Chapter 1. Ethnobotany and the Research Methods

Grain crops in the World

The seeds of Gramineae grain crops are mostly non-toxic with a few exceptions, nutrient-rich and live long. Their many wild grains had been used to eat until today, for example, *Dactyloctenium aegypticum* (annual) grown in the savanna area, Africa, wild rice, *Oryza rufipogon* (perennial) in east/south India, wild rice, *Zizania aquatica* (annual) in Great Lakes, north America and so on. The domesticated grain crops are shown in Table 1. You are astonished by various species, but several species have disappeared, and the other hand same species have been under domesticating process. I will a new model on the domestication process and disperse routes in chapter 5, after I have discussed the forerunners' hypotheses (de Candolle 1886, Vavilov 1926, Nakao 1967, Sakamoto 1988, Graeber and Wengrow 2021).

The grain crops domesticated in Africa are mostly annual C_4 plants. Triticeae domesticated in South-west Asia are annual C_3 plants. Also, the grain crops domesticated from Central Asia, India to East Asia are mostly annual C_4 plants. However, same species including rice are perennial plants and are grown as ecological annuals. These are changed from perennial to ecological annual by artificial selection during domestication process. The growth habit of annual was very important characteristics under the domestication process.

Millet is the collective term to the grain crops without major grains such as bread wheat, rice and maize. The total yield of grain crops was 3.9 billion tones including maize (37.7%), rice (25.3%) and bread wheat (23.3%) by the data of FAOSTAT 2022. The yield of millets was 0.5 billion (13.7%).

The remarkable characteristics of millet are numerous small seeds (caryopsis) attached a big panicle, mainly summer annuals which had been domesticated in savanna area conditioned under the tropical/sub-tropical zones, or in monsoon area under the temperate zone (Sakamoto 1988). These plants had been adapted under the climate change involving crustal deformation in the Quaternary. They are maintaining the local adaptability by higher genetical variability and plasticity through crossing with their relative weeds. Because most millets are C_4 plants which have higher photosynthetic ability, their yield are so much under the climatic condition in the semi-arid and mountainous condition.

The biomass of all plant in Millets have high. Namely, human being eats the seed grains, while animals eat their stems and leaves. Millets are very useful crop for small farmers conducting animal husbandry. It is true that millets are main food everywhere under the severe condition in Afro—Eurasia. Moreover, the demand of millets is promoting today, because they are healthy and functional foods for many urban citizens.

The concept of millet is confused commercially in Japan. I use the name "millet," as a narrow sense as shown in Table 2. I do not use a wide definition as commercial words in this book.

Table 1. Domesticated grains in the world.

Scientific name	English name	Indiann name	Chromosome number	Grawth habit	Photosynthesis	Ancester	Geographical origin
Africa							
Sorghum bicolor Moench	sorghum	jowar	2n=20 (2x)	annual	C4	*S. bicolor* var. *verticillifolrum*	Africa
Pennisetum americanum (L) Leeke	pearl millet	bajira	2n=14 (2x)	annual	C4	*P. violaceum*	Africa
Eleusinne coracana Gaertn.	finger millet	ragi	2n=36 (4x)	annual	C4	*E. coracana* var. *africana*	East Africa
Eragrostis abyssinica Schr.	tef		2n=40 (4x)	annual	C4	*E. pilosa*	Ethiopia
Digitaria exilis (Kippist) Stapf.	fonio		2n=54 (4x)	annual	C4	wild	West Africa
Digitaria iburua Stapf.	black fonio			annual	C4	wild	West Africa
Brachiaria deflexa (Schumach) C. E. Hubbard	animal fonio			annual	C4	wild	West Africa
Oryza glaberrima Steud.	African rice		2n=24 (2x)	annual		*O. barthii*	West Africa
Europe from India							
Digitaria sanguinalis (L.) Scop.	mana grass			annual	C4		Europe from India
Phalaris canariensis L.	canary seed			annual			South Europe
Asia							
1. South west Asia							
Avena sativa L.	oat		2n=42 (6x)	annual	C3		South west Asia
Avena strigosa Schreb.			2n=14 (2x)	annual	C3		South west Asia
Avena abyssinica Hochst.			2n=28 (4x)	annual	C3		South west Asia
Avena byzantina C. Koch.			2n=42 (6x)	annual	C3		South west Asia
Hordeum vulgare L.	barley	jao	2n=14 (2x)	annual	C3	*H. vulgare* ssp. *spontaneum*	South west Asia
Triticum monococcum L.	small spelt		2n=14 (2x)	annual	C3	*T. monococcum* ssp. *boeoticum*	South west Asia
Triticum trugidum L.		aja	2n=28(4x)	annual	C3	*T.trugidum ssp. dicocoides + Aegilops speltoides*	South west Asia
Triticum aestivum L.	bread wheat	gehun	2n=42 (6x)	annual	C3	*T.trugidum + A. squarrosa*	South west Asia
Triticum timopheevi Zhuk.			2n=28 (2x)	annual	C3	*Triticum timopheevi* ssp. *araraticum*	South west Asia
Triticum zhukovskyi Menbde & Ericzjan			2n=42 (6x)	annual	C3		West Goergia
Seale cereale L.	rye		2n=14 (2x)	annual	C3	*S. montanum*	South west Asia
2. Central Asia							
Setaria italica (L.) P. Beauv.	foxtail millat	thenai	2n=18 (2x)	annual	C4	*S. italica* ssp. *viridis*	Central Asia/South Tianshan
Panicum miliaceum L.	common millet	cheena	2n=36 (4x), 40, 49, 54 (6x), 72 (8x)	annual	C4	*P. miliaceum* ssp. *ruderale*	Central Asia/South Tianshan
3. India							
Panicum sumatrense Roth	little millet	samai	2n=36 (4x)	annual	C4	*P. sumatrense* ssp. *psilopodium*	India/Decan Plato
Paspalum scrobiculatum L.	kodo millet	kodora	2n=40 (4x)	perennial	C4	wild	India/Decan Plato
Echinochloa flumentacea Link.	sawa millet	jangora	2n=54 (6x)	annual	C4	*E. colonum*	India/Decan Plato
Brachiaria ramosa (L.) Stapf.	browntop millet	korne		annual	C4	wild	Inndia/East Garts
Setaria pumila (Poir.) Roem. & Schult.	yellow foxtail mil	kolati	2n=18 (2x), 36 (4x), 72 (8x)	annual	C4	wild	India/Decan Plato
Digitaria crusiata (Nees) A. Caus	Khasi millet	raishan		annual	C4	wild	India/ Khashi Hill
4. South east Asia							
Coix lacryma-jobi var. *ma-yuen* (Roman.) Stapf.	Job's tears	gurya	2n=20 (2x)	perennial	C4	*Coix lacryma-jobi* var. *lacryma-jobi*	Zomia
5.China							
Oryza sativa L.	rice	dhan	2n=24 (2x)	perennial	C3	*O. rufipogon* L.	China/ Pearl river
Echnochloa oryzicola Vasing.			2n=36 (4x)	annual	C4	wild	China/ Yunnan
Podiopogon formosanus Rendl				perennial		wild	Formosa
Fagopyrum esculentum Moench	buckwheat		2n=16 (2x)	annual	C3	*F. esculentum* ssp. *ancestrale*	South west China/Yunnan
Fagopyrum tartaricum (L.) Gaertn.	Tartary buckwheat		2n=16 (2x)	annual	C3	*F. tartaricum* ssp. *potanini*	South west China/Tibet
6.Japan							
Echinochloa utilis Ohwi et Yabuno			2n=54(6x)	annual	C4	*E. crus-galli*	North Japan
America							
Zea maays L.	maize	makai	2n=20 (2x)	annual	C4	*Z. mays* ssp. *mexicana*	Meso America
Panicum sonorum Beal.	saui			annual	C4	*P. hirticaule*	Mexico
Zizania aquatica L.	wild rice		2n=30	annual		wild	North America, Canada
Bromus mango E. Desv.				annual/perennial		wild	South Chile, South Argentina
Amaranthus hypocondriacus L.			2n=32, 34 (2x)	annual	C4	*A. cruentus* (*A. hybridus*)	Andes
Amaranthus acaudatus L.			2n=32, 34 (2x)	annual	C4	*A. cruentus* (*A. hybridus*)	Andes
Chenopodium quinoa Willd.			2n=36 (4x)	annual	C4	*C. quinoa* ssp. *miilleanum*	Andes

Table 2. Terminology of millets

name	explanation
strict definition	Millet is the collective term to the grain crops without major grains such as bread wheat, rice and maize.
	numerous small seeds (caryopsis) attached a big panicle, mainly summer annuals which had been domesticated in savanna area conditioned under the tropical/sub-tropical zones, or in monsoon area under the temperate zone
small millets	foxtail millet, common millet, finger millet, and so on.
	except large seed millets, i.e., sorghum, pearl millet and Yob's tears.
wide definition	millets and pseudocereals including *Fagopylum* ssp., *Amaranthus* ssp,, and *Chenopodeum* sp.
loosely difinition	the grain crops without major grains such as bread wheat, rice and maize. Recently, comarcial name adding barley, rye, oats, or reddish/purple rice, sesame, perilla, mung bean etc.

Research Methods and Materials

Botany

In the research methodology on plant domestication, de Candolle (1883) had indicated that botany was most important domain and more needed the different domains, for example, archeology, linguistics, etc. He had described each crop in detail, in addition, he pointed out that annuals were very useful. The important domesticated plants were mostly belonged to Gramineae, Fabaceae and Brassicaceae. We must explore the wild species in order to make the geographical origin clear. Botany was a valuable research method for clarifying the botanical origin of domesticated plant. Because ancient people were able to grow annuals species easy, annuals plants had very important role for people. Farming had begun very slowly for long term.

Vavilov (1926) had researched the botanical origins and geographical resources of domesticated plants by the differential phytogeographic method. Kihara (1954) had conducted the genome analysis on Triticeae and had elucidated the botanical origin of bread wheat. Nakao (1967) had proposed the botanical origin and their geographical resources with his wide conceptual ability, having a regard for de Candolle' methodology. Moreover, he had expanded the theory such as "Evergreen broad-leaved forest culture," together with Ueyama and Sasaki.

Sakamoto (1988) had changed his research interest from the phylogenetic of Triticeae to the domestication of millets, since he had been inspired by eating injera in Ethiopia. I have become his student about 1970. Then I have studied on the agricultural complex of millets all in Japan and Indian subcontinent.

Modern Ethnobotany

Cotton (1996) had written that the ethnobotany constituted a diverse field of study which examined all aspects of the reciprocal relationships between plants and traditional peoples. It is, by necessity, multidisciplinary in its approach and draws from a broad range of subject area, e.g., ethnoecology, traditional agriculture, cognitive ethnobotany, material culture, traditional phytochemistry and paleoethnobotany. Their applied areas are economic botany including agriculture, crafts, pharmaceutical, and ecology including flora management, biodiversity, human ecology. In addition, the ethnobotany is indicated need of environmental lows, the principle of

learning environment and practices to us. Their research methods are applied cultural anthropology, ethnology and botany.

I have respected strongly Nakao's achievement, the basic agricultural complex (1966, 1967), therefore, I have used it the most important concept to research millet and learning environment. However, I have never been affected his hypothesis, "Evergreen broad-leaved forest culture," and also Yanakita's concept "Rice-growing single ethnic group theory," which were taken the world by storm. Dr. Sakamoto had suggested me strongly that you never considered your paper under the influence from the other famous hypothesis, when I had written my first paper to Anthropological magazine. Therefore, I had decided that I never followed famous authoritative hypothesis and fashionable theory. I kept in mind using the data and results gotten by myself.

Because ethnobotany has natural scientific method, it is very important the stories heard directly from farmers and the observation on their field. Also, our experiences in the nature and social environment of villages are valuable. I had conducted the cultivation tests, biological experiments and observation using seeds, herbarium specimen and so on. I will consider the new model of domestication process and dispersal routs in this book.

Archaeology and history in Holocene, Quaternary

The studies on domestication process and dispersals are conducted not only in geographic space, but also historical times. Therefore, we must make use of their background materials. I have not directly examined and analyzed fossils, remains, etc., in the historical sites. I have visited many museums and historical heritages. I have read archeological books, and directly visited many archeologists in Japan and United Kingdom.

Resources of processing/cooking methods

The millets had rarely been excavated from archaeological sites. Their ancient documents were very few. Therefore, we need the field research data of millets on ethnology and cultural anthropology in order to solve the domestication and dispersal routs of millets. The dispersal of millets nearly always is followed by a basic agricultural complex (Nakao 1966, 1967), that is to say, "from Seeds to Stomach" such as the methods of growing, processing, cooking, food culture and agricultural rites. We consider the origin and dispersal of grain crops comparing with those cultural history. For example, the variety with glutenous starch of seeds had been dispersed in mostly east Asia including Japan, but they had never dispersed toward the west. Those varieties had not dispersed and disappeared on the way to India, because the west side people did not like the taste.

Bread is a processing food made from the flour of bread wheat, which has been dispersed from Middle East to the east and west. Boiled rice had been dispersed from China to the west. Pilaf made of rice had been dispersed from Central Asia to the west and south. Maze had introduced from America to Europe after 15th century. Today maize is used traditional cooking such as polenta in Italy or ugari in Africa. People substitutes a new ingredient for common millet or foxtail millet. We need carefully consider the processing and cooking in order to clear old/new.

The victor group had high yield grain, for example, bread wheat against einkorn wheat and emmer wheat. When they became the ruler, they discriminated traditional crops which an indigenous loser had eaten. However, those neglected crops have been continued to grow by the loser/escape

group for live and free under the harsh and poor condition (Scott 2017). Because the indigenous people have continued their daily life, they need use traditional crops for several millennial years. As Johonson (1992) had said that both crops are important. Three major crops of the winner, bread wheat, rice and maize, were the tax and commodities, while the other crops (including millets) of survivors/indigenous people, were important food for survival.

Comparative study on the vernacular names of millets and processing/cooking in Linguistics

Of course, I had tried to learn local languages, but we used English as a common language, because each local people had used so many languages. Nevertheless, we had needed doble and/or triple translations among English and local languages.

We had heard the methods on cultivation, processing and cooking, and also the local farmers had shown us their methods. They had written the vernacular names of crops and foods in English characters for us. Moreover, I had confirmed the names by the restaurant menus and cook books.

After Bellwood and Renfrew (2002) had proposed "language/farming hypothesis," many researchers had promoted the research method integrated among linguistics, archaeology, genetics, etc. Moreover, in order to reconsider, I have referred to the linguistic analysis by Ohno (2000, 2004) and Southworth (2005).

Now, I must give readers a heads-up on the two concepts. One is the terminological difference, using in 'origin' of plant domesticated from ancestral species under the relationship between human beings and plant, and using in 'resource' of farming around a geographical area (Tanaka 1975). The beginning of farming had been very slowly promoted as cultural phenomena. After several millennia, city states had established and also synchronically an agriculture had been stated by the helots. Another one is the terminological difference between 'farming' (subsistence) and 'agriculture' (industry). Therefore, it had been called 'Agricultural Revolution.' We do not consider 'Farming Revolution.'

Field researches at mountainous villages in Cultural anthropology

We had conducted many field researches on cultural anthropology in addition the botanical basic experiments. Today also, traditional farmers and people cultivate many kinds of millet on the farming fields in the foothills and valley of mountainous/hilly regions. We had visited directory to hundreds of farmers, and had heard the information on their methods of cultivation on the farm, processing and cooking in the kitchen. Furthermore, the farmers had given us many seeds of local millet varieties for the research and conservation.

We had visited all Japan from Okinawa to Hokkaido, mainly the Indian subcontinent, Central Eurasia, and so on. We had observed wide areas by car with corporation of regional agricultural stations, National Bureau of Plant Genetic Resources, Indian Council of Agricultural Research, All India Millet Improvement Project, and Pakistan Agricultural Research Council, Plant Genetic Resources Laboratory, National Agriculture Research Center. We did not stay at the particular village as typical anthropologists.

I had participated six times in expeditions for millet research and collected numerous accessions of millets and their relative species, with information on their agricultural complex, from hundreds of farmers in their villages and fields (Table 3). I mainly visited the southern foot of the

Himalayas and Western and Eastern Ghats in and around the Indian subcontinent between 1983 and 2001. The research team used many means of transportation, such as car, train, airplane, and their feet, for frequent field trips (Figure 1). Particularly, the trips extended widely over Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Telangana, Maharashtra, Madhya Pradesh, Orissa, Chhattisgarh, Jharkhand, West Bengal, Bihar, Uttar Pradesh, Uttarakhand, Himachal Pradesh, and Jammu and Kashmir in India and the North-West Frontier in Pakistan and Eastern Nepal. The concentrated field works were performed in Orissa (1987, 2001), Karnataka and Andhra Pradesh (1996, 2001).

Table 3. Expeditions of millet research in the Indian subcontinent between 1983 and 2001

Year (month)	Locality	Research Team
1983.9-11	Nepal, India (Hariana)	The Japanese Scientific Expedition for Nepalese Agricultural Research
1985.9-11	Pakistan (Northwest province), India (Karnataka, Andhra Pradesh, and Tami Nadu)	Kyoto University Scientific Expedition to the Indian Subcontinent
1987.9-11	India (Jammu and Kashmir, West Bengal, Orissa, and Assam), Pakistan (Sind)	Kyoto University Scientific Expedition to the Indian Subcontinent
1989.9-10	Pakistan (Azad Kashmir), India (Karnataka, Madhya Pradesh, and Maharashtra)	Kyoto University Scientific Expedition to the Indian Subcontinent
1996.9～97.6	India (Karnataka, Andhra Pradesh, Tamil Nadu, Orissa, Himachal Pradesh, and Utter Pradesh)	Research abroad supported by Japanese Government, University of Agricultural Sciences at Bangalore
2001.9-10	India (Karnataka and Orissa)	Tokyo Gakugei University Scientific Expedition to the Indian Subcontinent

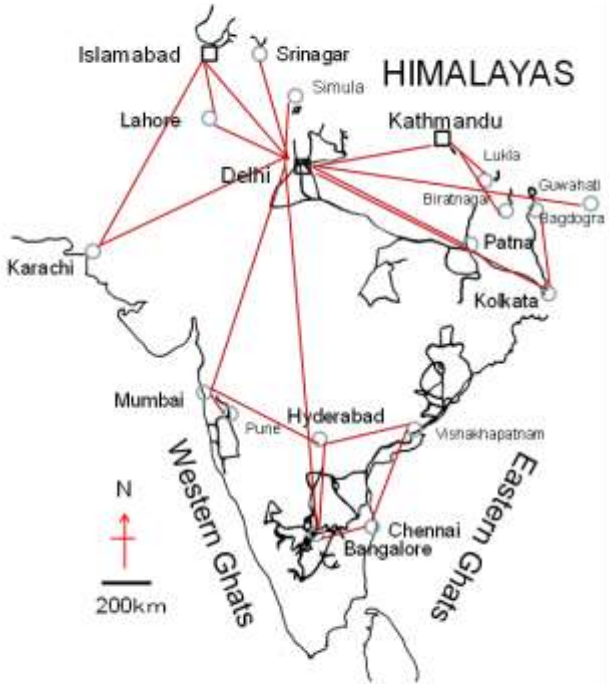

Figure 1. Expedition routes in the Himalayas, Western/Eastern Ghats

Procedure of research studies

The scholars such as Frazer (1911) and de Candolle (1883) had drawn specific information from numerous books, and deduced their hypothesis on the origin of domesticated plants. While the other scholars such as Vavilov (1926) and Kihara (1954) had conducted field researches and botanical experiments, they had induced their theory based on the results. Sakamoto (1988) had conducted field researches and eco-genetical experiments which had used many accessions collected. Those accessions were domesticated plants and the relative species for using materials under experimental condition.

The following wild species of Poaceae are gathered for grain food in the savanna aera, Africa. Those are so many, 33 species; genera *Aristida* (1 species), *Becheropsis* (1), *Brachiaria* (4), *Cenchrus* (2), *Dactyloctenum* (1), *Digitaria* (1), *Echinochloa* (3), *Eleusine* (1), *Eragrostis* (2), *Eriochloa* (1), *Hyphrrhenia* (1), *Latipes* (1), *Loudetia* (1), *Oryza* (1), *Panicum* (3), *Paspalum* (1), *Saccolepis* (1), *Setaria* (2), *Sorghum* (1), *Sporobolus* (1), and *Urochloa* (2) (Nakao 1967). These are mostly perennial plants which makeup main component growing in the grassland and wetland. However, annual plants are included around the savanna area. The first stage of pre-farming had been stared through gathering grains of annual plants. After that the following stage of semi-domestication, via cultivation including transplanting, weeding, plowing, etc. On the stage of domestication, farmers had conducted sowing, harvesting, processing and then cooking. The perennial plants, Poaceae are also gathered now, but they have been discontinued to domestication process. For example, 35species of genus *Setaria* are perennial plants in Africa, but these species had not domesticated (Nakao 1967). It is clear that annual plants are very important for domestication.

On the first of all my research plan, I had conducted the comparative studies on annuals and perennials. I had made the list of annuals and perennials belonging the same genera through the botanical encyclopedias. Then I had selected genera *Mazus*, *Cardamine*, *Rorippa*, and *Secale* for the evolution from perennial to annual, and more genera *Agropyron*, *Coix*, and *Oryza* for the ecological change from perennial to ecological annual. These comparative studies are written in Chapter 2.

The next, I have studied the domestication process and dispersal route of Common millet (*Panicum miliaceum*) as an ancient domesticated millet in all Eurasia (Chapter 3). The comparative study on the Indian original millets was conducted including morphological/ecological characteristics, analysis in biological components, genetical analysis of characters by artificial out crossing (Chapter 4). I had learnt the new technic of experimental methods, and then I had analyzed experimentally each species in the biological level from the population to the molecular (Chapter 4).

The third, changing the sight of research for the food processing/cooking methods, I had studied on their characteristics of resource and dispersal in each locality (Chapter 5). Finally, I propose the new model of hypothesis on the domestication processes and dispersals of millets/grain crops around Indian subcontinent (Chapter 6).

The conservation activities of biocultural diversity

I organize the materials of agricultural complexes and release them on my website which is registered the National Diet Library.
{http://www.ppmusee.org/goods.html and https://www.milletiimplic.net/index.html}

Chomin Nakae said that the most of Japanese academics were had imported and translated foreign books. Because we cannot understand many languages, the translated books are very comfortable. However, if the translation is wrong, it is necessary we will be required to read again the context by the original book. On the other hand, because it is seldom that the Japanese translators translate the Japanese book to some kind of foreign language, we must write our book and papers mostly in English for foreign readers.

I have been guided by Nakao' conceptional ideas (imagination) and Sakamoto' self-reliance (screwball), and then I have conducted many botanical experiments and wandered many places around 55 years. In the Indian subcontinent, I have been a member belonging to the research teams of Kyoto University, Tokyo Women's Christian University, Tokyo Gakugei University and so on (from 1983 to 2001). Also, I was an oversea research fellow belonging to University of Agricultural University (Bangalore, India) from 1996 to 1997. Moreover, I was an oversea research fellow belonging to University of Kent (Canterbury, UK) and Royal Botanic Gardens, Kew for collecting materials from 2005 to 2006. After my retainment (2014), I was a fellow belonging to Research Institute for Languages and Cultures of Asia and Africa, Tokyo University for Foreign Studies (from 2014 to 2019). I have studied Indian culture and archeology.

Within my short life, I have considered the importance that we must inherit biological diversity and traditional culture as an integrated cultural complex through the research on the domestication process of millet. It is suggestive and insightful that Shiva (1993) had written the phrase 'Diversity as a way of thought as a way of life is what is needed to go beyond the impoverished monocultures of the mind,' in her book "Monocultures of the mind." She had suggested that our minds had become week by the decline of our biocultural diversity.

We have conducted some projects, for example, workshops/seminars of millet farming, designated activities of Globally Important Agricultural Heritage Systems 'Millet Street.' As one of our activities on Plants and People Museum, we returned the seeds of local variety to farmers, if they had lost it. We had proposed a position paper, 'People and Seeds for the Future: The importance of conservating plant seeds for the sake of bio-cultural diversity' to CBD/COP10 in Nagoya (2010).

In the next year 2011, the Great East Japan Earthquake occurred, and then the nuclear reactor of Fukushima nuclear power plant collapsed. The radioactive material scattered in all directions including Tokyo. In order to avoid this pollution for plant genetic resources, immediately I had sent and transferred them (about 10 thousand accessions of millets) to Ryal Botanic Gardens, Kew, UK.

I have mostly spent my life for the study on millets, their conservation and popularization. However, Japanese people did not recognize the importance of millet and they did not evaluate the research on learning environment and biocultural diversity (Chapter 7). Most Japanese people have become a monoculture in their mind. Because they had lost their prides as self-sufficient farmers, they have indulged in their parasitic lives such as only consumers. The food security is the first priority in our daily life, but money is everything in the present world. The orphan millets have been neglected by deep-rooted prejudice even at rural hill area where their ancestors had grown many kinds of millet. It is a meddling that we suggest the daily life for connecting hope.

However, I hope that everybody thinks deeply again for your family, local community and country for becoming happy. It is a pure, peaceful and beautiful life. I have kept company a few of intelligent farmers, who have indulged themselves in rural life.