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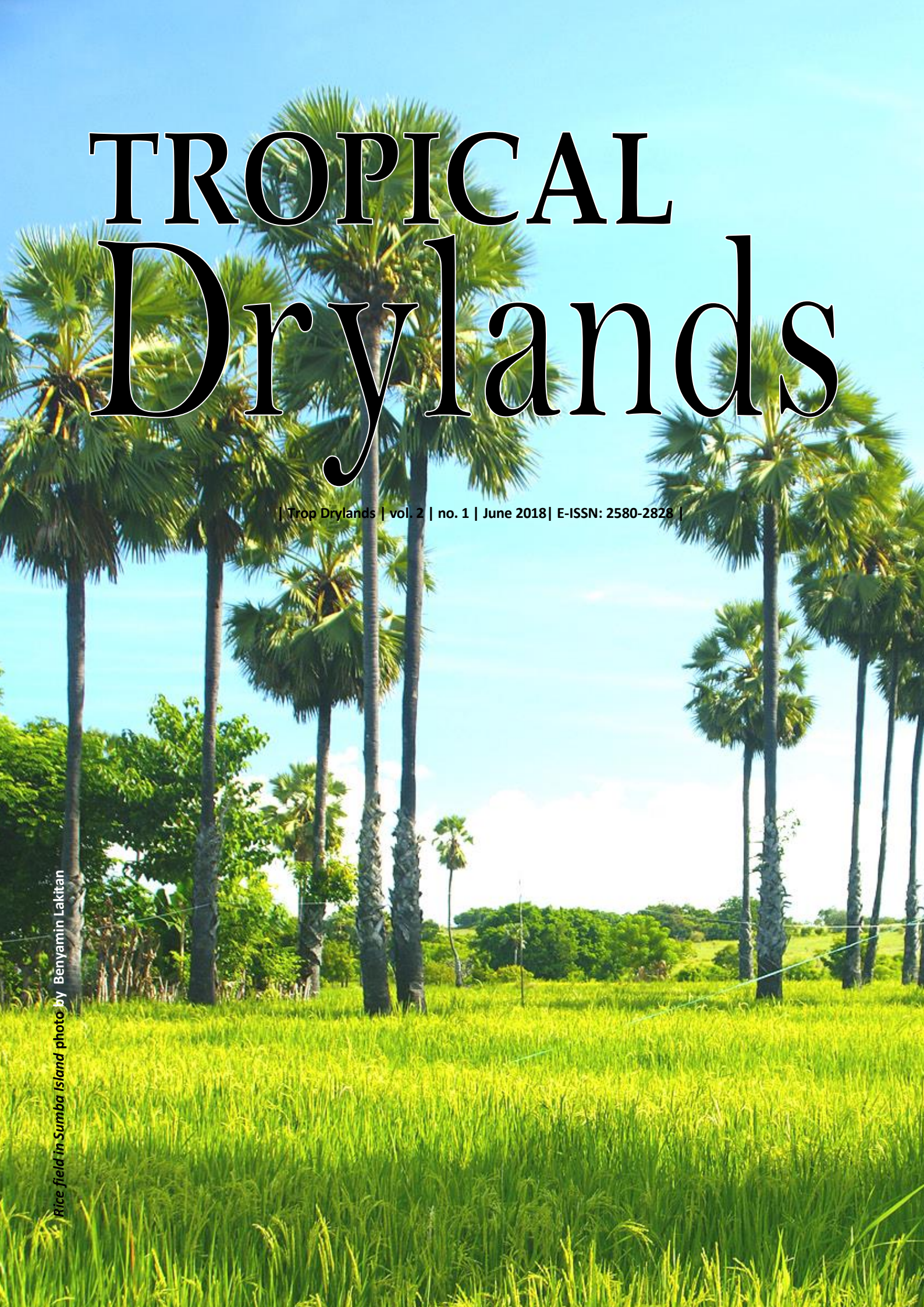

Rice field in Sumba Island photo by Benyamin Lakitan

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Book:

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Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta***.** 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

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Short Communication: The tolerance level of local sorghum genotypes from Sabu-Raijua and Belu Districts, Indonesia to saline soil

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Abstract. *Benggu YI, Nguru ESO. 2018. The tolerance level of local sorghum genotypes from Sabu-Raijua and Belu Districts, Indonesia to saline soil. Trop Drylands 2: 1-4.* Sorghum is potential agricultural crop developed in semi-arid region in Indonesia which is characterized by dry climate and saline soil. This study aimed to determine the level of tolerance of local sorghum from Sabu-Raijua and Belu Districts, Nusa Tenggara Timur Province to saline soil. The research was conducted in the experimental field and soil chemistry laboratory of Faculty of Agriculture, Universitas Nusa Cendana, from June to October 2016. The study was carried out in a factorial treatment design laid out in a completely randomized design with two factors. The first factor was the variety of sorghum, consisting of three levels: local sorghum from Sabu-Raijua, local sorghum from Belu and national Numbu variety. The second factor was the salinity levels of Vertisol, composed of five levels, i.e., 0, 6, 8, 10 and 12 mmos.cm^{-1}. In total, there were 15 treatments with three replications for each treatment. Variables observed were plant height, number of leaves, flowering date, and seed dry weight. Analysis of variance was conducted followed by Tukey test (5%). The result showed that there was an interaction effect between sorghum variety and salinity level of soil on all variables observed. In general, all varieties of sorghum grew normally with soil salinity level ranging from 0 to 8 mmos.cm^{-1}. At salinity level of 8 to 12 mmos.cm^{-1}, seedlings grew for a few weeks then gradually wilted and died. Local sorghum from Belu and national Numbu variety were semi or moderately tolerant to salinity while local sorghum from Sabu-Raijua was sensitive.

Keywords: Local sorghum, Sabu-Raijua, Belu, Numbu, salinity

INTRODUCTION

Dryland agriculture is an agro-ecological system promoted in the semi-arid region in Indonesia, including in the Province of East Nusa Tenggara (Nusa Tenggara Timur; NTT). The semi-arid climatic type is characterized by erratic and limited rainfall, high temperature and the slopping-dominant topographical area. Under these conditions, one of the main problems is the existing saline soil, because the amount of precipitation and surface water is not enough to wash out the salt from the topsoil. Saline soil in the context of crop cultivation, is soil which has DHL > 4 mmos.cm^{-1} and soil pH < 8.5 at 25°C (Tan 1998). This high concentration of salt causes high osmotic pressure in the plant cell, making it difficult to absorb water and nutrients for plant growth.

In Indonesia, the saline soils are known to be mostly present in NTT Province, especially in the island of Timor (Darmawijaya 1990) with the distribution of saline soil is formed in large coastal areas (Kleden 1995 *in* Batha 2003). The influence of salinity has become increasingly serious, both in the context of intensity and extensification, due to global warming that causes sea levels to rise. As a result, most of the productive agricultural lands, especially those located in the coastal zone, will be affected by salinity.

Utilization of agricultural land affected by salinity can be done through various approaches, such as leaching out the salt using irrigation water and drainage improvement, treating soil surface to facilitate salt leaching, using gypsum to exchange sodium ions with calcium in the soil, using organic fertilizers to improve soil structure and percolation, as well as using plants that are tolerant or semi-tolerant to salinity (FAO 1985).

In the dryland agricultural community of NTT, sorghum has traditionally been one of the preferred cultivated crops. It is one of the relatively adaptive cereals to marginal growth factors, i.e., low soil fertility and water availability, as compared to other cereal crops such as rice and maize. Sorghum is known to have resistance to drought with water requirements of 300-400 mm during the growing period, resistant to waterlogging and high salinity and aluminum poisoning (House 1985; FAO 2001; Siregar et al. 2016). Also, the nutritional composition of the sorghum grain is not substantially different from corn and rice, making it an alternative to substituting staple food. In 2013, the Agency for Agricultural Research and Development released 11 superior varieties of sorghum to be developed in Indonesia, including NTT as one of the regional development of sorghum in eastern Indonesia. Nonetheless, the development of sorghum cultivation in NTT Province has been hampered because the government attempted to displace this crop with other cereal commodities, such as corn and rice, through intensification and extensification programs.

To utilize saline soil in dryland agricultural ecosystems through the cultivation of tolerant and semi-tolerant plants, including sorghum, it is necessary to identify and determine the species or varieties of sorghum that are tolerant to salinity. There are various types of local superior sorghum varieties with different genotypes recommended to be developed in NTT Province. This type of local sorghum can be regarded as one of the local biological resources to be maintained and improved, as it is a type of sorghum that has been well adapted and proven to exist for long periods in the typical dryland ecosystem of NTT which become the comparative advantage. The local sorghum from Sabu-Raijua District, *Terrae meddi*, for example, has distinctive features such as the size of stems, leaves, large panicles, dark brown and mild orange seed, and flat oval-shaped seed. The agroecosystem condition in this region is dry and hot with average annual rainfall of 1,290 mm, average wind speed of 8 knots, and 86.5% of solar irradiance (BPS Sabu-Raijua 2013). The local sorghum from Belu District, *Batar ainaruk*, has oval-shaped dark brown seeds. Belu has an annual rainfall of 1,127 mm, average wind speed of 6 knots, and 80% of solar irradiance. Some areas in Belu have altitudes of up to 380 m above sea level (BPS Belu 2012). The present study was carried to determine the tolerance level of these local sorghum genotypes to saline soil.

MATERIALS AND METHODS

This research was out in the experimental field, and Soil Chemistry Laboratory, Faculty of Agriculture, Universitas Nusa Cendana, Kupang, Indonesia from June to October 2016.

This experiment was arranged in a Completely Randomized Design with a factorial treatment design consisting of two factors, i.e., local sorghum genotypes and level of soil salinity. The first factor consisted of three sorghum genotypes, i.e., (S1): Local sorghum from Sabu-Raijua District, (S2): Local sorghum from Belu District, and (S3): the national check variety Numbu. The second factor consisted of five salinity levels, i.e., (G1): 0 mmos.cm^{-1}, (G2): 6 mmos.cm^{-1}, (G3): 8 mmos.cm^{-1} (G4): 10 mmos.cm^{-1}, (G5): 12 mmos.cm^{-1}. Each treatment comprised of three replications

Sorghum seeds were planted in polybags according to the assigned treatment. It was done by immersing 3-5 seeds into the soil. At two weeks after planting (WAP), the seedlings were thinned out leaving only one plant per polybag. Watering was done homogeneously. The amount of water given was based on the plant water requirement while keeping the soil salinity level relatively unaffected. Weed, pests, and pathogens were controlled as needed.

Analysis of Variance (ANOVA) was performed to analyze the sorghum's tolerance response to salinity treatments. The following variables were observed: plant height, number of leaves, flowering date, and dry seed weight. The means of the different treatments were compared using Tukey Test (Montgomery 2012).

RESULTS AND DISCUSSION

In general, all sorghum varieties grew well on saline Vertisol soil. All seeds germinated and grew well with relatively normal and fairly good seedlings. The ability of sorghum seeds to germinate and grow into seedlings, presumably as a result of irrigation that was regularly (daily) provided homogeneously through surface precipitation. The water leached the salt on the surface layer, moving it toward the bottom layer due to water gravity. As a result, there was a decrease in the level of salinity on the surface zone to a level of salinity that still allowed the seeds to germinate. A similar result was stated by Hasanah et al. (2010) that dissolving salt in the soil at the beginning of the planting did not affect the further growth of the plant due to leaching caused by watering/irrigation.

In subsequent developments, there was an inhibition of the sorghum growth and its effects significantly varied depending on the different salinity level treatments. Even before the plants were entering the generative phase, characterized by the formation and development of panicles, some sorghum genotypes became dry (permanently wilted) and died, especially those treated with high salinity levels (10 and 12 mmos.cm^{-1}). This condition occurred due to the root penetration reaching the accumulated layer of salt in the middle and bottom of the growing medium. The effects of salinity stress observed in the present study was similar to the effects of drought, where the plants grown in saline soil will react by showing permanent wilting symptoms and then dry out.

ANOVA analysis showed significant interaction effect between sorghum genotype and salinity level on plant height and number of sorghum leaves. The results showed that salinity level treatments markedly determined variations of plant height and number of leaves. The ANOVA results for plant height and number of leaves at eight weeks after planting (WAP) are presented in Table 1 while the mean of plant height and the number of leaves are presented in Table 2.

Table 2 shows that the plant height and the number of sorghum leaves decreased along with the increase of soil salinity. In all sorghum genotypes, plant height and the number of leaves were higher in soil with a salinity level of 0 to 8 mmos cm^{-1} as compared to that of 10-12 mmos cm^{-1}. The decrease in plant height and the number of leaves in the soil with a salinity level of 10-12 mmos cm^{-1} may be one of the mechanisms of the plant to tolerate the presence of salt by reducing the growth components that in turn will decrease the transpiration rate (Hasanah 2010). All plants were dead at a salinity level of 12 mmos cm^{-1}. It is most likely that the toxic effects of salt-generating ions and the high pressure of osmosis media caused the plants could not be able to absorb water properly.

ANOVA results showed significant interaction effect between sorghum genotype and salinity level on the flowering date and dry seed weight of sorghum. It showed that variations of flowering age and dry seed weight were markedly determined by the salinity level treatment. The ANOVA results for flowering date and dry seed weight can

be seen in Table 3. The mean flowering date and dry seed weight are shown in Table 4.

Table 1. ANOVA results of plant height and number of leaves at eight weeks after planting on Vertisol soil with a different salinity level

Source of variation	DF	Plant height		Number of leaves	
		Mean Square	*Sig.*	*Mean Square*	*Sig.*
Sorghum genotype (S)	2	12699.198	0.000**	19.622	0.198ns
Salinity level (G)	4	104.318	0.607 ns	472.144	0.000**
S x G	8	583.315	0.018*	32.011	0.020*
CV		28.99		36.14	

Note: DF= Degree of Freedom, CV = Coefficient of Variation. **Highly significant effect (P<0.01), nsno significant effect (P>0.05).

Table 2. Mean number of plant height and number of sorghum leaves (8 WAP) planted on Vertisol soil with a different salinity level

Sorghum genotype	Salinity level	Plant height (cm*)	Number of leaves*)
Local Belu	0 mmos cm^{-1}	81.00 c*	15.33 de
	6 mmos cm^{-1}	65.83 bc	14.00 cd
	8 mmosn cm^{-1}	47.83 bc	10.33 bc
	10 mmos cm^{-1}	39.00 b	6.33 b
	12 mmos cm^{-1}	0.00 a	0.00 a
	Mean	46.73	9.20
Local Sabu-Raijua	0 mmos cm^{-1}	84.67 b	17.00 c
	6 mmos cm^{-1}	81.00 b	9.33 b
	8 mmos cm^{-1}	81.33 b	14.33 c
	10 mmos cm^{-1}	0.00 a	0.00 a
	12 mmos cm^{-1}	1.83 a	1.00 a
	Mean	49.77	8.33
Numbu	0 mmos cm^{-1}	85.67 b	15.00 b
	6 mmos cm^{-1}	81.33 b	14.67 b
	8 mmos cm^{-1}	77.93 b	21.00 c
	10 mmos cm^{-1}	15.00 a	2.33 a
	12 mmos cm^{-1}	0.00 a	0.00 a
	Mean	51.99	10.60
Grand mean		49.49	9.38
Tukey test 5 %		33.98	4.54

Note: *)Numbers within a column followed by different letters are significantly (P<0.05) different according to Tukey test.

Table 3. ANOVA results of flowering date and dry seed weight of sorghum genotypes grown on Vertisol soil with a different salinity level

Source of variation	DF	Flowering date		Seed dry weight	
		Mean Square	*Sig.*	*Mean Square*	*Sig.*
Sorghum genotype (S)	2	7110.600	0.000**	301.963	0.000**
Salinity level (G)	4	5936.256	0.000**	511.395	0.000**
S x G	8	2940.989	0.000**	132.278	0.000**
CV		6.80		38.10	

Note: DF= Degree of Freedom, CV = Coefficient of Variation. **Highly significant effect (P<0.01).

Table 4. Means of flowering date and dry seed weight of sorghum genotypes grown on Vertisol soil with different salinity level.

Sorghum genotype	Salinity levels	Flowering date (days)*)	Dry seed weight (g $plant^{-1}$)*)
Local Belu	0 mmos. cm^{-1}	70.67 a*	19.00 d
	6 mmos. cm^{-1}	75.00 ab	11.10 bc
	8 mmos.cm^{-1}	74.33 ab	5.58 b
	10 mmos.cm^{-1}	79.00 ab	0.00 a
	12 mmos.cm^{-1}	81.67 b	0.00 a
	Mean	76.13	7.14
Local Sabu-Raijua	0 mmos. cm^{-1}	85.00 b	0.00 a
	6 mmos. cm^{-1}	84.67 b	0.00 a
	8 mmos.cm^{-1}	0.00 a	0.00 a
	10 mmos.cm^{-1}	0.00 a	0.00 a
	12 mmos.cm^{-1}	0.00 a	0.00 a
	Mean	33.93	0.00
Numbu	0 mmos. cm^{-1}	82.67 c	13.90 b
	6 mmos. cm^{-1}	70.33 b	23.50 c
	8 mmos.cm^{-1}	75.67 b	20. 47 c
	10 mmos.cm^{-1}	0.00 a	0.00 a
	12 mmos.cm^{-1}	0.00 a	0.00 a
	Mean	45.73	11.57
Grand mean		51.93	6.24
Tukey test 5 %		8.37	5.63

Note: *) Numbers within a column followed by different letters are significantly (P<0.05) different according to Tukey test.

Table 4 demonstrates that the flowering period of local sorghum from Belu was not much affected by the salinity level treatment. The longest flowering period of tested sorghum genotypes was observed on plants grown at a salinity level of 12 mmos $cm^{-1,}$ which differed significantly (P<0.05) from that of the control (without salt treatment). Local sorghum from Sabu-Raijua was able to achieve their generative stage when they were planted on soil with a salinity level of 0-6 mmos cm^{-1}, however, at higher salinity levels, the plants died before reaching their generative phase. Furthermore, all flowering plants were also gradually wilted and died without producing seed. The flowering date of Numbu grown on soil with salinity levels 6-8 mmos cm^{-1} was significantly shorter than that of the control treatment, but at higher salinity levels, the plants died before reaching their flowering stage.

Local sorghum from Belu grown on Vertisol with salinity levels of 6-8 mmos cm^{-1} produced significantly (P<0.05) lower dry seed weight as compared to control. None of the plants of this sorghum genotype was observed to produce seed when they were grown at salinity level above 8 mmos cm^{-1} (10- 12 mmos cm^{-1}). Thus, it can be stated that the local sorghum from Belu has a moderate level of salinity tolerance. Local sorghum from Sabu-Raijua did not produce seed at all. After flowering, the plants of this genotype gradually dried out permanently and died before producing seed. Therefore, it can be stated that the local sorghum from Sabu-Raijua was susceptible to saline soil. Meanwhile, the Indonesian released superior variety Numbu exhibited a moderate level tolerance to saline soil. This sorghum variety was able to grow and produced seeds up to the level of salinity 8 mmos cm^{-1}.

Based on the present research findings, we concluded that: (i) Salinity level and sorghum genotype significantly affected the plant height, number of leaves, flowering date and dry seed weight of sorghum. (ii) Local sorghum from Belu and Numbu variety were moderately tolerant to saline soil. (iii) Local sorghum from Sabu-Raijua was susceptible to saline soil.

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Resistance response of fifteen sweet potato genotypes to scab disease (*Sphaceloma batatas*) in two growing sites in East Nusa Tenggara, Indonesia

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Abstract. *Mau YS. 2018. Resistance response of fifteen sweet potato genotypes to scab disease (*Sphaceloma batatas*) in two growing sites in East Nusa Tenggara, Indonesia. Trop Drylands 2: 5-11.* Scab disease is one of most prevalent problems of agricultural crops, including sweet potato, in tropical and sub-tropical regions. This study aimed to evaluate and determine the scab resistance levels of local sweet potato genotypes from Nusa Tenggara Timur (NTT) Province, Indonesia, and to identify sweet potato genotypes with good resistance levels to scab disease. Field experiments were carried out in two growing locations involving potential sweet potato clones from NTT Province. The experiment was carried out in the fields employing a Randomized Block Design with a mono-factorial treatment design in each location. The treatment assigned was sweet potato genotype, each consisting of two replicates. The variables observed were disease severity that was assessed at 2, 4, 6, and 8 weeks after inoculation (WAI), which then was used to calculate the Area Under the Disease Progress Curve (AUDPC) of the disease severity. The ANOVA of AUDPC was used to determine the treatment effect, and the disease severity at 8 WAI was used to assess scab resistance level of the sweet potato genotypes tested. The study results showed highly significant differences in disease severities among the tested sweet potato genotypes within each trial location. The majority of the genotypes tested were classified Resistant or Moderately Resistant to scab disease, except the check clone SLM-01 and KRA-01 that were, respectively, Susceptible and Moderately Susceptible to scab disease. The majority of sweet potato genotypes evaluated were consistent in their resistance performance in the two trial locations.

Keywords: Sweet potato, genotype, scab disease, resistance

INTRODUCTION

Scab disease is one of the most destructive diseases of sweet potatoes in the sub-tropical and tropical regions of the world. Scab disease has been reported to cause yield loss of sweet potato of about 30-65% in Indonesia (Saleh and Rahayuningsih 2013; Rista et al. 2017) and 60% in Papua New Guinea (Jackson and McKenzie 1991). In Indonesia, the disease has been recorded to be widespread in sweet potato productions centers, such as Papua, Bali, Jawa, and Nusa Tenggara (Saleh and Rahayuningsih 2013; BPS Indonesia 2015).

Scab disease in sweet potato is caused by the fungus *Sphaceloma batatas* Saw. (Anamorph) or *Elsinoe batatas* (Teleomorph) (Jackson and McKenzie 1991). This pathogen infects leaves and stems with early symptoms of tiny, circular to elliptical or elongate, brown spots or lesions. In favorable weather conditions, the symptoms may reach the top leaves, and the buds become twisted (Nayga and Gapasin 1986; Clark and Moyer 1988; Sumartini et al. 2006). High disease intensity may slow down the development of the leaves so that the leaves become curly and distorted, the petioles become shorter and twisted, and the stems grow wrinkled. Severe disease infection may result in low tuber production or total plant loss (Nayga and Gapasin 1986; Moyer et al. 1989; Ames et al. 1997).

The use of fungicide has been so far the primary control measure of sweet potato scab disease (Jackson and McKenzie 1991) as this method is known to be more comfortable in its application and the effect is immediately seen. This chemical control method, however, is, in many cases, neither affordable by the poor farmers and nor environmentally friendly. Therefore, the use of scab-resistant sweet potatoes varieties is considered more efficient and economically visible in controlling the disease. Nevertheless, scab resistant superior varieties are now limitedly available and hardly affordable by the farmers. The production of scab-resistant varieties in sweet potato can be initiated through the selection of local germplasm as a source of scab resistance, which then is further employed for generation of superior scab-resistant varieties through cross-breeding program.

Several local sweet potato genotypes from East Nusa Tenggara (Nusa Tenggara Timur; NTT) Province of Indonesia have been identified and selected for several traits. A few of this local germplasm were found to be drought-tolerant (Mau et al. 2008; Mau 2012), resistant or moderately resistant to sweet potato weevil *Cylas formicarius* (Mau et al. 2011), and also high yielding and stable across environments (Mau et al. 2009; 2013). This local germplasm with such superior traits is invaluable genetic resource that can be used as parental sources for generation of more superior varieties and can also be directly registered as superior local varieties for germplasm

conservation and the property rights of the local community represented by the local government.

In addition to the above-mentioned superior variety traits, resistance to scab disease is another important trait that needs to be possessed by the sweet potato genotypes from NTT Province. The scab disease is one of the many factors that caused the low sweet potato productivity in NTT (6.98 t ha^{-1}) (BPS NTT 2015) that is much lower than the national level (16.05 t ha^{-1}) (BPS Indonesia 2015). Local sweet potato clones with good scab resistance will enable them to be used to increase the sweet potato productivity and production and also more suitable to be used as superior parental sources as well as registration of superior local varieties. To date, information on scab resistance level of local sweet potato clones/genotypes from NTT is lacking. This study was carried out with the following objectives: (i) to evaluate and determine the scab resistance levels of local sweet potato genotypes from NTT, (ii) to identify sweet potato genotypes with good resistance level to scab disease.

MATERIALS AND METHODS

Research location

The present study was carried out in two sites in East Nusa Tenggara (NTT) Province, Indonesia, i.e., Detubapa Village (630 m asl), Detusoko Sub-District, Ende District and Kesetnana Village (810 m asl), Mollo Selatan Sub-District, Timor Tengah Selatan (TTS) District. *S. batatas* inoculum was obtained from the infected plants in the field and prepared in the Plant Pathology Laboratory, Faculty of Agriculture, Universitas Nusa Cendana, Kupang, Indonesia for inoculations of the plants in the fields. The study was conducted for five months during April-August, 2011.

Research design and materials

This study employed a Randomized Block Design in each of the two growing locations. The assigned treatments were sweet potato genotype consisting of 13 local clones from East Nusa Tenggara Province and two check varieties. The check varieties were Kidal (the scab-resistant variety) kindly provided by Indonesian Legumes and Tuber Crops Research Institute (*Balai Penelitian Tanaman Aneka Kacang dan Umbi*; Balitkabi), Malang, East Java, Indonesia, and SLM-01 (the scab-susceptible clone) collected from Sumber Arum Village, Sleman District, Yogyakarta, Indonesia. In total, 15 genotypes were evaluated in each location; i.e., Detubapa Village, Ende District, and Kesetnana Village, TTS District. A total of 60 experimental units were evaluated in two trial locations.

Research procedures

In each location, the experimental field was previously cultivated with maize plant. The field was first cleared from the plant debris and plowed at 30-40 cm depth to allow easy preparation of the planting plots. The planting field in each location was divided into two blocks as replicates, and each block was further sub-divided into single row planting plots of 3 m x 1 m size as the experimental unit. The number of planting plots prepared in each block/replicate was 15 to fit the number of sweet potato genotypes evaluated. The distance between blocks was 100 cm while that between plots within a block was 50 cm. Placement of treatments within each block was carried out randomly.

The planting materials were prepared from the sweet potato shoot cuttings of 25-30 cm in length or consisted of 3-4 stem internodes. Five sweet potato cuttings were planted in each plot with a planting space of 50 cm within the plot. Basal fertilizers containing 30 g Urea $plot^{-1}$ (100 kg Urea ha^{-1}), 30 g TSP $plot^{-1}$ (100 kg TSP ha^{-1}), and 45 g KCl^{-1} (150 kg KCl ha^{-1}) were applied at the time of planting.

Scab resistance evaluation was carried out by artificially inoculating the tested plants in the field. *S. batatas* conidia were obtained from the field-infected plants. The infected plant parts were cultured in a PDA medium in the laboratory to get a pure culture of *S. batatas*. Fourteen days old *S. batatas* pure culture was then used to prepare the inoculum for artificial inoculation using a conidial concentration of $2x10^6$ conidia mL^{-1}. The inoculum was prepared in a hand sprayer of 1000 mL size and was applied by spraying the sweet potato plants six weeks after sowing. Each sample plant was sprayed using the prepared inoculum until all the leaves and stems were thoroughly wet.

Observation and data analysis

The main variable observed in the present study was the disease severity, which was recorded four times during the study, i.e., at 2, 4, 6, and 8 weeks after inoculation (WAI) or at 8, 10, 12, and 14 weeks after planting (WAP). The observation was done on ten upper leaves of the main stem of each plant in each plot (five plants per plot). The scab disease severity was calculated using the following formula:

$$I = \frac{\sum(nxv)}{ZxN} x100\%,$$

Where: I = disease severity, n = number of leaves in each disease category/score, v = disease score, Z = the highest disease score, N = total number of leaves observed in each plant. The mean disease severity of each plot was obtained from the average of all individual plant disease severities within each plot.

The disease score was determined following the method of Zuraida et al. (1992) as follows: 0: healthy, no apparent infection; 1: visible scabs on leaves, petioles, and stems > 0-20%; 2: scabs on leaves, petioles, and stems > 20-40%; 3: scabs on leaves, petioles, and stems > 40-60%; 4: scabs on leaves, petioles, and stems > 60-80%, and 5: scabs on leaves, petioles, and stems > 80%.

Disease severity at the last assessment (8 WAI) was used to classify the scab resistance level of the tested sweet potato genotypes. Classification of sweet potato scab resistance was performed based on the range of disease severity as the followings: 0-10% = "Resistant" (R), 11-20% = "Moderately Resistant" (MR), 21-30% =

"Moderately Susceptible" (MS), >30% = "Susceptible" (S) (Mukelar et al. 1994).

Meanwhile, disease severities during the study, i.e., at 2, 4, 6, and 8 WAI were used to calculate the Area Under the Disease Progress Curve (AUDPC) following the formula by Campbell and Madden (1990):

$$AUDPC = \sum_{i}^{n-1} \left(\frac{Y_i + Y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

Where: Yi = disease severity at the i^{th} observation, n = the last disease assessment (number of assessment), t = period of assessment

RESULTS AND DISCUSSION

Isolation and identification of *S. batatas*

The scab-infected plant leaves from the field were brought to the laboratory and were cultured in PDA medium to obtain pure culture for isolation and identification of the pathogen. The pure culture of *S. batatas* (Figure 1.A) shows white hyphae while the fungal conidia are elliptical (Figure 1.B). This observed morphological pure culture characteristics of *S. batatas* were similar to the results of the previous study by Martanto (2010). We then concluded that the scab-infected plant leaves taken from the field were caused by the fungus *S. batatas*. Thus, the pure culture was then used to produce *S. batatas* inoculum for evaluation of scab resistance in sweet potato genotypes from NTT Province.

The observed symptoms of scab disease

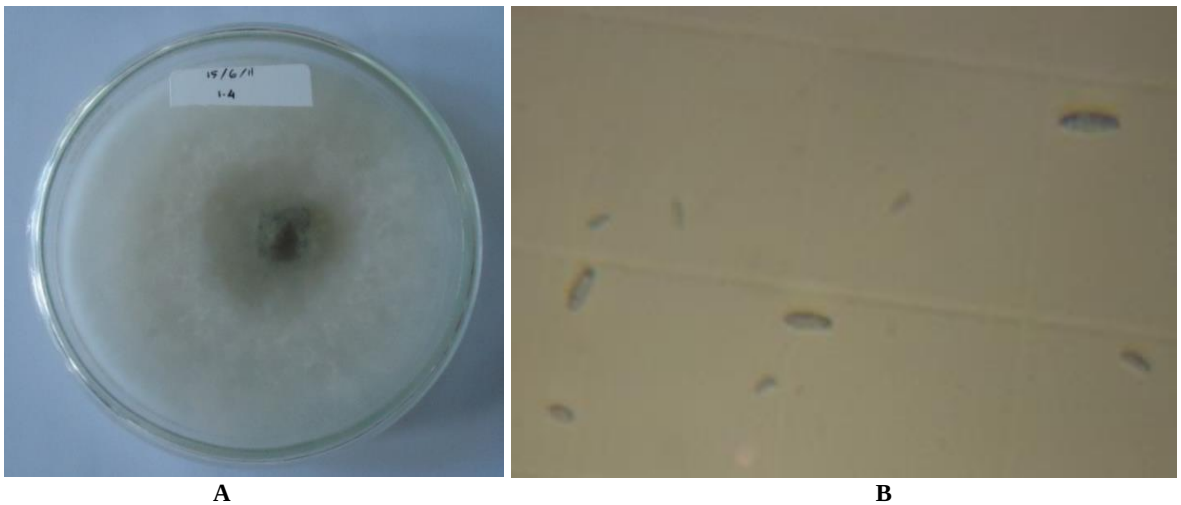
The tested plants showed early signs of reddish-brown spots/pustules on the stems and petioles, which then ruptured to form scabies symptoms. Rupture of the spots caused exfoliation of the epidermis which later resulted in a sunken scab symptom. In severe infections, the scab disease caused leaves in the young shoots to become curly and distorted; even no new leaves/stalks were produced at all. Most of the scabies symptoms were found in stems and petioles with varying lesion severities which depends on the sweet potato genotypes.

In mild disease infection, only a few scabies spots were observed on the affected plant parts, but in severe disease infection, the leaves appeared curly and dwarfed. The susceptible check clone SLM-01 exhibited severe scab symptoms on the stems, petioles, and young shoots while the resistant check variety Kidal suffered only a mild infection. Almost all local sweet potato clones from NTT Province generally showed just mild scab disease symptoms.

The observed scab symptoms in the present study were nearly similar to those observed in the previous studies (Nayga and Gapasin 1986; Clark and Moyer 1988; Moyer et al. 1989; Ames et al. 1997). These similar symptoms indicate the successful artificial inoculation in the field, even though the disease evaluation was carried out during the dry season, where the environmental conditions in NTT Province were, in general, not favorable for scab disease development. The two growing locations that are located at a medium altitude (about 600-800 m asl) might have been quite favorable to allow the artificial scab inoculation in the field was successful.

The progress of scab disease during the experiment

The development of scab disease severity during the observation period is presented in Table 1. At two weeks after inoculation (WAI), the observed disease severity was still below 10% except for the susceptible check SLM-01 that suffered 18.55% infection in Kesetnana and 13.50% in Detubapa. Consistently, the susceptible check SLM-01 demonstrated high disease severities in each of the two locations. Disease severity of the tested sweet potato genotypes tended to increase along with the increase in time after inoculation or along with the rise in the plant's age.



A **B**

Figure 1. Pure culture and microscopic characteristics of the fungus *S. batatas*. A. Pure culture appearance at seven days after culture, B. Shape of *S. batatas* conidia isolated from the pure culture

Table 1. The progress of disease severity (%) at two growing sites: Kasetnana village in Timor Tengah Selatan District and Detubapa village in Ende District

Sweet potato genotype	Growing site							
	Kesetnana				Detubapa			
	2 WAI	4 WAI	6 WAI	8 WAI	2 WAI	4 WAI	6 WAI	8 WAI
EBS-01	0.42	0.50	1.70	2.00	0.00	0.33	0.50	0.67
HK-02	0.11	0.09	0.78	1.00	0.00	3.50	5.67	6.33
KIDAL	3.30	4.73	8.25	11.00	0.33	1.50	2.17	3.00
KRA-01	2.64	2.86	8.36	11.00	5.83	9.50	13.00	18.33
LB-01	2.50	2.40	9.00	10.00	0.50	3.83	6.17	7.17
NBN-01	0.18	0.18	0.95	1.00	0.33	1.00	1.83	2.67
NLK-01	4.05	4.32	7.29	9.00	0.00	3.00	4.00	5.17
NPL-01	0.24	0.28	1.60	2.00	0.33	2.33	3.17	3.67
ON-02	0.72	0.80	2,96	4.00	2.83	5.83	6.83	7.67
ON-06	1.75	2.75	4.05	5.00	0.50	0.50	2.00	3.00
ON-07	0.80	0.95	4.50	5.00	0.17	1.67	2.33	2.83
ORM-02	0.81	0.72	2.22	3.00	0.67	0.83	1.33	1.83
SEO-01	3.60	4.08	5.46	6.00	0.00	1.67	3.00	4.00
SLM-01	18.55	19.25	31.15	35.00	13.50	17.33	20.83	23.83
SOE-02	0.47	0.49	0.89	1.0	1.17	4.00	5.00	5.50

Note: WAI = Week After Inoculation, 2 WAI (8 Weeks After Planting/WAP), 4 WAI (10 WAP), 6 WAI (12 WAP), 8 WAI (14 WAP)

Table 1 shows that the disease severity development varied considerably according to sweet potato genotypes as well as the growing locations. In Kesetnana, the highest disease severity was observed in the susceptible check SLM-01 while the lowest severity was shown by local clones NBN-01, HK-02, and SOE-02. The SLM-01 consistently exhibited high disease severity in Detubapa, followed by KRA-1, ON-02, and LB-01. The lowest disease severity in Detubapa was observed in EBS-01, followed by ORM-02 and NBN-01.

Overall, we did observe substantial differences in disease resistance reactions of the evaluated sweet potato genotypes. Even though the growing locations significantly affected the disease severity of the tested sweet potato genotypes; we did observe a tendency that most of the genotypes consistently showed almost similar disease severity at the two different sites except for Kidal, KRA-01, NLK-01, and ON-02. The SLM-01 susceptible check consistently demonstrated higher disease severities in both test sites. As with SLM-01, KRA also showed high disease severities in both locations, much higher than most local genotypes. Meanwhile, the resistant check variety Kidal showed much higher disease severity in Kesetnana as compared to the local clones, except for KRA-01 NLK-01 and LB-01, while in Detubapa, Kidal showed a lower disease severity than those of most of the local clones tested.

Observed differences in disease severity at different locations might have been caused by variations in environmental conditions, especially temperature, humidity and sunlight intensity that profoundly influenced the disease development and intensity. Also, other factors that might have affected the observed disease severity differences in the fields were the presence of wind, water droplets, and insects that can facilitate the spread of the pathogens among plants in the field. The existence of these factors may assist the spread of the fungus inoculum from one leaf to the others, most notably to the newly grown leaves, which overall affected the disease intensity as well as the disease progression rate.

AUDPC of scab disease

Area under the disease progress curve (AUDPC) analysis is an approach used to calculate the severity of the disease that is repeatedly observed over time, and thus the AUDPC data can be subjected to ANOVA to see the effect of the treatment on the observed variables (Campbell and Madden 1990). ANOVA results revealed a significant effect of sweet potato genotypes ($P < 0.01$) on AUDPC of scab disease severities during the observation period in each of the two locations. In Kesetnana, the highest AUDPC of disease severity was observed in the susceptible check SLM-01 (1086.75%.day), followed by KRA-01, LB-01, Kidal and ON-07, while the lowest AUDPC was shown by local clone NBN-01 (12.04%.day), which was not significantly different from that of other local clones such as HK-01, SOE-02, NPL-02, NLK-01, and ORM-02 (Table 2).

Table 2. Mean AUDPC of scab disease severity (%.day) of sweet potato genotypes evaluated in two growing sites.

Sweet potato genotype	Growing Site			
	Kesetnana		Detubapa	
EBS-01	156.35	bcd	16.33	a
HK-02	29.30	ab	172.67	cde
KIDAL	206.19	cde	74.67	ab
KRA-01	261.52	e	484.17	f
LB-01	235.06	de	193.67	de
NBN-01	12.04	a	60.67	ab
NLK-01	70.91	abc	134.17	bcd
NPL-02	41.72	ab	105.00	abc
ON-02	95.34	abc	250.83	e
ON-06	155.65	bcd	59.50	ab
ON-07	164.92	bcde	77.00	ab
ORM-02	68.46	abc	47.83	ab
SEO-01	117.50	abcd	93.33	ab
SLM-01	1086.72	f	795.67	g
SOE-02	29.79	ab	172.67	cde

Note: Means within the same column followed by the same letter (s) are not significantly different at $\alpha = 0.05$ DMRT

When grown in Detubapa (630 m asl), the susceptible check SLM-01 also showed the highest AUDPC of disease severity (795.67%.day), which then followed by KRA-01, ON-02 and LB-01 at the second, the third and the fourth place, respectively; meanwhile the local clone EBS-01 demonstrated the lowest AUDPC (16.33%.day), which did not statistically differ from other local clones such as NBN-01, Left, ON-06, ON-07, ORM-02, and SEO-01.

Higher disease severity AUDPC of the susceptible check SLM-01 indicated a higher disease progress rate in this check genotype as compared to other genotypes evaluated in the present study. Thus, SLM-01 produced a higher accumulated disease severity than other genotypes. In contrast, genotypes with lower disease severity AUDPC exhibited lower disease progress rates and also lower accumulated disease severity during the observation period. Levels/values of the disease severity AUDPC indicate the performance response of the tested sweet potato genotypes concerning their ability to resist/reduce the development and the progress rate of the disease (Campbell and Madden 1990).

In general, data in Table 2 demonstrate a considerable variability of the AUDPC of disease severity, both among the tested sweet potato genotypes in the same growing location and also between the same genotype at different test sites. These variations did occur, presumably, due to differences in the response of the tested genotypes under changing environmental conditions. However, in general, we observed consistency in the disease severity AUDPC rank among the tested genotypes within the two growing locations, where the susceptible check SLM-01 consistently accumulated the highest AUDPC, whereas the local clones ORM-02, NBN-01, and the resistant check Kidal consistently exhibited the lowest AUDPC. Thus, we can deduce from the present study results that variability in disease severity accumulation shown by the tested sweet potato genotypes during the two months observation period was mainly due to the genetic factor, although the effect of the environmental factor, i.e., growing sites, was also apparent.

Scab disease resistance level

Scab resistance level of tested sweet potato genotypes was determined based on disease severity assessment carried out eight weeks after inoculation or 14 weeks after planting. Scab resistance classification (Table 3) shows that the majority of local sweet potato genotypes were Resistant to scab disease when grown in Kesetnana location. Meanwhile, KRA-01 and the resistant check Kidal were Moderately Resistant whereas the susceptible check SLM-01 was Susceptible in the same location. These findings indicated that in Kesetnana growing location, the resistant check Kidal was slightly less resistant than its genetic potential as described in the varietal description while SLM-01 consistently showed a Susceptible reaction as it was supposed to be. Almost similar to the study results in Kesetnana growing location, almost all sweet potato genotypes that were grown in Detubapa location were also classified Resistant, except KRA-01 that was Moderately Resistant and SLM-01 that was Moderately Susceptible to scab disease.

Table 3. Scab resistance levels of tested sweet potato genotypes based on disease severity assessment at eight weeks after inoculation

Sweet Potato Genotype	Growing Site			
	Kesetnana		Detubapa	
	Severity (%)	Resistance Level	Severity (%)	Resistance Level
EBS-01	2.00	R	0.67	R
HK-02	1.00	R	6.33	R
KIDAL	11.00	MR	3.00	R
KRA-01	11.00	MR	18.33	MR
LB-01	10.00	R	7.17	R
NBN-01	1.00	R	2.67	R
NLK-01	9.00	R	5.17	R
NPL-02	2.00	R	3.67	R
ON-02	4.00	R	7.67	R
ON-06	5.00	R	3.00	R
ON-07	5.00	R	2.83	R
ORM-02	3.00	R	1.83	R
SEO-01	6.00	R	4.00	R
SLM-01	35.00	S	23.83	MS
SOE-02	1.00	R	5.50	R

Note: R = "Resistant", MR = "Moderately Resistant", MS = "Moderately Susceptible", S = "Susceptible".

Data in Table 3 demonstrate that most of the tested sweet potato genotypes exhibited consistent scab resistant reactions in two growing locations. However, the resistance responses of the two check genotypes were slightly deviated along with the change of growing locations. The resistant check, Kidal, was Resistant in Detubapa location but was Moderately Resistant in Kesetnana. Meanwhile, the susceptible check clone, SLM-01, was Susceptible in Kesetnana location but was Moderately Susceptible in Detubapa location. Slight differences in resistance responses observed in the two check genotypes may indicate the presence of genotype by environment interaction effect on the scab resistance phenotype.

Environmental conditions in the field such as temperature and humidity are highly dependent on the local climatic conditions of the growing locations. Although the scab resistance evaluation was done during the dry season, the scab infections in the fields did occur as expected. This might have happened because the growing locations were located at a medium altitude of above 800 m asl in Kesetnana and above 600 m asl in Detubapa, where the temperature and humidity were still in the optimal ranges for scab infection. Thus, the scab resistance performance of the tested sweet potato genotypes in the field did very much reflect their genetic potency regarding resistance to scab disease.

Overall, the results showed that 12 out of 13 local genotypes of NTT Province exhibited scab resistant reactions in the fields. This local sweet potato genotype's resistance performance was much higher than that found by Sumartini et al. (2006). By employing the same resistance classification method, Sumartini et al. (2006) observed only one genotype (Genjah Rante) of 14 sweet potato genotypes evaluated that showed Moderately Susceptible reaction while other genotypes were Susceptible to scab. In addition to genetic factors, the higher scab susceptibility

reactions shown by sweet potato genotypes assessed by Sumartini et al. (2006), presumably, might have been caused by the more favorable growing environmental conditions for scab infection since the evaluation was done during the rainy season.

This is in line with Lenne (1994) who found that the fungus *S. batatas* caused more severe scab infection on sweet potato during wet months (rainy season) as compared to that in the dry season. Additionally, the differences in the virulence levels of *S. batatas* isolates employed could have contributed to the observed variability in the scab resistance levels in the present study and that of Sumartini et al. (2006). Furthermore, in another scab resistance evaluation carried out during dry season by Martanto (2003) in Solo, Central Java, only one of four sweet potato clones evaluated was Resistant to scab, i.e., Muara Takus variety, while the three clones/varieties were, respectively, Moderately Susceptible and Susceptible to scab. In a laboratory experiment, Martanto (2010) also found only one Papuan local clone (Halake), out of four local clones of Papua and the check variety Bogor, that showed scab disease severity of <10%. Meanwhile, other clones/varieties tested in the same study suffered scab disease severity within the range of 12-22%, which, according to Mukelar (1994) classification, were classified as, respectively, Moderately Resistant and Moderately Susceptible to scab. Using another scab resistance classification according to Ramsey et al. (1988), Widiantini et al. (2015) found about 50% of 600 sweet potato genotypes of F1, parental and check populations that showed resistant reaction to scab disease during the dry season 2013 in Sumedang, West Java, Indonesia.

Based on the present study results, it can be said that variability in scab resistance levels of the tested sweet potato genotypes was mainly due to the genetic factor, while the influence of environmental factors, i.e., growing sites, was also apparent. The high scab resistance responses observed in the local sweet potato clones from NTT could be attributed to their genetic background. The fact that most of the local genotypes were resistant to scab might have also occurred due to the limited virulence level of *S. batatas* race used in this study. The local sweet potato clones with good resistance identified in the present study are invaluable genetic resources for future sweet potato breeding programs. Some of these clones had also been determined to be high yielding and stable across environments (Mau et al. 2009; 2013), drought-tolerant (Mau et al. 2008; Mau 2012) and resistant to sweet potato weevil (Mau et al. 2011). All these good traits will enable the selected clones to be used as the parental sources for the development of more superior varieties or can be directly released as superior local varieties.

In conclusion, we find in the present study that scab disease severities and AUDPC among sweet potato genotypes evaluated in two sites varied considerably. Almost all tested sweet potato genotypes exhibited scab resistant reaction except KRA-01 that was moderately susceptible, and SLM-01 that was susceptible in Kesetnana and moderately susceptible in Detubapa. The majority of sweet potato genotypes consistently demonstrated similar resistance responses between the two locations. Scab-resistant local sweet potato genotypes observed in the present study are invaluable genetic resources that can be used to generate scab-resistant superior varieties adaptable to the dryland and semi-arid agroecosystem conditions of NTT Province.

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The influence of edaphic factors on bamboo population in Mount Baung Nature Tourism Park, Pasuruan, East Java, Indonesia

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Abstract. *Sofiah S, Setiadi D, Widyatmoko D. 2018. The influence of edaphic factors on bamboo population in Mount Baung Natur Tourism Park, Pasuruan, East Java. Trop Drylands 2: 12-17.* There are 1250 bamboo species in the world with 161 of them are in Indonesia. Mount Baung Natural Tourist Park (MBNTP) is an important bamboo habitat in East Java. The purpose of this research was to study the influence of edaphic factors on the occurrence of bamboo. This research was carried out from September 2011 to May 2012. The principal component analysis (PCA) was performed to determine the relationships between edaphic components and bamboo occurrences. Six species of bamboo were found in MBNTP, namely, *Bambusa blumeana*, *Bambusa vulgaris*, *Dendrocalamus asper*, *Schizostachyum iraten*, *Gigantochloa atter*, and *Gigantochloa apus*. The edaphic factors affected the presence of bamboo in MBNTP. Phosphor (P) contributed significantly to *B. blumeana*, *B. vulgaris*, *D. asper*, and *S. iraten* presence in MBNTP. These bamboos grow in soil with high P levels of up to 27 ppm. The existence of *G. apus* was influenced by Manganese (Mn) and Sodium (Na) elements. This bamboo in this area was more commonly found in soil environments with low levels of Na (< 0.02 (cmol (+) kg^{-1})) and Mn (≤ 24 ppm). *G. apus* and *G. atter* populations were affected by solar radiation. The species of bamboo with the densest population in Mount Baung, namely *B. blumeana*, was influenced by environmental factors, i.e., the slope. The results of this study imply that each bamboo species has specific environmental factor(s) that affect its presence.

Keywords: Bamboo, edaphic, Mount Baung

INTRODUCTION

Bamboo is one of the high-value plants in Indonesia because it has a high diversity and a range of usability in the country. There are about 1250 species of bamboo in the world and Indonesia has 161 species that belong to 21 genera (Widjaja 1997). Bamboo has many benefits and utilities for human life (Dransfield and Widjaja 1995) and so many materials are produced from bamboo. Almost all parts of the bamboo can be used, from the roots to the leaves.

Bamboo also plays essential role in delivering ecosystem services particularly for soil and water conservation (Zhou et al. 2005). No wonder if this plant is often found along streams (riparian) and springs. The biological characteristics of bamboo make it a perfect tool for solving many environmental problems such as erosion control and CO_2 sequestration. Bamboo has rhizome-root system, wide and thick leaf litter, which enable them to mitigate erosion, with widespread roots that can absorb and store more water in the soil. Type of root in bamboo, the fibrous root, also makes the bamboo can bind the soil well. Based on the previous observations, it was known that bamboo is capable of holding up to 84.63% of rainfall. Sikumbang (2010) stated that compared to trees that absorb only 35-40% of rainwater, bamboo absorbs more rainwater of up to 90%.

Despite the great importance of bamboo, various human activities such as forest clearance, road and housing construction, agricultural activities affect the biogeographical distribution and population of bamboo (Holtum 1985). Several sources of information and studies suggest that certain bamboo species are rare in Indonesia. However, the species of bamboo in Indonesia are not listed in the International Union for the Conservation of Nature and Natural Resources (IUCN). Therefore, it is essential to study the ecology of Indonesian bamboo species, given that bamboo is often used by the community.

Distribution of endemic bamboo in Java Island is unique because some species are limitedly found in certain parts of the island (Widjaja 1987). In East Java, Indonesia, Mount Baung Nature Tourism Park (*Taman Wisata Alam Gunung Baung*/MBNTP) is considered an important habitat of bamboo on Java. Results of an inventory work by the Indonesian Ministry of Forestry (1998) showed that there were six species of bamboo in MBNTP, including *Bambusa blumeana*, *B. vulgaris*, *Dendrocalamus asper*, *Schizostachyum iraten*, *Gigantochloa atter* and *Gigantochloa apus*.

Studies indicating the effect of soil factors on plant populations are still rare. Widyatmoko (2006) said that

edaphic variables are important determinants of the abundance and distribution of palm lipstick (*Chyrtostachys renda*). The C/N ratio of soils appears to influence the palm densities and sizes. The relationships between plant communities and environmental factors are among the most fundamental questions contributing to understanding plant species composition and structure in a particular habitat, landscape, and region, as well as understanding the ecological character of plants in their environment (Zhang et al. 2013). About a century back, Brandis (1899) rightly stated that "each species has its particularities and its requirements." In this regard, studies on the effect of edaphic factors on the growth of bamboo population are still insufficient. This research aimed to study the influence of edaphic factors on bamboo's growth in Mount Baung Nature Tourism Park, East Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in Mount Baung Nature Tourism Park, East Java, Indonesia (Figure 1). Geographically, MBNTP is located between 7°49'9"-7°47'23" South Latitude and 112°16'23"-112°17'17" East Longitude. The altitude in this area ranges from 200-501 m above sea level. The average annual rainfall was 2654.10 mm, with an average number of rainy days was 141.05 days.

Vegetation sampling of bamboo

The abundances and densities of bamboo were expressed as importance value index, namely the resultant of the sum of Relative Density, Relative Frequency, and Relative Abundance. Two hundred plots of different sizes were made; 20 m x 20 m plots for trees, 40 m x 5 m plots for saplings, and 5 m x 5m plots for understory. Category of trees and saplings were determined by the size of diameter at breast height (DBH) of woody plants; tree (DBH > 30 cm) and saplings (DBH 5-30 cm). An understory plant is groundcover plant growing on the forest floor which is typically herbs. The observation of bamboo was done to explain the bamboo in the context of the individual that forms the population. Measurement or observation activities undertaken included the number of clumps that were carried out on individual plant and diameter of the bamboo clump.

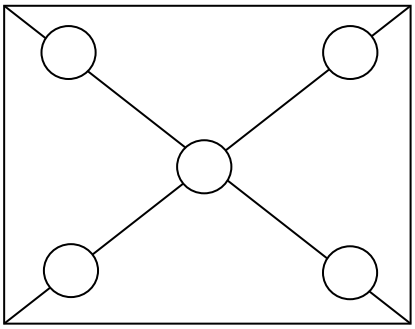

Figure 2. Map of soil sampling points at the research site

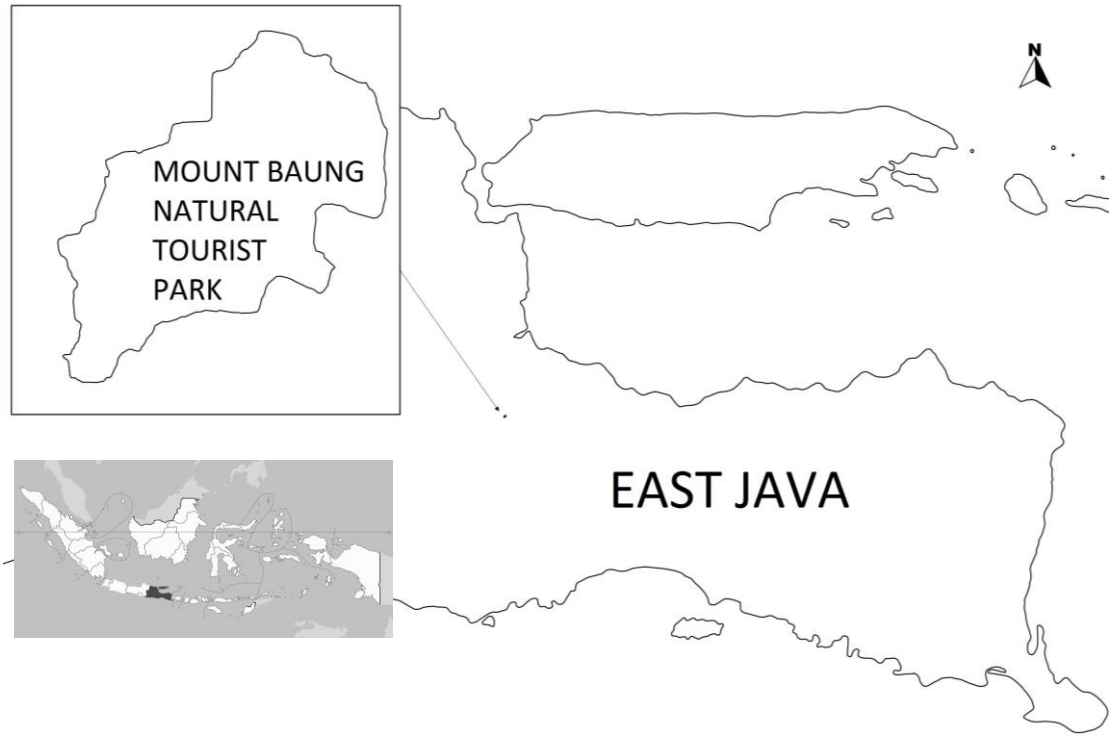

Figure 1. Map of area of Mount Baung Nature Tourism Park, East Java, Indonesia

Soil sampling

Soil sampling was conducted at five points in the form of a diagonal; soil sample from each point was then ground as a composite. Soil samples for analysis of soil physical and chemical properties were taken from the topsoil layer (0-30 cm) and subsoil layers (30-60 cm). The soil physicochemical properties were assessed in the soil science laboratory of Research Center for Soil and Agroclimate, Bogor and were analyzed through the drying stage temperature of 105°C. Soil physical property analyzed included soil texture (sand, silt, and clay), while the chemical properties included Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na), Soil-Cation Exchanges Capacity (CEC), Aluminum (Al), Forums (Fe), Manganese (Mn) and Zinc (Zn). Soil texture analysis was conducted by separation of sand, silt, and clay particles by a quantitative method through the mechanical analysis process. This process consisted of spreading the aggregated soil into single grains, followed by sedimentation. Soil acidity (pH) was measured in soil and water mixture extracts with a ratio of 1: 5, C content was analyzed by Walkley & Black method, while total N was determined by the Kjeldahl method.

Data analysis

The relationship between bamboo and edaphic factor was analyzed using Principal Component Analysis (PCA). The PCA analysis was performed using Minitab 14.

RESULTS AND DISCUSSION

Soil chemical property

The results of soil chemical property analysis are presented in Figure 3. Figure 3 shows bamboo populations were found in soil conditions with soil acidity (pH) ranging from 5.6 to 6.5. This data showed that bamboo could grow on soil conditions with pH levels slightly acidic (Hardjowigeno 2003). The C-organic content of the research area varied from 0.83 to 1.76% which fell into the low category, while soil nitrogen ranged from 0.07-0.18% which was also classified into the low category. C/N ratio was 9-12. According to Tisdale et al. (1993), C/N ratio of <20 indicates that the decomposition process is imminent. The cation exchange capacity (CEC) shows the soil's ability to bind, and exchange between the cation elements controls the availability of several nutrients in cation form and regulates the mobilization of hydrogen ions (pH actual) and Al-dd (potential pH). The content of CEC in the research area was between 10.90-18.52 cmol kg^{-1} which was classified in the medium category. The Ca, Mg, K and Na values in this area were, respectively. 12.40%, 4.66%, 1.23%, 0.09%. Even for potassium was very high.

Soil physical property (texture)

Soil texture was the only soil physical property observed in the present study (Table 1). Table 1 shows soil texture in MBNTP. The study results of soil physical property of soil samples taken from the Gunung Baung area indicate that the average soil texture class belongs to silty clay loam. This soil texture contains more dust, but also a considerable amount of clay content, while the sand content is minimal.

Results of PCA analysis

The Principal Component Analysis (PCA) results on the observed parameters are presented in Figure 4. This figure shows that there were two groups of soil factors that naturally affected the growth of bamboo. The first factor is soil chemical elements such as Al, Ca, Mg, Zn, pH, and Mn which affected the growth of *G. apus*, and especially the Na. The second group of soil chemical element consists of CEC, phosphorus, K_2O, K-Morgan, while the most naturally occurring effect on the growth of some bamboo are: phosphorus. *G. atter* was not affected by any soil chemical properties.

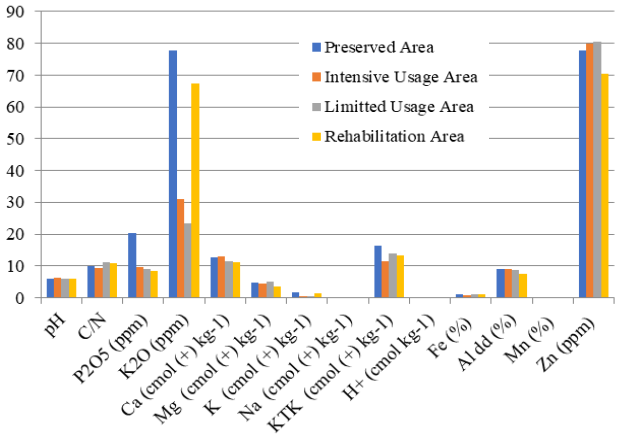

Figure 3. Soil chemical properties of the research area

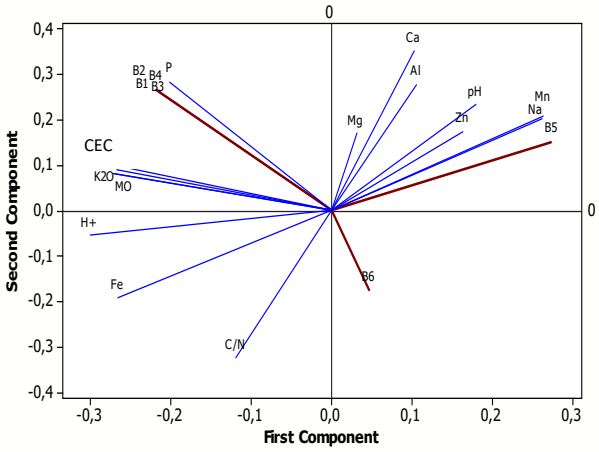

Figure 4. Results of Principal Component Analysis (PCA) of soil chemical properties on bamboos habitat in Mount Baung Nature Tourism Park. Soil chemical properties included soil acidity (pH), Phosphorus (P), C/N ratio, Potassium (K_2O), Potassium-K_2O Morgan (MO), Calcium (Ca), Sodium (Na), Cation Exchange Capacity (CEC), Hydrogen (H^+), Aluminum (Al), Manganese (Mn) and Zinc (Zn). Biotic environmental factors included the number of bamboo clumps: B1 (*B. blumeana*), B2 (*B. vulgaris*), B3 (*D. asper*), B4 (*S. iraten*), B5 (*G. apus*), and B6 (*G. atter*)

Table 1. Soil texture characteristics in MBNTP

Research area (replicates)	Soil layer (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture
Preserved area	0-30	14	51	35	Silty clay loam
Preserved area	30-60	13	59	28	Silty clay loam fine
Preserved area	0-30	12	51	37	Silty clay loam
Preserved area	30-60	12	47	41	Silty clay loam
Preserved area	0-30	8	61	31	Silty clay loam
Preserved area	30-60	8	67	25	Silty clay loam fine
Intensive usage area	0-30	16	52	32	Silty clay loam
Intensive Usage area	30-60	15	51	34	Silty clay loam
Limited usage area	0-30	7	49	44	Silty clay
Limited usage area	30-60	5	53	42	Silty clay loam
Rehabilitation area	0-30	12	58	30	Silty clay loam
Rehabilitation area	30-60	18	52	30	Silty clay loam

Table 2. The abiotic characteristics of bamboo habitat in MBNTP

Species of bamboo	Slope	Soil pH	Temp.	Solar radiation	Humidity	Altitude
B. blumeana	√					√
B. vulgaris					√	
D. asper			√			
S. iraten		√				
G. atter				√		
G. apus				√		

Abiotic characteristics

Characteristics of abiotic factors influencing bamboo growth are presented in Table 2. Data in Table 2 shows several variations of abiotic factors that affect bamboo species in MBNTP. Each bamboo has its own uniqueness in its growth. *B. blumeana was* affected by slope and altitude while *B. vulgaris* was affected by humidity, and *D. asper* was more affected by air temperature. *B. blumeana* and *B. vulgaris* have locally adapted to sloping/hilly terrain areas. The growing conditions of *D. asper* and *S. iraten* were on a slight slant. Gigantochloa genus, i.e., *G. apus* and *G. atter* are in place to grow in fall within the ramps criteria.

Discussion

Data in Figure 3 shows that the bamboo grew in the conditions of land with soil acidity (pH) ranging from 5.6 to 6.5, indicating that this plant can grow in soil with a slightly acid condition (Hardjowigeno 2003). In general, bamboo survives in a variety of soil conditions with a high degree of adaptability, which is indicated by the spread of bamboo, either naturally or intentionally planted, that can be found in flat areas, valleys, hills, and plateaus except for dessert and swamp areas (Pratiwi 2006). The soil pH is assessed either in water: soil mixture (pH H_2O) or in other electrolytes with different ionic strength, like $CaCl_2$ (pH $CaCl_2$) or KCl (pH KCl) (Gavriloiei, 2012). Based on the content of pH (KCl), the soil in MBNTP has a clay content dominated by the negative-colloidal charge. Due to the result of the reduction (ΔH) values against pH KCl and pH H_2O has a positive relationship, it can be concluded that the soil colloids charge is dominated by the negative charge, meaning that the soil has a high sequestering power of elements in soil, especially cations, so the absorption of soil nutrient can be adequate.

Values of C/N ratio in MBNTP ranged from 9-12, which was classified in a medium category. According to Tisdale et al. (1993), the C/N value of < 20 indicates the decomposition process to occur. It is also influenced by the nature of the soil colloids and cations sequestered in the soil. The organic matter quality is related to the provision of N, which is determined by the number of high nitrogen content, low lignin, and polyphenol concentrations. C/N ratio is an indicator to describe the speed of the reform process in the form of organic matter decomposition and mineralization of nutrients that are chemically bound in the form of complex compounds in the body of an organism. Bamboo is a plant species that have high silicate content in leaves as compared to other plant species (Lu et al. 2007); thus decomposition and mineralization of organic matter in this plant species are running very slow.

For Poaceae species, phosphorus is required for the elongation of segment and the development of stem diameter. Moreover, it can strengthen the stem so as not to fall down easily. Figure 3 shows that phosphorus content in the Preserved Area of MBNTP was the highest. In Preserved Area, soil phosphorus content was included in a medium category with an average value of 20.33 ppm, while that in other areas was classified in a low category. The P element in the soil is bound in the form of a phosphate compound, a readily available compound for plants. P, N, and K elements are classified as the primary element, but the P element is absorbed in small amounts as compared to the other two elements (N and K). *D. asper* is a bamboo species with a large stick character. Therefore, this species would require large amounts of phosphorus for its growth. Figure 4 shows that *G. atter* did not have the variety of data variation (indicated by a line on the short axis), so it is not enough to provide information about the chemical elements that are most influencing this bamboo species growth.

Tiongco (1997) said that positive logarithmic relationships occurred between the culm/biomass production and culm height/soil pH/available P/exchangeable cations (K+, Ca++, Mg++)/CEC. The content of each of Ca, Mg, K and Na in the area of Mount Baung was respectively, 12.40%, 4.66%, 1.23%, and

0.09%, which were classified in high category. Soil base cations are closely related to soil pH. Generally, the soil with high pH has high alkaline content. In MBNTP, although soil acidity was close to neutral, the content of base saturation was very high. The presence of soil pH content that was acidic could have come from the slow decomposition of bamboo litter so that when they are exposed to water, they will experience decay that is also running slowly. The high content of silicates in bamboo leaves causes the litter to decompose slowly so that the reshuffle of cellulose from bamboo litter leaves is also running slowly. Thus, this litter can cover the ground for a long time.

Results of Principal Component Analysis performed on 15 essential macronutrients showed that the soil chemical properties of the growing environment of bamboo can be grouped into two main components (Figure 4). Eigenvalues of > 1 indicate this. The two components can explain about 81.4% (i.e. 46.8% by the first component and 34.6% by the second component) of all variability in soil elements observed in the present study. Relatively, the first component had greater information than the second component, although the two components were not substantially different. Based on the analysis of the above components, the followings are the eigenvalue of each component.

Eigenvalues of Bamboo Habitat Index are as follows: PC1 = 0.17 pH- 0.12 C/N-0.2 phosphorus-0.27 Molibdenum + 0.11 Calsium + 0.04 Magnesium-0.27 Pottasium + 0.27 Natrium-0.28 CEC-0.26 Manganese + 0.17 Zinc-0.22 Clumps of *B. blumeana*-0.22 clumps of *B. vulgaris*-0.22 clumps of *D. asper*-0.22 clumps of *S. iraten* + 0.27 *G. apus* + 0.05 clumps of *G. atter*. PC2 = 0.23 pH-0.32 C/N + 0.29 phosphorus + 0.09 Pottasium + 0.08 Molibdenum + 0.35 Calsium + 0.21 Natrium + 0.11 CEC-0.05 hidrogen-0.19 Zinc + 0.28 Alumunium + 0.21 Manganese + 0.18 Zinc + 0.27 clumps of *B. blumeana* + 0.27 clumps of *B. vulgaris* + 0.27 clumps of *D. asper* + 0.27 clumps of *S. iraten* + 0.15 clumps of *G. apus*-0.17 clumps of *G. atter*.

Nonetheless, based on Figure 4, the phosphorus element is an element that was strongly influenced the bamboo habitat, especially for almost all species of bamboo, except *G. apus* which was very strongly affected by the elements such as sodium (Na) and manganese (Mn). Manganese is microelement, which is taken little in plant growth, but it is essential. The effect of phosphorus on the presence of bamboo in MBTNP was highly significant and positive.

Bamboos are planted for hedges and landscaping. Bamboo groves also act as a windbreaker and to prevent soil erosion (Alam 1992). Generally, bamboo growth is affected by temperature (Uchimura 1981) and altitude. Some bamboo is affected by light intensity; however, sometimes the soil factors influence more specific for some particular types of bamboo. Uchimura (1981) said that growth of bamboo was highly correlated with temperature when it overlapped by an annual rainfall of more than 1000 mm year^{-1}. For information, *G. atroviolaceae* can intercept rainwater approximately 84.63% (Sofiah 2011). Additionally, Sikumbang (2010) mentioned that compared to trees that absorb only 35-40% of rainwater, bamboo could absorb rainwater up to 90%. Plant canopy layer that fills the room stems dimensions will be an essential factor in determining microclimate/local bamboo plants. It is important to note that area of leaf blade also affects the amount of interception of rainwater through rain run-off detention.

Bamboos are plants that display rapid biomass growth after long periods of exclusively vegetative growth (Griscom and Ashton 2003), culminating in explosive flowering followed by widespread population death. The size of new culm was determined by the nutrient supply from the rhizome (Ueda 1960). The agronomy/silvicultural trials were conducted on four bamboo species. Four bamboo species responded differently to treatment not only because of their genetic traits but also because of their relative ages. The mature *D. asper* (giant bamboo) produced few shoots, on average c. 1 stalk per standing culm, but they were large if harvested for consumption (reaching 4.5 kg). In contrast, the young (3-7 years old during the trial) *B. blumeana* at the Capiz site produced very few stalks, although the poor soil or some other factors may have had an overriding effect, as average shoot number per clump did not increase during the 5-year course of the experiment (Midmore 2009).

The influence of slope on soil, especially in soil texture, partly determines the levels of available mineral nutrients, and consequently the establishment and spatial distribution of vegetation (Widyatmoko 2010). Based on Table 1, the pattern of bamboo population distribution in MNBTBP was influenced by environmental factors. The slope more specifically determined the dominant species of bamboo in the region, namely *B. blumeana*. Soils on slopping areas tended to be coarser and better drained than those on flat ground where run-off creates accumulations of small soil particles (House 1984; Kessler 2000; Costa et al. 2008). Several studies have shown that soil factors influenced the floristic plant in bamboo-dominated forests. Significant intercorrelations were found between Ca, Mg and organic matter for eleven species of *S. agittaria* (Wooten 1986). Salinity was the most crucial edaphic factor for the distribution and density of *C. americanum*, and the higher its value, the higher its population density. The other elements analyzed seemed to have little or no influence over the population density of *C. americanum*. The analysis did not highlight any edaphic factor as the determinant factor for the height of the individuals of this species in the Massaguacu River estuary (Ribeiro 2011). Meanwhile, the texture of soil in the average research area was silty clay loam (Table 2). This texture soil shows the proportion of soil particle content that contains more dust, but also a considerable amount of clay content, while the sand content is minimal. Based on the analysis, the soil base saturation of the entire area of MNBTBP was of high value. The high value of soil base saturation content is thought to be related to soil texture properties, where, in silty clay loam type, soil colloids are readily bonded within the soil tracking complex, due to adhesion and cohesion between the cations in the soil.

Edaphic constraints may play a role in the floristic of bamboo-dominated forests by shifting the competitive

balance in favor of tree species tolerant of excessive moisture and/or drought or of other characteristics of soils occurring in bamboo-dominated soils, such as reduced soil cations exchange capacity (Griscom 2003). Forest is highly dynamic and its structure and composition change in time and space. Bamboo dominance could be foreseen as a step in this process (Vinha 2011). Studies investigating these topics, as well as the effect of different bamboo species dominance on the abundance and survival of tree species, are of prime importance for understanding the impact of other bamboo species on tropical forest regeneration and the implications for forest management. Further research on ecophysiological characteristics of species regarding edaphic constraints, shade tolerance, growth rate, and traits affecting tolerance for mass-loading is needed to improve our understanding of the bamboo-dominated plant community.

Bamboo is one of the plant species that have high adaptability. Based on research results, one of the edaphic factors that influenced the growing environment of *B. blumeana*, *B. vulgaris*, *D. asper* and *S. iraten* species was the phosphorus element. The phosphorus element affects the existence of bamboo as it plays a vital role in growth activity. Phosphorus can strengthen the culm so as not to fall easily, which is vital for Poaceae family. The presence of *G. apus* was influenced by Manganese (Mn) and Sodium (Na) elements. In soil, manganese dissolves at low soil pH. The higher the soil pH, the solubility of manganese in the soil decreases. The slightly acid soil-pH in Mount Baung Nature Tourism Park may be one factor leading to the high solubility of manganese in the soil. Bamboo species with the densest population in Mount Baung, i.e., *B. Blumeana*, was influenced by environmental factors such as slope. Each bamboo has its uniqueness in its growth. Growths of *G. apus* and *G. atter* were affected by solar radiation.

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Review: Agriculture-industry linkage and technology adoption in Ethiopia: Challenges and opportunities

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Abstract. *Sisay T. 2018. Review: Agriculture-industry linkage and technology adoption in Ethiopia: Challenges and opportunities. Trop Drylands 2: 18-27.* High rate of agricultural growth has far-reaching positive implications for economic development of low-income countries in terms of increasing employment and accelerating poverty reduction. For Ethiopia to achieve middle-income status by 2025 and make substantial inroads against food insecurity, concerted and strategic investment and strategic choices in the agricultural sector are vital. Agricultural linkage encloses generating and transferring agricultural technologies to enhance productivity, reduce loss, and improve the livelihoods of beneficiaries as well as the country's economy. The objective of this paper was to review the current status of linkage between agriculture-industry actors, extent of technology adoption system, challenges and opportunities in Ethiopia. The result of the review study shows that different factors are constraining the system. Most of the agriculture industry linkage and technologies promoted through the extension system and adoption levels are far below the possible expectation in the country. Agriculture research institutions and industries lack effective mechanisms of transferring their technologies to the end users, inadequate technological skilled manpower, poor market linkage between technology multiplication enterprises and technology users and lack of responsible body to transfer technology which becomes the major challenges in Ethiopia. Factors constraining the linkage between stakeholders and technology adoption level of universities, TEVTs, agriculture research institutions, and agriculture sector are wide-ranging from poor linkage between stakeholders and weak involvement of professionals are among the main problems that constrain the system. Weak link between research, education, and extension and the contact these organizations have with farmers is among the main bottlenecks in agricultural technology development, adoption level. Therefore, strong university and research-industry linkage are needed in the country.

Keywords: Adoption, linkage, challenges, opportunities, technology

INTRODUCTION

Agricultural information is necessary for decision-making, and a resource that must be acquired and used to make an informed decision (Kaske 2007). Information and knowledge are powerful engine for development, but the attributes of information largely depend on the effective application of the information and the overall package of the technology. Improved agricultural technologies are central to transformation of farming systems and a path out of poverty in developing countries (Besley and Case 1993). In Sub-Saharan African (SSA) countries where agriculture is the predominant sector that underpins the livelihood of the majority of the poor, increasing technology adoptions, such as new agricultural practices, high-yielding varieties and the associated products such as crop insurance, have the potential to contribute to economic growth and poverty reduction among the poor (Kelsey 2011).

The pathway out of poverty trap of many SSA countries depends on growth and development of the agricultural sector. The main objective of the sustainable development goals is eradicating extreme poverty, hunger and investing in rural areas for inclusive and sustainable rural transformation. This is possible by increasing agricultural productivity through yield-increasing technologies in order to sustain food self-sufficiency. For many years, the government of Ethiopia has been working with extension programs in diffusing agricultural technologies to improve smallholders' crop productivity and farmers' income through surplus crop production. Paradoxically, recent study indicates that farmers' use of main agricultural inputs such as high-yielding varieties is less than 5% (Taffes et al. 2013). The low adoption rate and use can be partly explained by limited access to input credit (ATA 2014).

Agricultural system performance can be improved by having strong linkage between research, education, extension, farmer and other stakeholders. The aims of agricultural linkage enclose generating and transferring agricultural technological packages to enhance productivity, reducing loss, and improving the livelihoods of the beneficiaries in particular and the countries' economy in general. In the last decades, agricultural information has increased rapidly, however, the effective transfer of agricultural information/knowledge is still a big challenge. The main factors affecting the effective transfer of agricultural technological packages to the end-users are knowledge level of the information users, access to information of end users, and readiness of farmers for adoption (Taffes et al., 2013).

Ethiopia has many problems in balancing economic growth as the human population grow rapidly. Therefore to solve these problems, the linkage of agriculture with industry and technology adoption is of great importance. Imbalance between the population growth rate and the agricultural production growth rate is one of the pronounced national problems in Ethiopia and at sub-national level such as Amhara Region. Low-level productivity due to low level of improved technologies utilization and high risk due to adverse environment are among the most frequently mentioned major causes of the country's chronic food security problem. In order to meet the food requirements of the growing population, food grains and other agricultural products have to be increased. The immediately available means to attain the national goal of food self-sufficiency is improving productivity through improved technologies. Improved seeds, fertilizer, farming tools, pesticides, etc. are some of the major productivity-enhancing inputs.

Various factors contribute to the low productivity of the agricultural sector in the country. Of all the barriers, the low level of agricultural technology development and innovative technological package transfer system by smallholder farmers are among the important factors (Kassa 2003). Although agricultural extension has long history in Ethiopia, the coverage is very low and the linkage of the actors of the system is very poor, which is the main reason for low adoption of improved agricultural technology/production systems and inputs (Kassa 2003). The problem of weak linkages, existing gaps and poor inter-organizational relations still exist (Belay 2003). This calls for improvement of the linkage between the different stakeholders of the sector and adoption level so as to improve the livelihoods of smallholder farmers in particular and nations in general. Therefore, the main purpose of the current review study was to assess the status of the existing link between agriculture and industries, technology adoption of the institutions so as to indicate the future intervention areas in the country.

AGRICULTURE AND INDUSTRY LINKAGE IN ETHIOPIA

Ethiopian agriculture development for growth

For Ethiopia to achieve middle-income status by 2025 and make substantial inroads against food insecurity, concerted and strategic investment and strategic choices in the agricultural sector are vital. Concentrations of food insecurity and malnutrition are endemic in rural areas, with a population of six to seven million chronically food insecure, and up to 13 million seasonally food insecure. Over 90% of agricultural output is driven by smallholder farmers. Without expanding the cultivated lands, and given forecast population growth, the average landholding size in highland areas will be reduced to 0.7 ha by 2020, placing further pressure on rural incomes and food security. Agriculture contributes substantially to the overall Ethiopian economy. On a nominal GDP of USD 25.6 billion (World Bank, 2008), 43% was driven by the agricultural sector. Crop production accounts for 29%, with livestock at 12%, followed by the forestry sector with 4 percent. The sector contributed USD 1.4 billion to export earnings with crops and forestry account for 60% of overall export value, livestock for 28%, and the remaining exports is a combination of non-agricultural industry, primarily extractives and industrial production.

Agricultural growth as a driver of development

A high rate of agricultural growth has far-reaching positive implications for economic development of low-income countries in terms of increasing employment and accelerating poverty reduction. High agricultural growth also helps avoid the creation of mega-cities with large slum populations. In order to achieve this rapid agricultural growth with positive economy-wide linkages, however, it is necessary to engage medium-scale farmers, i.e. large enough to adopt new technologies and produce significant marketed surpluses, but small and numerous enough to have spending patterns that drive a vibrant rural non-farm sector. Finally, public and private investments in road, electricity and telecommunications are also needed to reduce marketing costs and enable growth in rural market towns and secondary cities (Stiglitz 2009).

Agricultural development as an input to the industry

Agriculture is the mainstay of Ethiopia's economy. According to the Food and Agriculture Organization (FAO) and the World Food Program (WFP), agriculture sector contributes about 45% to 50% of GDP and provides employment to nearly 80% of the country's population. Its growth is vital to the national economic development and well-being of the population. It produces a wide variety of products. The Government of Ethiopia drew up a long-term industrial strategy in 1994 known as Agricultural Development-Led Industrialization (ADLI). The Government is convinced that agriculture is the engine that can propel the socio-economic development of Ethiopia by providing the basis for industrialization and necessary surplus for the expansion of other sectors of the economy. The ADLI strategy gives priority to the development of agriculture as a primary stimulus for the sustainable growth of agro-industry and is expected to raise productivity in both agriculture and agro-industry through appropriate linkages between the two sectors (i.e. agriculture and industry) as well as management, technology, human resources and various incentive mechanisms. Unfortunately, seven years after the ADLI strategy was formulated, agriculture remains essentially undeveloped. Agricultural research, in particular, which is the backbone of the development and sustainable growth of the sector, does not seem to benefit from the support it needs from agro-industries (FDRE and MOFE 2002).

Agriculture is the foundation of the national economy and plays a major role in the socio-economic development of the country. The government launched the agricultural Development-led industrialization strategy where emphasis is put on linking research with development through well-focused and targeted transfer of appropriate technology to farmers. The agricultural development strategy is aimed at

promoting growth, reducing poverty and attaining food self-sufficiency while protecting the environment through safe use of improved technologies. The agricultural package program is spearheaded through demonstration and provision of improved varieties and required inputs such as improved seeds, fertilizers, and pesticides as well as better access to credit facilities (ICARDA et al. 1999). Moreover, Agricultural Development Led Industrialization (ADLI) sets out agriculture as a primary stimulus to generate increased output, employment and income for the people, and as the springboard for the development of the other sectors of the economy. A 'green revolution'-like intensification of smallholder agriculture was seen as central by the government in implementing the strategy (Keeley and Scoones 2000).

Agricultural Development Led Industrialization (ADLI) and food security in Ethiopia

ADLI is seen as a long-term strategy to achieve faster growth and economic development by making the use of technologies that are labor using, but land augmenting, such as fertilizer and improved seeds and other cultural practices. During the first stage of ADLI, agriculture is aimed to play a leading role in the growth of the economy. But the extremely small ratio of urbanization of the country threatens to make inadequacy of domestic demand a critical constraint. This implies that agriculture has to be made internationally competitive, and that part of its production has to be oriented towards exports. For agriculture to continue serving as an engine of growth in the coming years, through the domestic economy and international trade, there has to progress in terms of commercialization, with more intensive farming, increasing proportion of marketable output and correspondingly decreasing ratio of production for own consumption. Aside from deepening technological progress, it will mean greater market interaction on the part of the farmer. Extension of credit to the small farmer will gain importance with commercialization of agriculture, and give impetus to the establishment of rural banks. Cooperatives play important roles in facilitating input and output marketing as well as in promoting the provision of rural finance. The problem of food security and agricultural growth in pastoral areas is being conceived in terms of the development of the pastoral economy in its entirety (FDRE and MOFE 2002).

Unless industry (secondary-modern goods-producing sectors) and services (tertiary-distributive and other services) grow in conjunction with agriculture (primary – agriculture and allied activities), it is not possible to ensure accelerated growth and sustainable development. In an agrarian economy such as Ethiopia, the resources for the development of the industrial sector need to be generated by primarily creating strong bondage between agriculture and industry and subsequently exploiting these linkages via the concerted efforts of non-state actors, particularly the non-peasant private sector (FDRE and MOFE 2002). Core of ADLI are increasing agricultural output and productivity, increasing industrial output and productivity, and close input-output linkage between the two sectors (Figure 1).

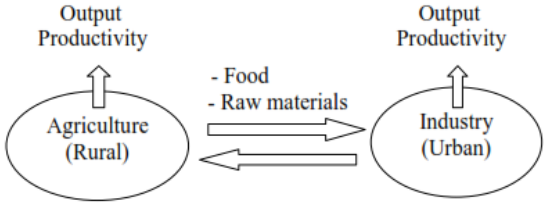

Figure 1. Commercialization of agriculture (left side); machinery, fertilizer, other agriculture inputs, consumption goods and export orientation, labor intensiveness (right side)

Formulation of Agricultural Development Led Industry (ADLI)

An Economic Development Strategy for Ethiopia (1994) implies productivity improvement of smallholder agriculture and industrialization based on utilization of domestic raw materials with labor-intensive technology. The strategy is akin to what is known as ADLI, framed into the Ethiopian context. Two-pronged approaches include: (i) Smallholder agriculture – better agronomic practices, more labor use, research and extension, technology transfer, rural infrastructure; (ii) Extensive mechanized agriculture and intensive farming – efficient land allocation, labor supply, health and road facilities for new lands, research and training, quality, marketing, etc. Besides direct input-output links (Core ADLI), the two sectors may have the following links, which may occur directly through financial system (Figure 2).

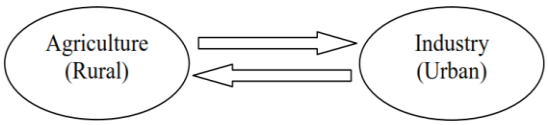

Figure 2. Labor supply, agro/land tax, price control, export earnings (left side); and production support, food and service delivery, agricultural protection, public investment (right side)

AGRICULTURAL LINKAGE AND TECHNOLOGY INNOVATION SYSTEM IN ETHIOPIA

Definition of technology

Any definition of technology encompasses a wide range of phenomena. In the broadest sense, technology is defined as the translation of scientific knowledge into machines, tools, mechanical devices, instruments, innovation, procedures and techniques to accomplish tangible ends, attain specific needs, or manipulate the environment for practical purposes (Shahin 2004). New agricultural technology is generally a bundle or package of different technological elements, such as improved production and productivity, plus the technical practices and skills needed for their effective use (SAMY 1998; Shahin 2004).

Linkages and linkage mechanisms

According to Hagmann et al. (2002), linkages between service providers and service delivery systems are critical to 'make the system work as a system'. To bring sustainable

agricultural development, partners within the sector must develop joint collaborative action to ensure efficient and effective input/service delivery system. To support actors in the sector, the Regional Research Extension, Farmers Linkage Advisory Council (REFLAC) started to strengthen the linkage among multiple actors. Potential actors like BoARD, Research stations, and FREG have participated in joint planning for action. The main aim of the council is to promote farmers participatory research through strong collaborative action by potential actors and to develop area-specific technologies through adaptation trials and farmers-to-farmers' seed exchange specifically on cereal and pulse crops. The Regional Rural Capacity Building Project (RCBP) is in charge of facilitating joint activities carried out by partners through budget and material support, i.e., capacity building, workshops, joint monitoring, and evaluations, for members of advisory council and FREG.

Linkages between technology and agriculture

Generation of technology is not an end by itself. It must be utilized by end-users. This can be realized through the presence of effective linkage among the major stakeholders in agriculture, agricultural knowledge, and information system. Linkages between major institutional actors in agricultural knowledge and information system are widely recognized as essential for an effective flow of technology and information between research, extension, and farmers. The types and nature of linkage between actors within the agricultural knowledge and information system directly influence the production and productivity of smallholder farmers. It is commonly recognized by agricultural knowledge and information system stakeholders that poor performance of the system is often related to linkage problems (Akalu and Adgo 2006).

Linkages and linkage mechanisms can be strong or sometimes poor or not working. The reasons for poor linkages are weak management capacity, inappropriate organizational structure, unfavorable reward systems, time and money constraints, inappropriate planning, little or no monitoring and evaluation of the process of interaction and different organizational cultures, expectations and operating procedures. Therefore, inter-organizational linkages should be assessed to maintain better aspects and negotiate improvements in existing linkages, linkage mechanisms and develop new relationships. Decisive factor that can influence the effectiveness of linkages includes intensity and formality of contacts, ways of contacts (one way or two), stakeholders' awareness of other stakeholders function, relevance of services, urgency, timeliness, accessibility, quality of communication, control over the relationship, and mandate of representatives (ICRA 2010).

Causes of poor adoption by agriculture industry of technologies

The majority of the agriculture industries do not link with local agriculture research industries which is a sign of serious disarticulation of the national system of innovation in Ethiopia. This situation is a serious constraint to the adequate growth of both agriculture and agro-industry in the country (Akalu and Adgo 2006). The slight improvement in the co-operation between agriculture industries and agriculture research industries after 1999 may be ascribed mainly to the awareness created through a workshop organized by EARO in November 1999.

Factors preventing the agriculture industries from forging links with local agriculture research industries are varied. Lack of information is the most overwhelming challenge as indicated by 74% of agriculture-industries that do not have any kind of collaboration with the agriculture research industries. According to 51% of the non-collaborating agriculture-industries, the second most important challenge is the poor relations between the agriculture-industries and local agriculture research industries. Only 11.4% of the non-collaborating agriculture-industries indicates that the technologies developed by local agriculture research industries either fail to respond to their needs or are irrelevant to the agriculture-industries. Agriculture research industries lack effective mechanisms of transferring their technologies to the end-users. They are not successful in communicating effectively with agriculture-industries and most likely with farmers and, therefore, do not take appropriate actions that are conducive to the adoption of their technologies (Hagmann et al. 2002).

ADOPTION OF NEW TECHNOLOGIES

Adoption is referred to as the degree of use of new technology in long-run equilibrium when a farmer has all the information about the new technology and its potential. Adoption refers to the decision to use new technology, method, practice, etc. by a firm, farmer or consumer. Adoption of the farm level (individual adoption) reflects the farmer's decisions to incorporate new technology into the production process. On the other hand, aggregate adoption is the process of spread or diffusion of new technology within a region or population. Therefore, a distinction exists between adoption at the individual farm level and aggregate adoption, within a targeted region or within a given geographical area (Feder et al. 1985).

Adoption of technological innovations in agriculture has attracted considerable attention among development economists because the majority of the population of less developed countries derives their livelihood from agricultural production and new technology, which apparently offers opportunities to increase production and productivity (Feder et al. 1985). Agriculture progresses technologically as farmers adopt innovations. The extent to which farmers adopt available innovations and the speed by which they do so determines the impact of innovations in terms of productivity growth (Diederen et al. 2003). If innovation is modified periodically, however, the equilibrium level of adoption will not be achieved. This situation requires the use of econometric procedures that can capture both the rate and the process of adoption (Getahun et al. 2000).

Process of agricultural technology adoption in developing countries

Literature on agriculture highlights two major drivers of successful agricultural technology adoption in developing countries: (i) the availability and affordability of technologies; and (ii) farmer expectations that adoption will remain profitable—both of which determine the extent to which farmers are risk-averse (Foster and Rosenzweig 2010). A number of factors drive the above expectations, ranging from availability and size of land, family labor, prices and profitability of agricultural enterprises, and peer effects. The conceptual framework presented here highlights the various pathways through which different factors influence household decisions to adopt agricultural technologies.

Based on extensive studies in Ethiopia, it has been shown that life-cycle effects are important drivers of agricultural technology adoption (Admassie and Asfaw 2004). In particular, younger as well as much older household heads are risk-averse and are less likely to adopt new technologies. On the other hand, the availability of adult family members within households may facilitate the process of technology because most farming households cannot easily acquire hired labor due to liquidity constraints.

Drivers for adoption of agricultural technologies and practices in Ethiopia

Adoption of improved technologies offers a myriad of potential advantages for increasing productivity and income for smallholder farmers. However, none of these advantages are single or immediate drivers for adoption of agricultural technologies by smallholders. Rather, there are many pushes and pull factors that force, encourage or discourage households to use improved technologies. Various models and approaches have been attempted and tested to identify drivers of adoption of technologies by potential clients (Zaltman et al. 1973; Rogers 1995). Some schools of thought approach the issue by combining the clients, technology attributes, and institutional factors (Solomon et al. 2011) to understand the drivers of adoption and what factors drive its speed of diffusion and the path it follows.

Understanding adoption remains a challenge and drivers of adoption are poorly understood. Studies have shown that the misconception of adoption prevails both at micro level where technologies are promoted and at vertical scaling where technologies are generated in institutional settings (Doss 2006). Different studies have been conducted on adoption of agricultural technologies in Ethiopia (Alemitu 2011; Hailu et al. 2014). However, many of them focused on a single commodity or technology and did not consider the possible inter-relationships between the various practices and intensity of adoption of a package of technologies. Agricultural technologies include all kinds of improved techniques and practices that affect the growth of agricultural output. The technologies and practices that were assessed for adoption are a selection of extension packages as promoted by the extension system and implemented at grass root levels. Four agricultural technologies have been considered for developing a new adoption index for crop technology. These include (i) seeds of high-yielding varieties, (ii) inorganic fertilizers, (iii) pesticides, and (iv) row seeding. Similarly, to assess dairy technology adoption, a composite index of improved breed dairy cow ownership, improved feed and forage utilization and use of Artificial Insemination (AI) services was employed.

Empirical review of the literature on technology adoption in developing countries reveals that the various factors that influence technology adoption can be grouped into the following three broad categories. Firstly, the factors related to the characteristics of producers, i.e., the farmers include: education level, experience with the activity, age, gender, level of wealth, farm size, plot characteristics, labor availability, resource endowment, risk aversion, etc. Secondly, the factors related to the characteristics and performance of the technology and practices include: food and cash generation functions of the product, the perception by individuals of the characteristics, complexity and performance of the innovation, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment, local adoption patterns of the technology, the susceptibility of the technology to environmental hazards, etc. Thirdly, the institutional factors include: availability of credit, the availability, and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure, extension support, etc. Enabling policies and programs, market linkages, access to institutional support and credit were found to play a positive role in stimulating farmer investment in and adoption of sustainable technologies (Shiferaw et al, 2009). A fourth category is a biophysical environment that many studies also find to be an important conditioning factor in adoption of agricultural technologies (De Graaff et al. 2008; Solomon et al. 2012).

The importance of adoption of new technologies

The increasing complexities of environmental problems are likely to increase the necessities of new agricultural technologies that can be used to minimize the potential contribution of negative environmental consequences of agricultural production. Climate change will affect crop and livestock yields worldwide, which will lead to change in food and fiber consumption, prices of agricultural commodities, and farm income (USDA 2014). Technology adoption practices can include good agrarian practices, irrigation scheduling, conservation tillage, organic farming, erosion reduction, nitrogen fertilization and plastic-covered horticulture (Bertuglia et al. 2006).

A study by Maredia and Minde (2002*)* explored the relationship between profitability of Agricultural technologies and their adoption by farmers in Eastern Africa. The study showed that some profitable technologies, such as improved cassava varieties in Uganda and improved coffee varieties in Kenya, were adopted. Some other technologies that were not fully adopted or had been restricted to on-farm demonstration plots included wheat variety and hybrid maize in Ethiopia and the application of inorganic fertilizer on maize in Kenya. The lower adoption level was related to non-technological

constraints (e.g. infrastructure, policies, input/output markets, and adverse climatic conditions) which reduced profitability and adoption of new technologies. For this reason, there is a need for continuous efforts to supply technologies that are adapted to the prevailing environmental conditions.

Factors affecting adoption

Technology adoption is important because it is a means that allows people to participate in a rapidly changing world where technology has become crucial to their lives. The word "adoption" refers to the stage in which technology is selected for use by an individual or an organization. Besides, technology users differ widely in their attitudes towards technology. According to this source, technology adoption consists of four steps: First, technology adoption requires awareness. At this step, the potential users get adequate information about the benefits of the technology. The second step is assessment. At this level, the expected users evaluate the usefulness and usability of the technology, and the ease or difficulty of adopting. This is followed by acceptance or refusal of the users. At this stage, they decide to acquire and use the technology, or not. The fourth stage is learning. If they decide to use the technology, the users need to develop the skills and knowledge required to use the technology effectively. A study by Gabre-Madhin and Haggblade (2001) found that large commercial farmers adopted new high-yielding maize varieties more rapidly than small farm holders.

Koundouri et al. (2002) argue that farmers' decision to adopt new technology is affected by risk factors that are related to production risk and how the new technology can change the amount of production and profitability of the farmers. Kosarek et al. (2001) also found that farmers' decision to adopt hybrid maize was determined by the expected returns (i.e., profitability) of the technology, the availability of hybrid seed, and risks associated with the expected outcomes of the new technology. The role of factors that influences adoption decisions is critical to successful agricultural development. Different factors determine the adoption of different agricultural innovations and technologies. Beliefs and perceptions of farmers, communities, and absence of institutional innovations have impact on adoption decisions. There are risk and uncertainty factors for small-scale farmers in adopting new technologies.

STAKEHOLDERS IN RURAL INNOVATION IN AMHARA REGION

Stakeholders involved in different rural innovation activities

Technology generation, technology experimentation, technology diffusion, technology learning and training, input supply, value addition, and financial support in Amhara Regional State are mapped in (Figure 3). The stakeholders are mapped according to the scale of involvement (user group, local, regional and national) and the role they play in rural innovation. It was found that the level of stakeholders involved in technology generation in Amhara Region ranged from national to regional level. However, there was no stakeholder involved in technology generation at district and zone levels, except at farmer level, where focus was given to technology experimentation and diffusion (ICRA 2010). Most of the stakeholder organizations were involved in technology learning and training at different levels followed by those involved in technology generation and diffusion. The number of stakeholder organizations involved in value addition (agro-processing) is very few, followed by those involved in input supply and financial services (Figure 3). In fact, Amhara Region is one of the regions in the country where there is surplus agricultural production, although there are areas in the region that are not yet self-sufficient. The results suggest that although the region could increase its production and productivity through technology generation, experimentation, and diffusion, the development of the agriculture sector is constrained by a lack of actors involved in value addition practices (ICRA 2010).

Most of the stakeholder organizations are very much interested in increasing agricultural production and productivity through generating, disseminating and supplying agricultural technologies/inputs (Figure 3). Others are interested in protecting the environment, increasing income of farmers, building their capacities and providing quality services to farmers (ICRA 2010).

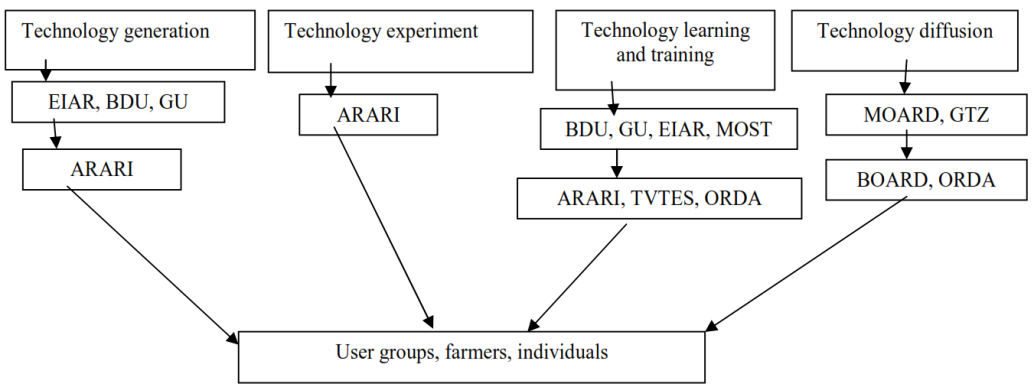

Figure 3. The level of stakeholders involved in technology generation in Amhara Region from national to regional level

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Experience in linking stakeholder organizations in Amhara Region

Technology generation as the main component of technology development and research coordination was started in the country in the 1960's (EARO 1998). Technology transfer and linkage remained as peripheral responsibilities. In addition, poor participation of farmers and other actors in the platforms, absence of decision making power of the platforms due to lack of legalized authority, poor documentation, lack of clarity in roles and responsibilities given to stakeholder organizations, lack of a monitoring and evaluation system, lack of incentives-especially for facilitators, lack of institutional memory in the stakeholder organizations and in the platforms because of high turnover of staff and committee members, poor coordination/facilitation, professional bias and continued top-down approach were serious problems observed in the efforts of technology transfer and linkage practices.

Reasons for poor institutional linkage are weak management capacity, inappropriate organizational structure, unfavorable reward systems, constraints on time and money, inappropriate planning, little or no monitoring and evaluation of the process of interaction and different organizational cultures, expectations and operating procedures. The weaknesses of earlier platforms were transferred to the next generation mainly due to the fact that new platforms were created without due evaluation of previous ones. Hence, any attempt that wishes to improve linkages and enhance multi-stakeholder rural innovation process in Amhara Region should consider and solve the problems indicated above but also strengthen existing and/or new platforms (e.g. Farmers Research and Extension Groups and ARDPLAC) (ICRA 2010).

Agricultural research and extension linkages in the Amhara Region

The term linkage is a broad range of collaborations and exchange of useful information among all actors of the technology generation, dissemination, and utilization system. Earlier empirical studies in developing countries have identified weak links between research and extension as the major factor limiting the flow of information, knowledge, useful new technologies, and resources among actors in the technology-delivery-utilization system and recommend measures to overcome the widely acknowledged weaknesses (Belay 2002; Anderson and Feder 2004).

Linked with the country's first Growth and Transformation Plan (GTP I), which was launched in 2010, the issue of research-extension linkage has received momentum. The plan targets the use of improved agricultural technologies along with transformation of the national agricultural technology delivery mechanisms. The national seed system is mainly considered as one of the key interventions in the transformation of the agricultural sector and also to achieve the target of doubling agricultural production by 2015 (MoFED 2010). This requires designing and implementing new and strengthening previous approaches in the agricultural research and development endeavors to ensure improved availability of agricultural technologies along with timely delivery to end users, farmers, and pastoralists.

All the necessary organizations and support services related to the generation of knowledge and technology, input delivery, advisory service, and marketing and credit services are in place. But these actors all function in a largely uncoordinated and fragmented manner. According to Havelock (1986), cited in Kassa (2008), coordination or linkage symbolizes two systems connected by messages to form a greater system. Agricultural research and extension are examples of two systems that can be linked by information flow and feedback (Munyua et al. 2002). Setting up the institutional linkage to foster proper information flow and effective collaboration is the most serious institutional problem in developing research and extension programs. The linkage between research and extension systems plays a significant role in the generation and dissemination of appropriate technologies. Strengthening research and extension linkages must mean cultivating greater and more effective interaction among the stakeholders in the agricultural sector. Past efforts and the current status of linkage between agricultural research and extension, as well as among the whole range of actors involved in agricultural commodity value chains in Ethiopia, with a focus on the Amhara Region.

Technology adoption in Amhara Region

Feed chopping technology adoption

Traditionally, the farmers provide their animals with all feeds without chopping. Maize stalk, the major feed in the areas, is given to the cattle as it is and sometimes little chopping is done. It actually results in great wastage but it is used for energy. In case of chopping of maize stock, it takes 2-3hrs to chop a feed sufficient for four cattle. In general, it has a great contribution since it reduces volume for both transportation and piling. The technology is best suited for transportation of feed. However, they indicated the need to create awareness to the larger community during grass harvesting, create conditions where community piling could be done in a specific place, continuous monitoring, and evaluation by local experts (Dagninet Amare et al., 2016).

Milk churns technology adoption

The horizontal churn is preferred for reduction of labor (tiresome) and possibility to be handled by even the men and young family members (Figure 4). Reduction of burden on women as in traditional methods is preferred as the women who would properly do that and its capacity to separate more butter than the traditional methods as other benefits of the technology. The reason for better production of butter is attributed to rotation of the whole milk at the same time that is not possible in traditional systems. The farmers confirmed that churn operation is simple. Further, the most vital advantage of churn is enabling extraction of butter that is marketed easily than milk. This is very crucial especially during fasting days and months where milk is mostly wasted (Dagninet Amare et al. 2016). The quality of butter extracted using modern churn is thought better as the churning leads to better drying. It takes on average 38mins and 23mins to extract butter using the modern churner for milk of same size, summer, and winter.

Figure 4. Milk churn technologies

Adaptive research to link research, extension and rural households for technology adoption

Given the high variability of agro-ecological zones, risk, and resource constraints facing rural households, there is a need for adaptive research that takes into account the diversity of conditions facing rural households. Establishing systematic linkages between research, extension, and rural households is an effective means of generating technologies appropriate for these conditions. Researchers must have frequent feedback about what is and is not working in terms of benefits to farmers. Rural household members and extension agents can not only provide that information but are often the best source of ideas on how to adapt technology to local conditions. In addition, linkages involving rural households to set the research agenda help to ensure that new technologies are not only technologically viable but indeed address priority problems as perceived by rural households who are the ultimate users of technological solutions (ICRA 2010).

AGRICULTURAL TECHNOLOGIES UNDER CONSIDERATION

DeJanvry et al. (2011) stated both yield-increasing and cost-saving technologies are reducing the costs per unit of outputs. Yield-increasing technologies also allow for higher gross output if some inputs (especially land) are limited. Examples of yield-increasing dairy technologies include improved dairy breed and improved feed. Cost-saving technologies may also include new dairy technologies that require fewer complementary inputs and cultivation practices that could produce equal results with less effort. Risk-mitigating technologies help to minimize the risk of very bad outcomes in times of unfavorable environmental conditions, but might not increase yield in times of favorable conditions. Some examples of risk-mitigating technologies and conditions under which their impacts might not be observable are drought-and disease-resistant cattle breed and livestock vaccines inoculation. These technologies help increase the quality of outputs in some respect even if yield does not improve. These types of technologies differ from the others in that the main benefits accrue to consumers. The impact of quality-improving innovation is difficult to evaluate, in part because the channel of transmission from the availability of the new variety to the manifestation of benefits involves several actors. Adoption by consumers requires that producers have already adopted and produced the variety so that it is available to consumers, and that consumers have chosen to consume it (DeJanvry et al., 2011).

OPPORTUNITIES TO IMPROVE THE PERFORMANCE OF AGRICULTURE

The existing government policies are considered to be in line with the CSOs and NGOs goals to bring about the smallholder farm development and ensure food security of the rural households. Over the last few years, the government's agricultural development strategy emphasizes market orientation and commercialization of smallholder agriculture. Hence, interventions that would support market creation and enhance market access have gained attention. Some NGOs have started to facilitate market functioning and value-adding through farmers' cooperatives and unions. The fact that there is a huge gap between the need and level of technology used by the smallholder farmers means that there is an opportunity for CSOs to operate towards filling this gap. It implies support for technology multiplication and training of farmers on how to multiply selected and adaptable agricultural technologies. Currently, although there is a high demand for improved agricultural technologies, the supply of inputs like improved seed does not meet the demand. Smallholder farmers can increase their income and food security if CSOs will support them to produce selected clean seeds and connect them to the market so that they can sell them (Berhanu et al. 2006). Market involvement increases the income opportunity of households and increases the adoption of agricultural and conservation technologies (Amsalu and de Graaff 2006). The positive association between poor access to market and adoption of improved breeds and feed is likely to be due to poorer households' access to NGO credit and extension programs in remote areas, which was the case also in the study by Benin et al. (2003). Improved access to irrigation through intervention in this area is another positive predictor of crop and livestock technology adoption (Wubeneh and Sanders 2006).

MAJOR CHALLENGES OF POOR ADOPTION BY AGRICULTURE INDUSTRY OF TECHNOLOGIES

The Ethiopian agricultural research system could not be as effective as expected for it has not been demand-driven and not able to solve the complex problems of the agricultural sector. It was indicated that due to lack of proper coordination among the institutions and organizations that provide development services for the sector and stake-holders at large, meaningful changes and improvement could not be attained (Berhanu et al. 2006). The effective development of technology and dissemination of the knowledge/information was obtained from the research challenged by different factors. According to Day et al. (1994) lack of effective communication is among the major barriers in the execution of research, dissemination of results to the desired user, and effective application of the

technology as proved by research. The absence of effective communication about the technologies might result in poor decision making, delay in the planned activities, and failure and deficiencies in the dissemination of research results thereby the technologies remain without use for the desired objectives/impacting the end user (Day et al.1994). This shows the importance of having strong linkage between the different information/knowledge system partners; having good linkage between stakeholders ensures the transfer of information and knowledge among the different stake-holders properly and helps to achieve the desired objective.

Weak link between research, education, and extension and also the contact these organizations have with farmers is among the main bottlenecks in agricultural technology development, transfer, and adoption level and thereby reduce the contribution of the technologies to development (Van Crowder and Anderson 1997). Government policy and organizational structure also affect the linkage between the different parties in the agricultural sector. This is because the different groups/members in the linkage/ information transfer system act in accordance with the policy. According to Van Crowder and Anderson (1997), interaction among different actors helps to produce better knowledge different from those produced by one actor alone. Moreover, Hall et al. (2001) suggested the need for collaborative relationships between public and private, and research and non-research organizations to assure successful technology development.

CONCLUSION AND RECOMMENDATION

From this review, it is possible to conclude that, a high rate of agricultural growth has far-reaching positive implications for economic development of low-income countries in terms of increasing employment and accelerating poverty reduction. The Government of Ethiopia draws up a long-term industrial strategy (Agricultural Development-Led Industrialization) in 1994. Increase agricultural output and productivity, increase industrial output and productivity and close input-output linkage between the two sectors are the core of Agricultural Development-Led Industrialization. Based on this review, it is concluded that strengthening the link between stakeholders, enhancing the innovation of the sector and involvement of professionals in the system are the basis to improve the efficiency of the system. Having a strong linkage between research, education, extension, farmer and other concerned stakeholders has the power to improve the performance of the agricultural system. Yet, collaboration among universities, research institutes, TVET colleges, and industries was weak.

Agricultural linkage encloses generating and transferring agricultural technologies to enhance productivity, reduce loss, and improve the livelihoods of beneficiaries as well as the country's economy. Technologies need to be properly packaged to meet the needs of the target clients and achieve the desired level of productivity. Linkages between major institutional actors in agricultural knowledge and information system are widely recognized as essential for an effective flow of technology and information between research, extension, and farmers.

Majority of the agriculture industries do not link with local agriculture research industries. Most of the agricultural technologies promoted through the extension system and adoption levels are far below the expectation. Agriculture research industries lack effective mechanisms of transferring their technologies to the end users. Most of the agricultural technology adoption was conducted focusing on a single commodity or technology, and do not consider the possible inter-relationships between the various practices and intensity of adoption of a package of technologies. Lack of responsible body to transfer technology and no attempt of impact assessment after technology is transferred to users are the major challenges. Existing poor linkage of agriculture-industries with local agriculture research industry is a serious constraint to the adequate growth of both agriculture and agro-industry in the country.

Factors constraining the linkage between stakeholders and technology adoption level of universities, TEVTs, agriculture research institutions and agriculture sector are wide ranging from poor linkage between stakeholders and weak involvement of professionals in the system. Weak link between research, education, and extension and the contact these organizations have with farmers is among the main bottlenecks in agricultural technology development, transfer and adoption level. Thus, several recommendations are suggested as follows. (i) There should be an action plan so as to effectively increase technology adoption and strengthen agriculture and industry in Ethiopia. (ii) Inter-organizational linkages should be assessed to maintain better aspects and negotiate improvements in existing linkages, linkage mechanisms and develop new relationships. (iii) Establishing systematic linkages between research, extension, and rural households is an effective means of generating technologies. (iv) Further study of the linkages between agriculture and industry and agriculture and research industry is needed. (v) Impact assessment of the transferred technology needed to bring about on the user's livelihood and different feedback mechanisms can be used to do so. (vi) Therefore, strong university and research–industry linkage is required in the country.

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Assessment of the rates of thiocyanate in treated and untreated red and brown finger millet (*Eleusine coracana*) cultivated in Mogotio Area, Baringo County, Kenya

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Abstract. *Chebet SJ, Nawiri M, Murungi J. 2018. Assessment of the rates of thiocyanate in treated and untreated red and brown finger millet (*Eleusine coracana*) cultivated in Mogotio Area, Baringo County, Kenya. Trop Drylands 2: 28-34.* Finger millet (*Eleusine coracana*) is a significant African primary diet crop in the tropics. But, the plant contains cyanogenic glycosides which can be easily altered to thiocyanate, impeding the absorption of iodine and eventually causing goiter. People of Mogotio, Kenya usually cultivate the red and brown varieties of finger millet. Therefore, this study aimed to assess the rate of thiocyanate in treated and untreated finger millet in Mogotio so as to mitigate goiter risks in the region. The rates of thiocyanate were examined from the finger millet in the form of dried, germinated or immersed beans, or in the form of fresh, fermented or cooked flour. The green and dried leaves of the plant were also examined for thiocyanate. Samples of the red and brown varieties of finger millet were arbitrarily picked out from the cultivators in the area. Thiocyanate content was examined utilizing UV-VIS spectrophotometric detection. ANOVA and independent T-test were utilized to analyze data. SNK test was utilized to do the separation of means. The results showed that the rates of thiocyanate content in the red finger millet were between 43.48±1.56 to 4.28±0.5 mg/kg with the highest rates was in fresh dried beans followed by germinated ones and the lowest rates were in cooked flour. While in the brown finger millet, it was between 53.30±0.78 to 4.96±0.40 mg/kg with the highest rates was in germinated beans and the lowest rates were in cooked flour. Green leaves held 31.69±0.71 mg/kg while the dried ones held 8.80±0.14 mg/kg. The results showed significant dissimilarities between the rates in the beans and that of in the flour ($p< 0.001$). They also showed that the thiocyanate content in finger millet samples was within the recommended rates (100 mg/kg), but the frequency of intake may still give a risk to health. Therefore, it is suggested to encourage the cooking of finger millet before processing as this treatment decreases thiocyanate rates.

Keywords: *Eleusine coracana*, Kenya, Mogotio, red and brown finger millet, treated and untreated

INTRODUCTION

Goiter is an intumescence on the thyroid gland. Its establishment is critically associated with the balance between iodine and thiocyanate. Adwok (2006) reported that more than 5% of the population of the world suffer from goiters. Many of these are related to various diseases and are considered a crucial communal health issue. Gaitan (1989) stated that although 300 million people with goiter settle in less highly developed countries where iodine inadequacy is usual, 100 million individuals with goiter settle in more highly developed countries where goiter keeps on to happen in particular regions, despite iodine prophylaxis. Elnour et al. (2000) claimed that in Africa, goiter is endemic in many countries such as Congo, Uganda, Kenya, and Sudan, in which the commonness is as high as 81% in some parts of these countries.

Toure et al. stated that a goitrogen is discovered in some African diets (2003). Millet (*Eleusine, Pennisetum, Setaria, Echinochloa,* and *Paspalum)* is a fount of thiocyanate whose goitrogenic influences are additive to those of the C-glycosyl flavanol (C-GF) (Makokha 2002). Thiocyanate and isothiocyanate have been shown as the goitrogenic principles of cyanogenic plants (Chandra et al. 2004). Millet and sorghum are founts of dhurrin which upon hydrolysis produce cyanide, sugar and ketone or aldehyde (Saidu 2004). After intake, these glycosides can be easily altered to thiocyanate by widespread glycosidases and the sulfurtransferase enzyme (Chandra et al. 2004). The highly potent thiocyanate is involved in the high cases of goiter in millet and cassava eating inhabitants (Toure et al. 2003). The intake of pearl millet is regarded as one of the factors responsible for high occurrences of goiter in rural inhabitants (Gaitan 1989). In Sri Lanka, the goitrogenic influences of the commonly utilized finger millet (*Eleusine coracana*) were accredited to three types of C-GF. Epidemiological attestation implies that millet might have significant role in the etiology of endemic goiter. In Sudan, a traditional fermentation procedure of two pearl millet cultivars cultivated in the area altered their effects on the weight of the thyroid gland and thyroid hormone profile in rats (Elnour et al. 2000). Millet's goitrogenic agent is obviously related to the bran and endosperm fractions and might be connected to the beans' high proportion of minerals (Klopfenstein et al. 2012). Nonetheless, the plant is a major source of energy, protein, vitamins, and minerals such as potassium, iron, zinc, copper and manganese (Ocheme 2007).

Before being cooked, millet can be treated by desiccation, immersing, germinating and fermentation

(Ikemefuna 1994). Dried beans are usually crunched to fresh flour which is utilized directly to make thin or thick porridge (cooked flour) or to be fermented before cooking process. Steeping of cereal beans in water followed by germinating them is a well-known household practice in developing countries including Kenya (Chove and Mamiro 2010). Sprouting decreases the high viscosity and water-binding characteristic of starch-based porridges. As soon as the bean seeds are dried, changes happen to result in partial breakdown of storage components, such as starch and proteins. The starch nature of the non-germinated beans enables these foods to absorb so much water, yielding a thick porridge (Onyeka and Dibia 2002). Dilution of the porridge enhances bulk and causes the diet more arduous for infants to consume in one sitting. The bulkiness of the porridge restricts sufficient amount of nutrient consumption by the infants. Thus, germination is mainly utilized to lower dietary bulk in beans because it converts remarkable amounts of starch, which is principally responsible for the viscosity in bean gruels, to sugars and short-chain oligosaccharides. These methods of processing, however, affect thiocyanate rates (Traoré et al. 2004).

Finger millet is the second most significant diet plant in Mogotio, Kenya after maize. Mogotio is located in the lower end of Baringo County at 900-1000 m above sea level. The area is mainly semi-dry land. Annual rainfall in this zone is from 400 to 750 mm. The little and erratic rainfall limits successful dryland cultivation to drought-resistant plants such as *E. coracana* and sorghum (Peter 1992). Finger millet varieties are based on their bean colors from white, orange, red, brown, purple to almost black, but farmers in the area plant the red and the brown varieties. Because of the serious drought, International Crops Research Institute for the Semi-arid Tropics (ICRISAT) together with Egerton University has produced the advanced varieties of finger millet to be cultivated in the area during the March and June rains (ICRISAT 2011). Millet is peeled and milled to produce flours, grits, and peeled whole beans. These products are utilized to prepare primary foods such as thin and thick porridges, bread and steam cooked products. The bean is also utilized to make alcoholic beverages, non-alcoholic beverages, and snacks. The husked bean of the plant has a nutty flavor and can be consumed whole after being roasted or cooked. The green, dry leaves and the straw are utilized as animal feed so that the whole plant is utilized (Tatham et al. 1996). Despite cases of goiter recounted in Mogotio, finger millet keeps on to be one of the favorite diet plants. As such this calls for investigation of thiocyanate rates in finger millet cultivated in this region.

The objectives of this research were: (i) To ascertain concentration of thiocyanate in the freshly dried, germinated and immersed beans of the red and brown finger millet from Mogotio in Baringo County. (ii) To ascertain the concentration of thiocyanate in the fresh, fermented and cooked flour of the red and brown finger millet from Mogotio in Baringo County. (iii) To ascertain the concentration of thiocyanate in the green and dried leaves of the red and brown finger millet from Mogotio in Baringo County.

MATERIALS AND METHODS

Research design

The experimental arrangement included sampling of the red and brown finger millet, sample processing which involved drying, germinating, immersing, cooking and fermentation and analysis of thiocyanate rates.

Sample collection

Random sampling was employed to pick out the cultivators in Mogotio, Baringo County, Kenya (Figure 1). Sampling of the red and brown finger millet beans was carried out in 2012 and 2013 between the months of October and December during harvesting time. Sampling of the beans was carried out two times every month during the three months. About 4.0 kg of each of the red and brown finger millet beans were sampled. Two months old green leaves were also gathered from the same cultivators between June and August 2013. The samples were put in different well-labeled plastic bags and brought to Kenyatta University, Chemistry laboratory.

Chemicals and reagents

Analytical grade chemicals were utilized in the analysis. The chemicals comprised potassium thiocyanate (KSCN), de-ionized water, HNO_3 (65% w/v), Trichloroacetic acid, saturated bromine water, Arsenous trioxide, pyridine, benzidine/phenyl, and hydrochloride.

Cleaning of apparatus

All glassware was immersed overnight in 10% analytical grade nitric acid, laved with detergent and rinsed with de-ionized water before being desiccated in an oven at 105 ^{o}C. Plastic bottles were thoroughly laved with detergent and also rinsed with de-ionized water then dried in open racks.

Preparation of the standard solution

Thiocyanate stock solution was set up by dissolving 1.68 g potassium thiocyanate in 100 ml purified water and then diluted to 1 liter to give 1000 µg/ml (1000 ppm) thiocyanate. The stock solution was stored in plastic bottles and was labeled appropriately. Working standards (1-15 ppm) were freshly set up each time analysis was performed.

Sample preparation

Finger millet beans were cleansed by winnowing to remove dust and other extraneous materials. Unviable and broken beans were handpicked. The beans were then separated into three portions and handled as given below.

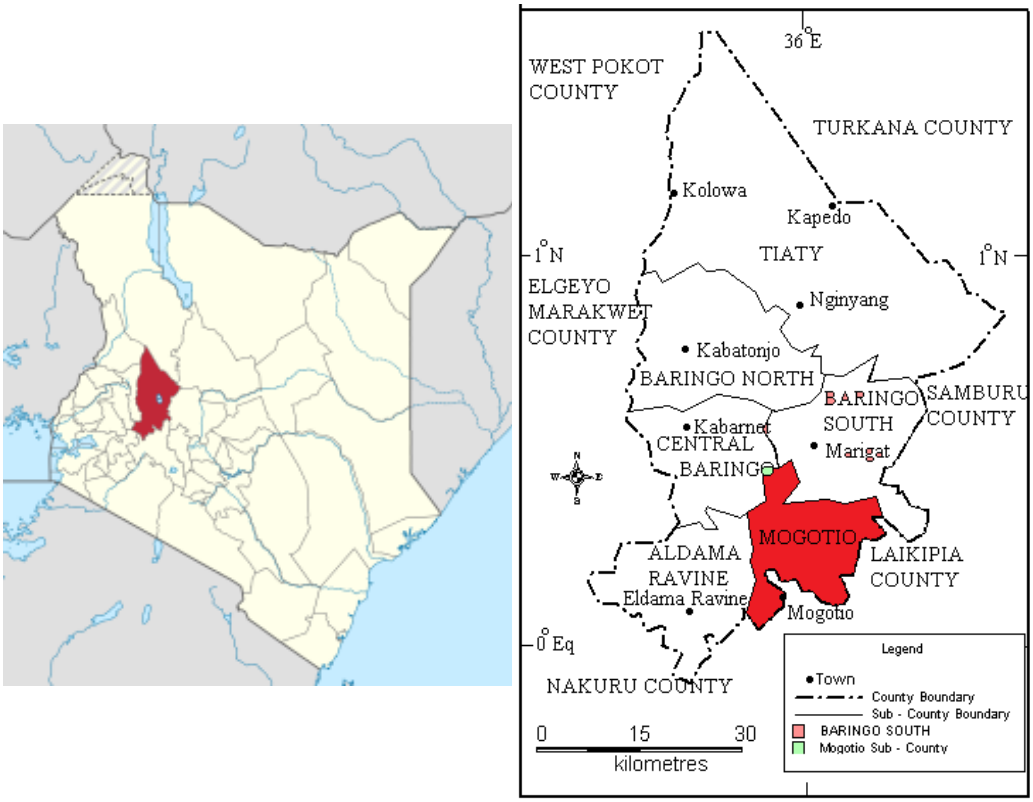

Figure 1. Study site in Mogotio Area, Baringo County, Kenya

Preparation of the freshly dried beans

The cleansed red and brown finger millet beans were spread on clean trays and sun-dried for 12 hours (Mbithi et al. 2002).

Sprouting of beans

A hundred grams of laved finger millet beans were put in large Petri-dishes, which were covered on top with perforated aluminum foil. Germination was followed at intervals of 12 hours to 72 hours at 30ºC. After germinating, the beans were sun-dried and milled along with the rootlets to become fine particles and stored in labeled polyethylene bags awaiting thiocyanate extraction (Mbithi et al. 2002).

Soaking of beans

About a hundred grams each of the red and brown finger millet beans were immersed in purified water (1: 2 w/v, beans to water) for 900 minutes. The water was drained and the beans were displaced to large Petri-dishes then sun-dried for 6 hours. The procedure was done again and the beans were immersed for 10 minutes, 30 minutes, and 60 minutes respectively (Chove and Mamiro 2010).

Preparation of fresh flour

The dried beans of the red and brown finger millet were milled into fine flour then wrapped up in polyethylene bags with weights of 100 g and stocked at room temperature awaiting extraction.

Fermentation of flour

A hundred grams of flour set up in the previous step was mixed with 200 ml of water and then kneaded to form dough. It was then left to ferment for 3 days at room temperature prior to thiocyanate extraction (Asegbeloyin and Onyimonyi 2007).

Cooked flour (porridge) preparation

A hundred grams of the fresh flour set up in the previous step was put in a 500 ml beaker and 200 ml of water was poured in to make slurry. The mixture was stirred continuously with a glass rod until it was boiled for 5 minutes. The cooked mixture was immediately cooled in an ice bath for 30 minutes then kept in a tightly closed plastic container awaiting extraction of thiocyanate. The procedure was repeated but for the next repeated procedure, the porridge was left to boil for 10 minutes and 30 minutes respectively (Adamafio and Ankrah 2009).

Preparation of the green and dried leaves

The green leaves of the red and brown finger millet were cleansed with purified water. The green leaves were placed in a clean mortar then ground with a pestle to produce an extract that was utilized in section 3.7. The dried leaves were set up by air-drying the green leaves then they were ground to form a fine powder.

Extraction and determination of thiocyanate

Two grams each of the red and brown finger millet samples (beans, flour, and leaves) set up in the previous

steps was weighed and displaced into a distillation flask, to which 20 ml of purified water was poured. Trichloroacetic acid solution (20% w/v) was poured into digest and precipitate proteins. The samples were then refluxed eventually at room temperature for 2 hours. The dispersal of the tissue was gained by intense shaking then centrifuged for 10 minutes at 1000 rpm. The supernatant comprising thiocyanate was poured into 50 ml clean dried volumetric flask and then liquefied to the mark with purified water. It was then displaced into separate plastic bottles, labeled and suitably stocked until the time for analysis (Chandra et al. 2004).

Following the method of Aldridge, the prepared sample extracts were examined for thiocyanate (Chandra et al. 2004). Saturated bromine water and 4% arsenous trioxide were poured into the extract followed by the addition of pure redistilled pyridine. Then, 2% phenyl-diamine hydrochloride solution was poured into it and it was left for 30 minutes at room temperature to allow for color development. The absorbance of the sample was read at a wavelength of 525 nm on the UV-VIS spectrophotometer (Cecil CE- 2041, 2000 series) (Chandra et al. 2004). The concentration of thiocyanate in the finger millet in µg/ml was immediately interpolated from the thiocyanate calibration curve.

Method of validation

To ascertain the exactness of the procedure, a recovery test was carried out. The recovery test was conducted by spiking a known amount of thiocyanate into a test portion of the sample and analyzing the spiked test portion along with the original sample.

Data analysis

To measure the dissimilarity of the concentration of thiocyanate in the various forms of the red and brown varieties of *E. coracana* subjected to different treatments, data was examined utilizing ANOVA test. Independent t-test was utilized to compare the mean values between the red and brown finger millet. The comparison of means was conducted by SNK test. Whenever a remarkable dissimilarity existed, the means were compared at p=0.05 significance level.

RESULTS AND DISCUSSION

Method validation

Regression analysis

Regression analysis was utilized to assess the linearity of the formed calibration curve. The absorbance readings and concentration of the standard were utilized to appraise the correlation coefficient (r). The calibration curve was set up by a plot of absorbance readings (y axis) against the corresponding concentration (x-axis) of the standard.

R^2 value from the formed calibration curve y=0.018x-0.001 was 0.9992 (Figure 2) indicating that there was an excellent correlation between concentration and absorbance.

Recovery test

The percentage recovery was appraised utilizing the following equation (EURACHEM guide 1998).

$$\% \text{ Recovery} = \frac{SSR - USR}{USR} \times 100$$

Where

SSR= Spiked sample result

USR= Unspiked sample result

The percentage recovery from the spiked sample (Table 1) was between 90 – 99.80%, while RSD was 3.65-5.01% and it was within the acceptable range for thiocyanate (Cardoso et al. 2004). This ensures that the method is of good precision and fits for analysis of the above parameter.

Rates of thiocyanate in finger millet beans

The rates of thiocyanate examined utilizing UV-Vis spectrophotometer are introduced and considered in the following subsections. The rates of thiocyanate in the fresh dried, germinated and immersed beans of the red and brown finger millet are presented in Tables 2 and 3.

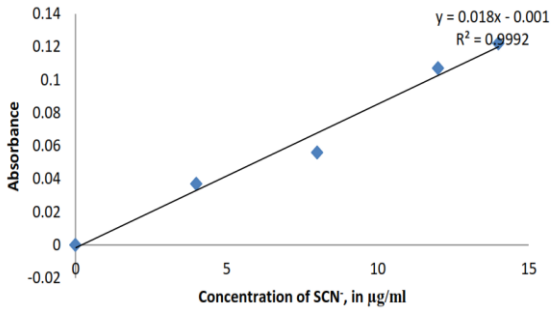

Figure 2. Calibration curve of SCN^-

Table 1. Percentage recoveries of thiocyanate

Test sample	% recovery	% RSD
Fresh dried bean	98.91	4.02
Sprouted bean	92.97	5.01
Fresh flour	99.80	3.65
Cooked flour	95.65	4.21
Green leaves	90.01	5.00

Table 2. Mean rates of thiocyanate (mg/kg) in the treated beans

Variety/ treatment	Concentration in (mg/kg)		P-value
	Red mean±SE (range)	Brown mean±SE (range)	
Fresh dried	43.48±1.56^b	31.83±1.88^b	0.471
n=8	(39.11-47.85)	(26.57-37.09)	
Sprouted	39.93±0.89^b	53.30±0.78^c	<0.001
n=8	(37.44-42.42)	(51.12-55.48)	
Soaked	10.5±1.73^a	9.73±1.72^a	0.718
n=24	(2.02-18.98)	(1.31-18.15)	
P-value	<0.001	0.015	

Mean values followed by the same small letter(s) within the same column or same row are not remarkably different (α=0.05, SNK-test). a<b<c

Table 3. Mean Levels of thiocyanate (mg/kg) in finger millet beans immersed at different times

Soaking time (minutes)	Concentration in (mg/kg)	
	Red (Mean±SE) (Range) n=8	Brown (Mean±SE) (Range) n=8
0	26.35±0.45[c]	22.31±0.34[c]
30	18.45±0.63b (13.2-18.98)	15.62±0.74b (14.3-18.15)
60	8.24±0.32a (5.23-9.6)	8.49±0.41a (7.08-9.02)
900	4.81±0.99a (2.02-7.6)	5.10±1.34a (1.31-8.89)
p-value	<0.001	<0.001

From Table 2, thiocyanate rates in the beans of the red and brown finger millet were within safe rates (100 mg/kg). The rates of thiocyanate were from 43.48±1.56 to 10.5±1.56 mg/kg in the red finger millet with fresh dried finger millet having the highest and the immersed one having the lowest, while for brown finger millet the rates ranged from 53.30±0.78 to 9.73±1.72 mg/kg. There was a statistically remarkable dissimilarity between the immersed and fresh dried beans, and between immersed and germinated in red finger millet and there was a remarkable dissimilarity between the fresh dried, germinated and immersed beans in the brown finger millet. Sprouted treatment showed a remarkable dissimilarity between the brown variety and the red variety ($P<0.001$ at 95% confidence level). This could be accredited to varietal dissimilarities such as the brand and endosperm contexture of the beans and metabolic breakdown of thiocyanate in the plant. The germinated brown beans recorded the biggest rates of thiocyanate followed by the fresh dried beans and the immersed beans had the smallest amount. The rise of thiocyanate during germinating could have been brought about by the enzymes which are active in the shoots during the young growing stages of the plant (Chweya 1990). The rates of thiocyanate in the fresh dried beans could be due to the fact that thiocyanate in millet is contained in the brand and endosperm portions of the seeds (Klopfenstein et al. 2012).

The rates of thiocyanate in the fresh dried and in the germinated beans were higher as confronted to the rates present in other foods such as cassava (12.95 mg/kg), cabbages (23 mg/kg) (Chandra et al. 2004) and pearl millet (35 mg/kg) (Gaitan et al. 1989). Therefore, frequent consumption of fresh dried and germinated finger millet beans could cause accruement of thiocyanate in the body. Previous studies discovered that the issue of production of cyanogenic glycoside (dhurrin) from sorghum during germinating is governable. Secondly, the glycoside and the dhurrin-synthesizing enzyme are mostly situated in the coleoptile, in a young shoot. This indicates that omission of the shoots after germination may help to assist thiocyanate (Chove and Mamiro 2010).

Table 3 shows the influence of various immersing time on thiocyanate proportion. In Table 3, mean values followed by the same small letter(s) within the same column or row are not remarkably different ($\alpha=0.05$, SNK-test). Table 3 shows that immersing decreased thiocyanate level in red finger millet from 26.45±0.45 to 4.81±0.99 mg/kg for 900 minutes of immersing and from 22.31±0.34 to 5.10±1.34 mg/kg for brown finger millet for the same immersing duration. There was a decrease in thiocyanate after an hour of immersing from 26.45±0.45 to 8.24±0.32 mg/kg in the red variety and from 22.31±0.34 to 8.49±0.41 mg/kg for brown finger millet after the same period of immersing. Various immersing time remarkably decreased the rates of thiocyanate ($p<0.001$), with longer immersing time (900 minutes) decreasing thiocyanate proportion to low rates, 4.81±0.99 and 5.10±1.34 mg/kg for the red and brown variety respectively. There was no remarkable dissimilarity between immersing for 60 and 900 minutes in both the varieties. This decrease indicated that thiocyanate is soluble in water and is leached away when draining water (Soetan and Oyewole 2009). Soaking in water increases detoxification as cells are broken by osmosis and fermentation which facilitates hydrolysis of the glycosides. Longer immersing times (18 to 24 hours) can decrease cyanide rates by up to 50%. For example, a study on cassava roots immersed for 3 days led to decrease of cyanide from 25.5 to 19.4 mg/kg (FAO 2005). Processing of millet showed that combination of drying and immersing was more effective in decreasing thiocyanate rates than drying alone.

Rates of thiocyanate in finger millet flour

Levels of thiocyanate in the fresh, fermented and cooked flour of the red and brown finger millet are shown in Table 4. Table 4 shows that thiocyanate in the fresh, fermented and cooked flour of the red and brown finger millet was within safe rates. The rates in fresh flour ranged from 20.54±1.39 in the red variety to 24.50±1.83 mg/kg in the brown variety. In fermented flour, the rates ranged from 19.43±1.37 in the brown variety to 20.03±0.87 mg/kg in the red variety. Levels in cooked flour ranged from 4.28±0.50 to 4.96±0.40 mg/kg in the red and brown varieties, respectively. Cooked flour had the lowest thiocyanate level, followed by fermented then fresh flour in both varieties. Independent t-test indicated that there was no remarkable dissimilarity between the varieties ($P>0.05$ at 95% confidence level). This implies that consuming any of the two varieties results in absorbing relatively the same amount of thiocyanate. Levels of thiocyanate in the fresh flour varied remarkably from the rates present in the cooked flour ($P<0.001$). There was a remarkable dissimilarity between the rates of thiocyanate in fermented flour and in the cooked flour. Levels of thiocyanate in the fresh flour did not vary remarkably from the rates in the fermented flour.

The thiocyanate proportion was slightly decreased during fermentation though not remarkable. This was due to the fact that fermentation inactivated the enzyme myrosinase thus decreasing the total thiocyanate proportion plus also the utilization of glucose and sulfur moieties of the compounds by microbial enzymes (Vig and Walia 2001). It is believed that some cyanidrophilic tolerant micro-organisms influence the breakdown of the cyanogenic glycosides (Tewe 2003). Fermented flour had enough time for their bond thiocyanate to be hydrolyzed by

the enzymes and thus allocated to various forms (Asegbeloyin and Onyimonyi 2007).

Cooking led to higher decrease thus appeared to be the most effective method of decreasing thiocyanate proportion. This was partly due to the heat-sensitive nature of the active principle and the fact that cooking devastates active enzymes included in thiocyanate composition at about 72^0C. This can also be accredited to the previous processing steps such as drying and grinding. Previous studies showed that drying and cooking, immersing and cooking decreased rates of thiocyanate than cooking alone (Tewe 2003). Heat treatment negatively influences glucosinolates proportion, wet heating/pressure cooking is more effective over dry heating (Jensen et al. 2001). Earlier studies showed that microwaving decreases the average thiocyanate result to one-half; steaming decreases this result to one-third. The influence of microwaving and steaming is dependent on the individual's intestinal flora and is thus highly varied, whereas the influence of boiling is more reliable and constant (Master 2008). Levels of thiocyanate gained in various cooking time are introduced in Table 5.

From Table 5, the rates of thiocyanate in cooked flour were from 8.78±0.40 to 1.56±0.74 mg/kg in the red variety when cooking time varied from 5 to 30 minutes, while the rates in the brown variety were from 8.92±0.37 to 1.85±0.63 mg/kg for the same cooking duration. There was a remarkable dissimilarity in the rates of thiocyanate when cooking time varied from 5 minutes, to 10 and 30 minutes respectively ($P<0.001$). Cooking for 30 minutes lowered thiocyanate to very low rates implying that longer cooking time could be a sure way of decreasing the rates of thiocyanate. Cooking for a short time will require inclusion of a previous treatment like immersing or sun-drying of the beans. Hydrolysis of cyanogenic glycosides yields hydrogen cyanide which was driven off during boiling. Free thiocyanate was quickly lost in boiling water (Tewe 2003; Adamafio and Ankrah 2009).

Rates of thiocyanate in the green and dried leaves of finger millet

Rates of thiocyanate in the green and dried leaves from the red and brown finger millet are shown in Table 6. From Table 6, it can be concluded that mean rates of thiocyanate in the green leaves were from 30.78±0.40 for the red variety to 31.69±0.71 mg/kg for the brown variety. Levels in the dried leaves were from 9.00±0.13 in the red variety to 8.80±0.14 mg/kg in the brown variety. There was an important dissimilarity in the thiocyanate proportion of the green and dried leaves of the red and brown finger millet ($P<0.001$).

Table 6. Mean rates of thiocyanate (mg/kg) in the green and dried leaves of the red and brown finger millet

Treatment	Red Mean±SE (Range) n=8	Brown Mean±SE (Range) n=8
Green leaves	30.78±0.40^b (28.88-32.56)	31.69±0.71^b (28.80-34.05)
Dried leaves	9.00±0.13^a (8.35-9.4)	8.80±0.14^a (8.25-9.15)
p-value	<0.001	<0.001

Mean values followed by the same small letter(s) within the same column or row are not remarkably different (α=0.05, SNK-test).

Table 4. Mean Levels of thiocyanate (mg/kg) in treated finger millet flour

Treatment	Concentration in (mg/kg)		P-value
	Red Mean±SE (Range) n=24	Brown Mean±SE (Range) n=24	
Fresh flour	20.54±1.39^b (13.73-27.35	24.50±1.83^b (15.53-33.47)	0.088
Fermented flour	20.03±0.87^b (15.77-24.29)	19.43±1.37^b (12.72-26.14)	0.713
Cooked flour	4.28±0.50^a (1.23-9.89)	4.96±0.40^a (1.79-10.21)	0.513
P-value	0.001	<0.001	

Note: Mean values followed by the same small letter(s) within the same column or row are not remarkably different (α=0.05, SNK-test)

Table 5. Mean rates of thiocyanate (mg/kg) in flour, cooked for 5, 10 and 30 minutes

Variety/ cooking time	Concentration in mg/kg				P-value
	Levels before cooking	5 mins	10 mins	30 mins	
Red Mean±SE (Range) n=8	20.54±1.39^d (13.73-27.35)	8.78±0.40^c (6.58-9.89)	2.51±0.20^b (1.89-3.30)	1.56±0.74^a (1.23-3.29)	<0.001
Brown Mean±SE (Range) n=8	24.50±1.83^d (15.53-33.47)	8.92±0.37^c (6.85-10.21)	4.10±0.26^b (2.9-4.9)	1.85±0.63^a (1.79-3.02)	<0.001

Note: Mean values followed by the same small letter(s) within the same column or row are not remarkably different (α=0.05, SNK-test). a<b<c<d

The green leaves bore the highest proportion of thiocyanate in both varieties while the dried leaves bore the lowest. It is therefore preferable that farmers should feed their animals with the dried leaves of finger millet which contain lower thiocyanate proportion and not the green leaves. The high thiocyanate proportion in green leaves could be accredited to the enzymes which were once active in the growing stages of plants but became inactive during drying. It has also been disclosed that environmental conditions and agronomic factors such as plant density and nitrogen fertilizer application influence the thiocyanate rates in kale leaves (Chweya 1990). Previous studies on cyanide potential of sorghum assured that after flowering, HCN maybe only 10% left of its initial rates at young age and vegetative and thus farmers are motivated to wait till maturity in order to feed their animals with sorghum (Wheeler and Mulcathy 1989; Ilza and Pinotti 2000).

In conclusion, all the forms of examined finger millet were discovered to have contents of thiocyanate within safe rates. The fresh dried and germinated bean samples of the red and brown finger millet showed higher thiocyanate mean rates than those shown by the immersed beans. Germinating brown finger millet remarkably raised the thiocyanate rate, therefore individuals willing to utilize germinated finger millet must be confirmed to immerse the grains first and then dry them properly before the process of fermentation and cooking is carried out to lower the thiocyanate proportion. Immersing within 900 minutes substantially reduced the thiocyanate proportion in finger millet to relatively low amounts. Cooking was discovered to be a powerful method of decreasing the proportion of thiocyanate to appropriate rates of normal consumption, particularly when the cooking time was lengthened for 30 minutes. Since the rates of thiocyanate were higher in the green leaves than that in the dried leaves, thus farmers should feed their cattle with the dried leaves.

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