# TROPICAL Drylands

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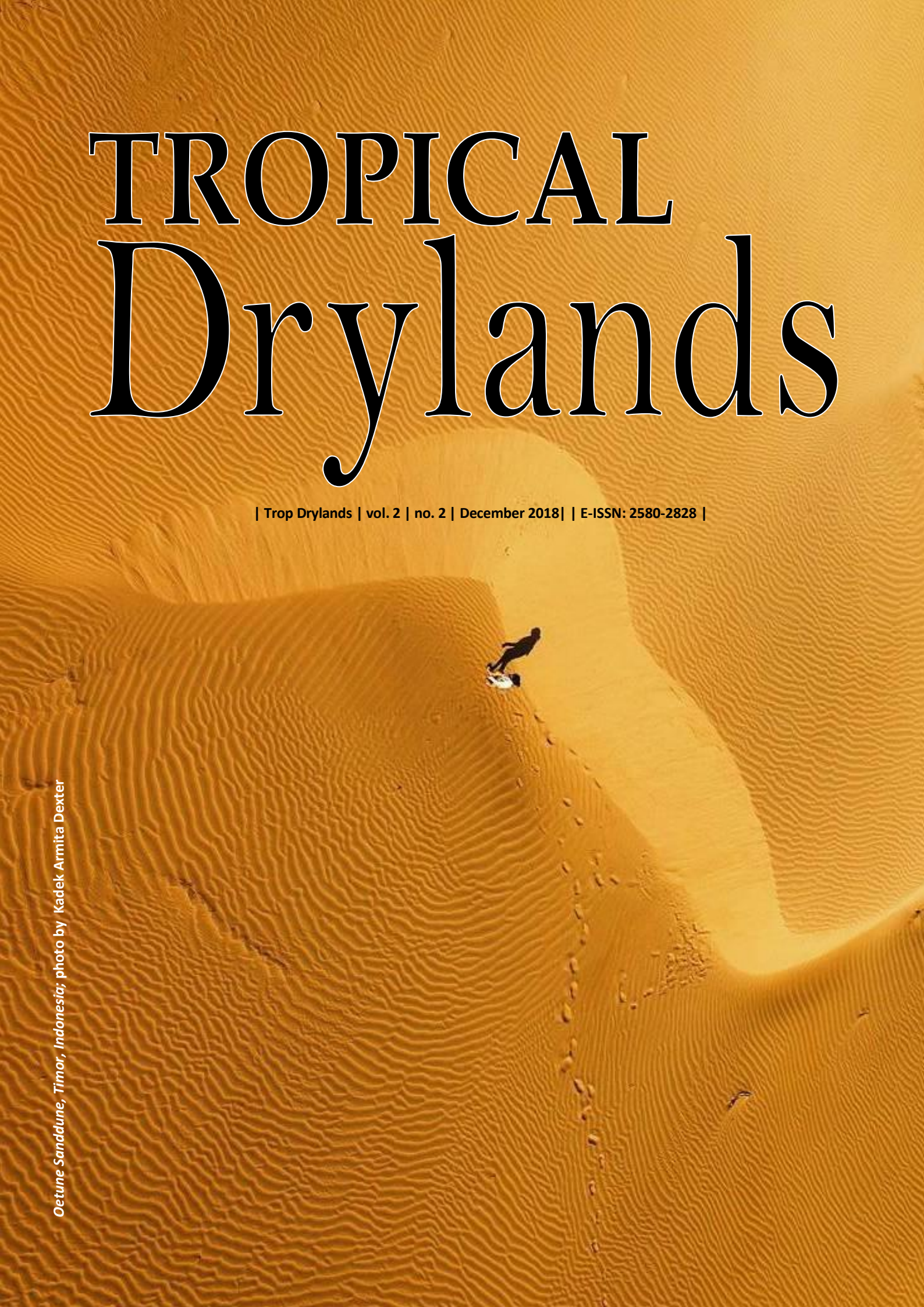

*Oetune Sanddune, Timor, Indonesia;* photo by Kadek Armita Dexter

# Tropical Drylands

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# Short Communication: Evaluation of drought tolerance indices for genotype selection of foxtail millet (*Setaria italica*)

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**Abstract.** *Lapuimakuni S, Khumaida N, Ardie SW. 2018. Evaluation of drought tolerance indices for genotype selection of foxtail millet (*Setaria italica*). Trop Drylands 2: 37-40.* Foxtail millet (*Setaria italica* (L.) Beauv) is one of underutilized crops cultivated for its nutritious grain and its relative tolerance to drought stress. However, the drought tolerance level of this crop is varied between genotypes. Thus, breeding approaches to develop drought-tolerant foxtail millet variety are of great importance. This study aimed to: (i) evaluate several drought tolerance indices to determine one or more predictors among studied indices, and (ii) identify the drought tolerance level of the evaluated foxtail millet genotypes. Eight foxtail millet genotypes were planted in a greenhouse with a completely randomized design and five replications under both drought and normal watering conditions. Staggered planting was applied to synchronize flowering time. Watering was withheld for 15 days during the flowering period, and then plants were re-watered until harvest time. Multiple indices for drought tolerance were calculated based on the potential yield (Yp) under non-stress and yield (Ys) under stress conditions. Based on the correlation, principal component analysis, and cluster analysis, yield index (YI) and harmonic mean (HM) were considered the best indices for the selection of drought-tolerant foxtail millet genotypes. By using the best indices, two foxtail millet genotypes (ICERI-5 and ICERI-6) were considered drought tolerant genotypes.

**Keywords:** drought tolerance index, selection tools, staggered planting, underutilized crop

## INTRODUCTION

Drought is one of the most significant abiotic stresses impeding global crop production. Foxtail millet [*Setaria italica* (L) Beauv.] is one of the staple crops potentially developed as functional foods, especially in drought-prone areas. Foxtail millet is reported to be relatively tolerant to drought (Lata et al. 2010; Karyudi and Fletcher 2003). The nutritious value of this cereal, such as low glycaemic index (Jali et al. 2012), high in protein content and rich in dietary fiber (Amadou et al. 2013), and containing anti-oxidant (Almaski et al. 2017), has made foxtail millet is potentially developed as a functional food. Zhang et al. (2012) also reported the potential of this crop as bio-energy source.

Although relatively tolerant to drought, the tolerance level of foxtail millet to drought stress varies among genotypes (Begum et al. 2013). Selecting highly drought-tolerant foxtail millet genotypes is therefore of great importance. Proper selection method is crucial in determining the best genotype for particular traits. The adverse effect of drought stress depends significantly on the time and duration of the stress. Matsuura et al. (2012) reported that drought stress during early flowering period leads to the most significant productivity loss in foxtail millet. Therefore, drought stress needs to be applied during the early flowering period to select tolerant genotypes accurately. However, Sulistiyowati (2015) reported that the flowering time of foxtail millet varied between genotypes. Staggered planting method for flowering time synchronization has been applied for drought tolerant wheat screening (Briggs et al. 1999).

The selection index is one of the selection tools commonly used in plant breeding. Mardeh et al. (2006) reported that genotypes with high productivity under optimum conditions may not always be drought tolerant. In this study, we analyzed several selection indices to determine the best selection index for the drought-tolerant trait in foxtail millet and to select the tolerant foxtail millet genotypes.

## MATERIALS AND METHODS

### Study area

This research was carried out in the Cikabayan greenhouse, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Indonesia from November 2016 to April 2017.

### Procedures

A completely randomized design was used in this experiment, consisting of two factors and five replications. The first factor was foxtail millet genotype and consisted of 8 genotypes (i.e. ICERI-2, ICERI-3, ICERI-4, ICERI-5,

ICERI-6, ICERI-7, ICERI-9, and ICERI-10) obtained from Indonesian Cereals Research Institute. The second factor was the drought stress, comprised of normal watering and 15 days of no-watering during flowering period.

The seed of each genotype was planted in a 5 L-pot containing planting medium of soil: sand (1:1, v/v). Seeds were sown according to the flowering time (Sulistiyowati 2015) in staggered planting method. Watering was withheld for 15 days during flowering period, and then plants were re-watered until harvest time. Grain weight per plant was weighed and used for the analysis.

**Data analysis**

Drought tolerance indices were calculated following various authors (Fischer and Maurer 1978; Bidinger et al. 1978; Bouslama and Schapaugh 1984; Gavuzzi et al. 1997; Farshadfar and Sutka 2002; Moosavi et al. 2008; Farshadfar and Javadinia 2011; Ali et al. 2013). The calculated drought indices were then further analyzed using principal component analysis, correlation analysis, and cluster analysis to determine the best selection indices for drought stress, and to select the most tolerant foxtail millet genotype(s) under drought stress.

## RESULTS AND DISCUSSION

Drought stress in the period of 15 days during early flowering time decreased grain weight per plant of foxtail millet by 87% compared to the non-stressed condition (Table 1). ICERI-7, ICERI-5, and ICERI-6 genotypes showed the highest grain weight per plant under drought stress (Ys), while ICERI-3, ICERI-7 and ICERI-4 genotypes showed the highest grain weight per plant under optimum condition (Yp). The highest TOL value was demonstrated by ICERI-3, ICERI-4, and ICERI-2 genotypes, indicating that drought stress caused the highest loss of grain weight per plant on these genotypes. In contrast, ICERI-5 and ICERI-6 showed the lowest TOL, suggesting that these genotypes were only slightly affected by drought stress. Similar genotype rank was obtained based on Ys, YI (Yield index), and HM (Harmonic mean), indicating that the two selection indices could select foxtail millet genotype with high grain weight under drought stress.

Based on correlation analysis, grain weight per plant under non-stressed conditions (Yp) had a very weak association ($r$=0.08$^{ns}$) with grain weight per plant under stressed conditions (Ys), indicating that high potential yield under optimum conditions does not necessarily result in high yield under drought stress condition. Therefore, genotype selection based on the yield under optimum conditions will not be efficient to select drought-tolerant foxtail millet genotype. Anwar et al. (2011) also reported a positive but non-significant association between the yield of wheat in stress and non-stress condition. Two selection indices, YI ($r$=1.00$^{**}$) and HM ($r$=0.99$^{**}$), showed a very high and significant association with grain weight per plant under stress (Ys).

The principal component analysis showed that the first components (PC1 and PC2) explained about 96.7% of the total variance (Table 2). The first PC explained 66.5% of the obtained variation and showed high coordination between Ys, GMP (Geometric mean productivity), STI (Stress tolerance index), YI, YSI YSI (Yield stability index), HM, DI (Drought resistance index), RDI (Relative drought index), and K2STI. The PC2 explained 30.2% of the total obtained variation and showed high coordination between Ys, YI and HM. Taken together, the data presented in Table 1 and Table 2 clearly indicates YI and HM as the best selection indices for foxtail millet under drought stress conditions.

**Table 1.** The mean grain weight per plant of eight foxtail millet genotypes under stressed (Ys) and non-stressed (Yp) conditions and their corresponding tolerance indices

| Genotype | Ys | Yp | SSI | TOL | GMP | MP | STI | YI | YSI | HM | SDI | DI | RDI | SSPI | K1STI | K2STI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICERI2 | 0.33 | 10.56 | 1.11 | 10.23 | 1.87 | 5.45 | 0.04 | 0.27 | 0.03 | 0.64 | 0.97 | 0.01 | 0.24 | 53.33 | 0.05 | 0.00 |
| ICERI3 | 1.55 | **13.05** | 1.01 | 11.50 | 4.50 | 7.30 | 0.22 | 1.25 | 0.12 | 2.77 | 0.88 | 0.15 | 0.92 | 59.94 | 0.41 | 0.34 |
| ICERI4 | 0.36 | **10.69** | 1.11 | 10.33 | 1.95 | 5.52 | 0.04 | 0.29 | 0.03 | 0.69 | 0.97 | 0.01 | 0.26 | 53.87 | 0.05 | 0.00 |
| ICERI5 | **2.32** | 7.06 | 0.77 | 4.75 | 4.04 | 4.69 | 0.18 | 1.86 | 0.33 | 3.49 | 0.67 | 0.61 | 2.53 | 24.75 | 0.10 | 0.62 |
| ICERI6 | **1.81** | 7.28 | 0.86 | 5.47 | 3.63 | 4.54 | 0.14 | 1.46 | 0.25 | 2.90 | 0.75 | 0.36 | 1.92 | 28.50 | 0.08 | 0.30 |
| ICERI7 | **2.66** | **11.60** | 0.89 | 8.95 | 5.55 | 7.13 | 0.33 | 2.14 | 0.23 | 4.32 | 0.77 | 0.49 | 1.77 | 46.63 | 0.49 | 1.53 |
| ICERI9 | 0.85 | 9.64 | 1.05 | 8.79 | 2.85 | 5.24 | 0.09 | 0.68 | 0.09 | 1.55 | 0.91 | 0.06 | 0.68 | 45.84 | 0.09 | 0.04 |
| ICERI10 | 0.08 | 6.85 | 1.14 | 6.77 | 0.74 | 3.47 | 0.01 | 0.06 | 0.01 | 0.16 | 0.99 | 0.00 | 0.09 | 35.31 | 0.00 | 0.00 |
| Min | 0.08 | 6.85 | 0.77 | 4.75 | 0.74 | 3.47 | 0.01 | 0.06 | 0.01 | 0.16 | 0.67 | 0.00 | 0.09 | 24.75 | 0.00 | 0.00 |
| Max | 2.66 | 13.05 | 1.14 | 11.50 | 5.55 | 7.30 | 0.33 | 2.14 | 0.33 | 4.32 | 0.99 | 0.61 | 2.53 | 59.94 | 0.49 | 1.53 |
| Mean | 1.25 | 9.59 | 0.99 | 8.35 | 3.14 | 5.42 | 0.13 | 1.00 | 0.14 | 2.06 | 0.86 | 0.21 | 1.05 | 43.52 | 0.16 | 0.35 |
| StdDev | 0.98 | 2.31 | 0.14 | 2.44 | 1.58 | 1.29 | 0.11 | 0.79 | 0.12 | 1.52 | 0.12 | 0.24 | 0.91 | 12.72 | 0.18 | 0.53 |

Note: Ys: grain weight per plant (g) under stressed condition; Yp: grain weight per plant (g) under non-stressed condition; SSI: Stress susceptibility index; TOL: Tolerance; GMP: Geometric mean productivity; MP: Mean productivity; STI: Stress tolerance index; YI: Yield index; YSI: Yield stability index; HM: Harmonic mean; SDI: Sensitivity drought tolerant; DI: Drought resistance index; RDI: Relative drought index; SSPI: Stress susceptibility percentage index; MSTI: Modified stress tolerance index: K1STI, K2STI. Values in bold are indicating the three highest values of Ys or Yp.

**Table 2.** Principal component analysis for drought tolerance indices in foxtail millet

| Variables | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 | PC8 |
|---|---|---|---|---|---|---|---|---|
| Ys | **0.306** | **0.029** | 0.006 | -0.060 | 0.094 | 0.017 | 0.325 | -0.403 |
| Yp | 0.004 | 0.450 | 0.208 | 0.169 | -0.014 | 0.045 | 0.066 | 0.212 |
| SSI | -0.289 | 0.134 | -0.239 | -0.073 | 0.067 | -0.218 | 0.173 | -0.301 |
| TOL | -0.119 | 0.415 | 0.194 | 0.184 | -0.051 | 0.036 | -0.068 | -0.412 |
| GMP | **0.280** | 0.174 | 0.135 | -0.258 | 0.441 | -0.571 | -0.522 | -0.036 |
| MP | 0.119 | 0.415 | 0.189 | 0.129 | 0.023 | 0.047 | 0.182 | -0.099 |
| STI | **0.275** | 0.190 | -0.207 | -0.226 | 0.011 | -0.063 | 0.156 | 0.195 |
| YI | **0.306** | **0.029** | 0.006 | -0.060 | 0.094 | 0.017 | 0.325 | -0.116 |
| YSI | **0.289** | -0.134 | 0.239 | 0.073 | -0.067 | 0.218 | -0.173 | -0.446 |
| HM | **0.303** | **0.066** | 0.022 | -0.182 | 0.245 | 0.057 | 0.436 | 0.260 |
| SDI | -0.289 | 0.134 | -0.239 | -0.073 | 0.067 | -0.218 | 0.173 | 0.081 |
| DI | **0.294** | -0.109 | -0.025 | 0.417 | -0.541 | -0.631 | 0.143 | 0.045 |
| RDI | **0.289** | -0.134 | 0.239 | 0.073 | -0.067 | 0.218 | -0.173 | 0.330 |
| SSPI | -0.119 | 0.415 | 0.194 | 0.184 | -0.051 | 0.036 | -0.068 | 0.288 |
| K1STI | 0.192 | 0.332 | -0.337 | -0.488 | -0.575 | 0.176 | -0.253 | -0.051 |
| K2STI | **0.260** | 0.124 | -0.665 | 0.544 | 0.284 | 0.202 | -0.226 | -0.001 |
| StdDev | 3.263 | 2.198 | 0.632 | 0.324 | 0.143 | 0.032 | 0.009 | 0.000 |
| Variance proportion | 0.665 | 0.302 | 0.025 | 0.007 | 0.001 | 0.000 | 0.000 | 0.000 |
| Cumulative proportion | 0.665 | 0.967 | 0.992 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 |

Note: PC: principal component; Ys: grain weight per plant (g) under stressed condition; Yp: grain weight per plant (g) under non-stressed condition; SSI: Stress susceptibility index; TOL: Tolerance; GMP: Geometric mean productivity; MP: Mean productivity; STI: Stress tolerance index; YI: Yield index; YSI: Yield stability index; HM: Harmonic mean; SDI: Sensitivity drought tolerant; DI: Drought resistance index; RDI: Relative drought index; SSPI: Stress susceptibility percentage index; MSTI: Modified stress tolerance index: K1STI, K2STI. Values in bold indicate indices highly coordinated with Ys in each PC

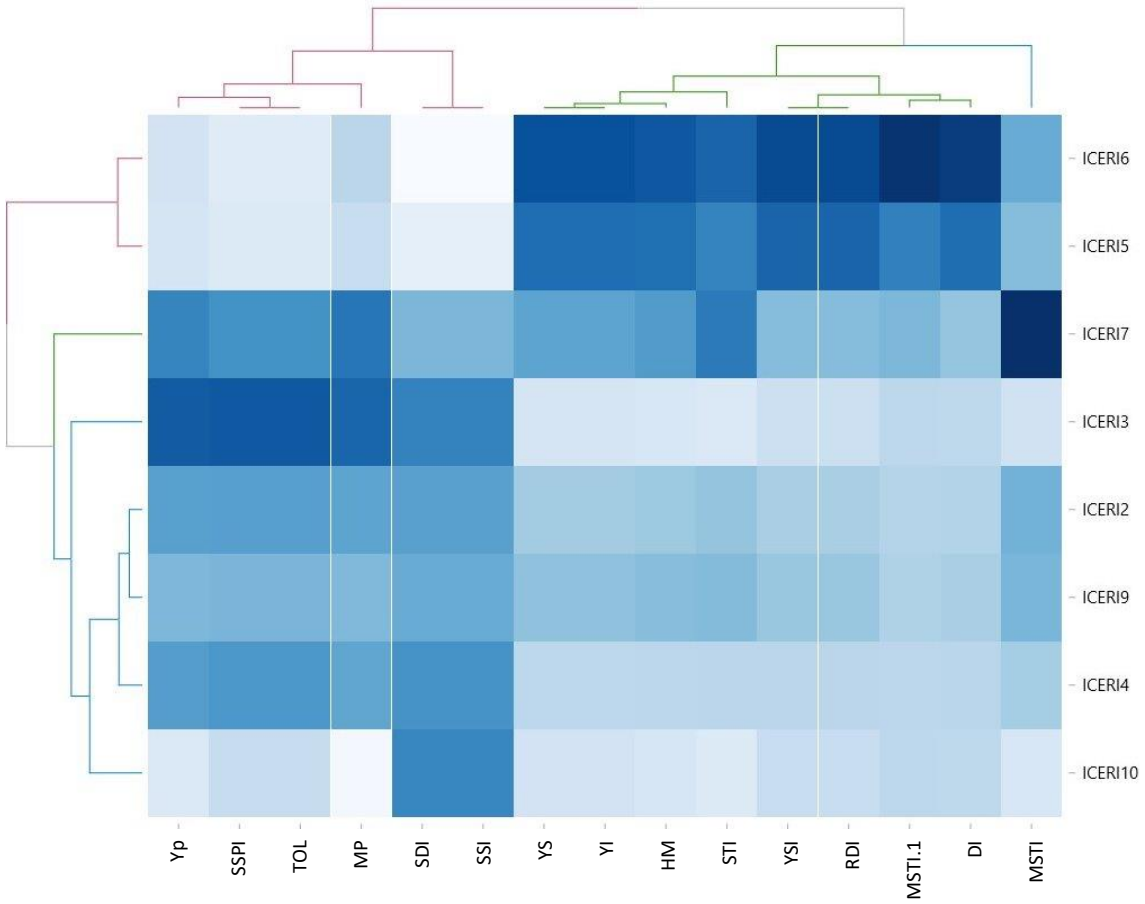


**Figure 1.** Clustergram showing the relation of selection indices for drought stress with 8 foxtail millet genotypes

Multivariate statistical analysis, such as cluster analysis, is an important approach for genotype classification based on their relatedness. Figure 1 shows the clustergram that clusters the tolerant and sensitive foxtail millet genotypes in different groups. In Figure 1, dark blue color in the column indicates high association between particular genotype and selection index. The interaction column between ICERI-6 or ICERI-5 genotype with grain weight per plant under non-stressed condition (Yp) shows very light blue color, indicating that these two genotypes have low yield under non-stressed conditions. In contrast, the interaction column between ICERI-6 or ICERI-5 genotype with grain weight per plant under stressed condition (Ys) shows very dark blue color, indicating that these two genotypes have high yield under the stressed condition. The clustergram classified ICERI-5 and ICERI-6 in the tolerant group, while ICERI-3 and ICERI-10 genotypes were classified as the sensitive group.

In this study, drought stress for 15 days during the early flowering period caused 87% decrease in yield, which can be considered severe drought stress. Ali and El-Sadek (2016) reported that moderate drought stress is more suitable to select drought-tolerant genotype in wheat. Therefore, further evaluation under various drought stress duration is necessary to validate the selected indices (YI and HM) obtained in this study.

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# Structural model of sandalwood (*Santalum album*) regeneration in the forest and community plantation in Timor Island, Indonesia

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**Abstract.** *Seran YN, Sudarto, Hakim L, Arisoesilaningsih E. 2018. Structural model of sandalwood (*Santalum album*) regeneration in the forest and community plantation in Timor Island, Indonesia. Trop Drylands 2*: *41-47.* Sandalwood (*Santalum album* L.) is a very important forest product in Nusa Tenggara Timur (NTT) Province, Indonesia due to its high economic value. However, the population of sandalwood is threatened, requiring regeneration to enhance its population. This study aimed to identify and produce a structural model of sandalwood regeneration in both natural forest and the community plantation in the districts of Timor Tengah Selatan (TTS) and Timor Tengah Utara (TTU), NTT Province. The method used in this research was vegetation analysis using purposive sampling method at 8 observation stations with total of 87 plots. The plot size was 20x20 $m^2$ (trees), 10x10 $m^2$ (poles), 5x5 $m^2$ (saplings), and 2x2 $m^2$ (seedlings). Data observed in the field included the mean sandalwood population size in the forms of trees, poles, saplings and seedlings phase; vegetation data in sandalwood habitat which included tree wealth index, diversity index, number of individuals and sandalwood host diversity index data. Geographical factors such as altitude and slope, and abiotic factors such as soil organic matter, soil pH and soil conductivity were also recorded. Climate data included the number of dry months and rainfall. Sandalwood regeneration data included sandalwood vitality, pests and diseases, and the number of seeds. Secondary data included climate data (ten years time) obtained from BMKG. Altogether, these data were used as the indicators of the latent variables (six variables) which consisted of geography, soil, climate, population, vegetation, and regeneration. Obtained data were subjected to both descriptive analysis and multivariate statistics with structural modeling of Warp Partial Least Square (WarpPLS 6.0). The results showed that most of the proposed indicators significantly influenced the six latent variables except the host diversity. Some indicators significantly or highly significantly affected the latent variable with 15 indicators that significantly composed the latent variable. The resulting structural model had of Q2 predictive value of 96,65%, suggesting that the structural model proposed in this study has very relevant and high prediction on factors that influence sandalwood regeneration. Therefore, this model is feasible to be used as recommendations in the framework of sandalwood development in the forest and the community plantation in the West part of Timor Island, Nusa Tenggara Timur.

**Keywords:** Forests, plantations, regeneration, sandalwood, *Santalum album*, structural models

**Abbreviations:** NTT: Nusa Tenggara Timur, TTS: Timor Tengah Selatan, TTU: Timor Tengah Utara, Warp PLS: Warp Partial Least Square

## INTRODUCTION

Sandalwood (*Santalum album* L.) is one of the most important forest products in Nusa Tenggara Timur (NTT) Province because it has high economic value. Yet, it has great conservation importance since it is an endemic species and is currently threatened with extinction (IUCN 2016). Therefore, the conservation and sustainable utilization of this species are essential for its long-term existence. One of important strategies for the conservation of sandalwood is by improving their population through regeneration.

Regeneration is vital because the current population of sandalwood in forests and gardens/plantations is very limited. The success of regeneration in forest is highly dependent on seed production and dispersal, seed germination into seedling, and seedling growth into juvenile (e.g. saplings) and adult stage (e.g. mature trees) (Wijayanto et al. 2011). The natural regeneration process is also influenced by the vitality (degree of success or life cycle) of a species in the habitat. Vitality determines the survival and growth rate of a species in response to environmental changes. In studying vitality, there are several indicators that can be used to determine whether the life cycle of a species is complete or not (Braun-Blanquet 1932; Doberrtin 2005). Vitality of 1 (one) means that the species can develop life cycle well and entirely through the stages of seedling, sapling, poles, and trees. Vitality of 2 means that the species can develop life cycle relatively well but is irregular. Vitality of 3 means that the species experiences a rare and incomplete life cycle in its habitat. Vitality of 4 means that the species have incomplete life cycle with only few seedlings and very few are able to survive

Natural regeneration of sandalwood in forest through seeds or root shoots are lacking due to habitat degradation and limited parental trees/seed sources. Thus, sandalwood regeneration depends largely on the success of sandalwood

cultivation carried out by local communities in agroforestry systems using secondary host plants (Wawo 2008). Sandalwood agroforestry systems applied in the community gardens/plantation can restore the sandalwood populations. The distribution and population density of sandalwood in agroforestry showed promising pre-liminary outcomes (Wiharto et al. 2008). However, sandalwood planting activities carried out in NTT are still very low with only 429 ha per year planted over a five years period (2004-2008). The efforts of sandalwood cultivation implemented by the government or related institutions through the Forestry Office are still very low, with only less than 30% of total sandalwood planting (Darmokusumo 2001; Surata 2006). In contrast, sandalwood logging activities reached 6.200-12.400 trees per year (Surata 2006).

One of the causes of the low success of sandalwood cultivation is pest and pathogens attacks, for example, the spike disease caused by mycoplasma which resulted in stunting and yellowing. Another pathogen that attacks sandalwood is *reetdauw* (sooty mold) with symptoms and signs of specks of mushrooms growing on the leaves. Some insects that attach sandalwood include *Zeuzeura ceffea* (a type of butterfly that hoists the young branch of sandalwood), *Chiaonapsis* sp, *Valanga nigricornis zehntneri* Kraus, and snout beetle (Shobha 1990).

Based on the above-mentioned rationale, this study aimed to develop a structural model of sandalwood regeneration in natural forest and community plantation in Nusa Tenggara Timur Province, Indonesia.

## MATERIALS AND METHODS

### Study area and period

This research was conducted in the districts of Timor Tengah Selatan (TTS) and Timor Tengah Utara (TTU), Nusa Tenggara Timur Province, Indonesia (Figure 1) at eight observation stations consisting of 87 nested plots (Figure 2). Of the eight observation stations, five were located in TTS District (three stations in plantation and two stations in forest) and three were located in TTU District (one station in plantation and two stations in forest). Five stations in TTS District were Oelbubuk (Oe), Binaus (Bi), Nununamat (Nu), Karang Siri (Ks), Tetaf (Te). Three stations in TTU District were Upfaon (Up), Banamlaat (Ba), and Oinbit (Oi) (Figure 1). This research was conducted from September 2015 to December 2016.

### Data collection

Field collected data included mean sandalwood population size in the form of trees, poles, saplings, seedlings phases, and vegetation data including tree wealth index, diversity index, number of individuals and sandalwood host diversity index. Geographical data included altitude and slope, soil organic matter, soil pH and soil conductivity, and the number of dry months and rainfall. Data regarding sandalwood regeneration included sandalwood vitality, pests and diseases, and number of seeds. These data were then used as indicators of the latent variables consisting of six namely geographical, soil, climate, population, vegetation and regeneration, while secondary data were in the form of climate data obtained from BMKG of NTT Province in Kupang (climate data for the last ten years at eight observation stations).

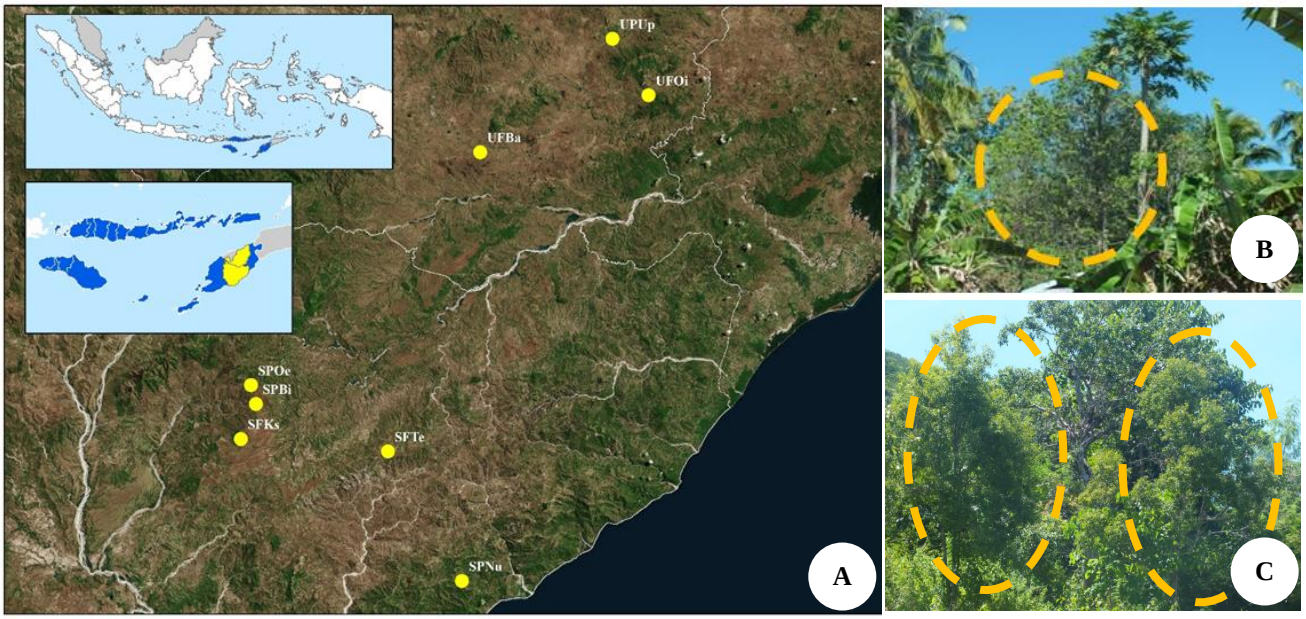


**Figure 1.** A. Map of the study area in the forest and community plantation in Timor Island, Indonesia, B. Sandalwood in mixed-plantation, C. Sandalwood in forest. Note: SPNu: Soe Plantation Nununamat, UFOi: Kefa Forest Oinbit, UPUp: Kefa Plantation Upfaon, SFTe: Soe Forest Tetaf, SPOe: Soe Plantation Oelbubuk, SPBi: Soe Plantation Binaus, UFBa: Kefa Forest Banamlaat, SFKs: Soe Forest Karang Siri stations. Dashed lines indicate of sandalwood plant

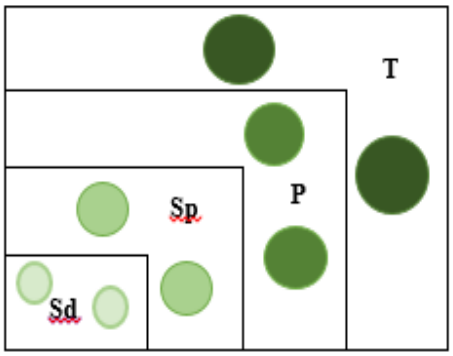


**Figure 2.** Nested plots. Note: T: *Trees*: 20 x 20 m plot, P: *Poles*: 10 x 10 m plot, Sp: *Saplings*: 5 x 5 m plot, Sd: Seedlings: 2 x2 m plot.

**Data analysis**

Identification of limiting factors for sandalwood regeneration was analyzed using statistical methods of multivariate structural modeling with Warp Partial Least Square (WarpPLS 6.0). The interaction of limiting factors in sandalwood regeneration was determined using structural modeling with WarpPLS 6.0, following these steps. First (i), determining the latent variables with indicators of each variable consisting of 6 latent variables and 15 indicators. Second (ii), determining the design of a structural model, which describes the relationship between latent variables. Geographic variables become exogenous variables that influence the endogenous variables of vegetation, population size, and sandalwood regeneration. Soil variables become endogenous variables that affect vegetation, population size, and regeneration. Climate variables become endogenous variables that affect vegetation, population size, and regeneration. Vegetation variables become endogenous variables that affect population size and regeneration. Variable of population size become an endogenous variable that affects sandalwood regeneration. The relationship/correlation between variables from this research is unidirectional/ parallel so that the nature of the relationship is recursive. Third (iii), determining the design of the measurement model which describes the relationship between indicators with the intended latent variables. In this study, the direction of the relationship is from the indicator to the variable so that the nature of the indicator is formative. The relationship between latent variables and indicators compiled in this study are as follows: altitude and slope of the compiler of geographic variables; soil organic matter, pH and conductivity of soil variables compiler; rainfall and dry months, the constituent of climate variables; taxa wealth, species density, species diversity index, host diversity index of the vegetation variable compiler, population density of trees, poles, saplings, seedlings the constituent/compiler of sandalwood population size; vitality, number of seeds and disease the compiler of sandalwood regeneration variables. Fourth (iv), creating a path/line diagram construction of structural models, which describe the results of the determination of the measurement model design and structural model then arranged in the form of a structural model line diagram. The results of the structural model in line construction diagram are shown in Figure 3. Fifth (v), testing the measurement model and structural model, which describes the feasibility or not the indicator of the intended latent variables. The feasibility is determined by the t-statistics value. The indicator is said to be feasible as a constituent/ compiler of the latent variable if the t-statistic value is greater than 1.96. In the opposite condition if the indicator t-statistic value is less than 1.96, then the indicator is said to be inappropriate or insignificant as a compiler of latent variables so that the indicator is excluded from the structural model. Testing the structural model aims to determine the variables that relate significantly or directly to other variables, the direction of the relationship and the closeness of the relationship between variables. Variables correlate significantly if the t-statistic value is greater than 1.96. The direction of the relationship between variables is determined by the value of the coefficient of determination ($R^2$). Sixth (vi), testing the goodness of the structural model, which aims to determine the accuracy of the structural model built. The accuracy of the structural model is determined by the coefficient of determination ($R^2$) and predictive relevance (Q2). Q2 value was calculated by the formula:

$Q2 = 1-(1-R1^2)\ (1-R2^2)\ \ldots\ldots\ (1-Rp^2)$,

where $R1^2$, $R2^2$, $Rp^2$ are the determination coefficient ($R^2$) of the latent variable. Seventh (vi), hypothesis testing carried out by t-test on each path/line which has a partial direct effect. The analysis result is determined by looking at the probability or the value of t-statistic. The t-table value for alpha 5% is 1.96 so that the hypothesis acceptance criteria is when t-statistics > t table, namely t-calculated > 1.96. If the t-statistic value or t calculated > 1.96 then the path/line of the relationship between these variables is significant or has a direct influence (Guinot et al. 2001; Jaya and Sumertajaya 2008; Husein 2015).

## RESULTS AND DISCUSSION

**Test results of the measurement model**

The study findings show that most of the proposed indicators were feasible or significant in compiling latent variables except the host diversity which had no significant influence on the latent variables (Table 1). The altitude, slope, and rainfall, as well as dry months indicators, had the same significant contribution to the combination of geographic and climate latent variables because they had the same measurement weights values namely 0.084 and 0.087. Soil organic material (BOT 10 and 20) gave an equal contribution to the formation of latent soil variables with a weighting value of 0.086. Indicators of the individual number of saplings and seedlings had almost the same contribution in the composition of the sandalwood population latent variable because it had nearly the same measurement weight value namely 0.084 and 0.085. The

vitality, and pests and diseases, each contributed to the preparation of sandalwood regeneration latent variables with the weight of the measurement value of 0.090 and 0.093. Sandalwood host diversity, vitality, diseases, and pests, individual number of sandalwood trees and soil conductivity at a depth of 20cm gave a highly significant influence on sandalwood regeneration. All indicators of each of the determined latent variables contributed significantly to the sandalwood regeneration process in both natural and cultivated habitats (Table 1).

The results showed that sandalwood can be isolated with other types of vegetation such as shrubs or grass without disturbing its growth. This is not too different from the results of the research by Surata et al. (2006) which stated sandalwood is a semi-tolerant plant that requires shade when it is 1-2 years old and when it is 3 years old sandalwood requires full sunlight and support from other environmental factors to survive. The studies by Putranto (2010) and Muskitta et al. (2017) stated that growth models and environmental conditions can be used to predict vegetation growth to formulate references for forest management.

**Results of test of goodness of fit of structural models**

Test of the goodness of fit of the model will provide information about how feasible the model is for sandalwood regeneration with the value of predictive relevance ($Q^2$) equals 96.65%. Thus, the structured model has a very relevant and very accurate predictive value. The information contained in the data of 96.65% can be explained by the PLS model developed while 3.35% was described by other variables. The closeness of the relationship influence of one variable to another variable was determined by the value of determination ($R^2$). The climate $R^2$ value was 0.493, which means that the geographic latent variable effect on the climate is equal to 49.3%. Geography and climate effect on the soil amounted to 38.2%. Geography, climate and soil effects on vegetation were 50.6%. The size of the sandalwood population was influenced by geography, climate, soil, and vegetation, i.e., 55.2%. Sandalwood regeneration as an output model or response variable was influenced by geography, climate, soil, vegetation and sandalwood population by 38.2% (Table 2). The study results are also consistent with the research of Hadiyan et al. (2016) which shows that the vitality of sandalwood plants varies greatly between locations from various conservation plots caused by the environmental factors, varieties of sandalwood populations and genetic factors. The results of the study by Surata et al. (2001) showed that sandalwood can grow in dry climatic conditions of the D-E climate type, according to Schmidt and Ferguson's classification.

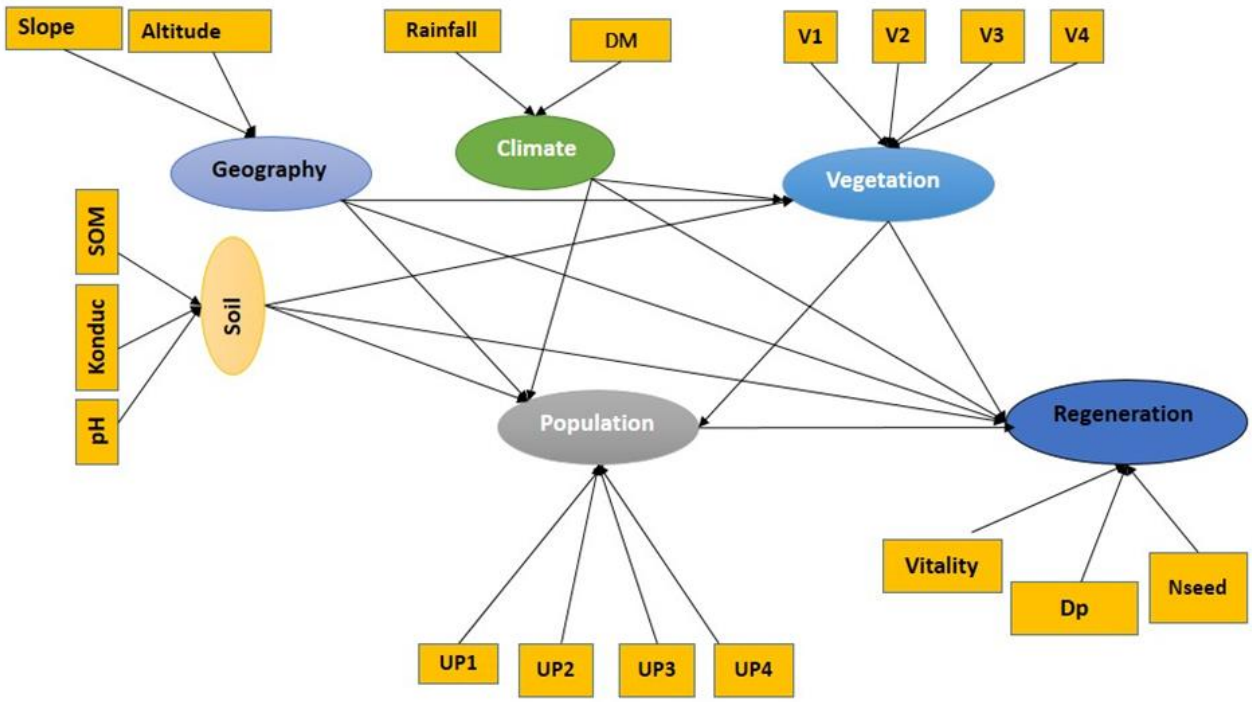


**Figure 3.** Model of the theoretical structure of exogenous latent variables that influence sandalwood regeneration in the forest and the community plantation in Timor Island. Figure Information: CH: Rainfall, BK: Dry month; V1: Vegetation density, V2: Taxa wealth, V3= Species diversity index, V4: Sandalwood host diversity index, SOM: Soil organic matter, Konduc: Soil conductivity; UP1: Trees population size, UP2: Size of the poles population, UP3: Saplings population size, UP4: Seedlings population size; Nbiji: Number of seeds, Vitality, Dp: Diseases and pets.

**Table 1.** Indicators that are feasible/significant as the compiler of a latent variable on the testing results of the measurement model (combination of loading and cross-loading factor)

| Variable/ indicator | Geography | Climate | Vegetation | Soil | Population | Reg. | P-value |
|---|---|---|---|---|---|---|---|
| Alt. | 0.851 | -0.349 | -0.029 | -0.540 | -0.023 | -0.037 | <0.001 |
| Slope | 0.851 | 0.349 | 0.029 | 0.540 | 0.023 | 0.037 | <0.001 |
| Rainfall | 0.248 | 0.702 | -0.056 | -0.480 | 0.045 | -0.085 | <0.001 |
| Dry months | -0.248 | 0.702 | 0.056 | 0.480 | -0.045 | 0.085 | <0.001 |
| KP_ (tax) | 0.132 | 0.235 | 0.830 | 0.267 | -0.009 | 0.023 | <0.001 |
| NP_ (ind) | -0.158 | -0.045 | 0.935 | -0.075 | -0.080 | -0.052 | <0.001 |
| H'P | -0.040 | -0.298 | 0.789 | -0.283 | 0.110 | 0.024 | <0.001 |
| Host | 0.828 | 0.970 | 0.084 | 0.850 | -0.054 | 0.128 | 0.212 |
| BO10 | 0.088 | -0.048 | 0.164 | -0.745 | -0.143 | -0.063 | <0.001 |
| BO20 | 0.038 | -0.062 | 0.186 | -0.745 | 0.018 | 0.010 | <0.001 |
| pH10 | 0.038 | 0.088 | 0.143 | 0.834 | -0.040 | -0.077 | <0.001 |
| pH20 | 0.146 | 0.102 | 0.124 | 0.743 | -0.088 | -0.048 | <0.001 |
| Kond10 | 0.147 | -0.137 | -0.042 | 0.634 | 0.039 | 0.268 | <0.001 |
| Kond20 | -0.267 | -0.275 | 0.146 | 0.523 | -0.036 | -0.211 | <0.001 |
| Trees | 0.030 | 0.342 | 0.196 | -0.321 | -0.550 | -0.480 | <0.001 |
| Poles | -0.148 | 0.019 | 0.040 | -0.129 | 0.750 | -0.171 | <0.001 |
| Saplings | 0.071 | 0.109 | 0.139 | 0.004 | 0.834 | 0.128 | <0.001 |
| Seedlings | 0.086 | 0.104 | -0.047 | -0.104 | 0.803 | -0.303 | <0.001 |
| Vitality | 0.123 | -0.665 | -0.159 | -0.140 | -0.305 | 0.587 | <0.001 |
| Disease pets | 0.231 | 0.950 | 0.146 | 0.497 | -0.090 | 0.492 | <0.001 |
| Number of seed | 0.249 | 0.104 | -0.029 | 0.218 | -0.299 | -0.747 | <0.001 |

**Results of structural model testing of variable direct effect**

The result of structural model testing is to test the hypothesis. Hypothesis testing was conducted by t-test at p-value <0.05 for significant and the p-value <0.01 for a highly significant effect on each path that had a direct or partial effect. The results indicated that the variables having an immediate effect were geographic, soil, and climate while the population had a direct impact on sandalwood regeneration. Meanwhile, vegetation had no significant effect on sandalwood regeneration. Vanclay (1994) states that the vegetation growth model is based on a system of statistical equations that can predict growth, regeneration, and yield of forest stands in various habitat conditions. However, to use this equation model, multivariate statistical tests need to be done with several variable combinations because each plant has different growth characteristics.

**Table 2.** Value of $R^2$ and $1–R^2$ for determination of $Q^2$ value

| Endogenous latent variable | $R^2$ | $1-R^2$ |
|---|---|---|
| Climate | 0.493 | 0.507 |
| Soil | 0.506 | 0.452 |
| Vegetation | 0.548 | 0.494 |
| Population | 0.552 | 0.478 |
| Regeneration | 0.382 | 0.618 |

**Results of structural model testing of indicator direct effect**

The result of structural model testing is to test the hypothesis. Hypothesis testing is conducted by looking at the p-value in each indicator and the path analysis coefficient value which shows a significant (direct) or partial relationship. The results showed that the indicator of the latent variable that did not give an immediate or significant effect was the sandalwood host, soil organic matter (BO10, 20, pH 10, 20, Kond 10, 20, tree population). Meanwhile, the other indicators had a direct or significant influence based on statistical tests with p-value < 0.001 for sandalwood regeneration in natural habitats and cultivation (Table 3).

The insignificant relationship between these variables and indicators requires further testing in the next study, namely the linearity test to ensure that variables and indicators do not have a linear influence on other variables. The test results of the linearity test and the new structural model are arranged in the form of structural model path diagram shown in Figure 4. In this study, geographic variables had a direct effect on population and sandalwood regeneration but did not directly affect vegetation. Climate variables directly affected the population and sandalwood regeneration but did not directly affect vegetation. Soil variables directly affected vegetation and population but had no significant effect on sandalwood regeneration in natural and artificial habitats because sandalwood that grows in Timor Island can develop well in any type of soil.

**Table 3.** The structural weight values of each latent variable and structural model test results indicators

| Variable/ indicator | Structural weight | P value | Information |
|---|---|---|---|
| **Geography** | | | |
| Alt. | 0.500 | <0.001 | Significant |
| Slope | 0.500 | <0.001 | Significant |
| **Climate** | | | |
| CH | 0.500 | <0.001 | Significant |
| BK | 0.500 | <0.001 | Significant |
| **Vegetation** | | | |
| KP_ (tax) | 0.314 | <0.001 | Significant |
| NP_ (ind) | 0.399 | <0.001 | Significant |
| H'P | 0.284 | <0.001 | Significant |
| Host | 0.003 | 0.359 | Not Significant |
| **Soil** | | | |
| BO10 | 0.183 | 0.008 | Significant |
| BO20 | 0.183 | 0.008 | Significant |
| pH10 | 0.229 | 0.003 | Significant |
| pH20 | 0.182 | 0.008 | Significant |
| Kond10 | 0.133 | 0.021 | Significant |
| Kond20 | 0.090 | 0.047 | Significant |
| **Population size** | | | |
| Tree | 0.137 | 0.007 | Significant |
| Pole | 0.255 | <0.001 | Significant |
| Sapling | 0.316 | <0.001 | Significant |
| Seedling | 0.292 | <0.001 | Significant |
| **Sandalwood regeneration** | | | |
| Vit. | 0.301 | <0.001 | Significant |
| HP | 0.212 | <0.001 | Significant |
| Nbiji | 0.487 | <0.001 | Significant |

Vegetation variables had a direct effect on sandalwood populations but had no significant effect on sandalwood regeneration process, and population variables had a significant impact on sandalwood regeneration process, which means that the size of sandalwood tree, pole, sapling, and seedling population were very influential on sandalwood regeneration both naturally and in the community plantation. The test results of this structural model were also in line with the observational data at eight observation stations which showed that the number of sandalwood populations at all observation stations showed significant changes (sandalwood population increased) both in Timor Tengah Selatan (TTS) and Timor Tengah Utara (TTU) Districts. The research results showed that the model of sandalwood growth and regeneration varied greatly between locations. This is also in accordance with the observations of Haryjanto et al (2005), Zobel et al. (1984) and Hadiyan et al. (2017). The growth of sandalwood plants varies between observation plots caused by the differences in the factors of genetic, vegetation, geography, soil and climate.

In conclusion, the results showed that the relevance value of the prediction of Q2 was 96.65% indicating that the structural model proposed was highly relevant and had high predictive values for the factors that influenced sandalwood regeneration. Thus, this model is feasible or appropriate to be used as recommendations in the framework of sandalwood development in the forests and plantations in West Timor, Nusa Tenggara Timur Province, Indonesia.

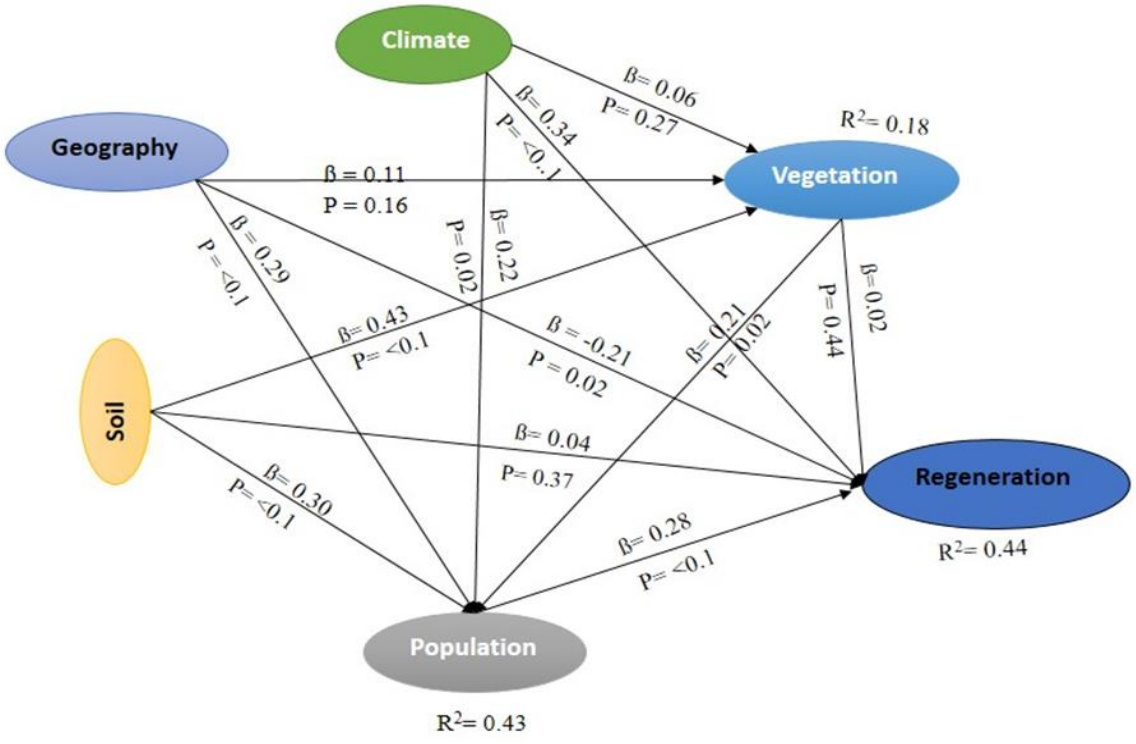


**Figure 4.** The structural model of the relationship/correlation of latent variables that affect sandalwood regeneration as a result of structural model testing which shows a significant relationship or had a direct effect with the p-value <0.05 = significant, and p-value < 0.01 = highly significant

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# Handling and marketing of dairy products in and around Bahir Dar Milkshed Areas, Ethiopia

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**Abstract.** *Sisay T, Alemayehu K, Haile M. 2018. Handling and marketing of dairy products in and around* Bahir Dar *Milkshed Areas, Ethiopia. Trop Drylands 2: 48-58.* Despite the great importance of milk in feeding the rural and urban population of Ethiopia, milk handling practices and marketing systems in the country are not well developed. This study was conducted to assess handling, processing and marketing of milk and milk products using 180 sample households in the formal survey with a pre-tested structured questionnaire. Market channels and chains of milk and milk products were described using market data from sample households, key informants and sale records. Overall, 45.6% of the sample households supplied milk for market with the highest in Bahir Dar City, followed by Tis Abay and lowest proportion was in Sebatamit rural *kebele*. Overall, the average amount of milk daily supplied to market was 6.6 liters/household and the figure in Bahir Dar City, Sebatamit and Tis Abay rural *kebele*s were 9.7, 5.6, and 2.33 liters, respectively. Daily milk was delivered through cooperative and other sale outlets as farm gate, customers` gate on delivery system and farm shop. Season, location and interaction of these factors had highly significant ($P \leq 0.01$) effects on volume of milk monthly collected at cooperatives. Different market channels, outlets, and agents were identified for various dairy products; butter being with the longest channel, followed by marketing of milk and low-fat milk/semi-skim milk to pass through about three channels. Milk supplied to market was generally constrained by feed shortage, lack of improved breed, unreliable milk market, unattractive price and producers` limited awareness. Dairy cooperatives generally created milk market outlets and supplied various processed milk products to market; of which low-fat milk (semi-skim milk) was sold in its fresh state which might be used as a less expensive product. Hence, the paramount role of the cooperatives in the area is to strengthen the linkage between producers and consumers, which in turn provides reliable milk market and benefits producers from market opportunity of dairying.

**Keywords**: Bahir Dar, dairy products, handling, marketing, processing

## INTRODUCTION

Milk plays a very important role in feeding the rural and urban population of Ethiopia. It is produced daily, sold for cash or readily processed and is a cash commodity in the milk-shed areas that enables families to buy other foodstuffs and significantly contributes to the household food security (MOA 1996). Despite huge potential and substantial development efforts to get the dairy subsector growing, there is a chronic shortage of the product in the country that calls for production more and above the domestic needs (Azage and Asfaw 2004). Milk marketing system in Ethiopia is not well developed where only 5% of milk production in rural areas is marketed as liquid milk (Getachew 2003). Large-scale marketing and processing of milk are limited to the area around Addis Ababa (i.e. the Addis Ababa milk shed). Currently, there are few milk processing plants in Ethiopia, including *Sebeta* Agro-Industry, Lame, Family, etc. owned by private sector (SNV 2008). Some of the processed products supplied to market are pasteurized fluid milk, table butter, hard cheese, yogurt, and cottage cheese (*ayib*) (SNV 2008).

According to CSA (2005), milk production in Amhara Region, Ethiopia was estimated at 466.7 million liters of which 2.4% was marketed as liquid milk, 49.8% was self-consumed and the rest 54.1% was processed to butter and other derivative dairy products. Accordingly, dairy potential areas in the region are identified and categorized into five milk shed areas, namely Bahir Dar, Dessie, Debre Berhan, Gondar and Debre Markos with each milk shed is targeted to centering the rapidly growing urban population and the rising demands for milk and milk products (BoARD 2004). In respect to this, establishment of dairy cooperatives in the milk shed areas emerged as one way of addressing the vast majority of smallholder producers. Thus, a total of about ninety dairy cooperatives and two dairy unions of which one is project-supported mini-dairy plant are found in the region at present (ARSCPA 2006). The Bahir Dar milk shed, besides its potential of supplying milk to Bahir Dar, dairy farms in the area have also a long time experience on dairy extension, technical support as well as service provision on breed improvement and animal health through different stakeholders. The study area, within Bahir Dar milk shed, is found along the main route from Bahir Dar City to Tis Abay South-East of Bahir Dar. Dairy cooperatives are emerged and come into existence to promote and foster milk production and marketing as a tool to realize market opportunities created in the area.

Despite emergence of cooperatives to facilitate milk market linkages, little is known about producers` handling, processing, and marketing practices as well as performance of cooperatives in the study area. Yitaye (2008) in their studies recommended the need to establishing, expanding and providing institutional support to dairy marketing cooperatives to advance the recent trend in commercialization of subsistence production with a good potential to catalyze market participation. In order to design relevant development plan for the area, it is a prerequisite to understand the prevailing situations. For the research to be effective and address the targeting groups, identifying the problems and understanding of the producers` handling, processing, and marketing practice of dairy products as well as evaluating the performance of cooperatives on monthly milk collection and processing efficiency in the study area is essential to open up way of mitigating the problems. In due concern, the present study was conducted to generate pertinent information on these and other relevant issues that may benefit future development plan strategies for smallholder dairy productions in the milk shed.

The objectives of this study were: (i) To assess the prevailing traditional handling and processing of milk and milk products in the studied milk shed areas. (ii) To describe the marketing system as well as channels observed in the marketing of milk and milk products. (iii) To evaluate performances of dairy cooperatives operating in the studied areas. (iv) To identify constraints and opportunities of dairying in the areas.

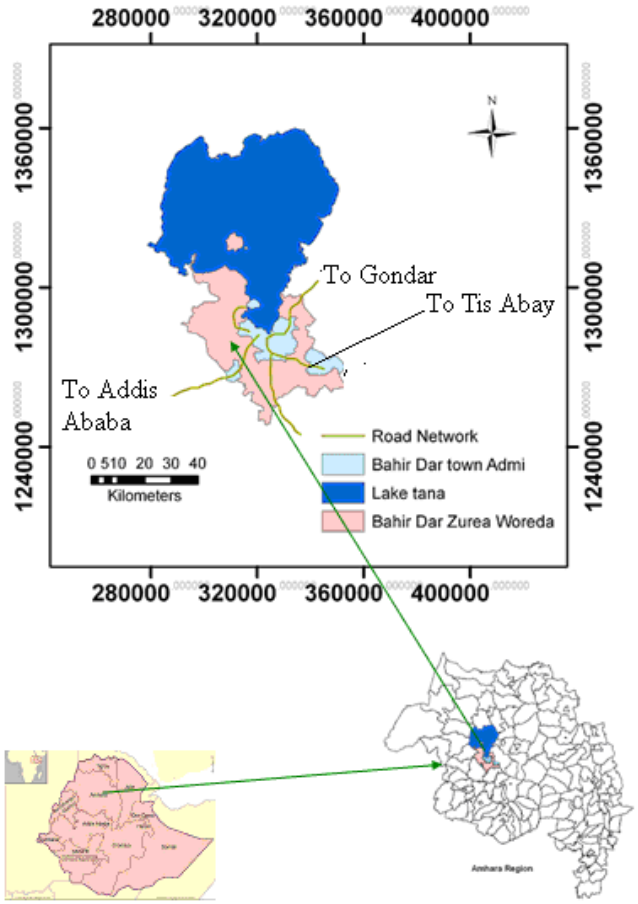


**Figure 1.** Location of the study area (Map of Ethiopia, Amhara Region, Bahir Dar city administrative and Bahir Dar Zuria *woreda*)

## MATERIALS AND METHODS

### Description of the study areas

The study was conducted in Bahir Dar city administration and its adjacent area of Bahir Dar Zuria *woreda* of Amhara Regional state (Figure 1). Bahir Dar city administration has an altitude ranging from 1700 to 1840 meters above sea level (m.a.s.l). Bahir Dar City is the capital of Amhara regional state, located 565 km northwest of Addis Ababa. It is situated at an altitude of 1840 m.a.s.l. The area receives an average annual rainfall ranging between 850-1250mm with the minimum and maximum average daily temperatures of 10-32$^0$C, respectively (BoARD 2006). Bahir Dar City is constituted of 17 urban *kebele*s. The human population of the town is estimated at 199,210 (CSA 2008).

Bahir Dar Zuria *woreda* is situated at an altitude ranging from 1700-2300 m.a.s.l. The *woreda* is constituted of 29 rural *kebeles* and has area coverage of 116,667 hectares. The human population is estimated at 245,820 (WoARD 2006). In the *woreda*, cattle population is estimated at 121,886 (CSA 2003). The major crops grown in the area are wheat, barley, millet, *teff*, and maize (WoARD 2006). In the area, both crop-livestock and livestock production systems are found, even though the mixed production system dominates.

### Sampling procedures and data collection

*Questionnaire-based survey work*

A three-stage purposive sampling procedure was conducted to select 180 specific dairy producers for this study. The primary sampling units, represented by dairy producers along the main route Bahir Dar to Tis Abay within the radius 32km Southeast of Bahir Dar, were selected. Finally, from census recording, individual households were selected at random. A total of 180 sample units (dairy producers) were selected, where 45, 65 and 70 dairy producers from Bahir Dar City, Sebatamit and Tis Abay rural *kebele*s, respectively. To assess producers` handling and processing practices and identify the type of dairy products produced, marketed as well as constraints of milk market in the area, farmers/producers were interviewed using semi-structured questionnaire.

Cross-sectional survey was employed with one-visit multiple subject interview (ILCA 1990). Information collected includes household characteristics, cattle number by breed, milk handling practices, daily milk output, and allocation during survey, marketing data, monthly income from milk product sale, participation in the cooperative and benefits, credit access, determinants for marketable milk supply, constraints and opportunities of dairy marketing. In

addition, related information such as productive and reproductive performance of cow, breeding method, major supply of feed resources in dry and rainy seasons. On the other hand, marketing of milk and milk processed products like butter, skim milk (defatted milk), sour milk (*Ergo*) as well as cottage type cheese (*ayib*) were studied at other marketing agents. Separate semi-structured informal interview checklists were used for the mobile traders, whole seller groups and dairy cooperative. Generally, ten mobile traders at Sebatamit participated in skim milk marketing and Tis Abay rural *kebele*s in butter marketing, respectively and at Bahir Dar City ten whole butter sellers were interviewed using separate semi-structured questionnaires to acquire and develop general information about the marketing of milk processed products in the area.

*Performance evaluation of dairy cooperatives in the study area*

To evaluate the performance of milk collection and unit price of milk paid at the cooperatives, recorded secondary data over the last five months were gathered from Bahir Dar City and *Abay Zuria* cooperatives, which had consistent recordings for the study period considered. To analyze monthly milk collection and unit price (in birr) paid over the period of five months, 8 observations in total on monthly milk volume collected and unit price paid (12 observations for each of the two variables from each of these two cooperatives) were collected for two seasons: dry season (October to April) and rainy season (May to September).

**Data analyses**

Statistical Package for Social Science (SPSS, 12 vers.2001) was used to analyze the data collected through the survey. Survey results were reported using descriptive statistical tools such as means, percentages, standard deviations, and frequencies. Performance of cooperative in promoting milk market access to producers` milk as well as for their substantial development; monthly milk volume collected and average unit price paid per liter of milk collected per cooperative was analyzed using general linear model (GLM) based on season and location of dairy cooperatives. In addition, processing efficiency for creaming and cream churning at cooperatives were analyzed based on sample collected for milk, skim milk obtained as well as cream churned at cooperatives. For the average milk volume monthly collected as well as unit price paid (in birr) per liter of milk collected at dairy cooperatives the factors were season (dry and rainy season) and location of dairy cooperatives as (Bahir Dar City and *Abay Zuria*) included into the model as fixed factors. Interactions between factors were removed from the model if they did not show a significant ($P< 0.05$) effect, following step-down procedures.

Mean comparisons were done using Turkey's method for variables if the F values showed a significant difference. Levels of significance are considered 5% and 1%. Data related to selling outlets for dairy product type collected to identify the dairy marketing system, channels and agents were analyzed using descriptive statistics of (SPSS, 12 ver.2001). In addition, the data collected with rapid market appraisal (RMA) and recorded at four selected sale points of the three dairy cooperatives reported with flow charts. The model used to analyze monthly volume of milk collected and average unit price paid per liter by cooperatives was as follows:

$$Yijk= \mu+ Si + Lj + (SL)ij + eijk$$

Where, Yijk = Monthly milk volume received or price paid per liter by the $k^{th}$ cooperative at the $i^{th}$ season and $j^{th}$ dairy cooperatives (location); $\mu$ = Overall mean; Si = the fixed effects of $i^{th}$ season (i= rainy, dry season)); Lj = the fixed effects of the $j^{th}$ location of dairy cooperative (j = 1,2); (SL)I = the interaction effect of the $i^{th}$ season and $^{jth}$ location of the dairy cooperative; eijk= the random error observed with $ij^{th}$ observations

## RESULTS AND DISCUSSION

**Household socio-economic characteristics**

*Landholding*

The average landholding was 1.67 ha and 1.37 ha per household for Sebatamit and Tis Abay rural *kebeles*, respectively. Obviously, land is one of the major important production factors for undertaking farming activities. However, it is a big issue and challenge in Bahir Dar City and the other two study sites, which might be resulted from increased human population of the rural areas. This calls for developing specific policy scheme to promote the potential contribution of dairy in the area. Even in Bahir Dar City, more than 77% of the interviewed households were running the dairy farming within their own backyard, and 4.4% were within their rented residence, whereas 17% of the interviewed households obtained land from the municipality for temporary dairy farming. In general, such practice, however, together with other factors might have caused some hygienic risks. Similarly, Yitaye (2008) reported in the north-western Ethiopian highlands of the urban dairy production system that 80.7% of the respondents were keeping their dairy cattle within their confined residence.

**Cattle holding and milk production**

*Cattle holding*

The overall average cattle holdings were 6.88 ($\pm$ 0.275) heads, and higher average cattle holdings were noticed at Sebatamit (7.23 heads) and Tis Aby rural *kebele*s (7.19 heads) than Bahir Dar City (Table 1). The average number of cattle holding per household and the proportion of cows constituting the cattle herd across study sites could be seen in connection with the size of land holdings in the rural *kebeles* as well as the location of milk production area-urban market center. Higher proportion (64.44%) of the cows in Bahir Dar City constitute the cattle herd and of which crossbred type cows constitute its larger proportion (84.75%). The reason might be partly due to the location that Bahir Dar milk shed is close to the urban market center, Bahir Dar City as well as the access to artificial

insemination service delivery. A similar study in the north-western Ethiopian highlands of the urban production system reported a significantly higher proportion of crossbred cows (Yitaye 2008).

Considering milking cows, it was higher in Bahir Dar City (2.62 heads) than the other two study sites of the total cows (Table 1), which might be due to better management practices of producers in feeding, health care, breeding, and other related activities. In addition, the larger proportion (87.3%) of milking cows in Bahir Dar City constituted with crossbred of indigenous Zebu and Holstein Friesian contrary to Tis Abay and Sebatamit rural *kebele*s, respectively. Access to artificial insemination service delivery, educated household heads, and the location could partly attribute to use of improved dairy type breed.

Overall daily milk off-take per cow was 1.23 (0.395) and 5.46 (0.223) liters for local and crossbred cows, respectively. A higher daily milk off-take per cow of local and crossbred was observed at Bahir Dar City and was the lowest at Sebatamit rural *kebele* (Table 2). Overall mean daily milk off-take per cow of both breed types was almost consistent with the average values (1.2 and 5.2 liters) for local and crossbred cows reported for Bahir Dar milk shed area (Asaminew 2007).

*Milk production*

Milk seller producers in Bahir Dar City, Tis Abay, and Sebatamit rural *kebele*s accounted for 97.8, 41.4 and 13.8% of the sample households, respectively with an average daily milk output of 7.6 ± 0.79 liters per household (Table 3). Average amount of milk daily produced for milk seller producers was significantly greater in Bahir Dar City and lower for Tis Abay. The difference might partly be due to higher number of crossbred milking cow holdings in Bahir Dar City than that of the other two study sites. This, among other factors, could possibly be attributed to the marked difference in the daily milk output (liters) per household among the studied sites. However, the relatively higher average value in Sebatamit than in Tis Abay might be due to small number of seller producers as well as these producers possessing mainly crossbred cows. Daily milk output per household for not milk seller (exclusively milk processor) producers had an overall average of 1.9 ± 0.15 liters. Relatively higher and lower (2.3 and 1.6 liters, respectively) average volume of milk daily were produced in Tis Abay and Sebatamit rural *kebele*s. The relatively higher number of milking cow holdings per household at Tis Abay than Sebatamit rural *kebele* (Table 1) might have partly attributed to the relatively greater volume of milk daily produced. Generally, the overall daily milk output in the studied areas was 4.5± 0.42 liters per household and this is highest in Bahir Dar City than the other two studied sites. Significantly higher number of crossbred milking cow holdings per household in Bahir Dar City than the other two sites might have attributed to the larger volume of milk daily produced per household.

**Handling and processing practices of milk**

*Handling practices of milk*

Overall, the majority of the respondents reported the practice of milker`s hand washes before milking. On the other hand, however, the practice of udder washing is almost insignificant with Bahir Dar City had relatively higher proportion of the sample households practicing udder washing before milking than the other two studied sites (Table 4). In general, lower proportion of the sample households in this study practiced udder washing for sanitary milking is consistent with the reports in Bahir Dar milk shed area, that majority of respondents do not follow sanitary milking practices (Asaminew 2007). However, Yitaye (2008) on the contrary, reported for northwestern Highlands of Ethiopia 94% of the respondents wash udder before milking in urban and peri-urban production systems. This variation might be due to the target population used for the study as well as area differences. The poor hygienic practice observed in this study is possibly indicating the gap in producers' awareness of sanitary practice on milk handling. To address the issue, it seeks training and extension service delivery targeted at skill development of the producer.

**Table 1.** Mean (± S.E) cattle holdings by breed type across three study sites in Amhara region, Ethiopia

| Cattle category | Study sites | | | Overall |
|---|---|---|---|---|
| | Bahir Dar City | Sebatamit rural *kebele* | Tis Abay rural *kebele* | |
| Total cattle/HH | 5.91 (0.389) | 7.23 (0.378) | 7.19 (0.555) | 6.88 (0.275) |
| Indigenous Zebu type | $0.84^{a}$ (0.275) | $6.54^{b}$ (0.377) | $6.74^{b}$ (0.6) | 5.19 (0.335) |
| Crossbred type | $5.07^{b}$ (0.448) | $0.69^{a}$ (0.181) | $0.44^{a}$ (0.15) | 1.69 (0.203) |
| Total cows/HH | 2.62 (0.212) | 2.31 (0.153) | 2.81 (0.202) | 2.58 (0.11) |
| Milking cows/HH | 2.05 (0.176) | 1.58 (0.088) | 1.8 (0.148) | 1.79 (0.081) |
| Indigenous Zebu | $0.26^{a}$ (0.095) | $1.31^{b}$ (0.1) | $1.64^{b}$ (0.162) | 1.17 (0.088) |
| Crossbred | $1.79^{b}$ (0.19) | $0.27^{a}$ (0.083) | $0.17^{a}$ (0.055) | 0.62 (0.08) |

Note: $^{a,b}$ Row means with different superscprit letters are significantly different (P≤0.05), HH: Household

**Table 2.** Mean (± S.E) daily milk off-take/ cow and average lactation length of cows across three study sites in Amhara region, Ethiopia

| Variables | Study sites | | | Overall (n = 180) |
|---|---|---|---|---|
| | Bahir Dar City ( n=45) | Sebatamit rural *kebele* ( n = 65) | Tis Abay rural *kebele* (n =70) | |
| Daily milk off-take (L/cow) | | | | |
| Zebu type cow | 1.7 (0.182) | 1.05 (0.046) | 1.33 (0.04) | 1.23 (0.29) |
| Crossbred cow | 5.88 (0.297) | 4.32 (0.21) | 4.95 (0.349) | 5.46 (0.22) |

**Table 3.** Average daily milk production (± SE) per household across three study sites in Amhara region, Ethiopia

| Description | Study sites[1] | | | Averages |
|---|---|---|---|---|
| | BDT | SRK | TARK | |
| Households (%) | | | | |
| Milk seller | 97.8 | 13.8 | 41.4 | 45.6 |
| Average daily milk output (liters)/ HH | $10.5^{c}$ | $6.6^{abc}$ | $3.4^{a}$ | 7.6 (0.79)[2] |
| Milk processors | 2.2 | 86.2 | 58.6 | 54.4 |
| Average daily milk output (liters)/ HH | 4.5 | 1.6 | 2.3 | 1.9 (0.15) |
| Total average daily milk output (liters)/ HH | $10.4^{b}$ | $2.2^{a}$ | $2.7^{a}$ | 4.5 (0.42)[3] |

Note: [1] Row means with different superscript letters are significantly different for the considered variables ($p<0.05$), [2] Average daily milk output (liters)/HH for milk seller producers,[3] Overall daily milk output (liters)/HH for the study area, BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*, HH: Household

**Table 4.** Milk handling practices of sample households in the study sites

| Variables | Study sites | | | Overall (n=180) |
|---|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) | |
| Udder washing practice (%) | | | | |
| Before and after milking | 17.8 | 7.4 | 1.4 | 7.8 |
| Before milking | 40 | 1.5 | 5.7 | 12.8 |
| If only udder contaminated | 40 | 32.3 | 24.3 | 1.1 |
| Milker`s hand wash before milking (%) | 95.6 | 98.5 | 100 | 98.3 |
| Utensil cleaning frequency (%) | | | | |
| Just before and after milking | 95.6 | 49.2 | 52.9 | 62.2 |
| Once in a day | - | 40 | 42.9 | 31.1 |
| Once every 2 to 3-days | 4.4 | 10.8 | 4.3 | 6.7 |
| Household used milking utensil (%) | | | | |
| Gourd | 13.3 | 96.9 | 100 | 77.2 |
| Plastic | 68.9 | - | - | 17.2 |
| Gourd and plastic | 17.8 | 3.1 | - | 5.6 |
| Total | 100 | 100 | 100 | 100 |

Note: n: number of respondents, BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*

Overall, the majority (62.2%) of dairy producers in the studied areas wash utensils before and after each milking. Majority (95%) of the sample households in Bahir Dar City did it in a day both before and after each milking, and quite larger proportion of the sample households at the other two study sites practiced cleaning once a day and even every two to three days interval (Table 4). Urban dairy producers acquainted with sanitary importance might have attributed to the difference in the practice of cleaning milking utensils in a day among the three studied sites. In this respect, differences were observed in the frequency of cleaning milk utensils in a day among study sites. Such practice of cleaning milk utensil in a day in Sebatamit and Tis Abay rural *kebele* coupled with substandard hygienic practice of milking could render milk spoilage, wastage and even might have resulted in consumers` health hazards.

Overall, 77.2% and 17.2% of the sample households used gourd and plastic containers, respectively for milking purposes and the rest (5.6%) used both types. Almost all the sampled households in Sebatamit and Tis Abay rural *kebeles* used gourd as opposed to sampling households in Bahir Dar City (Table 4). In a study, but for different production systems, the use of gourd by the majority (62%) of peri-urban producers, while 83% of urban producers used plastic containers reported for northwestern Ethiopian highlands by Yitaye (2008), was consistent with the overall result and for Bahir Dar City, respectively in the present study.

**Milk processing practices**

Overall fermentation time for milk at room temperature was 4.1 days and this varied from the longest (4.5 days) at Bahir Dar City to the shortest at the other two study sites (Table 5) which was mainly due to ambient temperature differences of the corresponding study sites. This could possibly favor the activity of lactic acid bacteria, which in turn results to shorten fermentation time of milk, while the relatively lower ambient temperature in Bahir Dar City might have possibly extended milk fermentation time.

Overall, the average amount of fermented milk required to produce a kg of butter was 21.2 (± 0.26) liters, and the highest (24.3L) was in Bahir Dar City with the lowest at Tis Abay rural *kebele* (20.2 L) (Table 5). Large number of crossbred milking cow holdings per household in Bahir Dar City as opposed to the other study sites, together with other factors might have attributed to an average volume of fermented milk required to produce a kilogram of butter is different. An average volume of milk (18.1 liters) to produce a kilogram of butter reported by Asaminew (2007) was less than the overall mean amount in the present study. The difference might be due to the proportion of crossbred and indigenous Zebu-type milking cows.

There were different reasons for processing milk into various processed products (Table 6). However, differences were observed among the studied sites for the reasons of processing of milk. For instance, most sampled households in Sebatamit rural *kebele* processed milk to produce diversified processed milk products mainly for household consumption and the surplus was for sale. However, sample households mainly in Bahir Dar City and to a lesser extent in Tis Abay processed milk due to the lack of regular milk market during fasting periods of the year. Orthodox Church followers comprise about 40% of the Ethiopian population where majority of them abstain from consuming milk and other animal products for about 200 days in a year.

**Table 5.** Average volume of fermented milk (liters) churned at a time and fermentation time across three study sites in Amhara region, Ethiopia

| Variables | Study sites | | | Overall Mean (S:E) |
|---|---|---|---|---|
| | BDT Mean (S.D) | SRK Mean (S.D) | TARK Mean (S.D) | |
| Amount of fermented milk churned at a time | 10.1 (5.67) | 5.7 (2.88) | 6.6 (3.29) | 6.73 (.31) |
| Amount of fresh milk to produce a kg of butter | 24.3 (2.90) | 21.1 (3.18) | 20.2 (2.7) | 21.2 (0.26) |
| Milk fermentation time for churning (days) | 4.5 (1.28) | 4..0 (1.3) | 4.1 (0.85) | 4.1 (0.09) |

Note: BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele;* SD: Standard deviation, S:E: Standard errors

**Table 6.** Role of family members in milk processing practices across three study sites in Amhara region, Ethiopia

| Variables | Study sites | | |
|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) |
| Do a household process milk (%) | | | |
| Yes | 51 | 100 | 97.2 |
| Household member involved in milk processing % | | | |
| Children less than 15-years | 11.3 | 8 | 6 |
| Female adults | 64.2 | 67 | 78.3 |
| Male adults | 22.6 | 25 | 15.7 |
| Hired labor | 1.9 | - | - |
| Reasons for milk processing (%) | | | |
| To extend product shelf life | - | 30.8 | 41.4 |
| Diversify processed products for consumption and/or market | 2.2 | 69.2 | 45.5 |
| Lack of regular market for milk | 48.8 | - | 11.3 |
| No churning practice | 49 | - | 2.8 |
| Time occasion for larger volume of milk to process (%) | | | |
| Long fasting period | 48.8 | 4.5 | 11.2 |
| *Kiremt* (rainy season) | 2.2 | 84.5 | 78.8 |
| Dry season | - | 11. | 7.2 |

Note: N: number of respondents, BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*

Accordingly, the majority of sample households in Sebatamit and Tis Abay rural *kebeles* reported processing larger proportion of milk in the rainy season (Table 6). In general, this could be seen in connection to better supply of feeds both quality and quantity-wise in the rainy season. Collecting and preserving feed resources in the rainy season need to be the focus of extension service delivery to improve dry season`s animal feeding for increasing milk production.

The majority of sample households in Sebatamit and Tis Abay rural *kebele*s reported processing milk into various processed products and further the majority of them process larger proportion of milk during the rainy season as opposed to sampling households in Bahir Dar City (Table 6). These, together with other factors, might have created enormous workload on female adults of the former two study sites than in Bahir Dar City. With this respect, generally considering benefits of milk market linkage in the area established through cooperatives, seeks for addressing the limiting factor to enhance milk production and selling at household level, which ultimately improves benefit of producers from milk selling as well as reducing the workload of female adults.

The traditional method of milk processing was employed using gourd and clay pot for churning to produce butter, but the method was reported to be labor-intensive and time-consuming. The majority of the sample households employed the traditional method of churning and further processing as well-practiced to produce other processed milk products. Generally, in respect to this, the further processed milk products in this study included cottage cheese, ghee, and *metata ayib*, where the production of *metata ayib* was reported to depend mainly on the volume of milk available for processing. Dairy producers in the study area produced traditional hard curd mass of products known locally as *metata ayib*. They *are* poured in a clay pot or pan and are heated similar to cottage cheese until a distinct curd mass is formed. The clay pot is then put away from the fire to facilitate cooling and by the time the curd whey mixture is transferred to another smoked clay pot or gourd and kept at room temperature. The procedure followed by producers in the manufacturing of this product is depicted in Figure 2.

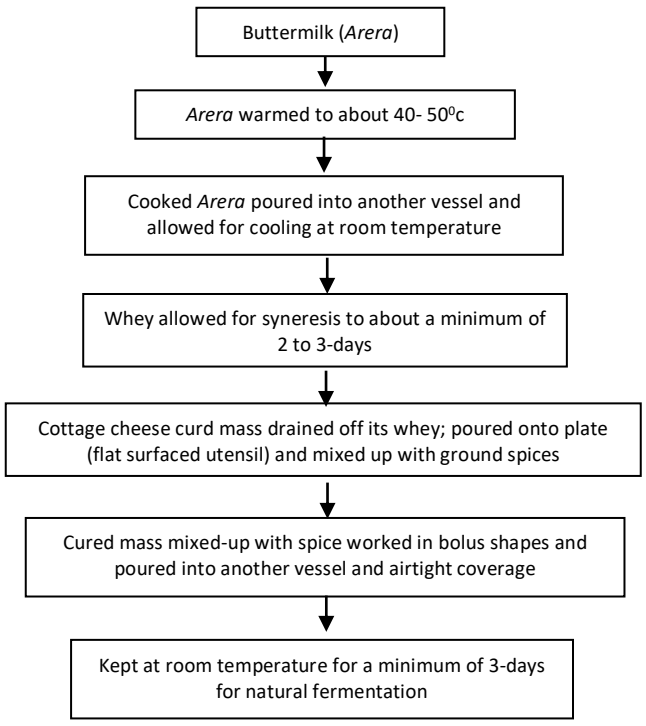


**Figure 2.** Flow diagrams for *Metata ayib* making in the study area

In general, the practice and procedures for making the product in the study area are indigenous knowledge developed for preservation and extending product`s shelf life. Hence, it deserves further investigation and research on the chemical composition of ingredients, reaction to the process, chemical composition and food quality of the product.

**Milk and milk products consumption of households in the studied area**

The overall daily milk consumption was 0.4 liters per household, and this was relatively high (0.5 liters) in Bahir Dar City and low in Sebatamit rural *kebele* (0.2 liters) (Table 7). Similarly, Lemma et al. (2004) reported almost similar average daily milk consumption at household level for East Shoa Zone of Oromia. In this study, the lower average amount of milk daily produced per household and the majority of the sample households at Sebatamit rural *kebele* processed milk might have attributed to the lower average amount of milk daily consumed. Generally, in the study area, children were prioritized in most of the cases (78.9%) for milk consumption of milk, which might be due to its nutritional value importance to young children.

**Characterizing dairy marketing system in the study area**

*Producers` involvement in milk and milk product marketing*

This study revealed that higher proportion of households in Bahir Dar City followed by Tis Abay rural *kebele* supply milk for market than Sebatamit rural *kebele* (Table 8). In addition, the majority and about two-fifths of the sample households in Bahir Dar City and Tis Abay rural *kebele*, respectively reported for milk produced is to market. Tis Abay is a small rural town with regular and frequent public transport access; this together with other factors could possibly create opportunity for the involvement of different milk marketing agents in the area. Thus, consequently, the sample households in Bahir Dar City and Tis Abay rural *kebele* might have been encouraged for delivering milk to other sale outlets as opposed to households in Sebatamit rural *kebele*.

The average volume of milk daily supplied per household was highest in Bahir Dar City (9.7 liters) and lowest in Tis Abay rural *kebele* (2.3 liters) (Table 8). The majority of the sample households in Sebatamit (100%) and Tis Abay (80%) were involved in butter marketing as opposed to sampling households in Bahir Dar City (Table 9). Nevertheless, cooperatives established milk market linkage within each of the respective study sites. Majority of the sample households in Tis Abay and Sebatamit rural *kebele*s reported for milk processing to produce diversified milk processed products for family consumption and the surplus was for sale. This, together with other factors might have attributed to the majority of the sample households selling butter. On the contrary, some households (44%) in Bahir Dar City might have processed unsold milk during the long fasting periods, mainly used for family consumption.

**Table 7.** Milk consumption of households across three study sites in Amhara region, Ethiopia as reported by respondents

| Parameters | Study sites | | | Overall (n=180) |
|---|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) | |
| Milk consumption (L/day/HH) | 0.58 | 0.2 | 0.4 | 0.4 (0.32) |
| Consumption priority (%) | | | | |
| Children | 64.5 | 80.0 | 87.1 | 78.9 |
| Husband | 18.4 | 3.1 | 1.4 | 6.2 |
| Sick and elders | 2.2 | 9.2 | 1.4 | 4.4 |
| No distinction | 13.7 | 4.6 | 5.8 | 7.2 |
| No consumption of whole milk | 2.2 | 3.1 | 4.3 | 3.3 |
| Total, % | 100 | 100 | 100 | 100 |

Note: BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*, HH: Household, n: Number of respondents

**Table 8.** Milk selling practice of producers across three study sites in Amhara region, Ethiopia

| Variables | Study sites | | | Overall (n=180) |
|---|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) | |
| Households sold milk (%) | | | | |
| Cooperative | 15.6 | 13.8 | 12.8 | 13.9 |
| Other sale outlets* | 82.2 | - | 28.6 | 31.7 |
| Farmgate | 35.6 | - | 20 | - |
| Customers` gate | 15.5 | - | 7.14 | - |
| Both types | 28.9 | - | - | - |
| Own farm shop | 2.2 | - | - | - |
| Average unit price paid/L of milk (Eth. Birr) | | | | |
| Dairy cooperative | 3.75 | 3.5 | 2.1 | 3.0 |
| Other sale outlets | 4.00 | - | 2.35 | 3.4 |
| Travel time (minutes) to reach milk collection center | 25 | 42.38 | 38 | 36.38 |
| Average daily milk sold (L/household) | 9.7 | 5.6 | 2.3 | 6.6 |
| Households faced with milk rejection (%) | 13.3 | 1.54 | 12.9 | - |

Note: n: Number of respondents, BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*, *= Means farm gate, customers` gate (delivery system) and own farm shop milk sale outlets

**Milk collection, processing, and marketing in the dairy cooperatives**

*Milk collection*

Milk was collected once daily in the morning time in Abay Zuria and Tis Abay cooperatives, however, Bahir Dar City cooperative received milk twice a day, i.e., morning and late afternoon time. On arrival at the collection center, the milk was observed for general appearance, adulteration or skimming off using lactometer readings and buying based on volume. The overall mean volume of milk (liters) collected monthly at the cooperative was 12321.6 ($\pm$107.45) liters. Highly significant difference was ($P \leq 0.01$) observed between the cooperatives and seasons considered on the average volume of milk received monthly.

**Table 9.** Processed milk product selling practices of producers across three study sites in Amhara region, Ethiopia

| Variables | Study site | | |
|---|---|---|---|
| | BDT (n = 45) | SRK ( n = 65) | TARK (n = 70) |
| Butter selling | | | |
| Households used sale outlets (%) | | | |
| Open market | - | 100 | 77.1 |
| Farm gate | 2.2 | - | 2.9 |
| Farm shop | 2.2 | - | - |
| Households' used market place (%) | - | - | - |
| Urban market | 4.4 | 100 | - |
| Local market | - | - | 80 |
| Buyers type of the product (%) | | | |
| Consumers | 4.4 | 81.6 | 21.6 |
| Mobile traders | - | 16.9 | 57 |
| Institution | - | 1.5 | 1.4 |
| Households sold other processed milk products (%) | | | |
| Ghee | 2.2 | 13.9 | 11.4 |
| Metata Ayib | - | 6.1 | 4.2 |
| Sour milk *(ergo*) | 2.2 | - | - |

Note: N: Number of respondents, BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*

The variance analysis revealed the monthly volume of milk collected in the dry season was significantly ($P \leq 0.01$) higher than in the rainy season`s monthly volume of milk collected at Bahir Dar City cooperative (Table 10). The majority of the sample households were restricted from consumption of milk during the long fasting periods of Orthodox Church followers. The overall mean monthly milk collection per cooperative of the present study (12321.6 liters) was much higher as compared to the report by Solomon (2006) for *Dejen woreda* (4217.56 liters). Result of variance analysis has shown that location of the dairy cooperative had significant ($P \leq 0.05$) effect on the monthly average unit price of milk paid. The overall mean monthly average unit price of milk paid per cooperative was 2.75 birr, being the highest in Bahir Dar City (2.9 birrs) and lowest in Abay Zuria cooperative (2.55 birr). Even if there was not marked difference in the average unit price of milk paid both for cooperative and season, relatively higher average unit price of milk paid in the rainy season as compared to that of dry season in both cooperatives. This might partly be due to the long fasting periods within the dry season, at which time the majority of Orthodox Church followers abstain from consuming milk and other livestock products. This consequently could affect consumers` number and further reduction of the product price.

*Processing*

Various processed milk products, i.e. cream, skim milk, sour skim milk, cottage cheese, butter, and occasionally sour milk were the major milk processed products produced in the cooperatives in the study areas. The cooperatives with the technological innovation introduced since their inception time, carried out milk separation and cream churning using centrifugal separator and hand-driven churner, respectively during the study period. In addition, aluminum milk cans and plastic containers were used for handling milk and milk processed products and a pan was used for heating and making cottage type cheese. The various processed milk products produced at the cooperatives were butter, fresh skim milk, sour skim milk, and milk as well as cottage type cheese.

**Table 10.** Mean (± S:E) volume of milk collected monthly and unit price (Eth.birr) paid in the studied cooperatives

| Variables[1] | | Monthly milk volume (lts) collected[2] | | Price (birr) paid per liter of milk[3] |
|---|---|---|---|---|
| | N | M ean (+ S:E) | N | Mean (+ S:E) |
| Bahir Dar City cooperative | 18 | 21234.9[b] (151.94) | 18 | 2.9[a] (0.16) |
| *Abay Zuria* cooperative | 18 | 3409.4[a] (151.94) | 18 | 2.55[a] (0.16) |
| Overall mean[4] | 36 | 12321.6 (107.45) | 36 | 2.75 (0.08) |
| Season | | | | NS. |
| Dry season (DS) | | 13193.9[b] (151.94) | | 2.65 (0.16) |
| Rainy season (RS) | | 11450.4[a] (151.94) | | 2.85 (0.16) |
| C.V | | 3.68% | | 17.12% |
| Season effect on levels of location | | | | |
| Interaction of location & season | | 2237.7 (214.84)[5] | | NS |
| Bahir Dar City cooperative *DS | 9 | 23225.5.[b] (214.84) | | |
| Bahir Dar City cooperative *RS | 9 | 19244.7[a] (214.84) | | |
| *Abay Zuria* cooperative *DS | 9 | 3162.3[a] (214.84) | | |
| *Abay Zuria* cooperative *RS | 9 | 3656.6[a] (214.84) | | |

Note: [1] Column means with different superscript letters are significantly different, [2, 3]: Comparison among respective variable means is along column wise, [4], Overall mean volume of milk monthly collected, Average unit price (Eth. Birr) of milk paid,, [5] Mean monthly milk volume of the interaction effects, Significant at $P \leq 0.01$, Significant at $P \leq 0.05$, NS= Not significant, S:E: Standard errors, C.V: Coefficient of variation, N: Number of observations, DS:Dry season, RS: Rainy season

*Marketing of milk and milk processed products at cooperatives*

In Bahir Dar City cooperative sold the highest (88%), followed by Tis Abay cooperative (67%) and *Abay Zuria* cooperative less than 1% of their own total volume of milk collected (Table 11). The location of Bahir Dar City cooperative in the town could possibly attribute to its larger volume of milk sold, as it is generally higher demand for milk and milk products in the urban center. Fresh defatted milk/ skim milk and semi-skim milk sold overall amounted to 11280.1 liters (70.6%) with the highest was at *Abay Zuria* (97.5%) followed by Tis Abay (82.5%) and lowest at Bahir Dar City cooperative (0.08%). In this respect, revenue from processed milk products and whole milk accounted for 9.9 and 90.1, 99 and 0.98 and 36.7 and 63.3%, respectively of total revenue obtained for Bahir Dar City, *Abay Zuria* and Tis Abay cooperatives. Larger proportion of defatted milk/ skim milk sold in its fresh state at *Abay Zuria* and Tis Abay cooperatives together with other factors might have attributed for the greater revenue fetched from processed milk products.

Average gross revenue obtained per liter of whole milk processed for investigated has shown that highest (4.13 birr) and (3.73 birrs) were generated at Tis Abay and *Abay Zuria* cooperatives, respectively than at Bahir Dar City cooperative (1.88 birrs), (Table 11). The difference could partly be linked with the types of processed milk products sold, average sale unit price received, disposal of unsold processed products, and the efficiency of processing. In line with this, generally fresh skim milk was exceptionally sold at *Abay Zuria* and Tis Abay cooperatives, which accounted for about 46 and 18.4%, respectively of the total revenue generated in the respective cooperative.

**Marketing chains and channels of dairy products**

*Market channels of dairy products*

Dairy products` marketing channels in the current studied area (Figure 3) involved various intermediates, for instance, producer-sellers, mobile traders, individual retailers, institutions (hotels, cafeterias, organizations) and cooperatives. In regards, whole milk in the study area passed from producers through cooperatives, different traders and institutions to reach final consumers in Bahir Dar city. In the present study area sour milk, sour skim milk and cottage type cheese (ayib) had the shortest channels and were commonly marketed by dairy cooperatives directly to the immediate consumers. Similarly, ghee and *metata ayib* had also the shortest channels but were marketed occasionally by producers directly to consumers. Whereas marketing of butter got the longest market channel passed through intermediaries between producers and/ or cooperatives and consumers.

*Market chains of dairy products*

The general picture for dairy product market chain of the present study is summarized in Figure 4 below. As indicated in Figure 4, for the marketing chain of dairy commodities, marketing agents involved include producer-sellers, mobile traders, retailers (hotels, cafes and other organizations), dairy cooperatives and individual retailers both outside and inside of the study area.

**Constraints and opportunities of dairy marketing in the study area**

*Constraints*

Feed shortage, lack of improved dairy breed, limited market access, lack of producers' awareness and unreliable milk market were among the major constraints limiting marketable milk supply as reported by sampled households (Table 12).

**Table 11.** Revenue generated from marketing operation of the three cooperatives studied

| Description | Cooperatives | | |
|---|---|---|---|
| | **Bahir Dar City** | ***Abay Zuria*** | **Tis Abay** |
| Total revenue | 112808.40 | 32246.00 | 53171.80 |
| Revenue from whole milk | 102219.4 | 316.00 | 33644.4 |
| Revenue from processed milk products | 10589 | 31930 | 19527.4 |
| Butter | 8226.50 | 17081.00 | 8413.00 |
| Fresh skim milk | 10.50 | 14821.00 | 9787.80 |
| Sour skim milk | - | - | 1326.60 |
| Sour milk | 177.50 | - | - |
| Cottage type cheese | 2174.50 | 28.00 | - |
| Average gross revenue/ lit milk processed | 1.88 | 3.73 | 4.13 |

**1. Whole milk**
- i. Producer → Dairy cooperatives → Retailers (mobile traders, Hotels, Cafes, Organization.) → Consumers
- ii. Producer → Dairy cooperatives → Local processor → Consumers
- iii. Producer → Dairy cooperatives → Consumers
- iv. Producers → Retailers → Consumers
- v. Producers → Consumers

**2. Skim milk**
- i. Dairy cooperatives → Individual trader → Hotel → Consumers
- ii. Dairy cooperatives → Retailers → Consumers.
- iii. Dairy cooperatives → Consumers.

**3. Sour milk**: Producer → Consmers

**4. Sour skim milk:** Dairy cooperative → Consumers

**5. Cottage type cheese (*ayib*):** Dairy cooperatives → Consumers

**6. Ghee:** Producers → Consumers

**7. Butter.**
- i. Producers → Individual traders → Hotels → Consumers.
- ii. Producers → Retailers → Consumers.
- iii. Producers → Consumers.
- iv. Dairy cooperatives → Mobile traders → Consumers.
- v. Dairy cooperatives → Consumers.

**Figure 3.** Marketing channels of each dairy product in the study area

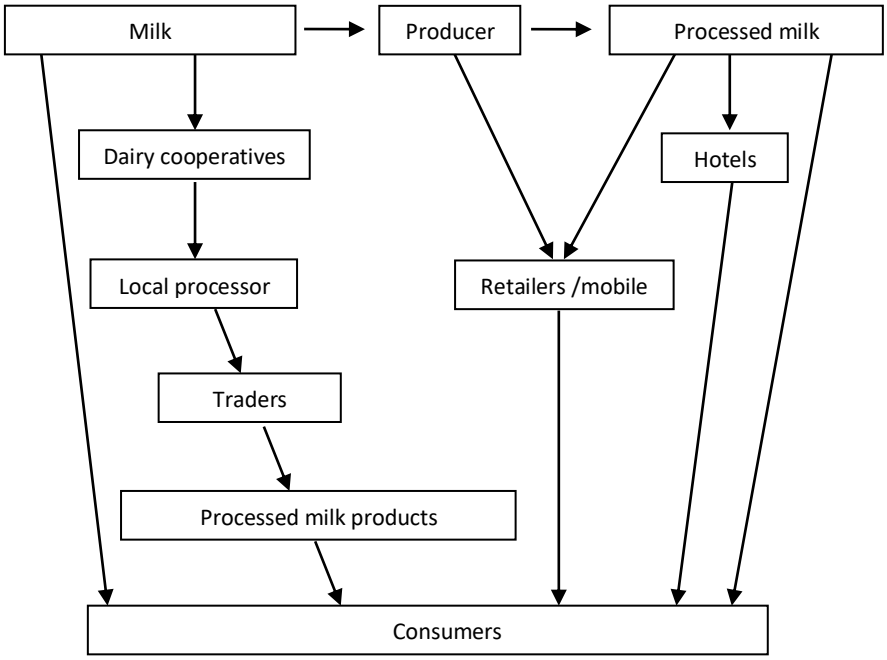


**Figure 4** Market chains of dairy products in the study area

**Table 12.** Average proportion of producers by determinant factors for marketable milk supply

| Determinant factors | Study sites | | | Overall (n=180) |
|---|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) | |
| | % | % | % | |
| Market access | 28.9 | 41.5 | 64.3 | 47.2 |
| Feed shortage | 77.8 | 73.8 | 92.7 | 82.2 |
| Lack improved breed | 46.7 | 86.2 | 57.1 | 64.4 |
| Lack of producer's awareness | 13.3 | 63.1 | 30.0 | 37.8 |
| Unreliable milk market | 57.8 | 29.3 | 28.6 | 36.1 |
| Low and unattractive milk price | 40.0 | 40.0 | 20.0 | 32.2 |

Note: BDT: Bahir Dar City, SRK: Sebatamit rural *kebele*, TARK: Tis Abay rural *kebele*, n: Number of observations

**Table 13.** Opportunities and advantages of dairy cooperatives in the study area as reported by respondents (%)

| Variables | Study sites | | | Overall (n=180) |
|---|---|---|---|---|
| | BDT (n=45) | SRK (n=65) | TARK (n=70) | |
| Creation of milk market outlet | 15.4 | 67.7 | 18.6 | 35.6 |
| Increased milk production | 8.8 | 13.8 | 20 | 15 |
| Better income | 15.4 | 13.8 | 15.7 | 15 |
| Access for market information | 15.6 | 6.2 | 21.4 | 14.4 |
| Awareness created on breed improvement | 66.7 | 100 | 85.7 | 91.1 |

Note: BDT= Bahir Dar City, SRK= Sebatamit rural *kebele*, TARK= Tis Abay rural *kebele*, n= Number of observation

In respect to improve dairy breed type, for instance, crossbred cows accounted for 10.7% of the total cattle in the study area as mentioned earlier. In addition, the existing breed improvement work through artificial insemination could not able to address the producers due to the limited number of technicians, low area coverage of the service and even the low frequency of supervision. Furthermore, lack of market for processed milk products, breakage of dairy equipment such as cream separator, milk thermometer and lactometer, were reported to be the most important factors limiting milk collection, processing and marketing activities of cooperatives.

*Opportunities*

In the present study area, the sampled households noticed that the emergence of milk collection centers in the nearby villages provide advantages and opportunities among which increased milk production, milk market outlet creation, income generation, access to market information and create awareness on breed improvement for producers were reported to be the major opportunities (Table 13).

## Conclusion and recommendation

To conclude, the contribution of milk production as income source, household consumption, employment creation and supporting crop production was substantially important in the study area. Generally, the handling practice of milk in the area was substandard. In the area, lower amount of milk daily produced and limited milk selling outlets restricted producers from milk selling. Furthermore, the absence of regular milk market access, as well as market outlet risks, could compound the problem of producers` milk selling in the area. Despite cooperatives in

the area creating milk market linkage, limited number of producers involved in the organization and amount of milk delivery will influence sustainable development of dairy cooperatives and benefits of producers from market opportunity. The amount of milk consumed daily at household level seemed to depend mainly on the average volume of milk daily produced as well as targets of milk produced as milk for selling and milk exclusively for processing. The marketing of butter passed through long channels, followed by marketing of milk passed through three channels. In general, various marketing agents were identified in the exchange function between producers and the final consumers, which included producers, cooperatives, individual traders and institutions (hotels, cafes, small food houses, government organizations). Generally, the absence of formal market information available to all involved market actors could possibly affect producers' market value as well as product supply to market. Feed shortage, lack of improved dairy type breed, lack of awareness on market-orientation and unreliable milk market were the major constraints reported limiting marketable milk supply of producers.

To recommend, concrete efforts should be coordinated and integrated in a planned strategy focusing on the domain of milk potential area to stimulate and strengthen sound development of dairy cooperatives as well as more market-oriented dairy producers. Governmental organizations and other related partners should focus to promote market-oriented dairying in the area; making access to finance, credit, artificial insemination, and veterinary services, leading for marketable milk production as well as build capacity of dairy cooperatives on milk collection, processing, and marketing. This, in turn, will strengthen and ensure supply of milk to cooperatives, facilitate for better processing operation, minimize wastage and losses of products, thus generally benefiting producers from the market opportunity of dairying in the area. Seasonal milk supply market problems at the dairy cooperatives and the market outlet risks for the producers` milk in the area need to be critically addressed. Accordingly, provision of opportunities for capacity building of cooperative committee members on managing and operating business-oriented dairy cooperatives should be in place by concerned parties mainly by extension team and department of cooperative promotion. Regular training on milk reception, processing, handling and marketing should also be given to hired workers and further setting standards of processing efficiency and field supervision have to be emphasized by the department of extension. The larger proportion of indigenous Zebu-type cows dominantly constituting the dairy herd cows and lower daily milk off-take observed in the studied area restricted producers to sell milk. Concerned governmental organizations should focus on addressing the issue, which will motivate market participation of producers to benefit from the opportunity of dairying in the area. Designing an appropriate breeding strategy should have to be given attention along with planned monitoring and evaluation of the progress in the focus area using AI service as one means. Feed supply shortage has to be addressed through designing and implementing sustainable forage development strategy compatible to the farming system supported with a planned monitoring and evaluation scheme. In addition, improving feed value of the available feed resources is the most crucial for livestock feeding that needs due attention.

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# Species composition and role of exotic invasive pioneers in vegetation establishment on Mount Merapi Volcanic Deposits in Java, Indonesia

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**Abstract.** *Sutomo. 2018. Species composition and role of exotic invasive pioneers in vegetation establishment on Mount Merapi Volcanic Deposits in Java, Indonesia. Trop Drylands 2: 59-64.* The volcanic deposits found in Mt. Merapi are relatively new in terms of years since the last known eruption. The objective of this study was to make use of the chronosequence method to describe changes in the species composition patterns in vegetation establishment, and to conduct observations on whether pioneer species, especially exotic and perhaps also invasive species, are decreasing or increasing species diversity in the succession. Results showed that the younger deposits were dominated by *Athyrium macrocarpum, Polygonum chinense, Paspalum conjugatum* and *Cyperus flavidus.* The older deposits were dominated by *Anaphalis javanica, Imperata cylindrica, Polytrias amaura,* and *Eupatorium riparium.* Invasive (native and exotic) pioneer species such as *I. cylindrica, A. javanica, Calliandra callothyrsus, Polyosma ilicifolia,* and *E. riparium* showed positive correlation with species diversity. It is important to understand the role of non-native, invasive alien species in the recovery process. Early recovery generally depends on these species to boost the succession, but in the longer term, invasive species may affect the successional trajectory.

**Keywords**: Invasive species, Merapi Volcano, vegetation, Indonesia

**Abbreviations:** NMDS: Non-metric Multi Dimensional Scaling; ANOSIM: analysis of similarity; PRIMER: Plymouth Routines In Multivariate Ecological Research.

## INTRODUCTION

Purely mineral deposits, such as those from volcanic eruptions, preserve no "memories" of previous vegetation which is indicated by the absence of seed banks (Thornton 2007). Hence, in order to begin primary succession, colonization by pioneer species must occur from other undisturbed places. Vegetation establishment on volcanic deposits has been documented in many parts of the world, such as in the USA, Italy and Japan, and their rates have been shown to vary (Aplet et al. 1998; Dale et al. 2005b; Tsuyuzaki 1991). For example, plant establishment and spread on the debris-avalanche deposits were slow during the first years after eruption of Mt. St. Helens in USA (Dale et al. 2005b). In contrast, Taylor (1957) has reported that six years after Mt. Lamington in Papua New Guinea erupted, vegetation regeneration was very rapid and this included pioneer species such as *Saccharum spontaneum, Imperata cylindrica, Pennisetum macrostachyum,* species of Vitaceae and several ferns. Mt. Krakatau in Indonesia had at least 64 vascular plant species (dominated by grasses species such as *S. spontaneum* and *I. cylindrica*) which colonized the island 3 years after the eruption (Thornton 2007).

Although they may be useful for specific purposes, such as re-vegetation or fallowing barren land, pioneer species, especially exotic species, may also have an undesired invasive characteristic that could damage the ecosystem. *Eupatorium* spp and *Lantana camara* have been shown to have the tendencies to become over-dominant and, thus, may inhibit species diversity (Kunwar 2003; Raghubanshi and Tripathi 2009). *Eupatorium riparium* and *E. sordidum* have been found to dominate the forests groundcover layer in Mt. Gede-Pangrango National Park in West Java, Indonesia at an elevation of 1,200-1,500 m (Wuragil 2009).

In the process of primary succession, there are two processes in which plant re-establishment through invasion could occur. Firstly, there has to be propagules from an outside source transported to the bare area. Secondly, germination of these propagules must occur, get to maturity stage and propagate, leading to the increase in the number of individual plants (Eggler 1959). Survival and recovery of plants following volcanic disturbance will be much affected by the type and intensity of volcanic activity, nutrients moved by the volcano, distance from the crater and types of propagules from near undisturbed areas (Dale et al. 2005a).

Mt. Merapi (7º 35' S and 110º 24' E) is administratively located in two provinces, Central Java (Magelang, Boyolali and Klaten Districts) and Yogyakarta (Sleman District). In Yogyakarta Province, Mt. Merapi (± 2,900 m asl) is located approximately 30 kilometres north of Yogyakarta City. Mt. Merapi is a representative of landforms, soils and vegetation of volcanic mountains that typify a large portion of montane ecosystems in Java (Whitten et al. 1996). The volcanic deposits found in Mt Merapi are relatively new in

terms of years since last known eruption with the last known eruptions occurring between 1994 and 2006 (MVO 2006). Although no detailed account is available of vegetation condition within the blast area after eruption, preliminary observations showed that it is rapidly developing. Therefore, the present study is significant in generating useful baseline data for the management of volcano-based-national park ecosystems in the region and elsewhere in Indonesia. The objective of this study was to make use of chronosequence method to describe the patterns of vegetation establishment on Mt. Merapi, and to conduct observations on whether pioneer species, especially exotic and perhaps also invasive ones, are decreasing or increasing species diversity in the succession.

## MATERIALS AND METHODS

### Study site and period

Vegetation was sampled in five *nuées ardentes* deposits in 2008 (Figure 1). *Nuèes ardentes* are hot turbulent gas and fragmented material resulting from a collapsed lava dome that rapidly moves down the volcanic slope (Dale et al. 2005). The accumulation of this material is called a *nuées ardentes* deposit and it may be up to ten meters thick (Franklin et al. 1985). These deposits were different ages (time since last known eruption); the youngest deposit was 2 years old and the oldest was 14 years old.

### Data collection

Sampling took place in ten 0.025 ha circular plots for each deposit age with plots assigned randomly to grid cells on map (Dale et al. 2005b). A total of 50 sample plots were obtained and each plot was located in the field with reference to compass and a handheld Global Positioning System GPS (Garmin E-Trex Legend). We measured plant abundance as density; a count of the numbers of individuals of a species within the plot. The abundance of seedlings, herbaceous and other pioneering shrubs were recorded. Their local name and species name, when possible, were noted. Vascular plant nomenclature was based on Backer and Bakhuizen van den Brink (1963). Within each quadrat, site physical characteristics (altitude, slope, distance to the crater and deposit thickness) were determined. Altitude, slope and distance to the summit were measured in the field. Altitude and distance to the summit was measured using a GPS and cross-checked with 1:25,000 topographic maps. A clinometer (*Suunto* clinometers) was used to determine the slope (in degrees).

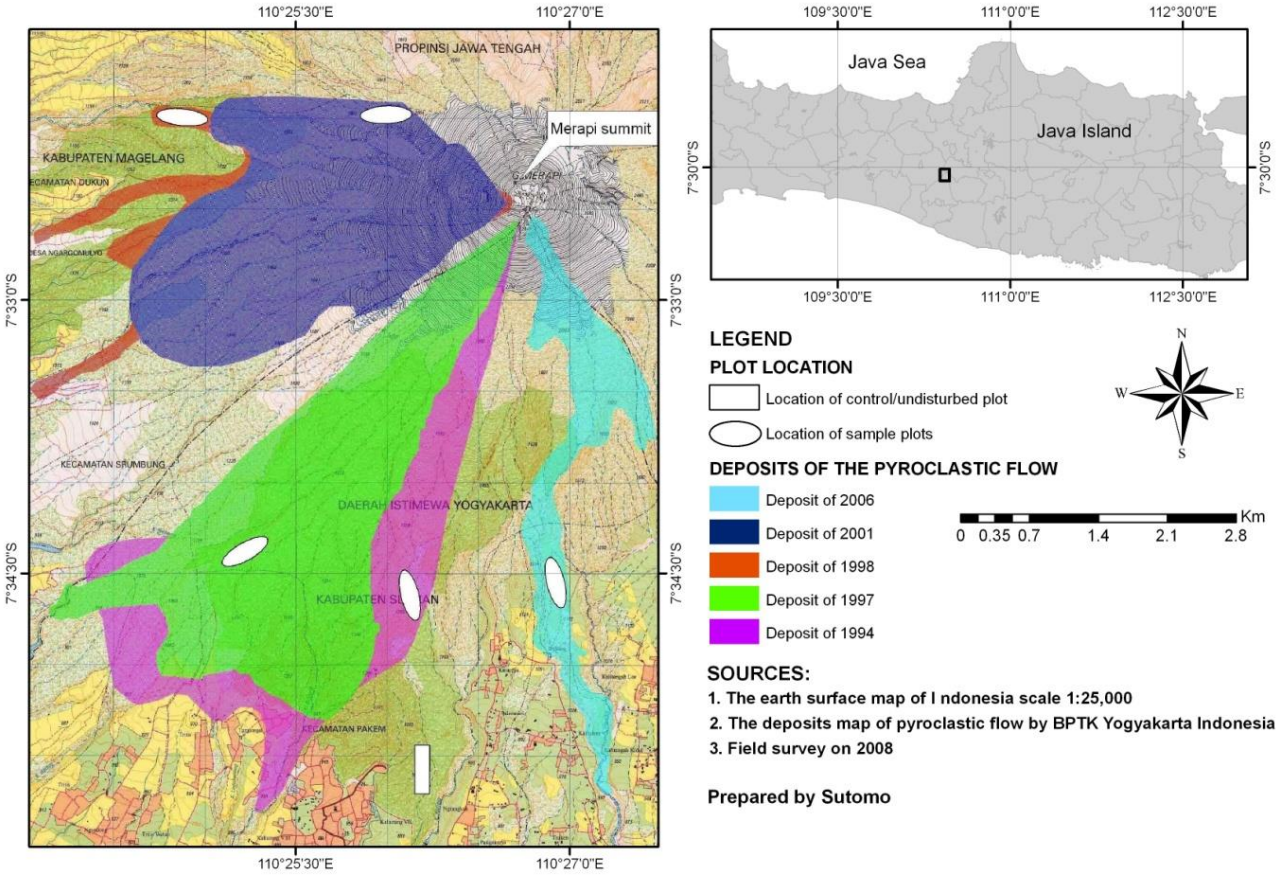


**Figure 1.** Map of Mt. Merapi National Park's eruption deposits. Circular symbols refer to position of sampling sites at each deposit. Rectangle refers to position of an undisturbed forest

**Data analysis**

Shannon-Wiener species diversity at each deposit (age category) was calculated using the DIVERSE feature for diversity measurement available in PRIMER V.6 (Clarke and Gorley, 2005). Differences between age categories (deposits) were tested for significance using one-way ANOVA and Tukey's Highly Significance Different (HSD) test. To examine the correlation between selected species and Shannon-Wiener species diversity, Spearman's bivariate correlation was computed to obtain the strength and nature of the relationship (Ramaharitra 2006). We tested differences in community composition between deposits using data on species abundance (density) per plot. The data were square-root transformed prior to constructing resemblance matrix based on Bray-Curtis similarity. Non-metric Multi Dimensional Scaling (NMDS) ordination diagram was then generated based on the resemblance matrix. Variation in community composition between deposits was subsequently tested for significance using one-way ANOSIM (analysis of similarity). The $R_{ANOSIM}$ statistic values, generated by ANOSIM, are a relative measure of separation of the *a priori* defined groups. A zero (0) indicates that there is no difference among groups, while one (1) indicates that all samples within groups are more similar to one another than any samples from different groups. These analyses were done using PRIMER V.6 (Clarke 1993; Clarke and Gorley 2005).

## RESULTS AND DISCUSSION

The number of species presents varied as time progressed with a rising trend of species richness and diversity over time (Table 1) and significant difference in species richness and diversity among deposits was detected (ANOVA $P$ = 0.05). There was a tendency of species richness to decrease with time at first, and then increase to become stable after more than 10 years. 2006 and 2001 were not statistically different, 1998, 1997 and 1994 were not different, but younger and older deposits were significantly different. Species diversity decreased slightly then returned to similar levels. The highest diversity was on the 1997 deposit whereas the lowest were in 2001 and 1998. Youngest and oldest deposits were not significantly different.

**Table 1.** Differences in species richness and diversity between groups of *nuées ardentes* deposit in Mt Merapi.

| Age group | Mean species richness | Mean species diversity |
|---|---|---|
| Deposit 2006 | 4.1 (±1.59)$^{a}$ | 1.03 (± 0.30)$^{ab}$ |
| Deposit 2001 | 2.9 (±0.56)$^{a}$ | 0.95 (± 0.29)$^{a}$ |
| Deposit 1998 | 6.5 (±1.26)$^{b}$ | 0.95 (± 0.34)$^{a}$ |
| Deposit 1997 | 6.6 (±1.26)$^{b}$ | 1.38 (± 0.16)$^{b}$ |
| Deposit 1994 | 6.4 (±1.35)$^{b}$ | 1.3 (± 0.35)$^{ab}$ |

Figure 2 shows that Mt. Merapi was dominated by species such as *Athyrium macrocarpum, Polygonum chinense, Paspalum conjugatum* and *Cyperus flavidus.* These species were either present at very low to intermediate abundance or were not present in the older deposits. The older deposits were dominated by species such as *A. javanica, I. cylindrica, Polytrias amaura* and *E. riparium.* These species were either present at very low abundance or were not present in the younger deposits, which indicated that the dominance of these species is related to the development of the habitat over a period of several years at the sites. *I. cylindrica, A. javanica* and *A. macrocarpum* dominated the deposits colonization. *A. macrocarpum* dominated the colonization in the youngest (2006) deposit, where it then decreased sharply in 2001 deposit, but only to increase again in 1998 and 1997 deposits whereas in the oldest deposit (1994) *A. macrocarpum* decreased in abundance. *I. cylindrica* and *A. javanica* abundance was absent in the youngest deposit but then increased throughout the younger deposits and declined in the oldest deposit. Although they both finally declined in the oldest deposit, *A. javanica* still retains the highest abundance. Comparable phenomenon was also found in Mt. St. Helens primary succession, where cover of the early pioneer pearly everlasting (*Anaphalis margaritacea*) increased after the eruption but then declined in the older phase (Dale et al. 2005b). The decrease in *I. cylindrica* abundance may be due to the absence of fire which normally stimulates flowering (Collins and Jose 2009) and perhaps competition with other dominant species such as *Polyosma ilicifolia* and *E. riparium* in the older sites.

The mean abundance of the invasive alien species *I. cylindrica* showed a positive correlation (ρ = 0.514) with Shannon-Wiener diversity index (Table 2). Similar positive correlations were shown by the native species *A. javanica* (ρ = 0.416), *E. riparium* (ρ = 0.582), *Calliandra calothyrsus* (ρ = 0.250) and the invasive *P. ilicifolia* (ρ = 0.349). Positive correlation coefficient indicates that the increase in abundance of these species is correlated with the increase in species diversity. These correlations, however, were not relatively strong.

**Table 2.** Spearman's bivariate correlation analysis between selected species and Shannon-Wiener species diversity

| Species | Correlation coefficient |
|---|---|
| *Imperata cylindrica*[1] | +0.514* |
| *Eupatorium riparium*[1] | +0.582* |
| *Anaphalis javanica* | +0.416* |
| *Calliandra calothyrsus* | +0.250* |
| *Polyosma ilicifolia*[1] | +0.349* |

Note: The correlation is significant at 0.01 levels. Plus (+) sign indicates positive correlation and superscript ([1]) indicates invasive alien species

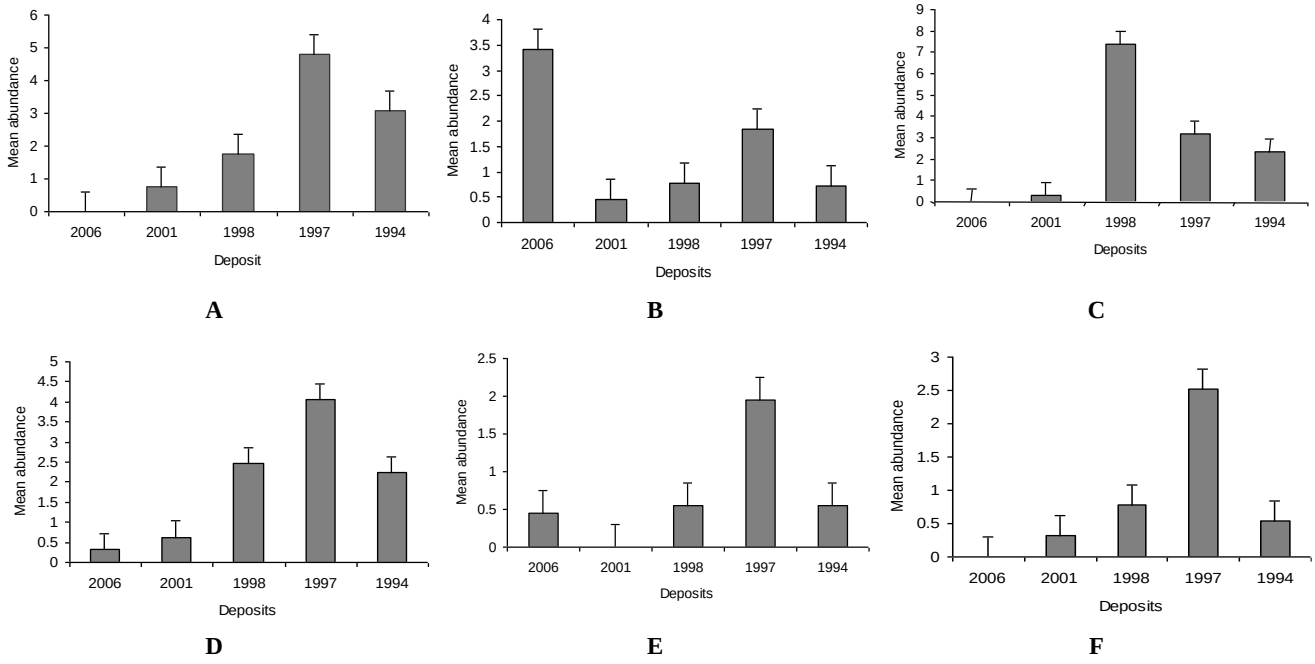


**Figure 2.** Mean abundance (count of the numbers of individuals of a species within the plot) of selected species within fifty 0.025 ha circular plots in the 2006, 2001, 1998, 1997 and 1994 *nuées ardentes* deposits. A. *Anaphalis javanica*, B. *Athyrium macrocarpum*, C. *Imperata cylindrica*, D. *Eupatorium riparium*, D. *Calliandra calothyrsus*, E. *Polyosma ilicifolia*

It is important to understand the role of non-native, invasive alien species in the recovery process; many of the phenomena in early recovery depend on these species to boost the succession, but in the longer term invasive species may affect the successional trajectory (Dale and Adams 2003). In a severely disturbed habitat, facilitation has a more vital role in species change and restoration, whereas competition tends to be important in a more productive and established habitat (Callaway and Walker 1997; Walker et al. 2007). In the primary succession on Mt. Merapi, sites with high abundance of *I. cylindrica* had high species diversity (Table 2). *I. cylindrica* is an aggressive alien invader that has a long record of colonizing cleared lands in Indonesia (A. Hamblin, personal communication). Domination by *Imperata* of *nuées ardentes* deposits on Mt. Merapi is presumably due to its widely spreading rhizomes and its wind-dispersed seeds (Jonathan and Hariadi 1999). *Imperata* may have contributed indirectly to the increase in the number of species colonizing the deposits, especially in the early stages, by assisting in ameliorating the deposits (Walker and del Moral 2003).

As with *Imperata*, sites with high abundance of *A. javanica* also showed an increase in species diversity (Table 2). *A. javanica* (Figure 3) is a pioneering shrub endemic to Java and Bali often found in groups in an active crater valley or on new volcanic montane soil. It is able to thrive in such poor substrates owing to its mycorrhizas, which increase its intake of nutrients by enlarging the area covered by the roots (van Steenis 1972; Whitten et al. 1996). This native species may have directly facilitated establishment of the later species by providing shade and organic material (Dale et al. 2005b).

**Figure 3.** *A. javanica*, a native species that was able to establish early in the succession following Mt. Merapi eruption by lodging among rocks

Because nitrogen is generally the most limiting essential macro-nutrient in new soil materials (Lambers et al. 2007), nitrogen-fixing species are often regarded as the main facilitators in primary succession, because they can directly influence establishment by providing nitrogen (Walker et al. 2003). The nitrogen-fixing legume *C. calothyrsus* also showed positive correlation with species diversity (Table 2). Native of Mexico, this species has been widely introduced in many tropical regions. *C. callothyrsus* is able to grow on a wide range of soil types, including the

moderately acidic soils of volcanic origin that are a common feature in Southeast Asia (Palmer et al. 1994).

Other invasive species also showed positive correlation with the diversity index and perhaps might have a role in facilitation. *E. riparium* abundance increased out through aged deposits in the primary succession sites except in the oldest deposit. This species was also the dominant groundcover species in Kaliurang, an intact forest on the southern slope of Mt. Merapi (Sutomo 2004). This alien species had significant (P = 0.01) positive correlation with species diversity (Table 2) and may have indirectly facilitated the co-occurring species such as *Gnaphalium japonicum* and *Melastoma affine* by assisting in stabilizing and preventing erosion on the deposit site. However, over domination by this invasive species could be a problem itself. The Mistflower or *Eupatorium* is native to South America, and this unpalatable and highly competitive species has become a problem elsewhere such as in Nepal (Kunwar 2003).

These findings seem to contradict the view that, as invasive increase, the diversity would decline, as shown in the decrease of diversity in a site with abundant cover of *Lantana* in Vindhyan dry tropical forest in India (Raghubanshi and Tripathi 2009). However, the findings in Vindhyan may reflect the future condition of the succession sites in Mt. Merapi. In longer periods, domination of invasive alien species may limit the chance of recruitment of other native species, including seedlings of woody species, and hence reduce the diversity, and even change the successional trajectory and ecosystem function (Dale et al. 2005b; Hobbs and Huenneke 1992; Raghubanshi and Tripathi 2009; Standish et al. 2009).

Plant establishment in primary succession is also largely influenced by the development of the site's physical environment. Generally, nitrogen and phosphorus are the most limiting essential macronutrients in new volcanic soil materials (A. Hamblin, personal communication, 28 May 2009). In the course of physical weathering of the materials in the new substrates through time, phosphorus will become available for plants (Walker and Syers 1976). For nitrogen, nitrogen-fixing plants such as legumes make this nutrient available for later plant species in the succession (Bellingham et al. 2001; Walker et al. 2003). Furthermore, the role of organic matter is also prominent in the retention of water and nutrients to support the growth of the species occurring there (Hodkinson et al. 2002).

Although it is not possible to provide a definitive explanation for the process and mechanism of recovery and establishment in primary succession, the observations show that vegetation does become established in the volcanic deposits of Mt. Merapi. If the process and mechanism of recovery and establishment in the primary succession is to be examined, a long-term study of the vegetation dynamics is needed. Such studies are an essential complement to chronosequence studies; hence, the establishment of permanent sampling plots and/or re-sampling the chronosequence sites is recommended. However, the understanding gained from this study provides the prospect of adapting strategies for succession-based management and restoration strategies in these volcanic ecosystems.

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# The diversity of wood-boring beetles caught by different traps in northern forests of Iran

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**Abstract.** *Varandi HB, Kalashian M, Barari H, Rezaei Taleshi SA. 2018. The diversity of wood-boring beetles caught by different traps in northern forests of Iran. Trop Drylands 2: 65-74.* Efficacy of trap types is an important factor for sampling, faunistic survey, evaluation of the population density, seasonal dynamic and monitoring of wood-boring beetles. In the present research, the diversity of Wood-boring beetles (i.e., Buprestidae and Cerambycidae) was studied by using different types of trap (window trap, color pan trap, color sticky trap and Malaise trap) in northern forests of Iran (Mazandaran Province, Iran). Different types of traps were employed in five study areas, collected a total of 3120 beetles belonging to 55 species (29 Buprestidae and 26 Cerambycidae). Window trap was the best one for collecting the beetles both in the case of different species and of individual numbers, while red pan trap collected only a few beetles (during 2008-2009). After a window trap, two color pan traps (white and yellow) were also very suitable for collecting the beetles. The majority of captured specimens were buprestid beetles (79.87%), while only one-fifth of the specimens were Cerambycidae (20.13%). All of the collected beetle specimens were identified to species' level. One genus (*Agrilus* spp) and the following five species were the dominant species: *Acmaeodera rufoguttata* Reitter, *Anthaxia hyrcana* Kiesenwatter et Kirsch, *Anthaxia intermedia* Obenberger, *Chrysobothris affinis* Fabricius and *Stenoprerus rufus* Linnaeus.

**Keywords:** Buprestidae, Cerambycidae, diversity, forest, Iran, traps

## INTRODUCTION

Metallic wood-boring beetles (Buprestidae), comprising of 15,000 species, and longhorn beetles (Cerambycidae), consisting of 35,000 species, are the most important wood-boring insects that occur in every biogeography region (Bellamy 2000; Hanks 1999) and fill particularly an important ecological niche in forest ecosystem (Belyea 1952; Gardines 1957). The larvae of these beetles are xylophagous, feeding in the phloem and xylem tissues of trees, mining deep into the heartwood and consequently causing severe damage to the wood. Concerning the wood industry, a heavy infestation of commercial wood by these pests can cause economic losses in the form of degraded wood and volume loss.

Most of these beetles are dangerous pests of forest and fruit trees, shrubs and herbaceous plants, implying an important biological position in forestry and agricultural entomology (Cerezke 1977; Post 1984; Orbay et al. 1995; Ozdikmen and Okutaner 2006; Costello et al. 2008). Even some species of wood-boring beetles bore into deadwood in the buildings including furniture, causing structural damage if unchecked for a long period. Moreover, many wood-boring beetles tunnel through fallen tree, trunks and branches, which are then exposed to more rapid decay by wood-rotting fungi, bacteria, and other organisms. Thus, these beetles play an essential ecological role in accelerating the process of wood decay and recycling the nutrients of dead trees, and also have a significant nutritional function for many insectivores including woodpeckers (Anderson 2003; Miller and Asaro 2005; Dajoz 2000).

Several different methods are generally used for collecting beetles such as direct active collection (hand collection), rearing larvae to adulthood, sweeping, bait traps and light traps (Borror and Delong 2005). Hand collection methods have the advantage of sampling directly from the woody substrate, plus the samples may be related to the volume and bark area of deadwood (Siitoren 1994). However, these methods have proved unsatisfactory in many respects (Bouger et al. 2008).

The use of traps for capturing flying insects, especially beetles, has long been an integral part of many field investigations in entomology (Hosking and Knightf 1975). The attraction of Buprestidae and/or Cerambycidae to sticky trap (Werner 2002; Oliver et al. 2004), to different color trap (Sakalian and Langourov 2004), to malaise and yellow pan trap (Bellamy 2000), to malaise and window trap (Michael et al. 2004; Bouget 2008), and to yellow pan trap and window trap (Wermelinger et al. 2002) had been previously studied. However, the trapping efficiency for different species depends on a variety of parameters (Adis 1979), which complicate the comparison of data presented by various authors (Topping and Sunderland 1992). Although many entomologists in the world have used different traps, such as color trap, malaise trap, window trap and sticky trap, for catching beetles (e.g., Bellamy 2000; Werner 2002; Oliver et al. 2004; Sakalian and

Langrov 2004; Bouget et al. 2008) but neither an effective trap nor a comparison test for the efficiency of different traps for collecting Buprestidae and Cerambycidae has been previously studied in the forests of Iran.

The objective of the current study was to compare the efficiency of four different kinds of traps (i.e. color, window, Malaise, and sticky trap) in catching the adult wood-boring beetles, and to discuss the behavior of these insects in response to the traps.

## MATERIALS AND METHODS

### Study area

The study was done in the northern forest of Iran (Mazandaran Province) located in the Hyrcanian forest zone with humid commercial and industrial broadleaves forests (Figure 1). This area stretches out from sea level up to an altitude of 2800 m above sea level. The forest consists of 80 woody species (trees and shrubs).

Trapping experiments were conducted at six altitude ranges of Mazandaran Province (Sari forest areas) (Figure 1) during 2008-2009 as follows: **Dashte-Naz** is located 36 km north of Sari City (53° 12' 36" E, 36° 41' 36" N; 20 m asl). The dominant vegetations in this area were citrus (*Citrus* sp.), peach (*Prunus persica*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oilseed rape (Brassica *campestris*), rice (*Oryza sativa*) as well as a protected park (ca 55 hr) containing *Quercus castaneifolia* and *Parotia persicae*. **Pahneh-Kola** (53° 03' 06" E, 36° 27' 14" N; 218 m als) is located in 13 km south of Sari City in a forestry nursery. It was surrounded by dominant trees such as *Q. castaneifolia. Carpinus betula, Zelkova carpinifolia, Acer velatinum, Alnus subcordata, Cratagus* spp. and some conifers trees: *Cupressus sempervirence* and *Pinus radiata*. **Alamdardeh** (53° 15' 60" E, 36° 21' 21"; 396 m asl): Alamdardeh is located 35 km south of Sari City in an oak forest. **Haftkhal** (53° 23' 43" E, 36° 17' 16" N, 855 m asl): Type of this forest is Fago-Carpino forest and is located 60 km of Sari City. **Posht Koh** (53° 46' 52" E, 36° 14' 58" N, 1501 m asl) is located in a rangeland region, 110 km south-east of Sari City. **Alikola** (53˚ 39′ 45″ E, 36˚ 13′ 00″ N, 1640 m asl) is located 90 km of Sari City and has Fago-carpino forest type.

### Methods

In 2008, color, sticky, window and Malaise traps were used. *Color pan trap*-The trap dimensions refer to Figure 2, based on Sakalian and Langourov (2004). Thirty-five color pan traps (blue, green, red, white and yellow) were arranged in a completely randomized design (5 treatments in 7 replications) and set up in Dashte-Naz, Pahneh Kola, Alamdardeh, Haftkhal and Posht Koh. Each trap was placed in 7 rows, with 100 cm spacing between each row, 120-1500 cm above ground, the space between each of the traps was 30 cm. They were fixed to a wire, which was stretched between rods. Each trap was half-filled with 50% water solution of ethylene glycol.

*Sticky trap*-The trap dimensions refer to Figure 3, according to Oliver et al. (2004). Thirty-five sticky color traps (blue, green, red, white, and yellow) were arranged in a completely randomized design (5 treatments in 7 replications) in Pahneh Kola region. Each trap was placed in 7 rows, with 100 cm spacing between each row. The space between each of the traps was 100 cm. Besides, 12 other color sticky traps (red, white, and yellow) were set up in Alamdardeh and Posht Koh (two traps from each color).

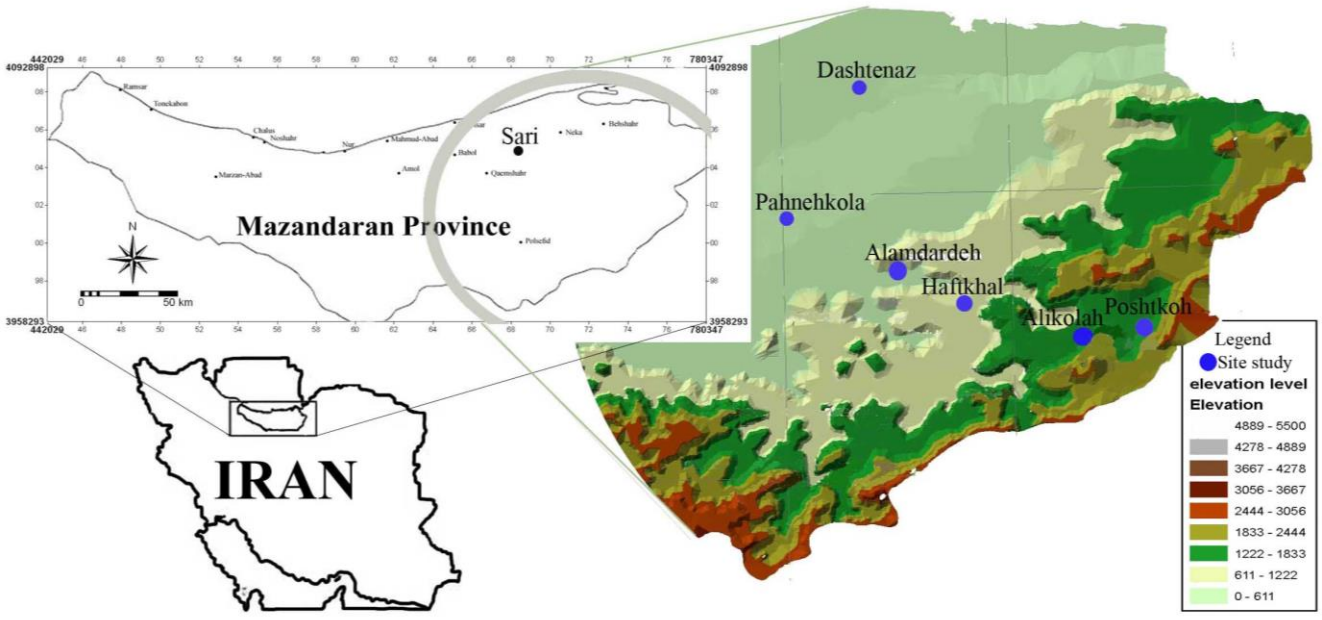


**Figure 1.** Map of the study sites in Sari City, Mazandaran Province, Iran

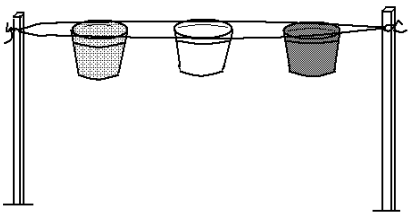

**Figure 2.** Design and construction of color pan traps (Sakalian and Langourov 2004). Each trap consisted of a plastic tray (with 80 mm and 105 mm diameter at the bottom and the top, respectively, and with 120 mm deep).

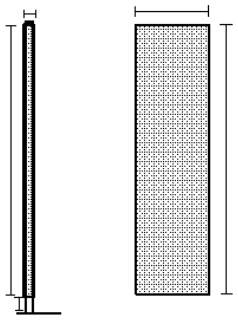

**Figure 3.** Design and construction of a sticky trap from Oliver et al. 2004). Each trap was a cylindrical tube (with 100 cm long and 2 cm diameter) stapled longitudinally with wallpaper strips (90 cm × 7 cm) and painted with red color. Pestick sticky glue was used to make the trap surface sticky.

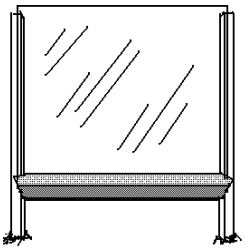

**Figure 4.** Design and construction of a window trap from (Barari 2005). The trap consisted of a vertically-held, transparent, hard-plastic sheet (window), 81 cm height and 85 cm long, mounted in a metal frame. It had a plastic gutter tray along its bottom edge. The tray was half-filled with water containing 1% detergent. The trap was positioned about 10 cm from the ground

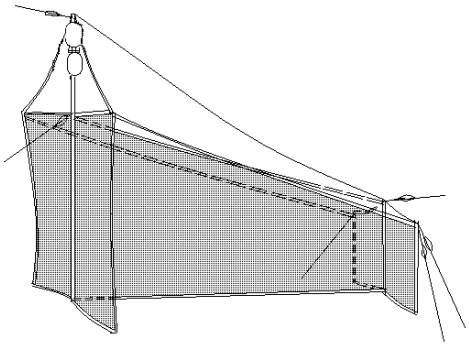

**Figure 5.** Design and construction of a Malaise trap (Matheus and Matheus 1983). The trap was 160 cm long and 190 cm sloping to 65 cm height. The open sides of the trap were 160 cm long, 95 and 60 cm height on the highest and lowest end, respectively (Barari 2005).

The caught insects were first put into vials containing gas (for cleaning them from glue) and then washed with a mixture of distilled water and detergent, and finally preserved in 75% ethanol in labeled glass vials for later study.

*Window trap*-The trap dimensions refer to Figure 4, consistent with Wermelinger et al. (2002) and Barari (2005). The gutter tray of each trap was half-filled with 50% ethylene glycol. The trap was positioned about 10 cm from the ground. Three traps were placed in Pahneh Kola, Alamdardeh and Poshtkoh only (one window trap in each site).

*Malaise trap*-The trap dimensions refer to Figure 5, according to Townes (1962). Malaise traps were placed in Dashte-Naz and Pahneh Kola only (one Malaise trap in each mentioned site).

Hundred color Pan traps (20 traps: 10 white and ten yellow alternately in each location) were set up in Dashte-Naz, Pahneh Kola, Alamdardeh, Haftkhal and Alikola in 2009. The color traps were placed in one row, 120-1500 cm above ground, the space between each of the traps was 30 cm. They were fixed to a wire, which was stretched between rods. Each trap was half-filled with 50% water solution of ethylene glycol. Also, ten window traps and 10 Malaise traps were set up in each mentioned altitude range (two windows and two Malaise traps in each site).

The caught insects were collected once in two weeks from early May to late September, preserved in labeled plastic pots containing 75% alcohol. The insect samples were transferred to the laboratory; removed from alcohol and placed on marked cotton beds for later sorting, counting and identifying the target insects. The target insects were identified to species by using literature and compared with identified materials in Collections of Institute of Zoology NASRA, Yerevan, Armenia. The collected species were kept in the collections of the institute as mentioned earlier and of Agricultural and Natural Resources Research Centre of Mazandaran, Iran.

**Data analysis**

Data were analyzed and compared using SPSS Ver. 16, at Chi-square ($\chi^2$) manner. The Biodiversity Program Ver. 2.0 (McAleece et al. 1997) was used to calculate the similarity index and to construct the dendrogram. The classification of Heydemann's (Weigmann 1973) was used to evaluate the dominance structure (cited in Sakalin and Langorov 2004). This classification has five degrees of dominance: eudominant (ED), dominant (DO), subdominant (SD), rare (RA) and sub-rare (SR), which are those species making up more than 30%, 10-30%, 5-10%, 1-5% and less than 1% of all the caught specimens, respectively.

## RESULTS AND DISCUSSION

The distribution of buprestid and cerambycid species and types of traps are tabulated in Tables 1 and 2. During this study, a total of 3120 specimens were caught by the traps (1292 in 2008 and 1828 in 2009). Among those, 29

species belonging to 12 genera were Buprestidae, and 26 species belonging to 23 genera were Cerambycidae (Tables 1 and 2). The majority of captured specimens were buprestid beetles (79.87%), while only about one-fifth of the specimens were Cerambycidae (20.13%) (Table 2, Figure 6). In 2008, the largest numbers of species were caught by the yellow pan trap (Figure 7), while the smallest numbers of species were caught by blue sticky tap and green sticky trap (Table 1, Figure 8). In 2009, the largest and smallest numbers of species were caught by the window trap and white pan trap, respectively (Table 2, Figure 9). There were significant differences amongst numbers of beetles caught by the traps ($P<0.001$; Tables 3, 4, 5). Regardless of the species, the largest and the smallest numbers of the specimens were caught by window trap (n=759) and red pan trap (n=22), respectively. No significant differences in the catch were observed in Malaise with white pan trap, yellow pan trap, blue pan trap, and red pan trap (Table 3). In 2009, 1828 individuals belonging to 36 species were collected. Of those, 759 individuals (28 species) were caught by window traps, 516 (13 species) by white pan traps, 425 (22 species) by yellow pan traps, and 128 (19 species) by Malaise trap.

**Table 1.** List of species of wood-boring beetles (Buprestidae and Cerambycidae) taken in different traps in 2008

| Family and species | Colour pan traps | | | | | Traps shape | | Colour sticky traps | | | | | DD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WhP | YeP | BlP | ReP | GrP | Malaise | Window | WhS | YeS | BlS | ReS | GrS | |
| **Buprestidae** | | | | | | | | | | | | | |
| *Acmaeodera pillosella* (Bonelli, 1812) | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | SR |
| *Acmaeodera rufoguttata* (Reitter, 1890 | 26 | 38 | 1 | 9 | 4 | 2 | 61 | 12 | 5 | 0 | 38 | 2 | DO |
| *Acmaeoderella flavofasciata* (Piller et Mitterparcher, 1783 | 0 | 5 | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | SR |
| *Acmaeoderella mimonti* (Bieeldieu, 1865) | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | SR |
| *Acmaeoderella gibbulosa* (Menetries, 1832) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Capnodis tenebricosa* (Oliver, 1790) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 52 | 0 | RA |
| *Dicerca fritillum* (Menetries, 1832 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Dicerca scabida* (Marseul, 1865 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | SR |
| *Lamprodila tuerki* (Ganglbauer, 1882) | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Sphenoptera cauta* (Jakovlev, 1904 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Anthaxia hyrcana* (Kiesenwatter et Kirsch, 1880 | 97 | 125 | 9 | 0 | 0 | 0 | 0 | 11 | 6 | 0 | 0 | 0 | DO |
| *Anthaxia intermedia* (Obenberger, 1913 | 1 | 2 | 0 | 4 | 1 | 0 | 0 | 15 | 7 | 5 | 122 | 5 | DO |
| *Anthaxia passerine* (Pecchioli, 18370 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Anthaxia hungarica* (Scopoli, 1772) | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Anthaxia cichori* (Olivier, 1790) | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Anthaxia bicolor* (Falderman, 1835 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | SR |
| *Chrysobothris affinis* (Fabricius, 17940 | 0 | 0 | 0 | 0 | 0 | 23 | 2 | 15 | 5 | 6 | 157 | 3 | DO |
| *Agrilus viridis* (Linneaeus, 1758) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Agrilus biguttatus* (Fabricius, 1777) | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | SR |
| *Agrilus derasofasciatus* (Lacordaire, 1835 | 1 | 1 | 1 | 0 | 16 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | RA |
| *Agrilus obscuricollis* (Kiesenwatter, 1857 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | SR |
| *Agrilus pratensis* (Ratzeburg, 1837 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Agrilus hyperici* (Creutzer, 1799) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | SR |
| *Agrilus graminis* (Kiesenwetter, 1857) | 9 | 7 | 10 | 4 | 48 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | SD |
| *Coraebus elatus* (Fabricius, 1787) | 1 | 1 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | SR |
| *Coraebus rubi* (Linneaeus, 1767) | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | SR |
| *Trachys phlyctaenoides* (Kolenati, 1846) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 43 | 3 | 0 | SD |
| **Cerambycidae** | | | | | | | | | | | | | |
| *Rhagium pygmaeum* Ganglb,1882) | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Anoplodera rufipes* (Sshaller, 1783) | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Stictoleptura scutellata* (Fabricius,1781) | 0 | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | SR |
| *Paracorymbia tonsa* (J. Daniel et K. Daniel, 1891) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | SR |
| *Cerambyx scopolii* (Fusslins, 1775) | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Stenopterus rufus* (Linnaeus, 1767) | 47 | 35 | 15 | 3 | 4 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | RA |
| *Callimellum angulatum* (Schrank, 1789) | 6 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Ropalopus macropus* (Germar,1824) | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | SR |
| *Paraplagionotus floralis* (Pallas, 1773) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Xylotrechus sieversi* (Ganglbauer, 1890) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SR |
| *Clytus arietis* (Linnaeus, 1758) | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | SR |
| *Phytoecia cylindricus* (Linnaeus, 1758) | 0 | 0 | 0 | 0 | 0 | 12 | 2 | 0 | 0 | 0 | 0 | 0 | RA |
| *Agapanthia persicola* Rtt. 1894) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | SR |
| Total | 195 | 236 | 52 | 22 | 80 | 51 | 103 | 76 | 25 | 56 | 385 | 11 | 1292 |

Note: color pan traps (WhP: white, YeP: yellow, BlP: blue, ReP: red, GrP: green) and color sticky traps (WhS: white, YeS: yellow, Bls: blue, ReS: red, GrS: green); DD: Degree of dominant (ED: eudominant, DO dominant, SD: subdominant, RA: rare and SR: sub-rare).

**Table 2.** List of species of wood-boring beetles (Buprestidae and Cerambycidae) taken in different traps in 2009

| Family and species | Color pan traps | | | | DD |
|---|---|---|---|---|---|
| | WhP | YeP | Mal | Win | |
| **Buprestidae** | | | | | |
| *Acmaeodera rufoguttata* (Reitter, 1890 | 28 | 32 | 2 | 320 | DO |
| *Acmaeoderella flavofasciata* (Piller et Mitterparcher, 1783 | 8 | 3 | 1 | 19 | RA |
| *Acmaeoderella gibbulosa* (Menetries, 1832) | 0 | 0 | 0 | 1 | SR |
| *Capnodis tenebricosa* (Oliver, 1790) | 0 | 0 | 0 | 3 | SR |
| *Lamprodila tuerki* (Ganglbauer, 1882) | 0 | 0 | 0 | 1 | SR |
| *Anthaxia hyrcana* (Kiesenwatter et Kirsch, 1880 | 118 | 120 | 1 | 4 | DO |
| *Anthaxia intermedia* (Obenberger, 1913 | 15 | 27 | 2 | 10 | RA |
| *Anthaxia hungarica* (Scopoli, 1772) | 0 | 5 | 0 | 0 | SR |
| *Anthaxia cichori* (Olivier, 1790) | 0 | 2 | 0 | 1 | SR |
| *Anthaxia bicolor (*Falderman, 1835 | 0 | 1 | 0 | 0 | SR |
| *Chrysobothris affinis* (Fabricius, 1794) | 2 | 7 | 5 | 35 | RA |
| *Melanophila decastigma* (Fabricius, 1787) | 0 | 0 | 0 | 1 | SR |
| *Agrilus* sp. | 195 | 123 | 73 | 249 | ED |
| *Coraebus rubi* (Linneaeus, 1767) | 0 | 0 | 1 | 2 | SR |
| *Trachys phlyctaenoides* Kolenati, 1846) | 0 | 0 | 2 | 41 | RA |
| **Cerambycidae** | | | | | |
| *Prionus coriarius* (L., 1757) | 0 | 1 | 1 | 0 | SR |
| *Rhagium pygmaeum* (Ganglb,1882) | 0 | 0 | 0 | 1 | SR |
| *Fallacia elegans* (Faldermann, 1837) | 0 | 0 | 1 | 0 | SR |
| *Alosterna scapularis* (Hey. 1878) | 11 | 6 | 3 | 4 | RA |
| *Anoplodera rufipes* (Sshaller, 1783) | 0 | 2 | 0 | 0 | SR |
| *Paracorymbia tonsa* (J. Daniel et K. Daniel. 1891) | 14 | 0 | 0 | 4 | SR |
| *Molorchus monticola* Plavilstshiko, 1933) | 5 | 4 | 1 | 5 | SR |
| *Stenopterus rufus* (Linnaeus, 1767) | 104 | 64 | 19 | 20 | DO |
| *Callimellum angulatum* (Schrank, 1789) | 13 | 18 | 0 | 2 | RA |
| *Ropalopus macropus* (Germar,1824) | 0 | 2 | 3 | 2 | SR |
| *Anaglyptus* sp. | 0 | 1 | 0 | 2 | SR |
| *Paraplagionotus floralis* (Pallas. 1773) | 0 | 0 | 3 | 0 | SR |
| *Chlorophorus figuratus* (Scop. 1763) | 0 | 2 | 0 | 1 | SR |
| *Clytus arietis* (Linnaeus, 1758) | 0 | 1 | 1 | 5 | SR |
| *Acanthocinus elegans (*Ganglb. 1884) | 1 | 0 | 0 | 0 | SR |
| *Terops gilvipes* (Fald. 1837) | 0 | 0 | 4 | 0 | SR |
| *Phytoecia cylindricus* (Linnaeus, 1758) | 0 | 1 | 3 | 1 | SR |
| *Agapanthia kirbyi* (Gellenhal, 1817) | 0 | 0 | 0 | 1 | SR |
| *Agapanthia walteri* (Reitter, 1898 | 0 | 1 | 0 | 2 | SR |
| *Agapanthia subchalybaea* (Reitter 1898) | 0 | 0 | 2 | 3 | SR |
| *Agapanthia persicola* (Reitter 1894) | 2 | 2 | 0 | 19 | RA |
| Total | 516 | 425 | 128 | 759 | 1828 |

Note: color pan trap (Wh: white and Ye: yellow), Ma: malaise trap and Win: window trap; DD: Degree of dominant (ED: eudominant, DO dominant, SD: subdominant, RA: rare and SR: subrare)

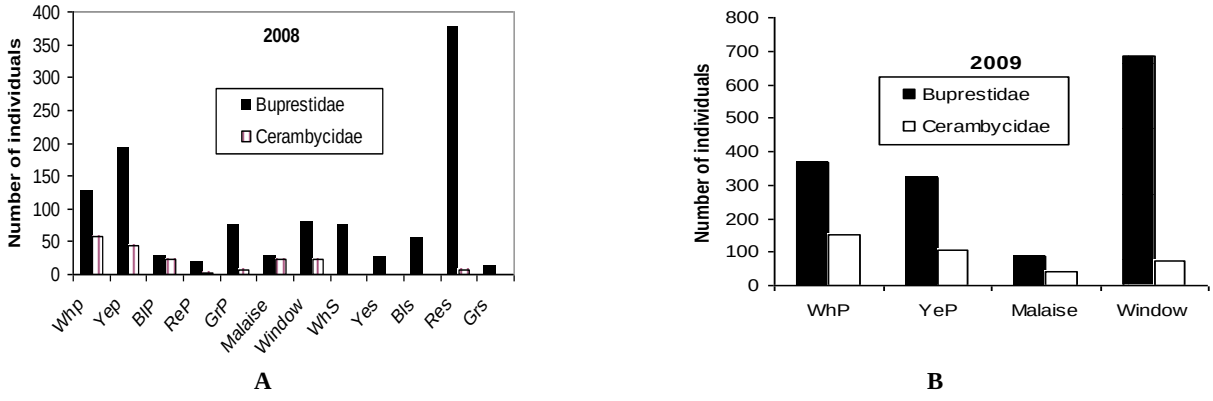


**Figure 6.** The total number of individuals of Buprestidae and Cerambycidae collected by using different traps: A. Color pan traps (WhP: white, YeP: yellow, BlP: blue, ReP: red, GrP: green); B. Color sticky traps (WhS: white, YeS: yellow, Bls: blue, ReS: red, GrS: green), Malaise and window traps (years 2008 and 2009).

**Table 3.** The $\chi^2$ test values for the differences in the attractiveness of the traps for wood-boring beetles (Buprestidae and Cerambycidae). Color pan traps (WhP: white, YeP: yellow, BlP: blue, ReP: red, GrP: green), Mal: Malaise and Win: window traps.

| Traps | WhP | YeP | BlP | ReP | GrP | Mal | Win |
|---|---|---|---|---|---|---|---|
| YeP | 174.716*** | | | | | | |
| BlP | 164.580*** | 133.632*** | | | | | |
| ReP | 100.091*** | 104.604*** | 62.743*** | | | | |
| GrP | 91.137*** | 11.332*** | 67.498*** | 64.606*** | | | |
| Mal | 24.021*ns* | 26.152 *ns* | 4.8 *ns* | 20.243 *ns* | 48.649** | | |
| Win | 106.213*** | 132.402*** | 71.437*** | 87.619*** | 70.23** | 44.583** | |

Note: ** P<0.001, *** P<0.001

**Table 4.** The $\chi^2$ test values for the difference in the attractiveness of the traps for wood-boring beetles (Buprestidae and Cerambycidae) in sticky color traps (WhS: white, YeS: yellow, Bls: blue, ReS: red, GrS: green).

| Color sticky trap | WhS | YeS | BlS | ReS | GrS |
|---|---|---|---|---|---|
| YeS | 109.485*** | | | | |
| BlS | 80.114*** | 59.706*** | | | |
| ReS | 119.461*** | 80.974*** | 99.751*** | | |
| GrS | 80.174*** | 99.444*** | 80.123*** | 120.307*** | |

Note: *** P<0.001

## Species similarity and abundance in different traps

The dendrogram of the similarity of the species composition and abundance in different traps are shown in Figures 5 and 6. The highest similarity (~ 79%) was between wood-boring beetles caught in the white and yellow pan traps during 2008 (Figure 10) and 2009 (Figure 11) samplings. Yellow and green sticky traps showed more than 60% similarity.

**Table 5.** The $\chi^2$ test values for the difference in the attractiveness of the traps for wood-boring beetles (Buprestidae and Cerambycidae). WhP: white pan trap, YeP: yellow pan trap, Mal: Malaise trap and Win.: window trap

| | WhP | YeP | Mal |
|---|---|---|---|
| Ye | 346.87*** | | |
| Mal | 129.63*** | 152.28*** | |
| Win | 251.29*** | 259.05*** | 157.06*** |

Note: *** P<0.001

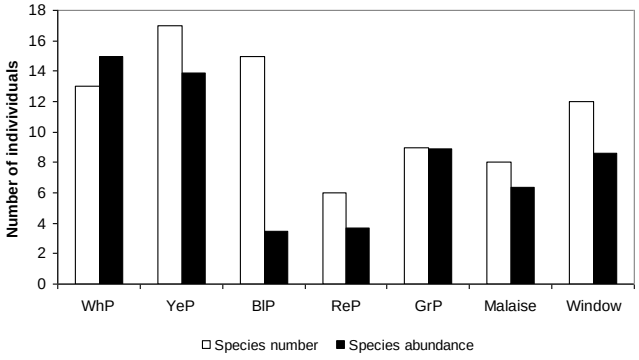


**Figure 7.** The total number of buprestid and cerambycid species and their abundance in color pan traps (WhP: white, YeP: yellow, BlP: blue, ReP: red, GrP: green), Malaise and window traps in 2008

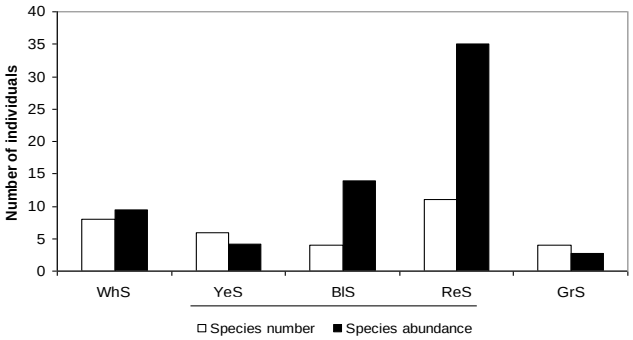


**Figure 8.** The total number of buprestid and cerambycid species and their abundance in sticky color traps (WhS: white, YeS: yellow, BlS: blue, ReS: red, GrS: green) in 2008

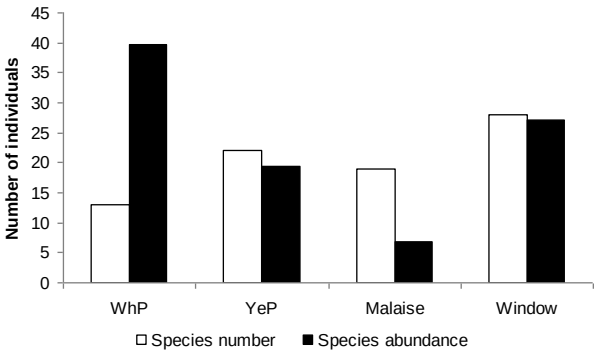


**Figure 9.** The total number of buprestid and cerambycid species and their abundance in color pan traps (WhP: white and YeP: yellow), Malaise and window traps in 2009

**The attractiveness of the traps to different species**

The results also indicated differences in the attractiveness of the traps for different species of Cerambycidae and Buprestidae (Tables 3-5). Among those 55 caught species, five species (mostly Buprestidae) and one genus were dominant (Figures 12-14). According to Figure 11, window trap was the most attractive trap for *Acmaeodera rufogutata* (Col.: Buprestidae) and *Agrilus* spp (Col.: Buprestidae), but not for *Anthaxia hyrcana* (Col.: Buprestidae) and *Stenopterus rufus* (Col.: Cerambycidae). White pan trap was the most attractive trap for *Agrilus* spp. It was also attractive for *Anthaxia hyrcana* and *S. rufus* but to a less degree. Yellow pan trap was attractive to *Agrilus* spp. and *Anthaxia hyrcana* but with a less degree for *Acmaeodera rufogutata* and *S. rufus*. Malaise trap was only attractive for *Agrilus* spp and S. *rufus* in small numbers. Red sticky traps were the best ones for collecting *Chrysobothris affinis* (Figure 13) and *Anthaxia intermedia* (Figures 14).

According to Tables 1 and 2, the following 15 subrare species were only caught by typical traps: *Acmaeoderella gibbulosa*, *Anthaxia passerine* and *Sphenoptera cauta* (all Col.: Buprestidae) by blue pan traps; *Lamprodila tuerki* (Col.: Buprestidae) by green pan traps; *Agrilus pratensis* (Col.: Buprestidae) by red pan trap; two buprestids (*Anthaxia hangarica*, *Agrilus viridis*) and two cerambycids *(Paraplagionotus floralis*, *Xyloterechus sieversi*) by yellow pan traps; *Dicerca fritillum* (Col.: Buprestidae) and *Teropes gilvipes* (Col.: Cerambycidae) by Malaise trap and four Buprestids (*Dicerca scabida*, *Agrilus biguttatus*, *Agrilus obscuricollis* and *Agrilus hyperici*) by red sticky traps. *Anthaxia bicolor* (Col.: Buprestidae) was only found in white color traps.

A rare buprestid species (*Capnodis tenebricosa*) was only attracted to red color (mostly red sticky traps).

**Flight activity of dominant species**

The seasonal activity of many caught species varied during sampling periods. A maximum number of wood-boring beetles (Cerambycidae and Buprestidae) were trapped in late May to early July (Figure 15). However, most of the dominant species were captured throughout the spring, with peak catches of *Ch. affinis* and *Anth. intermedia* on 25 April, *A. rufigutata* on 21 April, *Anth. hyrcana* on 5 May, *Agrillus* spp on 22 May and *S. rufus* on 9 April (Figures 16 and 17).

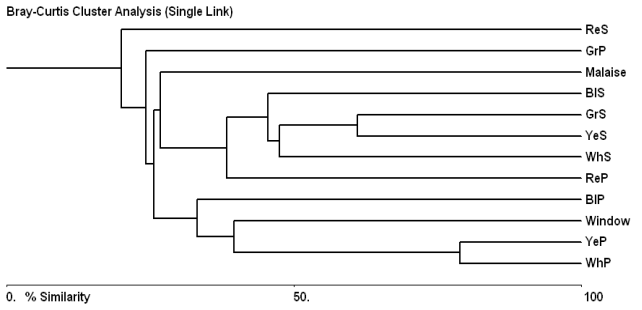


**Figure 10.** Similarity dendrogram of species composition and abundance in different traps: color pan traps (WhP: white, YeP: yellow, BlP: blue, ReP: red, GrP: green), color sticky traps (WhS: white, YeS: yellow, Bls: blue, ReS: red, GrS: green), Malaise and window traps (year 2008)

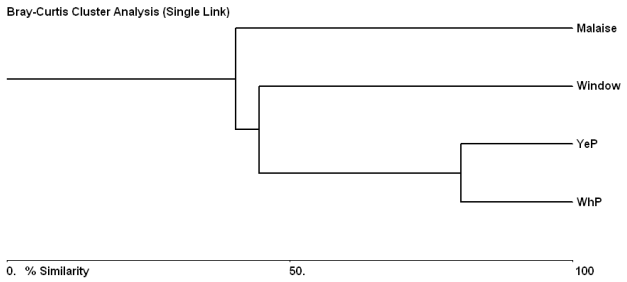


**Figure 11.** Similarity dendrogram of species composition and abundance in different traps: color pan traps (WhP: white, YeP: yellow), malaise and window traps (the Year 2009)

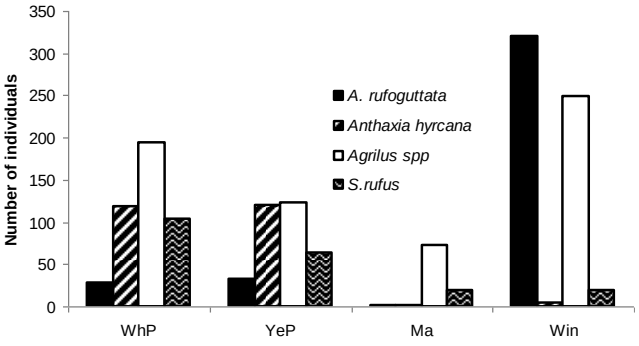


**Figure 12.** The dominant taxa caught by the various traps in 2009. WhP: white pan trap, YeP: yellow pan trap and Mal: Malaise trap and Win: Window trap

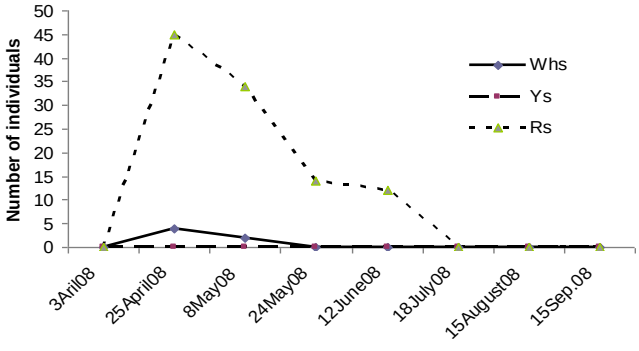


**Figure 13**. The dominant species (*Chrysobothris affinis*) caught by the various color sticky traps (Whs: white, Ys: yellow and Rs: red) during 2008 sampling

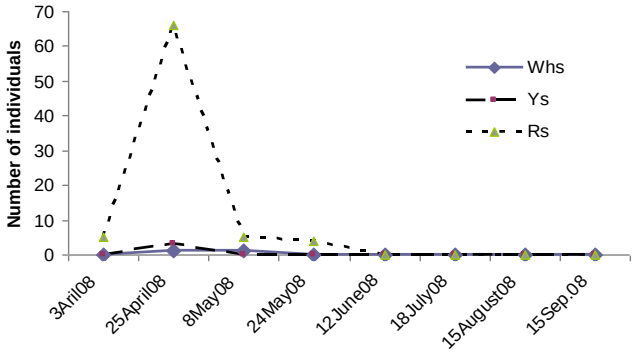


**Figure 14.** The dominant species (*Anthaxia intermedia*) caught by the various color sticky traps (Whs: white, Ys: yellow and Rs: red) during 2008 sampling

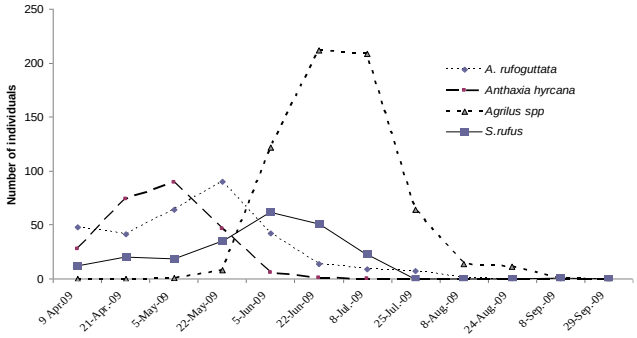


**Figure 16.** Seasonal dynamics of the dominant species (*A. rufoguttata*, *Anth. hyrcana* and *S. rufus*) and *Agrilus* spp caught by color pan traps (yellow and white), Malaise and window trap during 2009 samplings

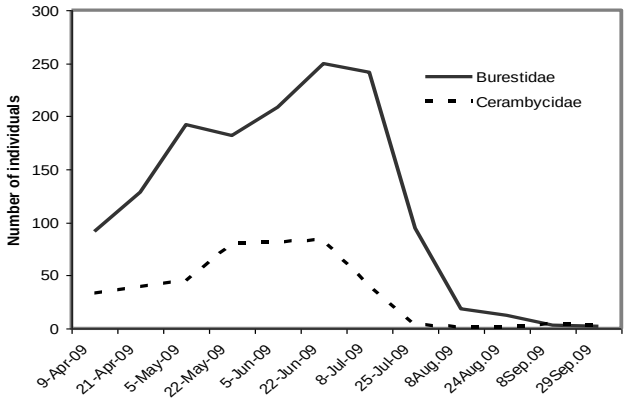


**Figure 15.** Seasonal dynamics of all number of wood-boring beetles (Cerambycidae and Buprestidae) caught by different tarps (yellow pan trap, white pan tap, Malaise and window trap) in 2009

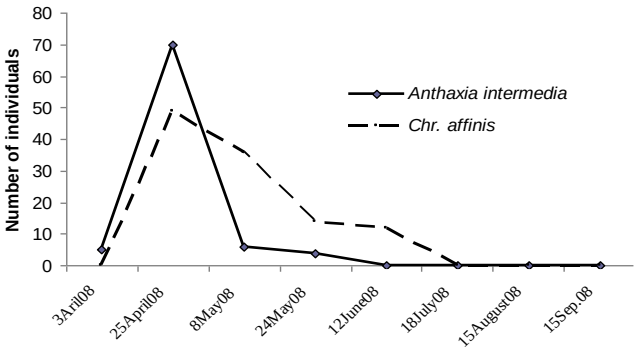


**Figure 17.** Seasonal dynamics of the two dominant species (*Anthaxia Intermedia* and *chr. affinis*) caught by color sticky traps during 2008 samplings

The results of this study suggested the significant differences in efficacy of different trap types (i.e. color pan traps, sticky color traps, Malaise and window traps) for collecting the members of the two important families of wood-boring beetles of Mazandaran forests (i.e., Buprestidae and Cerambycidae). Our findings are similar to those from Sakalin and Langourov (2004) (color taps), Olivier et al. (2004) (sticky color traps) and Michael et al. (2004) (window and Malaise traps). In 2008, window traps and malaise traps were set up in small number as monitoring action, but in 2009 our experiment was very comprehensive with setting more different traps in different areas which resulted in very reliable findings (Table 2). Window trap was the best one for collecting the beetles both in the case of different species and of individual numbers, while red pan trap collected only a few beetles (during 2008-2009) (Figure 6). After a window trap, two-color pan traps (white and yellow) were also very suitable for collecting the beetles. Wermelinger et al. (2002) used window traps and yellow pan traps as suitable collecting methods for capturing Scolytidae, Cerambycidae, and Buprestidae. Differences in the performance of the trap types can partly be explained by several factors that can influence the efficacy of the traps; trap shape, color and design might play an important role (Lindgren et al. 1983, Borden et al. 1986; Flechtmann et al. 2000).

According to our results in 2009, 28 of the total 36 species were caught by window traps. These suggested that the window trap is the most suitable trap for collecting different species in high numbers of individuals. It seems that species landing on the ground are fairly easily sampled by window trap. According to McIntosh et al. (2001), landing behavior is also likely to play a role in catching efficacy. Characteristic of landing behavior was also observed in other insects (Goodman 1960).

The high number of individuals caught by white and yellow pan traps (Table 2) is similar to what has been documented for buprestid species by Sakalin and Langarov (2004). They believed that the jewel beetles show a preference for white and yellow color traps.

As Tables 1 and 2 showed, 15 sub-rare species and one rare species were only caught by typical traps, and these species were not found in any other kinds of traps. Among all kinds of traps employed in the present study, yellow pan trap and red sticky trap were more effective. It might be concluded that these kinds of traps are more suitable for

monitoring subrare and rare species in the forests; however, catching single specimens by some traps may not be considered as indicative of trap performance.

The results also revealed that *Capnodis tenebricosa* and *Anthaxia bicolor* were only collected by red and white color traps, respectively. In this case, visual cues may play a role, because in many species, visual orientation may play a role in host location and selection (Schonherr 1977; Mathieu et al. 1997; Flechtmann et al. 2000), and an interaction between host attractants and visual stimuli might occur (Vite and Bakke 1979; Borden et al. 1982).

In our 2-year study, the majority of caught specimens were Buprestidae (~80%), while only 20% were Cerambycidae (Figure 6). This difference migh had been caused by the different duration of larval development stages of these beetles, which often take several years. Therefore, a more extended period of field study is needed. We found that maximum flight activity of the wood-boring beetles occurred in June and early July, which concurs with Wermelinger et al. (2002).

In conclusion, this study was the first comprehensive field study in Iran using different traps for a faunistic survey of Buprestidae and Cerambycidae, which introduced the suitable traps for sampling, monitoring, evaluation of the population density and seasonal dynamic of Mazandaran forest wood-boring beetles.

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