A Study of Sustainability in Local Agriculture and the Seed Supply System: A Case Study of the Indigenous Crop Tef in Ethiopia

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地域農業の持続性と種子供給システムに関する一考察
―エチオピアのテフ栽培を事例に―

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本研究では、エチオピアにおけるテフ栽培を事例として取り上げ、農業センターによる種子供給の効果や農家の種子調達の持続性について検討すると共に、国や地域における品種の多様性の維持に関して考察した。政府機関へのインタビュー、現地で得られた資料の分析、農村への追加的ヒアリングを実施した。テフの種子供給に関して、政府機関が開発したQUNCHOという品種が農村にかなり浸透している状況にあった。公的機関による新品種の導入は農家を収量増加に寄与している面もあるが、これらの品種は肥料提供とセットで行われる場合も多く、地域農業の持続性の観点からは課題があるといえる。また、農家は自家採種、近隣農家との種苗交換、市場での購入、改良品種の導入といった様々な方法でテフの種子を確保していた。これらの農家の多様な行動と、政府機関による継続的な新品種の導入とがあわせた形で、テフの品種多様性は維持されていると考えられる。

Key Words: biodiversity, ensete, food security, formal seed system, improved variety, indigenous variety

1. Introduction

Farmers select the varieties of crops that they grow, which contributes to the sustainability of local agriculture and affects the seed supply system. In many countries, crop seeds are developed and supplied to farmers by government organizations because they are considered an indispensable input for food production and food security. Farmers use government-supplied seeds or prepare the next year’s seeds by obtaining improved varieties released by the government. Hence, farmers have an excellent ability to preserve varietal characteristics by obtaining homegrown seeds. On the other hand, some researchers have suggested that total grain production could decrease because of quality degradation over time in the varieties cultivated or the seeds used (Zeven, 2002). In this case, farmers might purchase seeds every four to five years to replace their saved seed stocks with seeds that have a higher level of purity. Farmers also exchange seeds with other farmers according to their preferences. Scientific research is needed to examine whether degradation in the quality of varieties occurs. The release of seeds by the formal sector seems to complement farmers’ ability to preserve varietal characteristics.

Researchers have pointed out that the “formal” system of governments and private seed companies plays a critical role and that the “local/informal”
system of farmer-to-farmer exchanges or saved seed complements the formal system of national seed management (Almekinders et al., 1994). Recently, the United Nations re-evaluated the importance of small-scale/family farming. In this context, some researchers have reported that the local/informal seed system plays an important role in the sustainability of local agriculture (Andersen, 2008). Moreover, some researchers find dynamic events in seed supply or farmers’ seed management that are not explained by the dualistic concept of a formal and informal seed system. For example, Tsuruta and Fujiwara (2014, 2015) revealed the characteristics of in-situ conservation of traditional varieties in Nara prefecture in Japan. They found that a village enterprise, Local Japan Agricultural Cooperatives (JA), and competition among villagers, play important roles.

The challenge to be surmounted is the construction of a system of “indigenous agronomy” related to the seed system in many countries that goes beyond the concept of duality proposed by modern, and especially, western science (modern science). The concept of indigenous agronomy was proposed by Shigeta (1994). He emphasized the limitation of analyzing the situation of developing countries by exclusively using the concepts of modern science.

This study focuses on the seed system of the indigenous crop “tef” in Ethiopia. In the past, Ethiopia experienced crop failure because of drought. Subsequently, foreign countries brought in relief supplies, such as corn (maize). However, many small farmers continue to cultivate tef, and the “injera” food made by tef is still one of the soul foods of Ethiopian people. The purpose of this study is to examine the factors behind the phenomenon of continued large-scale tef cultivation. The distribution of improved seeds through the formal system has not been sufficiently surveyed. By interviewing the researchers of a government institution and conducting a supplemental field survey of farmers in rural villages, we verify the impact of formal seed supply on the sustainability of farmers’ seed preparation. We also examine the role of different stakeholders in preserving the diversity of crop varieties at the local and national levels.

In other words, the major objectives of our research are: (1) to identify the characteristics of the formal seed system, (2) to examine the achievements and problems in the distribution of improved seeds by government; and (3) to construct a hypothetical structure of the “informal” seed system for crops.

2. Targeted areas and research methods
(1) Country overview of Ethiopia

The Federal Democratic Republic of Ethiopia is located in the eastern part of Africa. It shares borders with Kenya and Somalia, among other countries. In Africa, it is the only country that has been independent for the last three thousand years. The population of Ethiopia, which was 55 million in 1994, has increased gradually and crossed 100 million in 2016 (see Fig. 1; FAO (Food and Agriculture Organization of the United Nations), 2017). Agriculture is the predominant sector of the economy. Crops, coffee, sugar cane, and potato are the major produce.

In Ethiopia, there are more than eighty ethnic groups (Oromo, Amhara, etc.). The official languages are Amharic and English. A typical local dish is “wot,” a hot spicy stew of meat or vegetables, seasoned with a blend of berbere (red chili). Injera, the traditional spongy pancake made from fermented tef flour, is their staple. Ethiopia is also the birth place of coffee. Tef and ensete (false banana) were also first domesticated in

![Fig. 1 Population growth in Ethiopia](image)

Source: FAO (2017)
this country.

Table 1 shows the trend of crop (and coffee) production in Ethiopia (FAO, 2017). The production of tef was not included in the database used for obtaining these statistics. Maize was the largest grown crop, followed by sorghum.

(2) Surveyed sites and research methods

We interviewed the researchers of an Ethiopian government research station (Debre Zeit Agricultural Research Center or DZARC) and analyzed the information obtained from the researchers. We also conducted a supplemental survey of two villages (Woliso and Ginchi) on farmers’ tef seed preparation and the characteristics of the government-supplied varieties. We visited the institution and villages between December 25, 2016 and January 7, 2017.

3. Characteristics of tef production and the seed system in Ethiopia

In this section, we summarize the characteristics of tef production and the associated seed system in Ethiopia by reviewing the obtained survey data and information, relying mainly on Assefa et al. (2013).

Tef (Eragrostis tef (Zucc.) Trotter) is a staple crop of Ethiopia. The crop was first domesticated in Ethiopia between 4000 to 1000 BC and the plant is an allotetraploid (Assefa et al., 2013: pp. 33–51). Tef is produced and consumed mainly in Ethiopia.

Table 2 shows the changes in the total cultivated area and production of tef in Ethiopia (2003–2010).

| Year | Cultivated Area (million ha) | Total production (million tons) |
|------|------------------------------|--------------------------------|
| 2003 | 1.99                         | 1.68                           |
| 2004 | 2.13                         | 2.03                           |
| 2005 | 2.25                         | 2.18                           |
| 2006 | 2.40                         | 2.44                           |
| 2007 | 2.56                         | 2.99                           |
| 2008 | 2.48                         | 3.03                           |
| 2009 | 2.59                         | 3.18                           |
| 2010 | 2.76                         | 3.48                           |

Source: Assefa et al. (2013: pp. 305–322)

increased gradually from 1.99 million ha in 2003 to 2.76 million ha in 2010. This means that there was an increase of 40% in the cultivated area in seven years. Further, the total production of tef increased from 1.68 million tons (2003) to 3.48 million tons (2010), about double gain in seven years.

It is the largest grown crop, covering about 2.6 million ha annually, which translates into approximately 28% (largest) of the total acreage for cereals (see Table 3) (Assefa et al., 2013: pp. 33–51). Annual tef production is 3.18 million tons, which constitutes approximately 20% of the gross yearly grain production of cereals. It is a crop of great importance for more than 60% of the Ethiopian population, which is over 80 million. The total production of other crops in Ethiopia during 2009/10 was as follows: maize (corn): 3.90 million tons; wheat:
3.08 million tons; sorghum: 2.97 million tons; and barley: 1.75 million tons. The average grain yield for cereals in 2009/10 was as follows: tef: 1.23 ton/ha; maize: 2.20 ton/ha; rice: 2.16 ton/ha; wheat: 1.83 ton/ha; barley: 1.55 ton/ha; and sorghum: 1.42 ton/ha. Thus, the average grain yield for tef was low, compared to maize or wheat. Therefore, the government and researchers have been attempting to improve productivity of this crop.

Tef has the following useful traits: a) tolerance to extreme environmental conditions; b) seeds that are resistant to pests during storage; c) the seeds are gluten-free, and hence, considered a healthy food. Although tef has these beneficial traits, scientific improvement of this crop has lagged that achieved in other major cereals, such as wheat and rice. The productivity of tef is low. The major factors limiting tef yields are the lack of cultivars tolerant to lodging, drought, and pests. Various attempts have been made to overcome these growth constraints using both conventional and modern breeding techniques. Using the former methods, approximately 32 improved cultivars have been released to the farming communities by the national agricultural research system.

Debre Zeit Agricultural Research Center (DZARC) is the oldest and biggest national center for tef research. It is located near the major tef growing areas. The worldwide collection of tef germplasm accessions amount to 5,966 samples. Most of them (5,169 accessions) are preserved at the Institute of Biodiversity Conservation (IBC) in Ethiopia (Assefa et al., 2013: pp. 15–20). Despite the large collection, the governmental research station continues to search and collect domestic genetic resources (Ethiopian Institute of Agricultural Research Debre Zeit Agricultural Research Center, 2015). The governmental sector has made an effort toward ex situ conservation of agricultural biodiversity by collecting crop genetic resources. A total of 18 varieties of tef have been released by DZARC between 1970 and 2009 (see Table 4) (Assefa et al., 2013: pp. 33–51).

Fourteen improved varieties have been released by other Agricultural Research Centers from 1998 to 2004. However, most of the varieties have not been adopted by farmers to increase crop productivity (Assefa et al., 2013: pp. 275–289). Popular improved varieties such as QUNCHO (DZ-Cr-387) and TSEDEY (DZ-Cr-37) were produced by crossbreeding. The formal sector sometimes releases these improved varieties by bundling them with commercial fertilizer. These varieties have enabled farmers to achieve yields of up to 3 tons per ha. These improved seeds are given freely when international development projects were in operation. Otherwise, the seeds and fertilizer were supplied for a fee.

QUNCHO was released in 2006 following identification of farmer-preferred traits. This variety has been developed through participatory plant breeding (Assefa et al., 2013: pp. 325–332). Farming communities in the various parts of Ethiopia have accepted it and there is a demand for this variety.

The seed system in Ethiopia is composed of both the formal and informal sectors. The formal sector

| CROPS | Cultivated Area (million ha) | Rate of Cultivated area (%) | Total production (million tons) | Gross yearly grain production of cereals | Average grain yield for cereals (ton/ha) |
|-------|-----------------------------|-----------------------------|--------------------------------|----------------------------------------|---------------------------------------|
| Tef   | 2.59                        | 28.1%                       | 3.18                           | 20%                                    | 1.23                                  |
| Maize | 1.77                        | 19.2%                       | 3.90                           | 25%                                    | 2.20                                  |
| Wheat | 1.68                        | 18.2%                       | 3.08                           | 20%                                    | 1.83                                  |
| Sorghum | 1.62                      | 17.5%                       | 2.97                           | 19%                                    | 1.42                                  |
| Barley | 1.13                       | 12.3%                       | 1.75                           | 11%                                    | 1.55                                  |
| Rice  | 0.05                        | 0.5%                        | 0.10                           | 1%                                     | 2.16                                  |

Source: Assefa et al. (2013: pp. 33–51).
includes national and regional-level public seed enterprises, as well as research institutions and private seed companies. Public tef seed enterprises were recently established. On the other hand, the informal seed system is the dominant sector in Ethiopia. Approximately 80–90% of farmers use their own saved seeds or seeds obtained (exchanged or purchased) locally (Assefa et al., 2013: pp. 275–289). Hence, the adoption of improved tef varieties by farmers is limited to a few of them. Most farmers still rely primarily on saved seed or farmer-to-farmer exchanges (Assefa et al., 2013: pp. 291–304). For the supply of improved seeds of major cereals especially maize, international bio-majors play a critical role.

In recent years, stimulated mainly by rapid agricultural growth and development in Ethiopia, the demand for improved seeds has increased sharply. Therefore, the government has encouraged the establishment of private and public seed companies/enterprises at the regional level.

4. Interviews with the government research station researchers and supplemental village surveys

(1) Tef variety improvements by government research station

In our interview with Dr. Solomon Chanyalew (Director) of DZARC, we asked him to explain tef variety improvements, the history of newly developed and released KORA, and the strategy for promoting and distributing KORA to farmers. Dr. Solomon has been a project leader in improving the KORA variety. KORA was developed by crossing QUNCHO and KEI MURII varieties of tef. QUNCHO had already been released to farmers earlier. KEI MURII is a farmers’ variety and is indigenous. The main purpose of breeding KORA was to improve lodging resistance. This variety was developed by introducing the characteristic of strong stalk of KEI MURII to QUNCHO in 2014.

Typically, tef has the lodging characteristic. Despite QUNCHO being a popular variety among farmers, its lodging characteristic was a challenge. After the cultivation test on DZARC station, cultivation trials were held in many fields at the research station, as well as those of farmers, throughout the country.

| Variety name | Common name | Year of release | Releasing center |
|---------------|-------------|----------------|-----------------|
| DZ-01-99      | Asgori      | 1970           | Debre Zeit      |
| DZ-01-354     | Enatit      | 1970           | Debre Zeit      |
| Dz-01-196     | Magna       | 1978           | Debre Zeit      |
| DZ-01-787     | Welkenkomi  | 1978           | Debre Zeit      |
| DZ-Cr-44      | Menagesha   | 1982           | Debre Zeit      |
| DZ-Cr-82      | Melko       | 1982           | Debre Zeit      |
| **DZ-Cr-37**  | Tsedey      | **1983**       | **Debre Zeit**  |
| DZ-Cr-255     | Gibe        | 1993           | Debre Zeit      |
| DZ-01-1281    | Ziquala     | 1995           | Debre Zeit      |
| DZ-01-974     | Dukem       | 1995           | Debre Zeit      |
| DZ-01-1281    | Gerado      | 2002           | Debre Zeit      |
| DZ-01-1285    | Koye        | 2002           | Debre Zeit      |
| DZ-01-1681    | Key Tena    | 2002           | Debre Zeit      |
| DZ-01-899     | Gimbichu    | 2005           | Debre Zeit      |
| DZ-01-2675    | Dega Teg    | 2005           | Debre Zeit      |
| **DZ-Cr-387** | Quncho      | **2006**       | **Debre Zeit**  |
| RIL355        |             |                |                 |
| Ho-Cr-136     | Amarach     | 2006           | Debre Zeit      |
| DZ-Cr-285     | Simada      | 2006           | Debre Zeit      |
| RIL355        |             |                |                 |
| DZ-01-2053    | Holetta Key | 1998/99        | Holetta         |
| DZ-01-1278    | Ambo Toko   | 1999/00        | Holetta         |
| DZ-Cr-387     | Gemechis    | 2007           | Melkassa        |
| RIL127        |             |                |                 |
| DZ-01-2054    | Gola        | 2003           | Sirinka         |
| DZ-01-146     | Genete      | 2005           | Sirinka         |
| DZ-01-1821    | Zobel       | 2005           | Sirinka         |
| Acc.205953    | Mechare     | 2007           | Sirinka         |
| RIL273        | Laketch     | 2009           | Sirinka         |
| DZ-01-1868    | Yilmana     | 2005           | Adet            |
| DZ-01-2423    | Dima        | 2005           | Adet            |
| DZ-01-3186    | Etsub       | 2008           | Adet            |
| DZ-01-1880    | Guduru      | 2006           | Bako            |
| 23-Taf-Adi-72 | Kena        | 2008           | Bako            |
| PGRC/E        | Ajorë       | 2004           | Areka           |

Source: Assefa et al. (2013: pp. 33–51).
Based on the trial data, the government tried to promote KORA to farming communities nationwide. The basic data for the distribution of KORA seeds are shown in Table 5. Compared to the total cultivated area of tef (2.59 million ha in 2009/10), the acreage of KORA seeds was quite limited. Additionally, DZARC is now developing a new variety, Dagen, which exhibited improved lodging resistance.

**Table 5. Distribution of KORA seeds by DZARC**

| Year          | Total Field | Farmers | (Female) |
|---------------|-------------|---------|----------|
| 2014 to 2015  | 50 ha       | 200     | (2)      |
| 2015 to 2016  | 140 ha      | 560     | (60)     |
| 2016 to 2017¹ | 2,320 ha    | 9,000   | (280)    |

Source: Interview by authors.
1) On going data.

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**Tef seed selection by farmers**

We also conducted a supplemental survey in two villages (Woliso and Ginchi) on farmers’ tef seed preparation and the characteristics of the varieties that the government institutions supplied. In Woliso village, the staple food is ensete, and people also grow and eat tef. In Ginchi village, on the other hand, tef is the main food crop.

We visited Woliso village and observed farmers heaping tef plants after the harvest near their houses. In the field, tef plants are harvested and carried to the farmer’s house on donkeys. Then, the tef plants are heaped in the farmyard, and the stack is typically higher than an average adult’s height (Fig. 2). The farmer we visited made five stacks of tef plants, which are equal to the annual supply of food for his family.

We also interviewed three farmers in Ginchi village. Regarding the varieties of tef cultivation, a male farmer grew Quncho, and he saved Quncho seed. He explained that the growth of this variety had been disappointing that year (2016/17) because of the climate conditions and that he had not cultivated KORA. The farmer had continued to cultivate Quncho for seven years. However, he mentioned that the productivity of Quncho had gradually decreased over the years. This result seems to support the opinion of researchers and government officers that it is optimal for farmers to purchase improved seeds from the formal seed system.

A female farmer grew Quncho to obtain the seed for her own use. She sowed 5 kg of tef seed on a 0.25 ha field. She also grew the variety Gorolisa on a 0.5 ha field. In most cases, the purpose of growing and harvesting tef is for food (and not for seed). After eating the stored tef throughout the year, if she still had stored tef crop, she would sow it as seed.

A question arose concerning the crop/seed operation of the second farmer: “If there is no stock of tef crop at seeding time, how does the farmer (female) prepare seed?” The third farmer we interviewed answered this question. In the previous year, she had obtained seed from another farmer when she lacked seed at seeding time.

**5. Results and discussion**

For tef seed supply, government research stations conduct breeding programs for high productivity, early maturity, and lodging resistance. These government stations develop new varieties every few years and promote and distribute those improved varieties to the farming community. Many farmers grow the tef variety Quncho, which the government research station developed and promoted many years ago. At the same time, the government promotes the newly developed KORA variety. Moreover, the government sector developed new varieties with improved lodging
resistance.

Some farmers are changing from QUNCHO to KORA, based on their preference criteria. However, in some villages, such as Woliso, farmers are unfamiliar with KORA (see Table 6). These results indicate that the promotion of improved varieties by government was not sufficient for the nationwide distribution of seeds. In Woliso, tef is not the only staple crop; hence, it was implied that farmers do not attach great weight on choosing the varieties they grow. On the other hand, people in Ginchi eat tef as their staple food, and thus, the farmers in this region recognize various varieties of this crop. The results implied that the degree of dependence on tef affects the difference observed in Woliso and Ginchi about farmers’ recognition of varieties.

Farmers change or renew the seeds/varieties that they grow because of the degradation in seed quality of their own saved seed that occurs every few years. However, we could not identify the reason for the degradation, that is, whether it occurred because of the quality of the seed-saving technique or the soil and climatic conditions. In both cases, farmers obtained tef seeds by purchasing/exchanging seeds from farmers in the local communities, purchasing tef crop for food in the market, and by getting seeds of the improved varieties from the formal sector.

The results show that newly developed varieties (the formal seed system) contributed to an increase in productivity. However, the formal sector sometimes releases these improved varieties by bundling them with commercial fertilizer. Hence, these formal seed supply systems face a challenge with respect to the sustainability of the local farming system. Because the productivity of tef is low and not stable, farmers would not choose the set of improved seeds and commercial fertilizer which raises the initial costs incurred.

The results implied that biodiversity of tef crop varieties has been conserved by dynamic interaction among governmental (formal) seed supply and seed management by various farmers. In other words, we showed the functional connection between formal and informal seed supply system, which are not eliminating each other. More specifically, securing cereal crop is the most important goal for the country to enhance food security. It was revealed that the farmers’ seed system played very critical role in the cultivation of tef crop, which is a staple crop in Ethiopia. We consider that these results contribute to the worldwide research on seed management.

Newly developed varieties may contribute to expanding diversity and sustainability of local agriculture. However, sustainable seed preparation mechanisms for farmers might face future challenges.

### Acknowledgments
We would like to thank Toshikazu Tanaka (Tohoku University), Kazuhiro Nemoto (Sinshu University), and Dawit Alemu (Embassy of Netherlands in Ethiopia) for their cooperation during our field survey and their valuable suggestions. This study has been partly supported by JSPS KAKENHI Grant Numbers 26304033 and 16K18767.

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