al*., 2013). **Rural seed production systems** strengthen exchanges between farmers and support the capacity to introduce and test new agrobiodiversity (Bazile *et al.*, 2008; Coulibaly *et al.*, 2008). There is always the risk of losing some of the local biodiversity, and this should be carefully assessed before increasing production (Bazile, 2006).

Historical account of the areas of research and the disciplines involved during the period 2006–2013

In 2006, teams from Italy, Argentina, Chile and Mali studied the tolerance of Chilean quinoas to salt stress. While the main objective was to investigate the tolerance mechanisms to saline stress in *Chenopodium quinua* Willd., the same genes are also tolerant to water-related stress factors, such as drought and frost (see chapter 2.2). The Malian team conducted field assessments on the adaptability of registered and traditional varieties of quinoa and studied their tolerance to the soil and climatic conditions in Mali. The assignment began in 2007 after a researcher from the *Institut Polytechnique Rural* (IPR) in Mali spent 6 months in Chile (CEAZA) and Argentina (University of Buenos Aires and INTA) learning the basics about this crop from the southern Andes.

The trials in Mali involved behavioural tests on quinoa seeds from Chile and Argentina. Drawing on the huge geographic distance between the north (18°S) and the far south (40°S) of Chile, traditional crop varieties were used, adapted over thousands of years to different combinations of photoperiod, temperature and rainfall, generating tremendous crop genetic diversity (Fuentes *et al*., 2012). Agronomic trials were conducted on crop cycles in dry and rainy seasons, and seed storage tests were carried out. Both activities followed agro-ecological protocols in line with ecologically and economically sustainable farming. Parallel studies in Chile, Italy and Argentina were conducted to assess the genetic mechanisms and responses that high tolerance to different types of stress confers to some of the traditional varieties tested in Mali (Orsini *et al*., 2012; Ruiz-Carrasco *et al*., 2012).

Genetic resources used and their origin

By the end of 2007, at the end of Dr Coulibay's stay in South America, 12 accessions of quinoa, including 10 from Chile and 2 from Argentina (Table 1), were provided for the adaptation trials in Mali's Sudano-Sahelian zone in the IPR/IFRA's experimental plots in Katibougou (75 km northeast of Bamako). The trials were conducted in successive years, each year using the results and seeds obtained. For the rainy season trials, an unspecified commercial variety of Bolivian origin was included (purchased on the European market).

International collaboration

International collaboration began thanks to the Third World Academy of Sciences, which together with the International Centre for Genetic Engineering and Biotechnology launched an international call for projects. The participation of developed countries depended on active collaboration with developing countries. For this reason, the call for tender was answered by an institution from a developed country (University of Bologna, Italy) and two research centres from developing countries (Centro de Estudios Avanzados en Zonas Áridas, CEAZA, Chile, and the University of Buenos Aires, Argentina). In addition, Mali, West Africa, was invited to participate, thanks to a former collaboration between the University of Bologna and a professor and researcher from the *Institut Polytechnique Ru-*

Table 1. Passport data for the quinoa accessions being assessed in Mali.

Accession	Origin	Grade of selection	Seed bank
A64	North Alteplano (District of Colchane)	Seed color (Yellow)	University of Arturo Prat, Iquique
R49	North Alteplano (District of Colchane)	Seed color (Red)	University of Arturo Prat, Iquique
Mix	North Alteplano (District of Colchane)	No selection	University of Arturo Prat, Iquique
PRP	Central coast of Chile (Palmilla locality, District of Pichilemu)	No selection	CEAZA collections for INIA seed bank
PRJ	Central coast of Chile (District of Pichilemu) Central Chile (District of Pichilemu)	No selection	CEAZA collections for INIA seed bank
VI-1	Central coast of Chile (District of Chanco) Southern Chile (District of Cunco)	No selection	CEAZA collections for INIA seed bank Collection of Univ. of Concepción, Chillán
UdeC 9	Southern Chile (District of Collipulli)	No selection	AGROGEN bank, donated to INIA
BO25	Hybrid variety Altiplano variety (Bolivia/Argentina)	No selection	AGROGEN bank, donated to INIA BAER seeds
BO78	Altiplano variety (Bolivia/Argentina)	No selection	Univ. of Buenos Aires bank, Argentina
Regalona		Selection for best yield and grain size	Univ. of Buenos Aires bank, Argentina
Sajama		Low saponin content	
Roja Tastina		No selection	
Boliviana	Unknown	Unknown	European market

ral for Agricultural Research and Training (IPR/IFRA) in Katibougou.

Another project involving France (CIRAD, IRD, INRA), Mali (IER, ICRISAT) and Chile (CEAZA), funded by the French National Research Agency (ANR, 2008–2012), studied quinoa seed systems in Chile and compared them with sorghum and millet systems in Mali (Bazile *et al*., 2011 and 2012).

Experiments conducted and the results

The experiments concentrated on four areas: (1) sowing in the dry season (Nov.-–Mar.); (2) sowing in the rainy season (June–Aug.), the period preferred by farmers because rain is more abundant; (3) seed germination and storage; and (4) use of different types of compost to improve soil quality. In all the studies, special attention was given to assessing the

presence of diseases and insects that are potential crop pests or predators (biological control).

1. Assessments in the dry season

The Chilean and Argentinian varieties of quinoa (Table 1) were sown in experimental plots of 18 m2 on 15 November 2007, which corresponds to the dry season. Five or six seeds were sown in **pockets** spaced at two different densities (every 10 and 20 cm) with 50 cm between the rows, except for the Argentinian varieties, for which less material was available. These varieties were sown at the higher density only (every 10 cm). Irrigation was spaced at 15-day intervals (3/4 of field capacity) and every 10 days after flowering. The only fertilizer used was compost from cattle manure (at a rate of 8 tonnes/ha). In the second period of assessment in the dry season (2008/09), seeds from plants that produced panicles and grains in 2008 were used (Figure 2). This time, seeds were sown slightly later (5 and 15 December 2008) in the same conditions as for the first period, using seeds obtained from the harvest in the first assessment. The germination capacity was assessed for the seeds from the first harvest. Not all results were viable (see results section).

2. Assessments in the rainy season.

In the 2009 rainy season (June–Aug.), trials were conducted to verify the findings of preliminary trials carried out in the 2008/09 rainy season which saw the emergence of fungal diseases that **decimated** the panicles (Figure 3). The Chilean Altiplano ecotypes ('A64', 'R49', 'MIX') were not used because there were recalcitrant seeds (no germination) following harvest in the dry season in Mali. In addition to direct sowing in the field (a little over 0.3 ha), the seed germination capacity was tested in the laboratory (evaluated at 5 days, n = 50 seeds), using cotton and soil from the same experimental plots.

3. Studies of seed germination and storage.

The quinoa seeds that arrived in Mali for the first time were assessed for their capacity to germinate at successive stages, involving quality assessment in storage conditions at ambient temperature. Temperatures ranged between 21°C and 26°C, with extremes (outside ambient temperature) of 45°C in the dry season and maximum inside ambient temperatures around 10°C less. Maximum ambient humidity was quite high in all periods (> 50%), therefore the seed weight was assessed before and after 3 months of storage. Once the first seeds were produced in Mali, germination was assessed following 12 hours in damp cotton under laboratory

Figure 2. Quinoa plants (traditional variety 'Roja Tastina') near the time of harvest at the IPR/IFRA experimental station in Katibougou, Mali, in February 2008 (dry season). The water tanks that can be seen in the background provide gravity-fed irrigation.

Figure 3. Plant from the variety 'BO78' during the rainy season in 2008, with fungal damage (unidentified) on the panicle that caused the entire apical panicle to abort and the plant to become bushy (many branches).

conditions at 5, 11 and 12 months post-harvest and after 3 years.

Insect control involved an assessment of the entomofauna that developed in 100 g packs of quinoa seeds. Controls (n = 8 for each variety) were compared with treatments in which seeds of each variety were juxtaposed and combined with material bags containing 10 g of dry residue (whole) or 6 g of ground residue (meal) from a plant species that is a potential insect repellent. Two plant species were tested for this biopesticide potential: *Cassia nigricans* and *Hyptis spigicera.* Seeds from 8 of the 12 varieties ('Boliviana', 'PRP', 'PRJ', 'VI-1', 'UDEC9', 'Regalona', 'BO25' and 'BO78') were assessed (for germination and associated entomofauna) after 3 months.

4. Study of the responses to compost use.

The yields of the same eight quinoa varieties tested for grain resistance to insect attacks were tested for sowing in the dry season (2 December 2010 to March 2011). There were three soil fertilizer treatments: manure from cattle/sheep (composted) applied at 8 tonnes/ha and at 4 tonnes/ha (control), and compost from the same manure but modified by earthworms, applied at 8 tonnes/ha. The harvest took place on 12 March 2011. Yields were recorded and the presence of insects was determined for each traditional variety.

Results

1. Assessments in the dry season.

The 12 traditional varieties from central southern Chile and the seeds harvested in Argentina showed germination rates of between 73% ('PRP') and 97% ('Sajama'). The north Altiplano varieties from Chile ('A64', 'R49', 'MIX') were recalcitrant (no germination). Ambient temperatures in the first period ranged from a minimum of 8.7°C (January 2008) to a maximum of 36.6°C (February), while in the second period they ranged from 14°C (December 2008) to 39°C (March 2009). Relative humidity ranged from 21% (February 2009) to 82% (November 2008).

Grain yields for the 2007 sowings varied from less than 0.5 tonnes/ha ('Sajama' at the highest sowing density) to just over 2.5 tonnes/ha ('BO25' and 'UdC9' at the lowest density) (Figure 4). In general, the best yields were obtained with the lowest sowing densities. Six of the ten traditional Chilean varieties achieved yields of around 2 tonnes/ha or more. The best yields were observed for 'UdeC9', 'BO78', 'BO25', 'PRJ' and 'PRP', all of which are from central and southern Chile.

For yields in the second campaign (sown on 5 and 15 December 2008), no grains were produced by seeds from Argentinian harvests ('Sajama' and 'Roja Tastina'). In general, yields were higher at lower seed densities and varied between 0.5 and 1.5 tonnes/ha. For 15 December sowing, yields were 0 tonnes/ha for the Argentinian varieties and 0.5–1 tonne/ha for the other varieties. There were no significant differences between the two sowing densities. For 5 December sowing, temperatures were lower during flowering than for 15 December sowing, and yields were at least 0.5 tonnes/ha higher for early sowing.

2. Assessments in the rainy season.

Seed germination rates in these trials were slightly higher for the traditional varieties germinating in cotton (80–97% on day 2) than in soil from the same plot (60–80% on day 2). 'Sajama' and 'Roja Tastina' varieties failed to germinate and 'Boliviana' germinated at a rate of less than 5%. 'BO25' was the slowest to germinate, both in cotton (60% on day 5) and in soil (just over 50% on day 5). Fungal disease was observed on seeds on day 5: the highest level of contamination (> 70%) in 'UdeC9', 'Roja Tastina' and 'Sajama' from Argentina and the lowest (< 20%) in 'BO25' and 'BO78' from Chile's humid south. All the other varieties showed intermediate results. The type of fungal disease and whether or

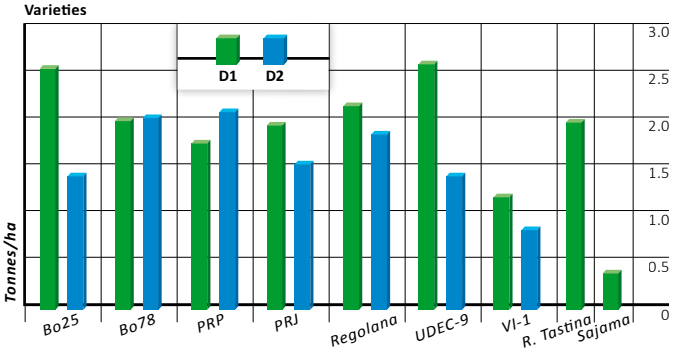

Figure 4. Quinoa grain yields (tonnes/ha) for sowing in 2007 at low (D1) and high (D2) density.

not it was already present on the seeds at the time of harvest is not known. Fungal diseases were recorded on day 5 of incubation.

In the field, emergence varied between 23.7% for 'BO25' and 51.27% for 'VI-1'. Panicles were also attacked by fungal disease (Figure 3). The variety 'BO25' had over 40 standing plants on 25 July 2009 and was least affected (16.7%). 'PRP' was the most affected, with fewer than 40 standing plants on the same date (54.5% of contamination). The other varieties ('BO25', 'PRJ', 'UdeC9') all had some degree of fungal contamination, and fewer than 15 plants survived the rainy season. The variety 'Boliviana' had just two surviving plants, while 'Roja Tastina' and 'Sajama' did not produce any plants.

The phtyophagous insects observed belonged to 30 species (13 unknown), 22 families and 7 different orders (Orthoptera, Homoptera, Heteroptera, Dermaptera, Diptera, Coleoptera and Hymenoptera), while the beneficial organisms (entomophagous organisms, predators) belonged to 10 families from 5 orders (Orthoptera, Heteroptera, Diptera, Coleoptera and Hymenoptera).

There are no available data on yields, given the high level of fungal infection observed in the two rainy seasons.

3. Studies on seed germination and storage.

In Mali, seed germination (assessed on day 5, observed at 5 months on 6 August 2008) was between 25% ('Roja Tastina') and 98% ('Sajama'). The majority had germination rates of about 65%. **In month 11 (25 January 2009), germination dropped below 70% for the varieties 'VI-1', 'Roja Tastina', 'Sajama', 'R49' (<5%) and 'Boliviana'. All the other varieties had values of over 70%, almost 100%** ('BO25', 'PRJ'). In month 12 (4 February 2009), 'Roja Tastina' had the lowest germination rate (30%). In the other varieties, 'BO78', 'PRP', 'PRJ', 'VI-1' and 'UdeC9s', germination ranged from 80% ('BO25') to 98% ('Regalona'). Seeds stored for 3 years had much lower germination rates – between 2% ('R49') and 12% ('PRJ', 'UdeC9' and 'BO25').

In the assessment of grain storage and the presence of insects, observations from the first grain inspection detected (using 10 g dry matter of *Cassia nigricans*) only two Coleoptera on eight varieties, and on the seeds only of 'Regalona'. With 10 g dry matter of *Hyptis spigicera,* Lepidoptera also appeared, although only on seeds of 'Regalona'. With 6 g of ground *Cassia nigricans,* one Coleoptera appeared again on 'Regalona' seeds and 15 Lepidoptera on 'Boliviana' seeds. With 6 g of ground *Hyptis spigicera,* only three Coleoptera and a single Lepidoptera appeared on 'Regalona'. The results were the same for the dried residues (with or without grinding) of both plant species.

Germination after 120 hours is approximately 90% for all traditional varieties. Fungal infections appeared on all varieties, with the lowest incidence (20% of seeds) on 'BO25' and the highest on 'VI-1' and 'UdeC9' (> 50% of seeds). After 3 months, the emergence of rootlets and cotyledons (indicators of seed germination vigour) decreased by at least 50% compared with initial observations (for the treatments with both dried plants). This could be related to the biochemical reactions resulting from the absorption of ambient humidity, since the weight of seeds increased by up to 3% after 3 months of storage at ambient temperature, particularly for the Altiplano varieties.

4. Study of the responses to compost use.

The best yields were obtained with half the dose of compost made from sheep/cattle manure. Application of worm compost to the eight varieties produced yields of between 0.8 tonnes/ha ('UdeC9') and 4.5 tonnes/ha ('BO25'), and an average yield of 2.6 tonnes/ha. For compost applied at a rate of 8 tonnes/ha, yields varied between 1.8 tonnes/ha ('Regalona') and 4.9 tonnes/ha ('PRJ'), with an average of approximately 3 tonnes/ha. When the dose was halved, yields were even higher, ranging from 2.2 tonnes/ha ('BO78') to 5.7 tonnes/ha ('BO25' and 'PRP') with an average of slightly over 3 tonnes/ha.

Compost applications also affected the insect burden on plants. For example, with vermicompost, thrip infestation did not exceed 150 insects/plant. In contrast, an 8 tonne/ha dose of normal compost resulted in over 600 thrips per plant, while halving the dose resulted in only 25 thrips/plant in the same period. Similar patterns were observed for other insects. For some varieties, insect abundance increased fourfold at certain times ('PRP' at the outset).

Current situation and outlook for the dissemination of the crop in the country in 5–10–20 years

At the end of the first campaign (2007–08), nine varieties seemed able to adapt to the dry season with an average production of 1–5 tonnes/ha, i.e. greater than farmers' yields for the traditional cereals (millet and sorghum) widely used in Africa. However, the trials were conducted on a small scale and at an experimental station with controlled parameters. Now, after 4 years of trials, there are enough frozen seeds to sow over 200 ha. A possible objective is to test quinoa in salinized soils where it is difficult to grow rice (the rice-growing territories of the Niger River, Lake Sélingué, the perimeter of Baguinéda, Dioro and Diré). During the next 5 years, the Malian people need to be better informed about quinoa. In 2008, trials took place to understand how well quinoa was accepted as a prepared food. Reception was good, grains were washed by hand to remove saponins and new recipes were created (Figure 5). In the next 10–20 years, quinoa could spread to the Kidal region.

It is important to remember that the strength of the organization in Mali does not depend only on the national authorities. The village chiefs and councils of elders are in a position to make decisions that the farmers are quick to follow. In addition, the national association of professional farmers' organizations (*Association des Organisations Professionnelles Paysannes*) is an important platform for diffusing innovations and an effective interface between research and farmers. For example, between 2005 and 2008, the NGO Helvetas persuaded village chiefs that organic cotton had a profitable future on the international market. In the 3-year period, Mali went from having just over 100 small-scale cotton producers (1 ha) to 6 000, with only a score of professional extension agents for the crop. Unfortunately, the international organic cotton market dropped its prices (for Turkey's entry into the market) and production was not very profitable. However, the experience demonstrated the Malian producers' versatility and capacity for rapid change and, moreover, it encouraged them to go back to their traditional agro-ecological practices, somewhat forgotten by the advent of the green revolution and agrochemicals. Thus, quinoa represents a potential solution for improving the prospects of maintaining ecological farming. From the outset, dissemination policies should raise public awareness about the product because it is highly nutritious, is tolerant to diverse abiotic stresses and provides an alternative for rotation (no risk of losing crop diversity).

Figure 5. Ms Salimata shows us a dish of quinoa prepared with vegetables and cheese, steamed in a cloth hung from a tree. The seeds come from the first experimental harvests in Katibougou (Mali, February 2008). The saponins were washed by hand. This demonstrates how well quinoa has been accepted for culinary use in Mali.

When contemplating potential areas for quinoa cultivation in Mali, the fields near the Niger River should be taken into consideration: the groundwater is close to the surface and could be used to irrigate deep-rooting plants. Quinoa's poor performance during the rainy season confirms its potential for sowing out of season, allowing for further agricultural production in the cereal-growing zone. Good soil fertility is not a limiting factor when considering two annual crops in plots that would produce more food without overlapping with local species and varieties. To date, all the trials have been restricted to the IPR/IFRA experimental plots.

Nevertheless, cutting-edge research is required in, for example, phytopathogenic fungal attacks and insect attacks during seed storage, so that sowing times can be adjusted accordingly.

Access to water in the dry season is likely to be a limiting factor for research on quinoa. It is important to consider the energy required to obtain water, for example, by pumping from wells or from the Niger River. Energy is also needed to install threshing machines for dry grains, which would also allow use of saponins for pest and disease control in quinoa

and other crops. Once there is access to water, it is important to avoid erosion through good soil management, for example by using compost and less tillage. This study clearly shows that yields improve considerably with the use of compost. All these considerations are more urgent and effective than, for example, improvement through genetic engineering, which is still very expensive. Lastly, it is important to monitor what is happening in India, where the 700 million small subsistence farmers, predominantly vegetarians, who desperately need to increase the sources of high quality protein, have already started to adapt varieties of quinoa (Bhargava, 2006).

Uses and Markets

The small quantities of quinoa harvested have already been used as an innovative food product in Mali (Figure 5). The organic cotton experience shows that it is not advisable to launch an agricultural product for export, with the sole objective of making money, in part because prices are frequently volatile, which can cause local tragedies. In Mali, millet and sorghum are produced as staple foods. Long before quinoa is a market item, it should be a high quality complementary food, as widely available as possible for malnourished people and children who do not have regular access to sources of animal protein.

Conclusion

In conclusion, quinoa is a crop that could be adapted to sub-Sahelian countries like Mali or other countries from both hemispheres, situated between 15°N and 15°S, with a climate characterized by contrasting dry and rainy seasons. Nevertheless, during torrential rain there is a high risk of losing seeds during the early stages of germination if the rainfall causes considerable soil erosion. Other losses can be due to fungal or insect attack (at both seed and plant stages). Traditional varieties should be selected in order to address these risks, and to have adaptation to the photoperiod and high temperatures during flowering. It is interesting to note that the varieties from southern Chile produced good yields during the dry season, particularly when organic compost was added to the soil. The seeds from these varieties demonstrated a high tolerance to ambient humidity when stored between sowing dates.

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