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A COST-BENEFIT ANALYSIS OF THE ADVANTAGES OF QUINOA COMPARED WITH MAJOR COMPETING CROPS IN WAG-HIMIRA ZONE, ETHIOPIA

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Abstract. A household survey was conducted to assess the cultivation of quinoa in Wag-himira zone, Ethiopia. Farmers' perceptions of quinoa, its profitability, and relevant production practices and constraints, as well as their acceptance of the crop and willingness to grow it, were profiled. A total of 247 farmers were purposively sampled based on their involvement in quinoa farming for at least one year. Data were collected using a semi-structured questionnaire, then analyzed using descriptive statistics, a cost-benefit analysis, a Likert rating scale and a ranking index. The results reveal that except for poor resistance to insect pests and marketability, farmers had a good perception of quinoa according to most preference parameters. It had a higher grain yield than teff, but had lower grain and straw yields than other competing crops. The gross margin was higher than for other crops, and quinoa was ranked third according to its benefit-cost ratio, behind sorghum and faba beans. The farmers' sensory preferences for quinoa food types were injera, bread, kitta and porridge in descending order. Among the respondents, 67.6% were interested in continuing with quinoa production, but the rest refused due to labor shortages, market problems, seed shortages and food recipe knowledge gaps. Susceptibility to pests, marketing and straw palatability problems and the requirement for fertile soil were constraints on quinoa production. Therefore, concerned bodies such as research institutes should pay attention to developing and/or devising appropriate pest control mechanisms. Seed-producing and marketing cooperatives should be strengthened to make quinoa crop production viable.

Keywords: production constraint, quinoa technology, sensory evaluation

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) belongings to the plant family *amaranthaceae*, which is native to Andean regions and adaptable to diverse soil types and climatic conditions (Rambal et al., 2015). Until the early 1970s, traditional quinoa farming was mostly restricted to its country of origin; however, the opening of the international organic market and the consequent increase in the quinoa price has led to quinoa being cultivated in other areas of the world (Angeli et al., 2020). Quinoa is considered one of humanity's most promising crops in the fight against hunger and food insecurity, and is seen as a viable alternative crop to feed growing populations in food-insecure countries (Ruiz et al., 2016). It has attracted the attention of the scientific community as a result of its high nutritional value. It is rich in proteins, fats, dietary fiber, vitamins and minerals, with an extraordinary balance of essential amino acids (Park et al., 2017). In general, the nutritional characteristics of the crop, combined with its adaptation to a wide range of growing areas, make it very promising for the future of Ethiopia, particularly in areas where there is malnutrition and recurrent drought (Vasconcelos et al., 2019). At the same time, it is comparable in energy content to the major crops that are vital in Ethiopia's food system. As a nutritious and drought-tolerant crop, quinoa can play a significant role in addressing malnutrition and

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stunting problems, which affect nearly half of the children in Ethiopia (Maliro et al., 2021).

Wag-khimra zone is one of the dry-land areas in Ethiopia and is characterized by a lack of rainfall or extremely dry land, low crop productivity, narrow livelihood diversification, and limited or low nutritional diversity and consumption (Mihiretu et al., 2019b). The zone is thus identified as an insecure food system, which requires nutritionally dense and drought-tolerant crops. The Dan Church Aid (DCA) project has introduced quinoa to the project target woredas in Wag-khimira zone (Kindye and Ademe, 2020, unpublished) in the last few years. However, the feasibility of the crop, namely its production prospects, farmers' perceptions and reactions and its comparative advantage when compared with major competing crops, have not been studied and documented. This study aimed to assess the feasibility of quinoa crop using cross-sectional survey data, but more specifically:

- to assess farmers' knowledge and perceptions, production practices, acceptance of and willingness to grow the new crop;
- to evaluate the profitability and comparative advantage of quinoa compared with other competing crops grown in the area;
- to identify the most important constraints faced by farmers in quinoa production.

METHODOLOGY

Sampling procedure and determination

To find representative sample households, multistage sampling procedures were implemented. Firstly, Dehana woreda was randomly selected from the project woredas in Wag-khimira zone. Then, farm households signifying the project beneficiaries from six sample kebeles were purposively selected from the woreda. The sample size was determined based on the required level of precision using the simplified formula (Eq. 1) described by Yamane (1967). This equation is appropriate because the beneficiaries of the project are known and the project participants in the study area are homogenous in their livelihood strategies and cultural and socioeconomic setups.

$$n = \frac{N}{1 + N(e)^2} \qquad (1)$$

where: n – sample size, N – population size, e – level of precision or the error term.

Data collection and analysis

The primary data were collected from 247 sample households from May to June, 2020 through a formal interview schedule using a semi-structured questionnaire. The collected data were analyzed using the benefit-cost ratio and descriptive statistics, but the data from five respondents were not used due to an underestimated yield.

Cost-benefit analysis: Farm-budgeting techniques were employed to determine the costs and returns of factors of production for competing crops in the study area. The crops were selected for their area coverage and importance to farmers' livelihoods. The analysis was carried out by estimating the gross margins of each crop on a per-hectare basis. The gross margin (Eq. 2) represents the difference between the monetary value of all the output (gross returns) and the total variable cost per hectare (Mihiretu et al., 2019a). The gross return is obtained by multiplying the total quantity of output produced by the local average market price, while the total variable cost is obtained by summing up all the costs that vary, i.e. land preparation, seed and fertilizer, planting, weeding, harvesting and threshing. Finally, a comparative assessment of competing crops grown in the study area was implemented using benefit-cost ratios. For an investment to be feasible, the ratio should have a value of 1 or above.

$$GM = \sum P_i Y_i - C_k \text{ (k = 1, 2, 3…)} \qquad (2)$$

where: GM – gross margin, P_i – average price of the ith crop at the local market, Y_i – annual yield of the ith crop, C_k – variable costs incurred to produce different crops.

Knowledge, perception and production constraints of quinoa: Data on farmers' perceptions of and reactions to quinoa were analyzed using a Likert scale and the relative importance index (RII) formula (Eq. 3), following Ogwal-Kasimiro et al. (2012). Scales for measuring the farmers' preferences were given values from lowest (1) to highest (5). To identify the major constraints associated with quinoa production, rank index[1] was employed (Vasconcelos et al., 2019).

[1]

$$\text{Rank Indeks} = \frac{\text{Sum(nX no of hhs ranked 1st + (n–1) no of hh ranked 2nd + } 3n_3 + \ldots \text{.1 X no of hhs ranked last for 1 factor}}{\text{Sum(nXno of hhs ranked 1st + (n–1) no of hh ranked 2nd + (n–3) ranked 3 + … .1 X no of hhs ranked last for all factors}}$$

$$\mathrm{RII} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (3)$$

where w – is a weight given to each factor by the respondent ranging from 1–5, n_1 – number of respondents who strongly disagree, n_2 – number of respondents who disagree, n_3 – number of respondents who are undecided, n_4 – number of respondents who agree, n_5 – number of respondents who strongly agree, A – the highest weight, N – the total number of respondents.

RESULTS AND DISCUSSION

Socioeconomic characteristics of the study population

The descriptive statistics revealed that among sample respondents, 75.3% were from male-headed households (Table 1). The average family size of the households was 6, which was higher than the national average (5.4). About 64% of the respondents were alliterate and the rest were complete their primary education. The respondents were experienced in crop farming, with an average age of 27.4 (±11.32). Despite most respondents (65.6%) in the woreda depending on crop-led mixed farming, 30.8% were engaged in opportunistic crop farming. Irrespective of fertility, the average land holding per household was 1.6 (±0.87) hectares. Bread wheat, food barley, faba bean, teff and sorghum were the main crops produced in the woreda. The produce from their farms did not cover respondents' annual food demand; rather it was sufficient to feed the entire family for 8.4 (±1.73) months on average.

Experience in quinoa production: training and awareness

All respondents received training on how to apply and use the new quinoa crop. The training for 81.4%, 16.6% and 1.6% of them was delivered by DCA, Mekane

Table 1. Socioeconomic characteristics of sample households (n = 247)

Demographic and socioeconomic variables	Indicators	Estimates
Sex of the household head (%)	Male (Female)	75.3 (24.7)
Age of the household head (years)	Mean (Std)	47.7 (±11.81)
Family member of the household (numbers)	Mean (Std)	6.14 (±1.77)
Educational level of the household head (%)	Lit. (Illit.)	36 (64)
The level of education completed (grades)	Mean (Std)	5.78 (±2.43)
Farm experience of the household heads (years)	Mean (Std)	27.36 (±11.32)
The households' main means of living (%)	Crop production	30.8
	Mixed farming	65.6
	Crop and non-farm	3.6
Major crops produced by the households (%)	Wheat/food barley/*teff*/sorghum/faba bean	28.3/20.5/19.6/11.2/20.4
Total land operated by the household (ha)	Mean (Std)	1.56 (±0.87)
Did the yield from own land covers the household's annual food demand? (%)	Yes (No)	45.7 (54.3)
If no, for how many months it can cover?	Mean (Std)	8.4 (±1.73)
Based on the local criteria, how is the fertility status of your farmland? (%)	Fertile	11.3
	Moderate	64.3
	Infertile	24.4

Std – standard deviation, Lit – literate, Illit – illiterate.
Source: own elaboration.

Table 2. Training and awareness of respondents on quinoa crop (*n* = 247)

Response variables	Indicators	Percentage (%)
Where do you get the quinoa seed?	DCA (ME) (WoA)	89.9 (6.9) (3.2)
When did you start growing quinoa?	2017 (2018) (2019)	26.7 (45.7) (27.6)
Have you got training on quinoa?	Yes	100.0
If yes, who gave you the training?	ME (DCA) (WoA)	16.6 (81.4) (1.6)
Did the training include practical components?	Yes (No)	88.7 (10.9)
Do you believe the training provided was sufficient to apply?	Yes (No)	87.9 (11.7)
Do you think trainers have skills?	Yes (No)	(3.2)

Note: DCA – Dan church aid, ME – Mekane Eyesus, WoA – Woreda office of agriculture
Source: own elaboration.

Eyesus (ME), and the Woreda office of Agriculture (WoA) respectively. Most respondents (88.7%) confirmed that the training provided covered practical and/or technical components, but 11.7% of them agreed that it would not be possible for them to apply the training in practice (Table 2). 96.4% of the respondents thought that the trainers had no skill gaps that affected their training, but the others identified a lack of practical knowledge as the main gap for trainers. The investigation revealed that quinoa had been cultivated in the study area since 2017, but the highest percentage of farmers involved in quinoa production, i.e., 45.7%, was recorded in the production year of 2018.

Agronomic status and farmland management

About 74.9% of the respondents plowed their land at a sufficient level (≥3×), but the rest tilled their fields below the optimum level due to a lack of draft animals and farming tools. This result is in agreement with the findings of Maliro et al. (2017), who suggest that ‘three times tilling is an optimum level’ for improved cereal production. Among the respondents, 78.9% were planting at an appropriate time while the rest were planting early or very late (Fig. 1) due to a lack of awareness of the crop calendar and the inaccessibility of draft animals. Similarly, 97.2% of them had quinoa farmland with good and very good weed management status while the rest had poor management because of labor shortages. Planting and weeding on time contribute to adequate aeration and water movement in the soil, which promotes better crop growth (Qureshi and Daba, 2020). Due to soil fertility decline and nutrient degradation, the application of commercial fertilizers is recommended for better production. 5.2%, 89.5% and 5.3% of the respondents applied fertilizers for quinoa production early, on time and late, respectively. Earthling (raised soil bed) as an agronomic practice is recommended for quinoa production, hence 58.3% of farmers applied it on time. Most (78.5%) of the respondents harvested quinoa crop at

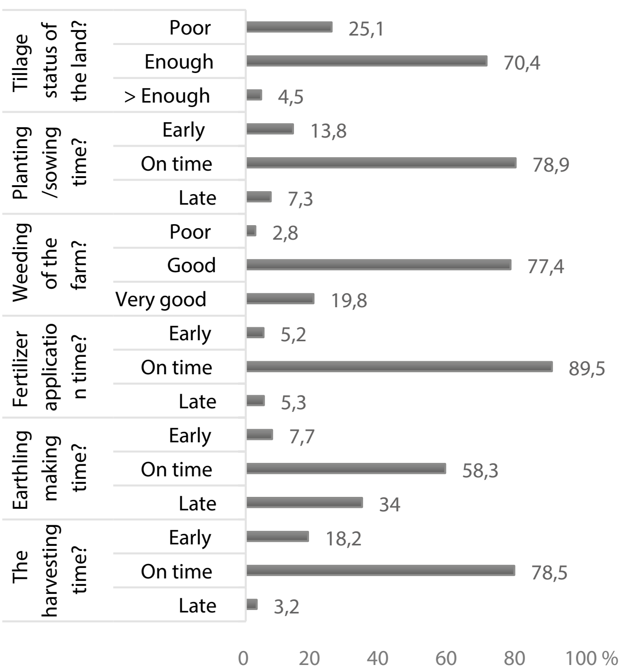

Fig. 1. Agronomic status and farmland management of the study households
Source: own elaboration.

a critical time, but the rest harvested early or late due to a lack of awareness and experience with the new crop.

Yield performance and profitability of quinoa crop

As depicted in Table 3 below, the mean grain and straw yields of quinoa were 1,067.8 and 559.8 kg ha^{-1}, respectively. Hence, except for teff (944.2 kg ha^{-1}), the average productivity of quinoa was below that of the competing crops. The observed yield variation among the crops was due to variations in agronomic management and the inputs applied by the farmers. This finding underscores that the production gap among respondents could be eliminated by adopting the recommended package components for improved quinoa production. For the cost-benefit analysis, production costs that are common across crops were not calculated, but other costs were calculated by averaging market prices over three years (2017–2019). This method was adopted to eliminate the problem of price cyclicality, because experience has shown that prices fluctuate every year (Mihiretu et al., 2019a). For ease of calculation, it was assumed that all production goes to market, though this is not the reality, as part of the grain is used for consumption and sowing. The highest total variable costs were recorded for quinoa, teff, wheat, food barley, faba bean and sorghum in descending order. In terms of profitability, however, quinoa had a higher gross margin per hectare than other competing crops. The cost-benefit ratio also shows that producing quinoa could generate a higher profit (ETB 1.7) than teff and wheat crops after covering the production costs (Table 3). The cost-benefit analysis therefore shows that producing quinoa is more profitable than producing teff, wheat and food barley.

Applicability of quinoa crop technology in the local context

Of the respondents, 27.9% believed that quinoa as a new technology was labor intensive, especially in the weeding and earthling (raised soil bed) stages, and 13.4%

Table 3. Profitability comparison of quinoa with major competing crops (*n* = 247)

Indicators	Quinoa	*Teff*	Wheat	Faba bean	Sorghum	Food barley
Land preparation costs (ETB ha^{-1})	3 195.0	5 406.5	5 377.2	3 434.0	3 106.3	4 870.0
Planting costs (ETB ha^{-1})	2 884.6	2 780.0	1 741.0	1 808.3	1 950.8	1 576.7
Seed and chemical costs (ETB ha^{-1})	352.4	867.6	2 212.0	3 663.6	518.5	2 395.0
Fertilizer costs (ETB ha^{-1})	1 326.0	1 532.0	1 530.7	–	1 334.5	1 363.9
Earthling/weeding/thinning costs (ETB ha^{-1})	7 719.3	4 174.8	3 010.3	1 934.4	3 007.4	2 787.1
Harvesting and threshing costs (ETB ha^{-1})	4 198.9	4 332.3	3 572.6	2 991.9	2 948.0	3 434.2
Total variable cost (ETB ha^{-1})	19 676.3	19 092.8	17 443.8	13 832.2	12 865.4	16 426.8
Average grain yield (Kg ha^{-1})	1 067.8	944.2	1 492.2	1 105.2	1 949.0	1 582.0
The average price of the grain (ETB Kg^{-1}).	30.8	26.9	16.1	23.3	12.5	15.3
Revenue from grain yield (ETB ha^{-1})	32 888.1	25 398.4	24 062.9	25 761.5	24 265.1	24 173.0
The average straw yield (Kg ha^{-1})	559.8	825.3	1 238.1	876.0	1 431.0	1 307.1
The average price of straw (ETB Kg^{-1})	0.9	3.5	2.4	1.4	0.8	2.4
Revenue from straw yield (ETB ha^{-1})	509.4	2 924.8	2 927.3	1 232.2	1 069.4	3 187.6
Total revenue (ETB ha^{-1})	33 397.5	28 323.3	26 990.2	26 993.7	25 334.5	27 360.5
Gross margin (TR-TVC)	13 721.2	9 230.3	9 546.5	13 161.6	12 469.1	10 933.7
Benefit-cost ratio (BCR)	1.7	1.5	1.6	2.0	2.0	1.7

ETB – Ethiopian Birr; TR – Total revenue; GM – Gross margin; TVC – Total variable cost; BCR – Benefit-cost ratio.
Source: own elaboration.

Table 4. Farmers' opinions on the applicability of quinoa production in the local context (n = 247)

Variables	Indicators	Percentage (%)
Do you think quinoa production is labor-intensive?	Yes (No)	27.9 (72.1)
If yes, have you faced labor shortage to apply?	Yes (No)	13.4 (14.5)
If yes, what are the possible reasons?	Smaller family size	9.4
	Female-headed	2.0
	Older household	2.0
Do you think producing quinoa is difficult?	Yes (No)	6.5 (93.5)
If yes, what are the possible reasons?	Market problem	3.6
	Shortage of labor	1.6
	Lack of knowledge	1.3
Do you think tinning quinoa is difficult?	Yes (No)	13.8 (86.2)
If yes, what are the possible reasons?	Lack of experience	4.9
	Shortage of labor	6.1
	Cultural taboo	2.8

Source: own elaboration.

of them faced labor shortages due to smaller family sizes, being female-headed and having older household members in descending order (Table 4). However, most farmers who participated in quinoa production used labor from their household, hired labor and a mixture of household and hired labor in major agronomic activities (starting from planting up to threshing). Similarly, 6.5% of the respondents said that producing quinoa was difficult because of market problems, a shortage of labor and a lack of knowledge in descending order. On the other hand, 13.8% of the respondents mentioned that tinning the quinoa plant is difficult because of a lack of experience, a shortage of labor and the existing cultural taboo in the study area. Nonetheless, most of the respondents (93.5%) agreed that producing quinoa as per the recommendation was very helpful for increasing yield and yield components.

The farmers' perception of quinoa crop technology

The farmers' qualitative perceptions of the properties of the quinoa crop, such as the germination and vegetative performance of the crop, insect and disease resistance, food quality, marketability, earliness and other criteria were assessed using a Likert rating scale (Table 5). To gain an understanding of the farmers' perceptions, the sum and average scores[2] of the Likert scale were calculated (Lutz and Bascuñán-Godoy, 2017). If the average score is greater than 3.51, we can say that farmers have a good or very good perception of the crop. If the average score is 2.51–3.50, farmers are indifferent towards the crop. If the average score is below 2.50, we can conclude that farmers do not have a good perception of it (Tim Willet cited in Mihiretu et al., 2019a). A reliability test was carried out to check for internal consistency among 11 perception questions on the Likert scale, and the coefficient ($\alpha = 0.73$) revealed that the variables were reliable and appeared to be worthy of retention. The results in Table 5 show that most of the respondents had a positive outlook and good perception of the new crop according to most preference parameters. However, a large number of farmers (51.8%) had no confidence in

[2] Sum score = $\sum_{i=1}^{5}$ Strongly disagree, disagree, neither agree nor disagree, agree, strongly agree;

$$\text{Average score} = \frac{\text{Sum score}}{\text{Sample size}}$$

Table 5. The farmers' perceptions of the new quinoa crop (*n* = 247)

Variables	Indicators	Percentage (%)
Do you think quinoa production is labor-intensive?	Yes (No)	27.9 (72.1)
If yes, have you faced labor shortage to apply?	Yes (No)	13.4 (14.5)
If yes, what are the possible reasons?	Smaller family size	9.4
	Female-headed	2.0
	Older household	2.0
Do you think producing quinoa is difficult?	Yes (No)	6.5 (93.5)
If yes, what are the possible reasons?	Market problem	3.6
	Shortage of labor	1.6
	Lack of knowledge	1.3
Do you think tinning quinoa is difficult?	Yes (No)	13.8 (86.2)
If yes, what are the possible reasons?	Lack of experience	4.9
	Shortage of labor	6.1
	Cultural taboo	2.8

The values in the table are in percentage points (%).
SD – strongly disagree, D – disagree, NAD – neither agree nor disagree, A – agree, SA – strongly agree.
Source: own elaboration.

the insect pest resistance capacity of the crop, as it was highly susceptible to different insect pests, especially in the ripening stage. Most farmers (87%) had a neutral view on marketability since the crop is new for the area and there is no market demand. During the demonstration stage, however, the crop sold at a premium price for the DCA project as it was required for up-scaling. The average score of 3.8 implies that the farmers accepted the new quinoa crop with full confidence (Table 5). The farmers agreed or strongly agreed that the crop exhibited good germination and vegetative performance. One of the farmers said that "though they had poor stand count because of pests after germination, got longer spike length and better tillering at vegetative stage."

Sensory evaluation of quinoa food types

A sensory test was conducted to evaluate the taste of food products prepared from quinoa crop as consumed by panelists (Lutz and Bascuñán-Godoy, 2017). With due consideration of the social acceptability of different foods, eight staple foods and local beverages were prepared using quinoa and tasted. The farmers selected *injera*, bread, *kitta* and porridge as their 1st, 2nd, 3rd and 4th food choices, respectively (Table 6). As well as these preferences, the farmers offered their positive

Table 6. Farmers' preferences for different food items prepared from quinoa crop (*n* = 247)

Major constraints	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	Index	Ranks
Injera	90	35	19	14	–	–	–	–	0.305	1
Bread	20	42	25	17	–	–	–	–	0.162	2
Kitta	24	38	44	12	–	–	–	–	0.121	3
Porridge	58	41	25	10	3	–	–	–	0.023	4
Tella	4	3	3	1	1	–	–	–	0.021	5
Muke	3	–	–	–	–	–	–	–	0.006	6
Shiro	1	–	2	–	–	–	–	–	0.005	7
Kinche	1	–	–	–	–	–	–	–	0.002	8

'Injera, Kitta and Shiro, Muke and Kinche' are the common staple foods while *'Tella'* is the local alcoholic beverage in Ethiopia; R – ranks.
Source: own elaboration.

and negative observations on the foods prepared from quinoa. The good water absorption of the flour, the good gloss and appearance of *injera*, the good fermenting (yeast) and inflating capacity of the bread, and the softness and palatability of the prepared food were the positive observations. As negative feedback, the farmers noted that if the mixing ratio of quinoa grain with other crops was at equal or higher rates, the taste and flavor of the food became bitter and sour. Preparing and consuming quinoa on its own (without mixing it with other crops) was not pleasant because the bitter and sour nature of the crop reduces its palatability.

Farmers' demand and continuity of quinoa production

As depicted in Table 7 below, among the respondents, 29.1%, 50.6% and 20.3% had produced quinoa for one, two and three production years respectively. On average, 67.6% of the respondents were highly interested in producing quinoa in the coming years, but the remaining respondents refused to produce it due to labor shortages, market problems, seed shortages and knowledge gaps on utilization in descending order. The seed shortages arose because the farmers were producing the crop in small plots and sold the whole product to the project (DCA) at a better price. As far as market linkage is concerned, the farmers have no confidence in the potential buyers, because even the DCA is reducing its purchases compared to preceding years. On the other hand, 87.9% of the total respondents proudly recommended that other neighboring farmers should produce quinoa, explaining the advantages and disadvantages of the new crop. Among the farmers to whom the crop was recommended, about 74.9% were positive and willing to adopt it in the future while those who refused did so because of the labor-intensive nature of the crop, although they were fascinated by its performance.

Diffusion of quinoa technology: seed exchange system

Farmer-to-farmer seed exchange systems would consolidate sustainable technology promotion and diffusion in the conventional research-extension system (Ogwal-Kasimiro et al., 2012). In this study, the farmers' solid seed exchange system played a key role in the wider dissemination of the new crop. As a result, among participant farmers, 44.9% shared the crop with 207 interested fellow farmers living within or outside of their villages using existing exchange arrangements in the local community (Fig. 2). The farmers exchanged 156.8 kg of quinoa seed with 186 farmers from within their villages and 21 fellow farmers from outside their villages.

Table 7. Farmers' demand for and statements on quinoa crop (n = 247)

Variables	Indicators	Percentage (%)
For how many years did you grow quinoa crop?	1 (2) (3)	29.1 (50.6) (20.3)
Did you continue growing quinoa since started?	Yes (No)	67.6 (32.4)
If not, why do you stop growing?	Seed shortage	5.3
	Knowledge gap	3.2
	Labor shortage	17.4
	Market problem	6.5
Would you suggest other farmers to grow quinoa?	Yes (No)	87.9 (12.1)
Have you told about the merit/demerit of quinoa?	Yes (No)	76.9 (23.1)
How did you tell to the farmers?	Inviting to visit	54.6
	Storytelling	22.3
What was their response?	$+^{ve}$ ($-^{ve}$)	61.9 (15.0)

Source: own elaboration.

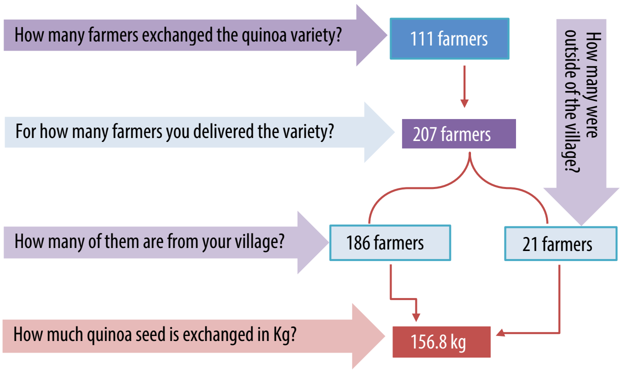

Fig. 2. Seed exchange and diffusion network of the new quinoa crop
Source: own elaboration.

Constraints associated with quinoa production

Among other factors, the ease of application of any new technology plays a significant role in increased adoption rates. Though most farmers agreed that quinoa is very helpful for increasing crop diversity, they identified ten major constraints linked with its production (Table 8). Susceptibility to insect pests, marketing problems, poor palatability of the quinoa straw and the fertile soil required for production were ranked as the first, second, third, fourth and fifth most significant constraints respectively.

CONCLUSION AND RECOMMENDATIONS

The survey results confirmed that the quinoa crop provided a higher grain yield than teff, but it was lower than that of other competing crops. The straw yield of quinoa was far lower than that of any other crop, as well as being characterized by poor palatability for livestock. The higher benefit-cost ratio of quinoa revealed that it was more profitable than teff and wheat. The farmers acquired considerable knowledge about the new crop and its attributes. Except for poor insect pest resistance and marketability, most of the farmers had a positive perception of the new crop according to most preference parameters. Different food types were prepared from quinoa and tasted by farmers, and based on the overall comparison criteria, the farmers selected *injera*, bread, *kitta* and porridge as their 1st, 2nd, 3rd and 4th choices, respectively. The results affirmed that the susceptibility of the crop to insect pests, marketing problems, the poor palatability of quinoa straw and the need for fertile soil are the top four constraints on quinoa production. Nearly half of the studied farmers shared the seed with fellow farmers within and outside their villages, so a reasonable

Table 8. Major constraints associated with quinoa production (n = 247)

Constraints	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	Rank index	Ranks
Palatability problem of quinoa crop straw	33	14	12	6	–	–	–	–	–	–	0.134	3
Marketing problem of the new crop	47	17	12	3		–	–	–	–	–	0.163	2
The crop requires very fertile land	23	24	17	1	1	–	–	–	–	–	0.131	4
Susceptible to wind	6	12	3	–	–	–	–	–	–	–	0.043	8
Low resistance to snow (icefall)	24	18	6	–	–	–	–	–	–	–	0.102	5
Uneven maturity time of the crop	6	3	0	–	–	–	–	–	–	–	0.019	10
Susceptible to insect pests	34	42	9	1	–	–	–	–	–	–	0.179	1
Lodging problem after weeding	11	18	9	1	–	1	–	–	–	–	0.078	7
Difficult to separate the crop and weeds	16	16	7	4	–	–	–	–	–	–	0.081	6
Very low straw yield	5	2	8	11	–	–	–	–	–	–	0.029	9

Note: 'R' represents the 'rank' of each factor according to its importance.
Source: own elaboration

demand for quinoa was established in the area. The authors hence recommend that quinoa production should be scaled out to similar agro-ecologies by providing practical training on its cultivation and suitable food recipes. The respective agriculture offices and concerned bodies should create market linkage for the crop, on top of developing appropriate technologies for insect pest control. The digestibility and better protein concentration of quinoa straw call for researchers to improve its palatability for livestock. Finally, seed-producing and marketing cooperatives should be established and strengthened to make quinoa production sustainable.

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REFERENCES

Angeli, V., Silva, P.M., Massuela, D.C., Khan, M.W., Hamar, A., Khajehei, F., Graeff-Hönninger, S., Piatti, C. (2020). Quinoa (*Chenopodium quinoa* Willd.): An overview of the potentials of the "golden grain" and socio-economic and environmental aspects of its cultivation and marketization. Foods, 9(2), 216. https://doi.org/10.3390/foods9020216

Kindye, A., Ademe, M. (2020). The cost-benefit and comparative advantage of quinoa variety with major competing crops grown in Wag-himera Zone Eastern Amhara Ethiopia. Unpublished techinical report. Retrieved from: https://www.researchgate.net/publication/350896909

Lutz, M., Bascuñán-Godoy, L. (2017). The revival of quinoa: A crop for health. In: V. Waisundara, M. Shiomi (Eds.), Superfood and functional food – An overview and its utilization to processed foods (p. 37–54). Intechopen.

Maliro, M.F.A., Abang, M.M., Mukankusi, C., Lung'aho, M., Fenta, B., Wanderi, S., Kapa, R., Okiro, O.A., Koma, E., Mwaba, C., Isse, M.M., Bazile, D. (2021). Prospects for quinoa adaptation and utilization in Eastern and Southern Africa: Technological, institutional and policy considerations. Addis Ababa, FAO. https://doi.org/10.4060/cb2351en

Maliro, M.F.A., Guwela, V.F., Nyaika, J., Murphy, K.M. (2017). Preliminary studies of the performance of quinoa (*Chenopodium quinoa* Willd.) genotypes under irrigated and rainfed conditions of central Malawi. Front Plant Sci, 8, 227. https://doi.org/10.3389/fpls.2017.00227

Mihiretu, A., Asresu, M., Wubet, A. (2019a). Participatory assessment of lentil (*Lens culinaris Medik.*) production practices in marginal dry lands of Wag-lasta, Ethiopia. Archiv. Agric. Environ. Sci., 4(3), 288–294. https://doi.org/10.26832/24566632.2019.040305

Mihiretu, A., Assefa, N., Wubets, A. (2019b). Participatory evaluation of sorghum technologies in the marginal dryland zones of Wag-lasta, Ethiopia. Cogent Food Agric., 5, 1671114. https://doi.org/10.1080/23311932.2019.1671114

Ogwal-Kasimiro, O.J., Wakulira, M., Kiyini, R., Mwebaze, M., Yiga, D. (2012). Dissemination of agricultural technologies: A new approach for Uganda. Paper presented at Third RUFORUM Biennial Meeting 24–28 September, Entebbe, Uganda.

Park, J.H., Lee, Y.J., Kim, Y.H., Yoon, K.S. (2017). Antioxidant and antimicrobial activities of quinoa (*Chenopodium quinoa* Willd.) seeds cultivated in Korea. Prev. Nutr. Food Sci., 22(3), 195–202. https://doi.org/10.3746/pnf.2017.22.3.195

Qureshi, A., Daba, A. (2020). Differential analysis of five quinoa (*Chenopodium quinoa* W.) genotypes under different salt stresses in a controlled environment. Am.-Eurasian J. Sust. Agr., 14, 14–21. 10.22587/aejsa.2020.14.1.2

Rambal, S., Ratte, J.P., Mouillot, F., Winkel, T. (2015). Trends in quinoa yield over the Southern Bolivian Altiplano: Lessons from climate and land-use projections. In: K. Murphy, J. Matanguihan, Quinoa: Improvement and Sustainable Production (p. 47–62). https://doi.org/10.1002/9781118628041.ch4

Ruiz, K.B., Biondi, S., Martínez, E.A., Orsini, F., Antognoni, F., Jacobsen, S.E. (2016). Quinoa – a model crop for understanding salt-tolerance mechanisms in halophytes. Plant Biosyst., 150, 357–371. https://doi.org/10.1080/11263504.2015.1027317

Vasconcelos, E.S., Echer, M.M., Kliemann, M.A., Lang, M.J. (2019). Selection and recommend of quinoa (*Chenopodium quinoa*) genotypes based on the yield genotypic adaptability and stability. Rev. Ceres., 66(2), 117–123. http://dx.doi.org/10.1590/0034-737x201966020006

Yamane, T. (1967). Statistics: An introductory Analysis, 2nd edn., New York: Harper and Row.