ACACIA SPECIES FOR FOOD SECURITY AND ENVIRONMENTAL REHABILITATION IN THE DRYLAND AREAS OF NORTHERN ETHIOPIA

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PREFACE

Niguse Hagazi

Director for Natural Resources Research Directorate, Tigray Agricultural Research Institute (TARI), Mekelle, Ethiopia

The Tigray Agricultural Research Institute (TARI) has been implementing a World Vision Australia funded project in collaboration with World Vision Ethiopia and other national and regional partners. The Project entitled **"Acacia Species for Food Security and Environmental Rehabilitation in the dryland areas of northern Ethiopia"** has been implemented since March 2010 mainly in three districts of the eastern zone of Tigray Region, namely *Kilte-Awlaelo*, *Saese Tsaeda-Emba* and *Atsbi-Wenberta* to contribute to the efforts underway to improve food security and environmental rehabilitation situation in the dryland areas of northern Ethiopia. The project objectives were mainly to address the impact and role of Australian Acacias in general and *Acacia saligna* in particular for rehabilitation of degraded drylands, food and feed security as well building capacity and creating awareness on *Acacia saligna* socio-economic and environmental impacts including its multi-service functions and benefits. *Acacia saligna* was introduced to northern Ethiopia for environmental rehabilitation purposes in 1980s and planted extensively since 2000 in many degraded areas of the region. The species was considered as most important only for environmental rehabilitation as it can grow fast in drought prone, moisture stressed and degraded areas, and produce high biomass where it can also create good microclimate in many of the hillsides, exclosures and rural institutions. However, since the inception of this project, many investigations have been done and being recognized as a multipurpose tree species and demonstrated its future potential ability for food security, agroforestry development and also enabling the community to adapt the changing climate. In addition to this, gaps have identified which needs further investigation and evidence.

Based on the project's research outputs and other countries experiences, TARI in collaboration World Vision organized this international conference with the following major objectives:

1. To share and review research outputs of *Acacia saligna* tree and set modalities of scaling up for good results that can contribute to the socioeconomic and environmental benefits and services as well as identifying gaps and challenges that required further research and improvement measures,
2. To exchange knowledge and share experiences on the contribution of Australian Acacia species to the efforts underway to improve food and feed security and adapt to the changing climate,
3. To facilitate and strengthen the collaboration between governmental and non-governmental organizations for the completion of Acacia seed food safety and human volunteer trials in a way to address all the safety procedures for its use as a human food in the future,
4. To synthesize ideas that can help in formulating the second phase of the project to complete the ongoing and remaining research activities of the project and scale up of successful findings,
5. To publish the results to reach a wider audience and create networking in order to use the research outputs as well as doing further research and development activities.

With this brief conference objectives, on behalf of myself as a project coordinator, the natural resources directorates of TARI, World Vision Ethiopia, and the Acacia project team members' including from World Vision Australia, I would like to express my in-depth appreciation and acknowledgment to the following organizations and individuals who contribute in one way or the other.

- World Vision Australia for providing funding and technical backstopping through its highly experienced experts and consultants,
- The community particularly the Farmers Research Group (FRG) members involved in the project implementing activities,
- The offices of agriculture in each project implementing districts including *Saese Tsaeda-Emba, Kilte-Awlaelo and Atsbi-Wenberta,* the Regional Bureau of Agriculture and Rural development (BoARD) and the TARI management for their overall facilitation and support during project proposal writing and implementation,
- The Ethiopian Health and Nutrition Research Institute, Ethiopian Food, Medicine and Health care Administrative & Control Authority, Drug Quality Control and Toxicology Laboratory Department and Melbourne University for their active involvement in research activities and support,
- Mekelle University for its involvement in capacity building of graduate students.

Special thanks and acknowledgment go to the World Vision Australia team (Tony Rinaudo, Peter Cunningham and Peter Yates) for their overall guidance and active involvement in all endeavors of the project (project development, technical backstopping, conducting research, and preparation of this international conference). A great appreciation for those coming from Australia, Kenya, Uganda and Chile supporting their own expenses to participate in this important conference and to share their knowledge and experiences.

I believe we had a successful conference and participants were happy and encouraged with the interaction between participants and research results delivered in this conference. We also had success in terms of participation, scientific contribution, and sharing of knowledge and experience. I believe the results of this conference are technically sound and provide a great opportunity for further development of *Acacia saligna* in a way to contribute more to the efforts underway to improve food security and environmental rehabilitation situation in the dry land areas of Ethiopia and beyond.

I am very grateful to Liz Rinaudo from Australia for taking notes during the whole conference period as well as to Dr Abbadi Girmay for his excellent facilitation as chief of the conference.

WELCOMING ADDRESSES

Mrs Worknesh Tayachew

Representative for the National Director of World Vision Ethiopia, Addis Ababa, Ethiopia

It is a great privilege and honour to welcome you to this conferemce. The project has been implemented since 2010 and we realized that the *Acacia saligna* introduced to Ethiopia in general to the Tigray region in particular has been underutilized. I belive in this conference, research outputs of the project will be presented the mulitipurpose benefits and sevices as well as the challenges encountered during the project implememtation period. I hope also that indepth dialogue at this conference will strengthen our partnership and future collabrations. I am here representing the national director of World Vision Ethiopia and myself and wish you all to have fruitful deliberations.

Dr Eyasu Abreha

Director General, Tigray Agricultural Research Institute (TARI), Mekelle, Ethiopia

It gives me a great pleasure to extend to you all a very warm welcome on behalf of myself, my regional research institute, TARI and the conference organizing committee to this International Acacia species for Food Security and Environmental Rehabilitation in the dryland areas of Northern Ethiopia Conference. Much appreciated with great pleasure for distinguished conference participants come from Australia, Chile, Kenya and Uganda, you are most welcome to Mekelle, a beautiful and historical capital city of the Tigray National regional State.

We all are well aware that poverty and land degradation have been deep-rooted in the dry and moisture stressed areas of Ethiopia in general and Tigray region in particular. Thus, the government and non-government organizations have been working in multiple interventions to improve livelihoods and restore the highly degraded landscapes. Conservation based agricultural and natural resources development is a key pillar and direction in Tigray region where this time many degraded areas have rehabilitated with active participation of the whole community. The region has a strong believe that research supported development endeavors can bring a significant change in livelihood improvement and sustainable natural resources management. In line with this, the regional research institute (TARI) is actively working across the region through its nine research centers established based on agro-ecology and potential commodities. The research agendas are usually implemented through government fund as well as in partnership with national and international research and development organizations. Of these, World Vision Australia (WVA) in partnership with wing World Vision Ethiopia (WVE) is our key partner and have been supporting TARI both financially and technically. TARI in collaboration with WVA and WVE has been implemented Acacia species for Food Security and Environmental Rehabilitation in the dryland areas of Northern Ethiopia and Farmer Managed Natural Regeneration (FMNR) mainstreaming endeavors in Tigray region and beyond.

Therefore, in these two days conference, the research and development related outputs, lessons learnt and future possible directions of the "Acacia species for Food Security and Environmental Rehabilitation in the dryland areas of Northern Ethiopia" will be presented and discussed in a way to contribute to our future research and development endeavors as well as strengthening our partnerships and collaborations. Before I conclude my welcoming address, I would like to thank WVA and WVE for the financial support of the project as well highly appreciated for continues technical backstopping both in the Acacia project and FMNR. Thanks to our Farmer Research Extension Groups (FREGs) members and each respected districts (Saese Tsaeda Emba, Kilte-Awlaelo and Atsbi-Wonberta) where the project has been implemented in and the Regional Bureau of Agriculture and Rural Development (BoARD) for their overall facilitation and support.

Special thanks to the project coordinator, Niguse Hagazi and his project team members for their tireless effort and I would like to congratulate them.

Excellencies, Distinguished participants, and Ladies and Gentlemen, I warmly welcome you again and have a very pleasant stay in Mekelle.

OPENING SPEECH

Dr Kindeya Gebrehiwet

President, Mekelle University, Mekelle, Ethiopia

It is my great pleasure, to welcome you all to this international conference entitled **"Acacia species for food security and environmental rehabilitation in the dryland areas of northern Ethiopia"** organized by Tigray Agricultural Research Institute and World Vision Australia and Ethiopia.
As we know all forest resources are an essential and very vital part of the global sustainable development and integral part of the livelihoods of the local and vulnerable communities particularly farmers. They provide timber and non-timber products including wood for construction, lumber, food, feed, fuel, shelter, gum, resin, medicine etc. Trees/shrubs sequester carbon and contribute to the mitigation and adaptation of climate change.

The continuous loss of forest resources and their unwise utilization has resulted in land degradation and consequently reduction in agricultural production and productivity across the whole nation.

To address this, currently the government of Ethiopia has long standing and commitment in fulfilling the international conventions including convention to combat desertification, climate change, and the clean development mechanisms in line with its Growth and Transformation Plan (GTP) and the Climate Resilient Green Economy (CRGE) strategy. The government has come up with clear strategy in the CRGE Strategy document to reduce deforestation and forest degradation significantly, to increase afforestation, reforestation and forest management programs to increase carbon sequestration and ensure sustainable socioeconomic development. The CRGE and Growth and Transformation Plan (GTP) have put many targets. To achieve those targets the government of Ethiopia has been working aggressively in collaboration with its research and development partners.

The research institutes in general and the forestry and agroforestry research programs in particular undertaking by the regional, federal and international research institutes, and higher learning institutions has to play essential role on conducting and providing appropriate, up-to-date, and cost effective forestry and agroforestry technologies and information to be applicable by different stakeholders and more importantly generated technologies and information should be properly disseminated to be applied on time. I am sure, the results to be delivered in this conference are going to be more informative, applicable and easy to disseminate across the region and the nation as whole.

We know all, the Australia tree species like Eucalyptus and Gravillea have been benefiting our small holder farming communities as a livelihood improvement strategy. However, the Australian Acacias particularly *Acacia saligna* have been with us for many decades and are considered one of the most important trees for restoration of degraded lands, rehabilitation of gullies and soil fertility enhancement by showing its excellent growth performance. Actually, farmers may have their own mechanism to use for different purposes, but in spite of its diverse distribution and abundance in northern Ethiopia, I recognized now it has been under-utilized for a long time.

I believe it is a timely organized conference that will help to share experiences and create understanding among the participants on the Australian acacia in general and *Acacia saligna* in particular and I urge you all to participate actively and reach at consensus in order to achieve the expected outcomes of the conference. The lessons learnt will help to enhance appropriate management and utilization of the Australian acacias (*Acacia saligna*).

Hence, on behalf of myself and the government of Tigray my great appreciation is to all of you particularly for those who travelled from a long distance from Australia, Chile, Kenya, Uganda and Addis to participate, contribute and share your experiences and knowledge on the Australian Acacia species. Special thanks to Tigray Agricultural Research Institute, its researchers and World Vision for their strong commitment to organize this international conference.

Finally, I would like to express my in-depth appreciation to World Vision Ethiopia and Australia for their financial support and active engagement in such research for development endeavors in collaboration with TARI as a government institution. Indeed it is a lesson for other Non-Governmental Organizations. I would like to confirm also that Mekelle University wants to work with all of you in the future.

With this brief remark, I wish you all very successful participation and deliberations and now I declare the conference is officially opened.

KEY NOTE ADDRESS

Turning Agriculture on its head: The case for Acacia agroforestry

Tony Rinaudo

Principal Advisor, World Vision Australia, Melbourne, Australia

Thank you for the vote of confidence you have given by attending this conference. I wish to thank and congratulate TARI and especially Niguse for organizing this event. I am very happy and proud to participate. I wish to capture why we are here. Why TARI, World Vision and others have invested so much time and effort into acacia research.

As a child growing up in a temperate part of Australia, I was shocked when I saw on television that children just like me were starving on the other side of the world. I wanted to do something about it and this has contributed to my passion to find solutions.

In 1980, my wife, 6 month old son and myself went to Niger Republic. I was again shocked – this time, by the extent of environmental devastation and the impact that this was having on people and how it limited their ability to produce food and an income.

Another turning point in my life occurred in 1984. There was a severe famine in Niger and across the Sahel. This time it was personal, these people were my friends, not abstract figures on TV. Fortunately, we were able to help many through famine relief.

I was very happy to be able to help people but I was worried: by relying on a single annual crop famine could occur in any year. People were growing and relying on annual crops such as millet, in a climate biased against them. Hence, even if rains were good, there was no guarantee of a successful crop because strong winds, too much rain, insect attack etc. could cause heavy losses. So, I started a search for a crop that could complement the millet (or, in Ethiopia's context, wheat, barley, teff etc.). Not to replace these very important crops, but to act as a backup and to utilize ecological niches or conditions, which may not be usable by annual crops.

It's very easy to use drought as a scapegoat for crop failure. It's very convenient as we don't have to take responsibility for drought – it's an act of God after all! However, drought should be considered a normal climatic occurrence, particularly in arid and semi-arid zones. We should have strategies to deal with drought.

As I visit other countries, I see that we are using the same crops year after year. Millet and sorghum in West Africa, maize in much of East Africa, teff, wheat, barley and maize in Ethiopia, depending on region. I want to challenge us: will our communities graduate from the Safety Net (food assistance) by the end of our programs? Will they be more food secure and less vulnerable to environmental/climatic shocks because of our interventions?

A man who experienced the American dustbowl in the 1930's said "We kept thinking that things would change. We didn't try something different but just worked harder on the same things that didn't work."

Einstein's definition of insanity is doing the same thing over and over again and expecting different results. We are delusional if we think we can solve agriculture's problems in a changing climate by simply doing the same things, but only doing them harder. Let's work harder, but also let's work smarter!

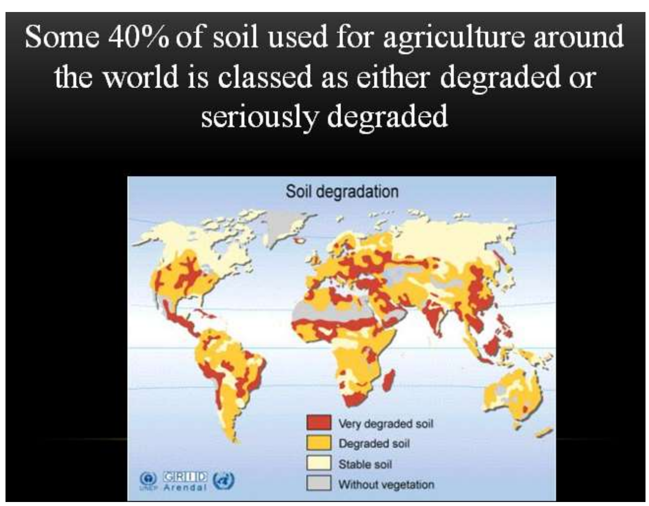
In 1980, in Niger if I asked 'what is a farmer', the response would have been "a farmer is somebody who grows millet". Again, Einstein said, *"we cannot solve our problems with the same thinking we used when we that created them"*. We need to broaden our view of 'what a farmer is' and of agriculture. Today, if I asked a Nigerien farmer the same question, most likely the response would be *"a farmer is somebody who grows anything"*.

Like the Nigeriens, we need to step outside of norms and conventions and examine whole ecological systems. We need to dismantle agriculture and turn it on its head! Agriculture started to focus on monoculture annual crops around 10,000 years ago, and by default, began down playing the role of other types of crops and mixed cropping. The path taken has put the world's population in a very vulnerable situation. As with Nigerien farmers in the past, reliance on single annual crops and utilizing the same narrow range of genetic material over vast acreages increases susceptibility to environmental and climatic shocks.

All biological energy comes from the sun via green plants. Yet, our annual crop-based agriculture is water-centric, not sun-centric, even though most agriculture that is practiced is rain dependent, and out of the reach of irrigation schemes. Many plant species can grow well and produce products (foods, timber, fibre, medicines.) in the dry season and without irrigation. Why not incorporate more of these into our farming systems to take advantage of 12 months of sunshine, instead of only utilizing the sunshine that falls during the rainy season?

By relying predominantly on annual crops, where we have a four-month rainy season, only 33% of the days in the year are utilized i.e. only 33% of available sunlight is utilized. If drought or other calamities occur during the rainy season, effectively 0% of the available sunlight may be used for food production in the whole year. This represents an enormous lost opportunity. If this reliance on annual crops is occurring on a landscape scale, which is the norm, the lost opportunity is enormous. For the foreseeable future, most agriculture will remain beyond the reach of irrigation schemes. What is stopping us from approaching agriculture with a different viewing lens?

Typically, Niger has an eight-month dry season – eight months in which on many farms, nothing is growing, and no sunlight energy is being converted to usable forms. By simply adding one perennial species, food, fuel wood and organic matter is produced in the dry season, and in this particular case with Acacia colei, annual crop yields increase in the rainy season due to improved soil fertility, reduced wind speeds and lower temperatures afforded by the presence of the trees. And, there are many other species which could be added to the farming system to make it even more robust and more productive.



Prevailing agricultural practices have significantly contributed to the sorry state of the world's agricultural soils. Some 40% of soil used for agriculture around the world is classed as either degraded or seriously degraded. Seriously degraded means that 70% of the topsoil, the layer allowing plants to grow, is gone. In too many of the WV operational regions that I visit, up to 50% of the land is so degraded that it is unusable for agriculture.

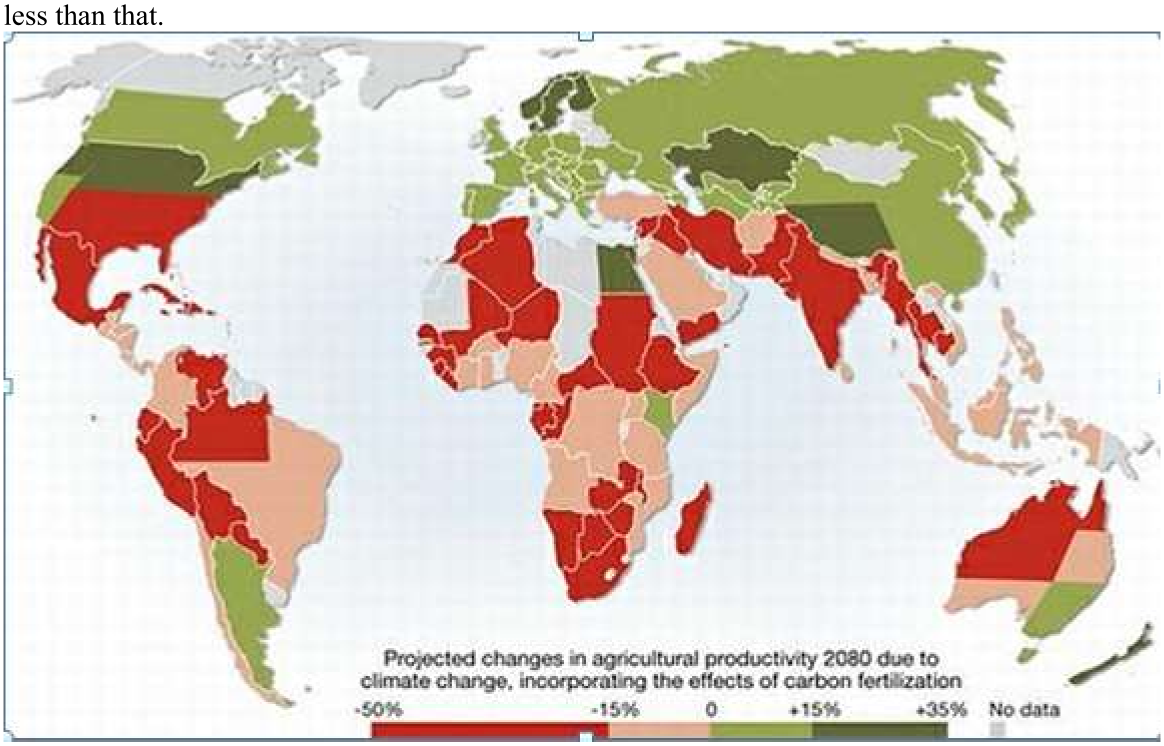
By incorporating perennial species, such degraded landscapes can be restored, even becoming usable again for annual crops.

Agroforestry can extend the range of farming and agriculture. For example:

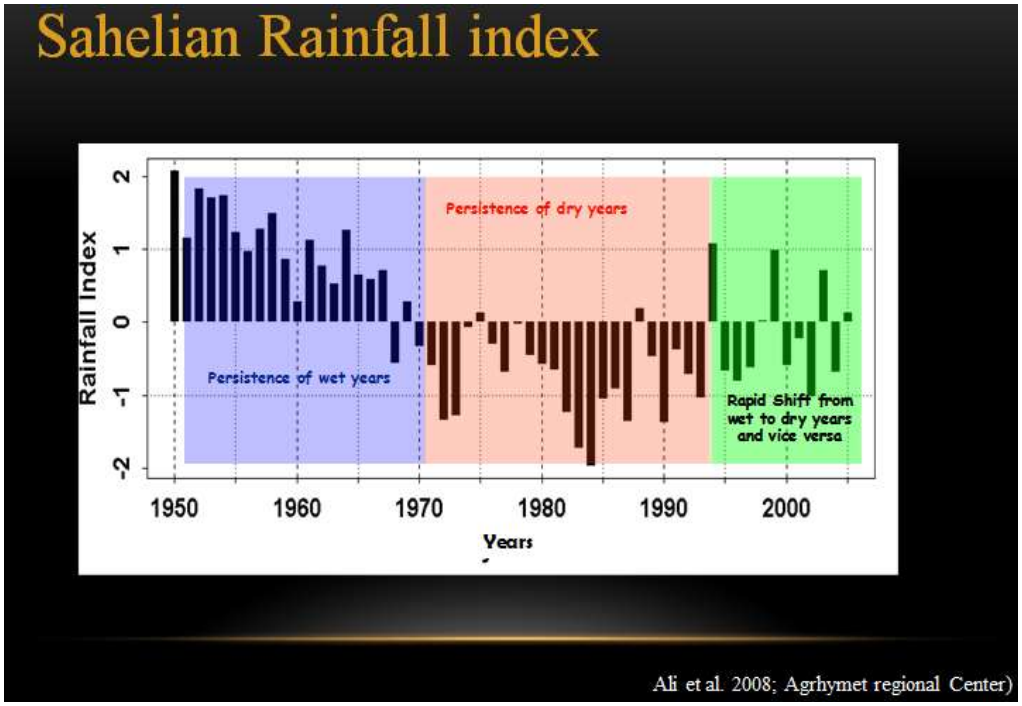
- The topography of many locations makes them unsuitable for conventional agriculture. In the case of Tigray, 50% of the land is too steep for annual crops and should not be cultivated. We can take advantage of this land by using agroforestry.
- Many areas are too dry all year or are too prone to droughts to be suitable for annual crops. Most acacias thrive under such conditions.
- Some sites may be too saline or alkaline for most crops. There are species of acacias suited to such conditions.

This generation faces an additional challenge – that of climate change. An increase in global average temperatures of 4^0 C will translate to an average increase in sub-saharan Africa of 7 ^{0}C. This is a very dangerous situation as for each 1^0C temperature increase above an optimum threshold, crop yields begin to decline by as much as 10%. Many crops are already growing near, or at their threshold temperatures.

In addition, average figures are dangerous and can lead to complacency. According to this map, countries in red will experience yield decreases of up to 50% by 2080. This is based on average figures. However, even now, regions are experiencing days with 'heat spikes', as in Melbourne in 2009 when a record breaking 46^0C heat spike destroyed many crops – despite the average for the growing season being much less than that.



Climate change will also affect rainfall – total amount, variability and the incidence of extreme events. If what is happening in the Sahel over the last decade and a half, with violent swings from above average to below average rainy seasons is anything to go by, rain fed, annual crop-based agriculture is in for a very difficult time.



Trees provide a buffer to weather extremes, both withstanding greater variability to temperature and moisture stress than annual crops and creating more favourable microclimates through which annual crops can survive better. I call this free weather insurance.

This conference will highlight diverse research streams, including nutrition and safety, forage and feed value, impact on honey production and bees and agroforestry. Presentations will be heard on work being conducted in Chile, Australia, Niger and Ethiopia. I will not steal their thunder but will just touch on some of these:

Livestock fodder: In regions with extended dry seasons, supplying adequate protein for livestock is difficult. Crop residues and dry grass are high in lignin and low in digestibility and protein. Acacia species such as *A. saligna* have edible leaves, which if dried in the shade and mixed with the usual forage available, can increase digestibility and hence weight gain and milk production. The seeds of edible-seeded acacias can also a source of protein for livestock and there is a particular interest in poultry feed.

Species and provenance trials: Over the years, various governments and organizations invested in identifying optimum species and Acacia-based farming systems. Findings to date will be shared.

Nutritional profiles and food safety: typically, traditional weaning foods do not provide the balanced diet required for normal health and growth of children. By developing acacia-based weaning foods and through using locally sourced and accessible ingredients as far as possible, serious malnutrition issues could be addressed without creating dependency. Studies have shown that a nutritionally superior weaning food can be developed within the means of poor households. Such foods are not therapeutic foods like Plumpy Nut, but they are nutritionally far better than traditional weaning foods. This route has been chosen to maximize the potential for these foods to be accessible and affordable to the poorest households and to let 'food be food', demystifying it so that any household can feel confident that they are providing well for their children. At the time of writing, small businesses have been selling acacia-based weaning foods in Niger and Senegal. In addition, a range of tasty traditional dishes have been nutritionally enhanced through addition of acacia flour.

Conclusion
The green revolution bypassed Africa. We cannot continue with business as usual. We need to look at what can be done with what we have and work smarter, not just harder.

If there is to be a ‘green revolution’ for the arid and semi-arid subtropics, it will have to be through plants that thrive under such conditions, yield well and require minimal inputs. Millions of third world farmers have no access to the usual green revolution inputs. Increasingly they are farming on exhausted, marginal lands under adverse climatic conditions that are unsuitable for conventional crops.

For them, a biological revolution, in which plants are selected and bred to suit the prevailing environmental conditions is needed, rather than a green revolution, in which the crop environment is modified (through irrigation, fertilisers and pesticides) to suit the plants.

SECTION A: USE OF *ACACIA SALIGNA* IN AGROFORESTRY SYSTEMS

The potential for *Acacia saligna* agroforestry farming systems in Tigray, Ethiopia

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Abstract
The dryland regions of Tigray in Ethiopia are in great need of environmental restoration and innovations to improve food security. This paper outlines progress on the domestication and multi-purpose development of *Acacia saligna* for use in agroforestry farming systems such as farm borders, small farm enclosures, compounds and community enclosures. The naturalised *A. saligna* in Tigray is highly outcrossing and genetically diverse with high potential for rapid improvement. *A. saligna* is easy to establish, drought tolerant, nitrogen fixing, exhibits coppicing, produces valuable fodder for livestock, fuelwood and timber and seed for poultry and potentially human food. Trial results show good progress in the selection and development of multi-purpose trees and various pole types. *A. saligna* and *A. glaucocaesia* were the most promising species at a lower rainfall site. Further research and development are required to quantify the economic and environmental benefits of *A. saligna* in agroforestry applications and to develop optimal silvicultural management practices to facilitate adoption and uptake by smallholder farmers. The principles and practice of the Farmer Managed Agroforestry Farming System are a vehicle for rapid agroforestry scale-up on farms in various agro-ecological zones of Tigray and other regions of Ethiopia.

Keywords: dryland agroforestry, environmental restoration, Farmer Managed Agroforestry Farming System, food security, Horn of Africa, multipurpose tree

Introduction

The Tigray region is one of the most degraded and food insecure regions of Ethiopia. There has been extreme environmental degradation evidenced by the loss of trees, grasses and general biodiversity. Low and declining soil fertility with high soil erosion rates, climate change, crop pests and diseases, high population growth, limited arable lands and lack of land ownership are all challenges that contribute to food insecurity (Rinaudo and Admasu 2010). Despite the many challenges to food insecurity, there have also been significant efforts at environmental restoration which is a key foundation to sustainable and productive agriculture. The creation of vegetation enclosures covering at least 1.2 million hectares of mostly hilly land has been significant in recent decades. One of the main tree species planted in these enclosures is *Acacia saligna*. Although generally known as a conservation species, the recently completed project *"Acacia species for Food security and Environmental rehabilitation is the dryland areas of Northern Ethiopia"* (2010- 2014) has identified the valuable multi-purpose benefits of this species, including animal and bee fodder, sustainable fuel wood and timber, improved soil fertility and high protein seed for poultry and potentially human food (Anon 2014). This paper outlines the type(s) of *A. saligna* naturalised in Tigray, current and future uses, together with progress in domestication, development and the significant potential for various agroforestry applications.

A. saligna in Tigray

A. saligna was first introduced into Tigray in 1972 and has shown outstanding performance in the rehabilitation of degraded lands due to its rapid establishment and growth, drought tolerance and nitrogen fixation (Rinaudo and Admasu 2010). Most of the *A. saligna* in Tigray is found in enclosed areas and in household compounds where large mature trees provide shade. The naturalised type of *A. saligna* in Tigray is highly variable for a range of phenotypic characters and there are no records of what types of *A. saligna* were introduced (Cunningham 2011).

An important starting point in any domestication and development program is to identify the genetic makeup of the localised type(s). There are no formal taxonomic descriptions of the genetic entities present in the *A. saligna* species complex, but geographic descriptors have been assigned to informal subspecies names and at a broad level comprise subspecies *stolonifera, saligna* and *lindleyi.* At a finer level the *saligna* subspecies has also been divided into subspecies *stolonifera*, the Western *saligna* and Eastern *saligna* entities, the Northern *lindleyi* entity and the remaining populations of the subspecies *lindleyi* (Millar *et al.* 2011). More recent taxonomic research indicates that the variation in *A. saligna* is best accommodated by four subspecies, i.e. *saligna, pruinescens, lindleyi* and *stolonifera* which have consistent differences in bud morphology (Maslin *et al.* 2011).

In order to determine the genetic entities and levels of diversity in the localised *A. saligna* in Tigray, phyllode samples were taken from 12 individual trees in each of four diverse enclosures (1. Adishehu; 2. Abreha Atsbeta; 3. Haikimeshal; 4. Bizert) and from ten trees in the TARI compound in October 2011. These samples were then processed by the Department of Environment and Conservation in Western Australia for genomic DNA and genotypes obtained using five diagnostic microsatellite loci (Millar and Byrne 2007) to differentiate the genetic structure of *A. saligna*. The results showed that in general there was a high degree of genetic diversity and heterozygosity within enclosure populations. On a broad level, most of the *A. saligna* individuals were identified as the informal subsp. *lindleyi* with some individuals from subsp. *saligna* and others with mixed co-ancestry for two or more of the broad genetic entities. At a finer level, most of the *A. saligna* individuals were assigned to the Northern and general *lindleyi* entities, with other individuals assigned to Western and Eastern *saligna* and *stolonifera* entities and others with mixed co-ancestry (Figure 1). These results, which reflect a high local genetic variation in Tigray, suggest there is good potential for rapid progress for the selection of suitable *A. saligna* types from within the localised populations of *A. saligna* for various end uses (e.g. fodder, timber, multi-purpose, and seed). When this material is also combined with the range of *A. saligna* provenances available from Western Australia, there is a high likelihood of success for the rapid development of improved *A. saligna*. It should also be noted that *A. saligna* is a highly outcrossing species with random mating and pollen dispersal within the stand (Millar 2008). Provenance Resource Stands (PRS) and seed orchards should therefore be kept separate to avoid contamination.

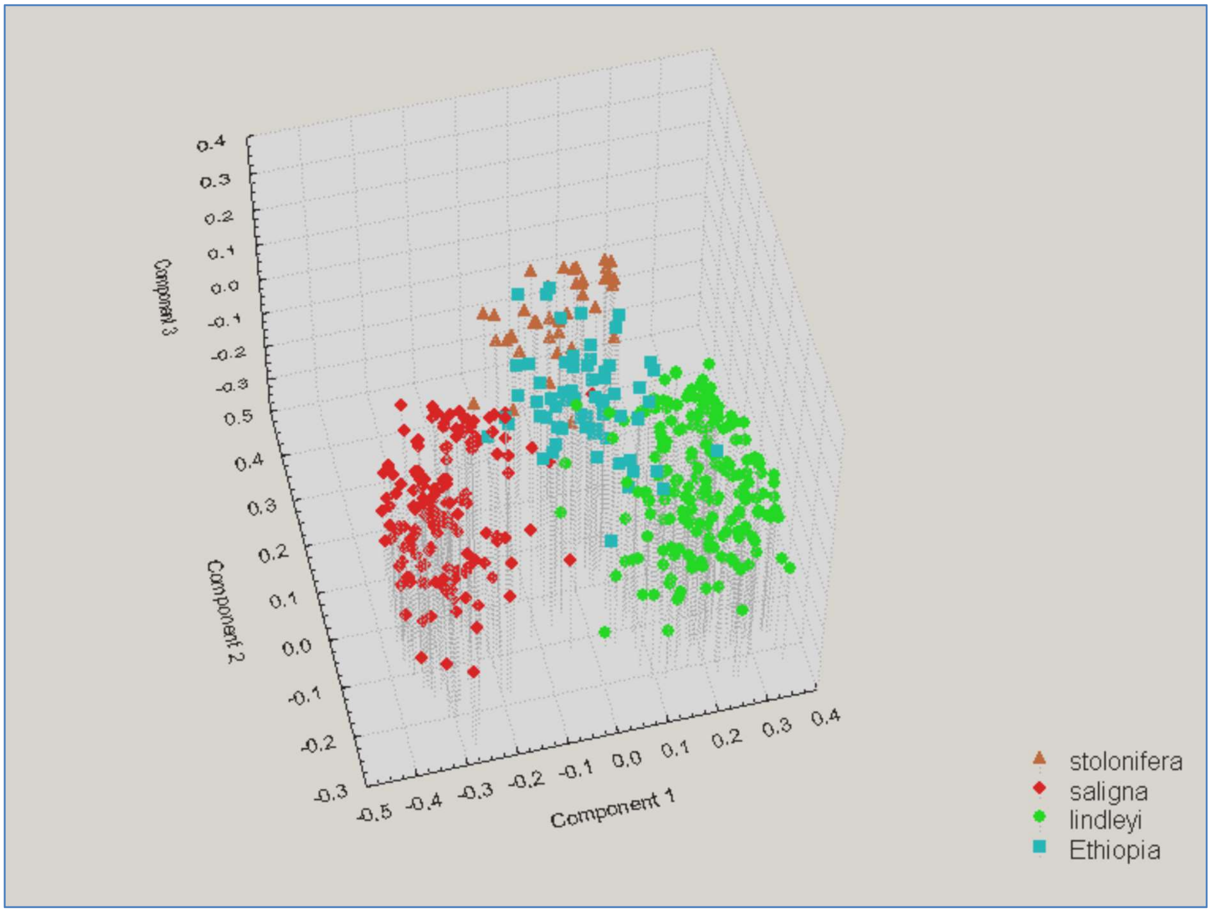

Figure 1. Principal coordinates analysis of *Acacia saligna* 'populations' from Ethiopia and populations of three genetic entities across the native range in Western Australia (from Millar and Byrne 2012)

Uses of *A. saligna*

The first phase of the WVA-funded project, *"Acacia species for Food security and Environmental Rehabilitation is the dryland areas of Northern Ethiopia"*, clearly identified the valuable multi-purpose uses for *A. saligna*, such as its ease of establishment, rapid growth in low fertility and degraded soils, drought tolerance, good biomass production and nitrogen fixing ability, which contribute to its ability to diminish wind and water erosion and hence have high value for land restoration. In addition to these attributes, *A. saligna* foliage provides valuable fodder for small ruminants (Shumuye and Yayneshet 2011; Gebre 2011) and its pollen is a valuable source of bee fodder for hive health and enhanced honey production. The wide range of phenotypic forms also gives potential to select types for building poles, particle board manufacture, farm tools and sustainable fuelwood via multi-branching types with good coppicing ability. Annual production of high protein seed has potential for poultry production (Anon 2014).

The Acacia project also demonstrated how *A. saligna* could be successfully used in four agroforestry farming systems: 1. Farm borders, 1. Small farm enclosures, 3. House compounds and 4. Community enclosures (Figure 2-5). Pruning demonstrations on *A. saligna* trees ranging from 3-8 years of age with three Farmers Research and Extension Groups (FREGs) in the above four Agroforestry farming systems were completed in May 2014 (Cunningham 2014a). These demonstrations with the FREGs were well received by the communities as trees provided valuable fodder (foliage) at a time of year when fodder was in demand, and branches and larger wood that could be used for fuelwood. A follow up visit to these FREGs in December 2014 (7 months later) showed excellent recovery and regrowth after pruning for all ages of trees (Cunningham 2014b). An example of a five-year old *A. saligna* tree, with regrowth after 7 months is given in Figure 6 and 7, respectively.

Figure 2. *A. saligna* farm border (3 yrs)

Figure 3. *A. saligna* in small farm enclosure

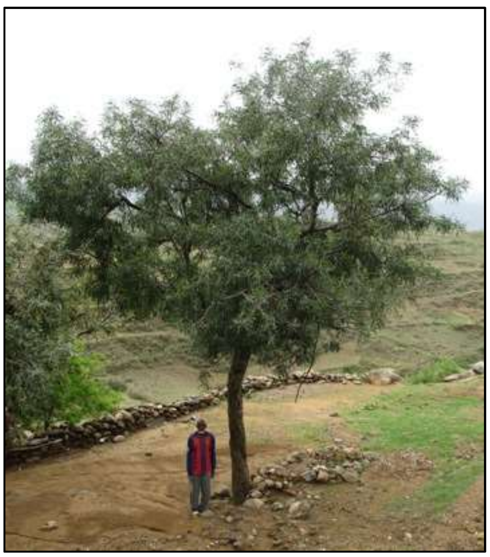

Figure 4. *A. saligna* house compound (6 yrs).

Figure 5. *A. saligna* in community enclosure (Bizert)

Figure 6. FRG at Abreha Atsbeta with *A. saligna* products (Foliage, branches, wood). May 2014.

Figure 7. Regrowth after 7 months

Domestication and development of *A. saligna*

There are important principles and practices required for the domestication and development of improved tree types from wild tree types such as *A. saligna*. These include: 1. deciding on what products and services are required from the trees; 2. a knowledge of the target environment; 3. selection of appropriate germplasm with a broad genetic base; 4. a knowledge of its breeding system; 5. conducting appropriate field trials with tree measurements of key selection criteria and 6. establishing Provenance Resource Stands (PRS) where only elite trees are retained to produce seed orchards of the improved types.

The project team at the Tigray Agricultural Research Institute (TARI) decided that two improved *A. saligna* types for the mid-high (1500-3000m) agro-ecological zones in Tigray would be a useful starting point. 1. Multi-purpose for biomass (fodder), wood and seed; 2. Tall type for poles/wood. A rapid method to develop these *A. saligna* cultivars was applied by selecting the best types of 20-40 trees in four diverse enclosures (1. Adishehu; 2. Abreha Atsbeta; 3. Haikimeshal; 4. Bizert). Each tree was labelled, and seed collected in December 2012, then bulked for each enclosure. In Adishehu enclosure, seed from tall tree forms were collected from 12 trees and bulked. PRS's of spaced trees (e.g. 3x4m), of each of these two localised bulks 1. Bulk of 4 enclosures (234 trees); 2. Tall type- Adishehu (100 trees) were established at TARI in August 2012. Data (tree characterisation) was then recorded for individual trees based on Key Selection Criteria (KSC) such as: adaptability (survival rate), growth rate (tree height/width), growth habit, seed production, coppicing ability, fodder quality and biomass/wood production for at least three years. The best 20-40 trees based on the KSC for each type would then be retained (other trees eliminated) and allowed to inter-pollinate to produce a uniform and improved type. These trees then become the improved seed orchard.

A complementary approach to produce the improved *A. saligna* types was also initiated with the introduction of *A. saligna* provenances from Western Australia. A comprehensive provenance trial (3 replicates of 20 trees) with 10 introduced provenances, two localised bulks and other control species was established at TARI in August 2012 (Table 1). A further PRS was also established with the best *A. saligna* subsp. Bambun road provenance (252 trees). This has been the most productive *A. saligna* provenance for biomass and seed production in Western Australia (R Mazanec, *pers. comm*). Some results of the *A. saligna* provenance trial are presented in Table 2.

Seedling vigour in the tree nursery was generally good for *A. saligna* provenances with the exception of subsp. pruinescens and all the other comparison *Acacia* species had poor seedling vigour. A growth habit score (May 2014) on the whole trial clearly showed that the Parkeyeering and Muntagin provenances were the most erect types with good potential for the development of pole types. Some trees in these provenances were clearly identified as pole types, reaching 8-10 metres in height after 2 years and 9 months of growth (Figure 8).

Seed production was observed when trees were two years and nine months of age but was highly variable among replicates. In replicate one, a heavy clay loan soil, 39% of trees had seed, but there was no seed production in replicate two and only 6% of trees had seed in replicate three. All trees in both replicates two and three had much slower growth rates, primarily due to the lower fertility sandy loam soil. Seed production was therefore only estimated in replicate one. All trees were assigned a score (1-9), then a number of trees for each score was randomly selected across the trial and harvested for seed. Regression analysis of score vs actual seed weight is in progress. There was significant variation between trees within and between provenances. The standout provenance for seed production was Murchison River with a mean tree score of **8.05** (Table 2). All trees (20) in this provenance were heavily laden with seed which was uniform in maturity, but approximately 2 weeks later than other provenances.

Table 1. *Acacia* species and provenances established at TARI, Tigray 2012

Treatment No.	Species	Subsp.	Provenance
1.	*A. saligna*	lindleyi	Arrowsmith River
2.	*A. saligna*	lindleyi	Mingenew
3.	*A. saligna*	lindleyi	Murchison River
4.	*A. saligna*	lindleyi	Parkeyeering
5.	*A. saligna*	lindleyi	Muntagin
6.	*A. saligna*	saligna	Bambun Rd
7.	*A. saligna*	saligna	Flynn Drive
8.	*A. saligna*	saligna	Lake Coolengup
9.	*A. saligna*	pruinescens	Palmer Block
10.	*A. saligna*	stolonifera	Pruinescens
11.	*A. saligna*	lindleyi	Bulk of 4 enclosures
12.	*A. saligna*	lindleyi	Tall Seln Adishehu enclosure
13.	*A. daphnifolia*		Coorow
14.	*A. microbotrya*		Tincurrin
15.	*A. microbotrya*	Tall form	Dandaragan
16.	*A. baileyana*		Stawell 2011
17.	*A. pycnantha*		Stawell 2011
18.	*A. microbotrya*		Stawell 2011

Biomass was also estimated for all trees in replicate one in late April 2015. All trees were assigned a score (1-9), then a number of trees for each score was randomly selected across the trial and harvested at 1 m above ground level. Biomass was divided into three parts- leaves, small branches and larger wood (Figure 9). Both fresh and dry weights for each sample were/will be recorded for all tree harvests and regression analysis of score vs actual biomass component weights determined. The Murchison River, Bambun Rd and Lake Coolengup provenances had the highest biomass scores (Table 2).

Table 2. Results of *A. saligna* provenance trial (Rep 1) at TARI, 2012-14

Species	Subsp.	Provenance	Seedling vigour score[1]	Growth habit score[2]	Seed prodn score[3]	Biomass score[4]
A. saligna	lindleyi	Arrowsmith River	7	4.84	3.36	4.8
A. saligna	lindleyi	Mingenew	5	4.78	2.5	3.7
A. saligna	lindleyi	Murchison River	8	5.0	8.05	5.7
A. saligna	lindleyi	Parkeyeering	6	6.65	5.0	3.26
A. saligna	lindleyi	Muntagin	6	6.24	1.0	3.95
A. saligna	saligna	Bambun Rd	9	5.3	2.71	5.2
A. saligna	saligna	Flynn Drive	8	4.59	1.0	2.0
A. saligna	saligna	Lake Coolengup	9	4.8	2.67	5.1
A. saligna	pruinescens	Palmer Block	4	5.44	0	4.25
A. saligna	stolonifera	Pruinescens	6	4.72	4.0	2.6
A. saligna	lindleyi	Bulk of 4 enclosures	8	5.53	3.69	3.89
A. saligna	lindleyi	Tall Seln Adishehu enclosure	7	5.53	2.87	2.88
A. daphnifolia		Coorow	2	5.05	2.0	1.0
A. microbotrya		Tincurrin	2	5.69	0	1.33
A. microbotrya	Tall form	Dandaragan	1	-	-	-
A. baileyana		Stawell 2011	1	5.61	1.0	-
A. pycnantha		Stawell 2011	1	-	-	-
A. microbotrya		Stawell 2011	2	5.4	-	-

[1]Seedling vigour score: 1= poor, 9 = excellent. Mean for reps 1-3.
[2]Growth habit score: 1= prostrate, 9 = erect. 6/5/2014. Mean for reps 1-3.
[3]Seed production score: 1 = low, 9 = high. Rep 1 only.15/12/2014. *A. microbotrya*- Stawell. Seeded in May 2015.
[4]Biomass score: 1= low, 9 = high. Rep 1 only. 29-30/5/2015.

Figure 8. *A. saligna* pole type >10m. (2 yrs, 9 months)

Figure 9. *A. saligna* biomass (leaves, branches, wood) (Tree biomass score = 9).

Data was also collected on the Bulk of enclosures and Adishehu A. saligna PRS's.

Seed production was recorded on 28.3 % of the Bulk enclosures trees and on 61.2% of the Adishehu enclosure trees in December 2014. A seed production score (1-9) was also assigned to all trees in these PRS's for comparison. An improved seed bulk (approx. 1 kg) was taken by sampling the best 20 trees (out of 116) that had high biomass and seed production scores of 7-9.

Biomass was also estimated for all trees in both PRS's by assigning a score (1-9).
There was a total of 285 trees in both PRS's. Based on both biomass, seed production and general appearance, a total of 113 trees were retained and pruned to 1 m in height for further evaluation and selection. All other trees (172) were eliminated from the trial.

Acacia development for low rainfall regions of Tigray
There has been considerable interest to evaluate a range of semi-arid edible Australian Acacia species in hot dry infertile regions of Tigray. An Acacia species elimination trial was established at Koraro in July 2013. The site was lower in elevation with approx. 450 mm annual rainfall, a generally hotter climate than Mekelle and with deep infertile red sandy soils. Thirteen species and 22 seed lots were established in a replicated trial (Table 3). A trial evaluation after 10 months showed that growth and survival of most species was generally poor (37.5 % overall survival rate) with the exception of *A. saligna* (80-85% survival). In addition to challenges in the tree nursery, a combination of small seedling size at planting, lack of nodulation, rodent damage, weeds, deep sandy soil and lack of adaptation may have all been contributing factors to this result (Cunningham 2014a). A further trial evaluation after 22 months indicated that *A. saligna* had the best growth and survival (75-80%). *A. glaucocaesia* (50% survival) is known for good fodder production had good vigour and was the only Acacia producing seed (Figures. 10, 11). *A. glaucocaesia* also displayed considerable phenotypic variation and is worthy of further testing. There were also isolated examples of *A. victoriae, A. pachyacra, A. adsurgens, A. tumida, A. melleodora* and *A. anuera* with good vigour, possibly due to good nodulation (Cunningham 2014b).

Table 3. Survival of Australian Acacia species at Koraro (22 months)

Acacia species	Seed lot type/No.	Survival % (22 months)
A. saligna	Bulk of enclosures	75
A. saligna	Bambun Rd	80
A. micobotrya	Tincurrin	55
A. pycnantha	Stawell 2011	25
A. colei var. colei	WV11-006	50
A. colei var. colei	WV12-09	5
A. colei var. colei	WV12-033	15
A. colei var. ileocarpa	WV12-021	10
A. colei var. ileocarpa	ATSC 18813	5
A. colei var. ileocarpa	ATSC 18817	5
A. tumida var. pilbarensis	WV12-011	40
A. elachantha	WV11-003	25
A. adsurgens	WV11-012	25
A. melleodora	WV12-008	15
A. anuera var. tenuis	WV11-011	25
A. anuera var. tenuis	WV11-016	55
A. steedmanii	WV12-028	40
A. victoriae	WV12-052	25
A. victoriae	WV12-053	25
A. victoriae	WV12-054	20
A. pachyacra	WV12-039	15
A. glaucocaesia	WV12-017	50

ATSC = Australian Tree Seed Centre


Figure 10. *A. glaucocaesia* (22 months)


Figure 11. *A. glaucocaesia* seed production

Agroforestry farming systems

There are vast areas of arable and non-arable land in Tigray where agroforestry farming systems with *A. saligna* could bring underutilized land into production (e.g. Hillsides), help to restore degraded farm land and improve the livelihoods of small-scale farmers through sustainable wood production, improved crop production and building farm resilience to climate change. The first phase of the *"Acacia species for Food security and Environmental rehabilitation is the dryland areas of Northern Ethiopia"* project demonstrated how *A. saligna* could be successfully used in four Agroforestry farming systems: 1. Farm borders, 1. Small farm enclosures, 3. House compounds and 4. Community enclosures (Figure 2-5). Preliminary pruning demonstrations of *A. saligna* trees within all these agroforestry farming systems (Cunningham 2014 a, b) with three FRG's showed the potential for sustainable harvest of fuelwood, poles, and fodder. There is now great opportunity to revisit these farming systems to quantify the outputs and multiple benefits of *A. saligna* where trees are in situ. These demonstrations could also be used to determine the best silvicultural practices for maximum outputs from *A. saligna* trees (Figure 12).


Figure 12. Agroforestry farming with *A. saligna* (3 yrs.) on field borders. Mariamagamat.

Whilst improved *A. saligna* types can be grown in small farm enclosures (20-30 trees) and in household compounds, the greatest benefits can be expected from the development of *A. saligna* in integrated farming systems on farmland and enclosure areas. The main agroforestry principles and practices of the Farmer Managed Agroforestry Farming System (FMAFS) (Rinaudo and Cunningham 2008; Cunningham 2010) could be followed, where Farmer Managed Natural Regeneration (FMNR) (Rinaudo 2007) is enriched with *A. saligna*, other valuable trees, crops and livestock in an integrated system. There appears to be vast plain and valley areas of Tigray that have been cropped continuously for centuries and that are devoid of trees stumps or seed reserves so FMNR would have limited potential. These areas will require targeted planting and management of various tree species. There is also an estimated 1.2 million hectares of land in protected enclosure areas which are poorly managed (Rinaudo and Admasu 2010). Many of these enclosure areas have mature *A. saligna* tress which could be pruned and sustainably harvested for fuelwood, fodder and seed.

A significant paradigm shift in land use policy, attitude change to include trees on farmland and field borders and the opening up of enclosures to community management and utilization is required. We estimate that community managed enclosure areas could provide significant amounts of *A. saligna* fodder, and fuelwood. This would enhance livestock production removing the pressure from degraded grazing lands and remove the need to exploit local forests for fuelwood and provide income generation from wood sales.

Conclusion

The foundation for sustainable and productive agriculture in Tigray is a healthy and functioning environment. Whilst much progress has been made through the creation of vegetation enclosures (Hillsides), tree planting and soil and water conservation activities, much more needs to be done to reverse land degradation and improve soil fertility on cropping land. Appropriate management and utilization practices need to be developed for *A. saligna* and the benefits of existing *A. saligna* in enclosure areas quantified. Utilization of *A. saligna* from these areas would provide direct benefits such as fodder, fuel and building timber and encourage the development of integrated agroforestry farming systems with *A. saligna* on farmlands.

Our preliminary results indicate good progress in the domestication and development of improved *A. saligna* types for agroforestry applications. Further selections and assessment of *A. saligna* provenance trials are still required to ensure the best genetic resources are identified and PRS's can be established to produce orchards of improved types for seed production and wide dissemination to smallholder farmers. This ongoing development together with the quantification of the economic and environmental benefits of *A. saligna* in various agroforestry farm demonstrations, refinement of silvicultural requirements and management should provide confidence for wide scale up and out. Where possible, the vast and now treeless Tigrayan farming landscapes could be transformed with FMNR and fast-growing *A. saligna* in integrated agroforestry farming systems using FMAFS principles and practice. There would also be significant potential for adaptation of these farming systems to a range of agro-ecological zones in Tigray and other regions of Ethiopia.

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Annex 1. The Farmer Managed Agroforestry Farming System (FMAFS)
The Farmer Managed Agroforestry Farming System (FMAFS) (Figure 1) is an Integrated Agroforestry farming systems developed in Niger as a whole farm system to overcome the main limitations to farming in the fragile Sahelian climate. It represents an incremental gradation into a more complex farming system, offering more benefits than Farmer Managed Natural Regeneration (FMNR) for enhanced food security and reduced vulnerability to famine. The FMAFS builds on the strengths of FMNR and is an alley cropping, agro-pastoral forestry system which incorporates a wide range of annual and perennial, indigenous and exotic plant species and livestock. The diversity in its design makes it flexible enough to meet individual farmer's varying needs and priorities.

Figure 1. A typical FMAFS in Niger with Acacias, FMNR and annual crops.

In the FMAFS, farmers determine the density and layout of tree plantings and annual crops and the types of indigenous and exotic trees. The foundations laid by FMNR are complemented by the introduction of other species including a range of fast-growing multi-purpose Australian Acacias which produce wood and seed. The Acacias are planted along farm borders and in rows within the farm, providing human and animal food, firewood, timber, mulch, environmental restoration and crop protection (Figure 2). Australian Acacias have high tolerance to drought and low susceptibility to most African crop pests and diseases. Other valuable agroforestry species are used in FMAFS such as Pomme du Sahel (*Ziziphus mauritania*), Tamarind (*Tamarindus indica*), Boabab (*Adansonia digitata*) and Moringa. Annual cash crops such as millet, sorghum, cowpeas, peanuts, hibiscus, sesame and cassava are planted in rotation between the tree rows, providing food and fodder and income. Crop residues are used as mulch for soil improvement and protection.

The FMAFS provides significantly increased farm income compared to traditional millet farming or to FMNR alone, and more diversity in income sources. Farm labour inputs and income are also spread much more evenly across the year instead of being concentrated within a four-month period. As with FMNR, the biomass produced by the trees counters the impact of low soil fertility and water stress by providing mulch and soil organic matter as well as protection from winds and fuel for firewood implementation of FMAFS results in greater insurance against total crop loss during adverse events such as drought, insect attack or storms because not all species and products will be equally disadvantaged by the same event in a particular year. This biologically diverse farming system also tends to offer a range of habitats for beneficial predators of crop pests. Hence the FMAFS assures a minimum income every year, even when annual crops fail.

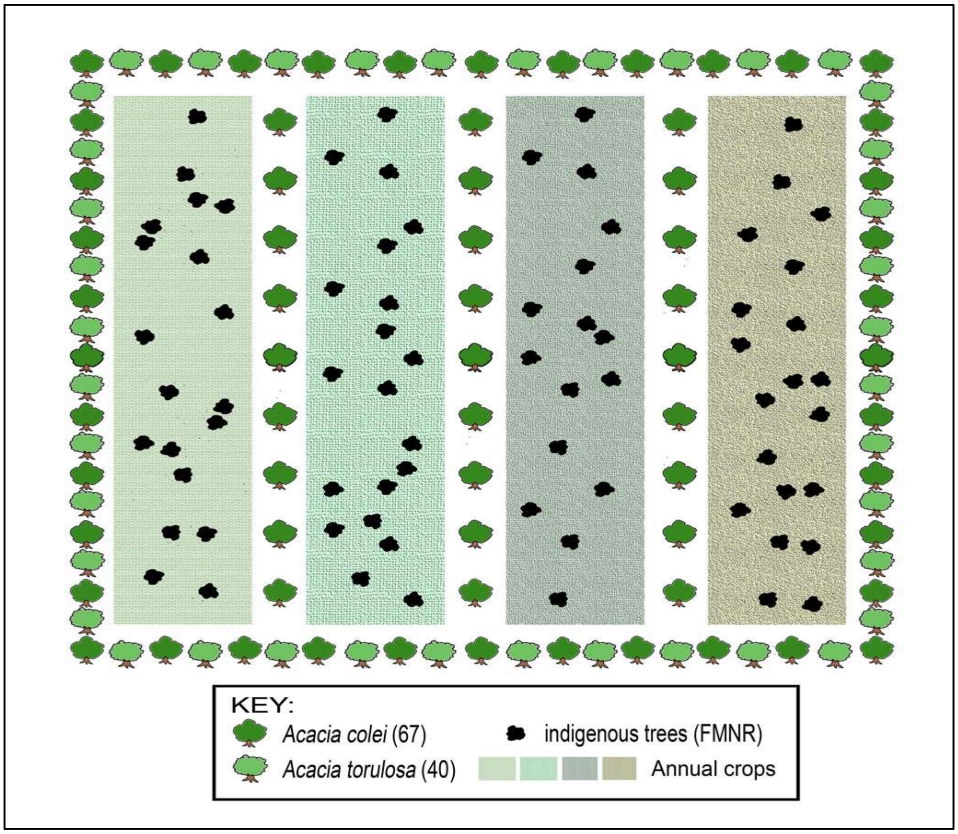

Figure 2. The Farmer Managed Agro-forestry Farming System, one-hectare model. Trees on the boundary are spaced 5 m apart. Trees inside the borders are planted 10 m apart in rows with 25 m between rows. The rows of trees are oriented across the prevailing wind direction. Total number of acacia trees =107 per ha. Shaded area: FMNR with 40 to 120 trees per ha and annual/perennial crops in rotation.

Introduction and evaluation of *Acacia saligna* trees as backyard agroforestry system in eastern Tigray

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Abstract
Acacia saligna is a very adaptable and fast-growing tree native to Western Australia. These attributes have led to its widespread distribution as an important species used extensively for soil stabilization, animal fodder, and a source of fuel wood in many countries around the world. This study was done in the Eastern zone of Tigray with the objective of introducing the tree as a component in the backyard agro forestry system. In each of five villages in three woredas, 30 interested farmers (30% females) were selected to form Farmer Research and Extension Groups and trained on how to prepare and manage pre and post plantation activities. The total number of *Acacia saligna* seedlings planted in 2010 and 2011 in the three woredas were 1921, 1875, and 2661. Two-year average survival rates were 74.1%, 66.9% and 62.6%, respectively, with overall mean survival rate of 67.9%. Natural mortality rates of the planted *A. saligna* seedling thus is low. If not properly managed at their seedling stage however, survival rates will reduce by animal trampling and browsing, which is a common problem in the study areas. Size measurements on 3-year old *A. saligna* saplings show growth potential. Mean tree height, diameter and crown width ranged between 2.48 and 4.41m (height), 6.30 and 11.95cm (diameter), and 2.16 and 3.28m (crown width). Seedling survival rate was highest (74.1%) in Atsbi-Womberta, probably resulting from better fencing and care. Growth performance was best in Kilte Awulalo where soils are sandy and relatively deep at middle altitude. Better management of seedlings will improve survival rates of the trees and better adoption by the farmers.

Keywords: *Acacia saligna,* backyard agroforestry, growth performance, survival rate

Introduction

The Golden Wreath Wattle (*Acacia saligna*) grows as a large shrub or small tree, between 3 and 8 meters high. It has long, dark green 'leaves' between 8 and 25cm long and 0.5 to 5 centimeters wide. Golden Wreath Wattle produces several golden colored, globular flower heads in a 'bunch', has a long seed pod (to 14cm) and large black seeds (around 5mm long). It is a very adaptable and fast-growing tree native to Western Australia (Midgley and Turnbull 2003). These attributes have led to its widespread distribution as an important species used extensively for soil stabilization, animal fodder, and a source of fuel wood in many countries around the world. Even though in some areas *A. saligna* has become an invasive species with a wide range of impacts, it has been identified as one of the priority multipurpose species for arid and semi-arid zones (Midgley and Turnbull 2003).

A. saligna trees tolerate a wide range of conditions, including temporary flooding, moderate salinity, limestone and soils with a low water holding capacity (eg non-wetting sands). It reproduces from seeds and root suckers and seeds can spread by ants and birds. The species has also been spread by people, either intentionally - wanting to grow the species, or accidentally - assuming it is a local native species and collecting it for rehabilitation projects. The production of root suckers may be stimulated by mechanical disturbance such as ripping the root apart and earthworks on road verges. Currently, emphasis is given to fast growing species with potential for producing large amounts of wood biomass that may find uses as solid and reconstituted wood products and for bio-energy, and which may possess commercially attractive by-products such as extractives (especially tannin and gum) and fodder.

A. saligna is a drought-tolerant and fast-growing tree which makes it one of the prominent tree species for rehabilitation of dryland areas. In Tigray many plantations of *A. saligna* trees have been established on communal lands. However, few initiatives have tried to introduce and familiarize this multipurpose tree as part of a backyard agro-forestry system. Our goals here were to: (1) evaluate the survival rate and growth performance of planted *A. saligna* trees in backyard agroforestry systems in different locations with different levels of management; and (2) investigate factors which affect the early survival and growth performance of the tree in farmers' homesteads.

Materials and Methods

The study area

The study was held in the Eastern zone of Tigray in Saesie Tsaeda Emba, Atsbiwenberta and Kilte Awulalo districts (or woredas). In these woredas, there are five villages which have been World Vision pilot project areas in the field of natural resource management, like plantation establishment, and soil and water conservation activities. In Tigray and specifically in these areas, *A. saligna* trees were introduced several decades ago. As a result, different land uses such as gullies which were considered as marginal lands have changed into potential lands through rehabilitating the land from erosion hazards. Beyond this, people have started to sense the importance of the tree for livestock feed particularly during dry periods. Even though this tree is seen as positive in the study areas, planting and domesticating the tree as a backyard agroforestry tree is very rare.

Data collection and analysis

137 farmers of the three woredas were interested to participate and organsised in a Farmer Research and Extension Groups (FREGs). All 137 farmers were trained in the significance of the tree, how to prepare plantation sites and how to manage the seedlings after planting. All 137 FREG members prepared plantation pits of 40 by 40 by 40 cm two weeks ahead of planting. Seedlings were planted in the prepared pits. Seedling survival rates were determined, and growth parameters from randomly selected trees were also collected and analysed by ANOVA.

Results and Discussion

In the three study areas (Atsbi-Wenberta, Kilte Awulalo and Saesie-Tsaeda Emba woredas) a total of 137 farmers (52 female and 85 male) farmers participated in the study and planted between 20 and 40 *A. saligna* seedlings on their farm land. Over the two years (2010 and 2011), a total of 1921, 1875 and 2661 seedlings were planted at Atsbi-Wenberta, Kilte-Awlaelo and Saesie -Tsaeda Emba woredas, respectively These seedlings had survival rates of 66.9% 74.1% and 62.9%, respectively (Table 1), with an overall mean survival rate of 67.9%. There was no significant difference in survival rate of planted *A. saligna* seedlings between study areas. Overall survival rates (all seedlings combined from the three woredas) were 66.5% and 66.8% in 2010 and 2011, respectively.

Table 1. FREG members and survival rates of *Acacia saligna* plantation by site

Woreda (District)	Peasant association	Number of FREG members	Female	Male	No. planted, 2010	No. alive, 2010	% survival	No. planted, 2011	No. alive, 2011	% survival
Kilte Awulalo	Abreha-we-Atsbeha	33	12	21	727	454	62.4	1146	818	71.4
Atsbi-Wenberta	Haiki-meshal	16	8	8	149	117	78.5	324	253	78.1
	Barka – adisibha	36	15	21	450	302	67.1	998	727	72.8

Saesie-Tsaeda Emba	Mariam-agamat	30	7	23	767	571	74.4	738	573	77.6
	Guila-abenea	22	10	12	316	159	50.3	840	404	48.1
Total		137	52	85	2409	1603	66.5	4046	2775	68.6

Growth data was also collected of three-year old trees grown on-farm with FREG members (Table 2).

Table 2. Growth parameters and statistical analyses of *A. saligna* trees of 3 years old (2010 plantation)

Site	Diameter at breast height (cm)	Plant height (m)	Crown diameter (m)
K. Awlaelo	11.95 ± 6.36	4.41 ± 1.30	3.28 ± 1.24
A. Wenberta	7.66 ± 3.29	2.48 ± 0.91	2.16 ± 0.94
S. Tsaeda Emba	6.30 ± 3.94	3.43 ± 0.9	2.47 ± 1.00
Statistical analyses from between groups			
F values	9.39	19.83	7.13
P values	ns	ns	0.002

Averages were taken from 24 trees in each location; standard deviations are also provided; ns is not significant at P<0.001

Conclusion

The overall survival rate (67.9%) and growth performance of the planted *A. saligna* is promising. Highest survival rate (74.1%) of seedlings was recorded in Atsbi-Wenberta. This could be due to better fencing to avoid browsers eating the plants. Best growth performance is shown in K. Awlaelo on sandy and relatively deep soil with altitude between 1760 and 1900m above sea level, compared to the rocky and shallow soils with high altitude as found in Atsbi Barka Adisibha (2368-2390 m.a.s.l) and Saesie Tsaeda Emba Mariamagamat (2514-2584 m.a.s.l.).

For successful introduction of *A. saligna* as a backyard agroforestry tree, FREG members could play a strong stimulating role. Better communication and courses for FREGs can improve management of the seedlings, leading directly to increased survival rates. Awareness and knowledge of FREG farmers on how to plant trees and specially how to utilize home gardens and enclosures to improve survival of the seedlings will have strong example effects to other farmers. Additionally, the multipurpose nature of the tree should be well and widely understood and increasing the number of FREG members would help to scale up the adoption of the trees. Knowledge of farmers' perceptions will help to identify the knowledge gaps and the bottlenecks for farmers adoption levels. Finally, to disseminate the technology needed for introduction of *A. saligna* in home gardens, capacity building for different stakeholders is needed. Better understanding, and especially popularization and extension of silviculture and utilization of *A. saligna* would trigger wider utilization.

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Awareness of *Acacia saligna* importance, and socioeconomic and livelihood conditions of farm households in eastern Tigray, Ethiopia

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Abstract
The study focused on assessing the socioeconomic livelihood status of households and their awareness on the importance of the *Acacia saligna* tree. A survey was conducted in three districts, using a structured questionnaire with 180 randomly selected households. The livelihood activities of the sample respondents were mainly based on agriculture, which is a mixed crop-livestock production system. Likewise, the main source of income of the households of the districts includes income from crops, livestock, timber/forest, and non-farm or off-farm activities. The average annual income was 11,740 ETB (USD $587) per household. The input the farmers use, the agricultural practice they employ, the skills and knowledge they acquire, the level of production they operate, their behavior towards risk taking, their awareness on improved technologies and their production efficiency is still very basic. As to the awareness of the farmers on *Acacia saligna*, almost every farmer knew the tree and planted it in gullies and around their homesteads. About 71% of the households responded that *Acacia saligna* outperforms other trees in terms of survival rate, growth rate and drought resistance. There is experience in using *Acacia saligna* as animal feed in seasons lacking sufficient feed and/or during the dry seasons. About 56% of the sample farmers believe Acacia is an important source of bee forage. The majority of households were not aware *Acacia saligna* seeds are edible for humans. Overall, it is important to create awareness, capacity building and demonstration of *Acacia saligna* for different purposes to utilize the tree's potential for food security and environmental rehabilitation.

Keywords: Food security, Environmental rehabilitation, Farmer perceptions, Farmer awareness, Focus group discussions

Introduction
Eastern Tigray is a dryland area and under increasing pressure. In this region rainfall is the most limiting factor to production and productivity and is declining in amount and follows irregular distribution patterns. The variability in rainfall amount and distribution is one of the factors contributing to vulnerability of communities and households. Additionally, the increase in population pressure, with an annual growth of 2.5%, has created pressure on the environment and resulted in land fragmentation and degradation. To reverse the environmental degradation, high commitment is needed from both the community and local government in environmental rehabilitation, soil and water conservation and reforestation programs. Sustaining livelihood of people in drylands through sustainable natural resources management is one pathway out of poverty; the participation and empowerment of communities being actively involved in these efforts is crucial to building livelihoods and resilience. This study reports on a project in which communities will potentially benefit by utilising the multiple benefits provided by *A. saligna* based agroforestry systems, such as environmental rehabilitation, land reclamation, income generation activities through the harvesting and sale of products (food, feed, fodder, or timber). Families may even increase their income while sustaining their environment through the utilisation of *A. saligna*. To be able to evaluate the project impact, baseline information is a necessary component. We describe the socioeconomic and livelihood status of the households of the project areas and present results from a household awareness survey of *A. saligna*.

Materials and Methods
The project is conducted in Wukro (Kilte-Awlaelo), Saesie Tsaeda-Emba and Atsbi-Wonberta woredas. the three most dry districts of eastern Tigray, all three being food insecure.

Data sources
Primary data was collected from various sources to satisfy the informational needs of the baseline survey. Secondary data was collected from different sources, including all stakeholders. Data collection was categorized under three main unit of analysis: household level, community level and institutional level. A community questionnaire was administered to each homogenous group through focus group discussions (FGD) and group interviews. Household interviews were used to address the elements and interactions of the livelihood system and the food security status of individual households. In addition, the study team gathered primary and secondary information from government and community institutions like the woreda government offices, community-based organization, and self-help groups.

Qualitative data
Employing a qualitative data collection method is helpful to substantiate and validate the data collected from the sample households through the structured interviews, and to capture latent variables that may not be amenable by survey/quantitative data collection methods. Stakeholder interviews, FGD, key informants and group interviews and transect walks were employed to collect general and specific information on socio-cultural, environmental, gender, community participation and empowerment. Additionally, the interviews and discussions were used to collect qualitative information about attitudes, perceptions and practices of the community members.

Quantitative data
We randomly sampled 180 households from the three woredas, 60 from Kilte-Awlaelo, 95 from Atsbi-Wonberta and 35 households from Saesie Tsaeda-Emba. The sample size for each Peasant Association (PA) was determined by using probability proportional to size (PPS) sampling method.

Primary data on respondents' demographic and socio-economic characteristics, practice in terms of using alternative means of livelihood, and attitude, knowledge and practice of the target population related with *Acacia saligna* was gathered using structured interviews. In addition, practices of improved agricultural and conservation practices and its challenges, and respondents' need and demand for the *Acacia saligna*, and other types of quantitative data was collected by the household (HH) survey questionnaire. These interviews involved both open-ended and close-ended questions. Interviews were constructed, pre-tested, and administered by the evaluation study team, supervisors and enumerators. They were oriented on the objective of the study and trained on the procedure of filling out the interviews, and manner of approaching the respondents. There were daily review meetings between supervisors and data collectors to assure the quality of the data.

Data analysis
Qualitative data analysis methods were used to analyze the data collected through unstructured techniques. This includes interpretations, explanation building and synthesis of various opinions and concepts and assembling of ideas; and summarizing, categorizing, and presenting them into convenient forms.

Depending on the quantitative data at hand, data was coded and subjected to analysis using descriptive statistics tools, such as the mean, standard deviation, percentage and frequency of occurrence, etc. Tables, diagrams, graphs and were incorporated in the survey report as appropriate. These tools and presentations were used to categorize, and present quantitative data collected through the structured interviews. Categories of sample units were compared with respect to their characteristics. The collected data was manually cleaned and coded for data entry. The data was entered and analyzed using SPSS.

Results and Discussion

Socio-demographic characteristics

Over 70% of the households are headed by males (Table 1). The average age of the household head was 45 years, 45-60% of the household heads were illiterate, and only 18-30% had completed elementary school. Nearly all are Orthodox.

Table 1: Demographic characteristics of the three districts

		Atsbi Wenberta	Kilte Awlaelo	Saesie Tsaeda-Emba
Age of HH head	Mean	45.3	45.8	45.9
Sex of HH head	Male	73.9%	80.8%	81.7%
	Female	26.1%	19.2%	18.3%
Education level of HH head	Illiterate	58.0%	55.8%	46.7%
	read and write	18.2%	9.6%	18.3%
	Elementary school complete	18.2%	28.8%	30.0%
	High school complete	4.5%	3.8%	3.3%
	College educated	1.1%	-	-
Religion of HH head	Orthodox	100.0%	98.1%	98.3%
	Muslim	-	1.9%	1.7%
	Catholic	-	-	-
	Protestant	-	-	-

Production assets in this context means assets used to produce crop or livestock like bee hives, motor pumps, hand pumps, treadle pumps and HH drip irrigation systems. These assets are rare to observe in subsistence households as more capital investment is needed. Accordingly, the average number of motor pumps, hand pumps and treadle pumps were 0.07, 0.006 and 0.22 per household respectively. Drip irrigation systems were also not observed in the community (Table 2).

Table 2: Production assets of the three districts (mean values per household are given)

Production assets (numbers)	Atsbi Wenberta	Kilte Awlaelo	Saesie Tsaeda Emba	Total
traditional bee hives	.24	.25	.35	0.28
modern bee hives	.65	1.23	.22	0.7
transitional bee hives	.05	.02	.00	0.023
motor pumps	.10	.02	.10	0.073
hand pumps	-	.02	-	0.007

treale pumps	.08	.56	.03	0.22
HH drip irrigation systems	.02	.10	-	0.04

The major valuable house items were considered such as presence of a bed, radio, chair/table, TV, mobile phone, wooden box and cart. It is not common to see an animaldrawn cart and TV in the areas. The average number of beds, radios and chairs were 0.3, 0.5 and 1.24 per household respectively. Moreover, there is better experience in adopting mobile phones by the farmers in short period which may help them to get information regarding production and marketing of their agricultural products. An average of 0.12 mobile phones were available per household in the woredas (Table 3).

Table 3: Number of house items (mean number per household)

Items	**Atsbi Wenberta**	**Kilte Awlaelo**	**S. Tsaeda Emba**	**Total**
Number of beds	.42	.37	.12	0.30
Number of radio	.36	.62	.45	0.48
Number of chairs	.15	.17	3.40	1.24
Number of tables	.23	.15	.07	0.15
Number of TV	-	-	-	-
Number of mobile phones	.14	.12	.12	0.13
Number of boxes	.06	.06	.07	0.06
Number of animal-drawn carts	-	.02	-	0.007

As to the livelihood activities of the sample respondents, agriculture, which is mixed crop-livestock production system, is the major economic activity. In the rural parts of the study areas, there is a system of which out puts or products and/or by-products of crop and livestock are inputs for one another. As it is indicated in the table below, the majority (81.8%) of the sample households respond as their primary livelihood activity is agriculture only (both crop production and livestock herding). In addition to this 6.5% of the households use agriculture and trading, other 6.5% households also use farming and wage income as source of their livelihood. Within the agriculture sector, 90.2% of the sample respondents practice both crop and livestock production whereas, 8.5% of them practice crop production only. The average number of years of farming experience, as indicated by the HH head, was 38.7 years (Table 4).

Table 4: Source of livelihood according to district

		Atsbi Wenberta	**Kilte Awlaelo**	**S. Tsaeda emba**	**Average**
Main source of income to the household	Farming	77.3%	86.5%	81.7%	81.8%
	Farming and trading	9.1%	3.8%	6.7%	6.53%
	Farming and government employee	2.3%	1.9%	3.3%	2.5%
	Wage laborer	1.1%	1.9%	1.7%	1.56%
	Farming and wage laborer	9.1%	3.8%	6.7%	6.53%
	Farming and carpenter	1.1%	-	-	0.36%
	Farming, government employee and wage	-	1.9%	-	0.63%
If farming, which enterprise	Crop production	14.8%	3.9%	6.8%	8.5%
	Livestock production	1.1%	.0%	1.7%	0.93%
	Both	83.0%	96.1%	91.5%	90.2%
Mean number of years experience in farming		68.86	24.30	22.92	38.69

The main source of income of the households of the districts is income from crops, livestock, timber/forest, and non-farm / off-farm (Table 5). Crop production provides most of the income, with livestock production and products being second.

Annual income of the households is the sum of crop production income, livestock production income, forest income and non-farm income. Crop production, covering annual food demand of the households, constitutes a significant households farm income (6,298 ETB annually) (Table 5). Income from livestock (2,270 ETB) and off/nonfarm (2,644 ETB) follows and income from non-tree/timber products is also an important source of income in the study area. The average annual income of farmers in the three districts was 11,740 ETB.

Table 5: Mean of total annual income per household in the three districts (ETB)

Source of income	**Atsbi-Wonberta**	**Kilte Awlaelo**	**Saesie Tsaeda Emba**	**Average**
Crop	5,000	5,118	8,775	6,298
Livestock	2,360	2,257	2,192	2,270
Tree/timber	235	616	730	527
Non-farm/ Off-farm	2,940	3,036	1,955	2,644
Grand total	10,536	11,029	13,654	11,740

The average rain-fed cultivable land holding per HH is 2.56 timad[4], which includes cultivable land, grazing land and forest land (Table 6). Farmers sometimes rented land from others, especially those whom have irrigation access based on local agreements. The total cultivable land under irrigation, which includes both own and shared land, was 0.47 timad. As to the total cultivated land, it is 3.07 timad per household and it seems a bit larger in Kilte Awlaelo (3.37 timad) than Saesie Tsaeda Emba (2.97 timad) and Atsbi Wonberta (2.93 timad).

Table 6: Land area (timad) for various uses in three woredas

Land use	**Atsbi Wenberta**	**Kilte Awlaelo**	**Saesie Tsaeda Emba**	**Average**
Own land under rainfed	1.20	2.23	1.77	1.73
Rented in land under rainfed	.19	.13	.33	0.22
Shared in land under rainfed	.62	.90	.60	0.71
Shared out land under rainfed	-	.11	.08	0.06
Total land under rainfed	**1.91**	**3.20**	**2.58**	**2.56**
Own land under irrigation	.51	.27	.17	0.32
Shared in land under irrigation	.15	.11	.22	0.16
Total cultivated land	**2.93**	**3.37**	**2.97**	**3.09**
Fallow land	.47	.38	.29	0.38
Pasture land	3.69	.25	.42	1.45
Land for tree planting	4.80	.19	3.76	2.92

The goal of public support for microcredit is to improve the welfare of poor households through better access to small loans. Seemingly, in the study areas, finance was primarily obtained from micro credit institutions, NGOs and informal lenders such as farmers, local money lenders and relatives. The problem, however, was that the credit system was not well developed, the commercial banks are predominantly state-owned and require collateral before offering loans, private banks are not eager to finance agriculture in general and because of the associated high risk in agricultural activity. Farmers find the risks too high and are unable to provide the needed collateral. Therefore, money to finance agriculture sector is mostly obtained from micro credit and informal institutions. Credits from relatives and/or friends often bearing

[4] *Timad* is the traditional unit of land in Ethiopia, equivalent to one-eighth of a hectare (approx. 1,250 m^2)

no-interest, are also an alternative source of finance (Embaye *et al.* 2011). The credit given to the rural areas in the study area can be classified into two types: regular credit and household package credit. A farmer cannot get credit of more than one type. The activities for which regular credit is given include the purchase of dairy cows, fertilizer and improved seeds, livestock fattening, poultry production, horticultural production, apiculture, handicraft, and small businesses. The available sources of formal credit, as the households pointed out, are Dedebit Credit and Saving Institution (DESCI) and woreda cooperatives. These institutions serve the household credit needs and at the same time provide training and workshops with regard to credit utilization for improving agricultural productivity.

Use of Market information

According to respondents, the main sources of market information in the woredas are other farmers (21.3%), personal observation (14.3%), traders (3.5%), and radio (3%).

Livestock production

The study area is home for a large and diverse livestock resources and favorable production environments. A majority of the rural population rely on livestock production. Livestock production systems in the woredas have evolved largely as a result of the influence of the natural production environments and socio-economic circumstances of farmers, rather than market forces. Livestock production is of subsistence nature. Livestock is kept under traditional extensive systems with no or minimal inputs and improved technologies, which results in characteristically low productivity. The livestock holdings are small for most households in the study areas (Table 7). The majority of the livestock breeds are of local type, which is believed to be low productivity and performance.

Table 7: Livestock ownership, in average numbers per farm

Livestock	Atsbi Wenberta	Kilte Awlaelo	Saesie Tsaeda Emba	Total
Oxen	.98	1.52	1.03	1.14
Bulls	.34	.38	.30	.34
Local cows	.75	.87	.77	.79
Hybrid cows	.12	.08	.25	.15
Local heifers	.28	.44	.28	.32
Hybrid heifers	.09	.04	.22	.12
Calves	.41	.50	.37	.42
Goats	1.89	1.60	1.03	1.55
Sheep	1.49	1.54	4.98	2.55
Donkeys	1.55	1.02	.80	1.123
Mules or horses	-	.02	.02	.01
Camels	-	.10	.00	.02
Poultry	2.80	4.46	2.85	3.25
Traditional bee colonies	.16	.13	.40	0.23
Transitional bee colonies	.01	.04	-	0.016
Modern bee colonies	.26	.54	.13	0.31

Food security and expenditure

In this study we defined food security as producing enough food for consumption throughout the year. Therefore, the majority of households in woredas are not food secure: 91.8% of HH in Atsbi Wonberta, 90.2% of HH in Kilte Awlaelo and 86.2% of HH in Saesie Tsaeda Emba could not produce enough food for their family last year. The food shortage occurs for about 4.4, 5 and 4.7 months for the same three woredas respectively. Against these food deficit periods farmers provide different coping mechanisms to survive. Among these decreasing food intakes, engaging in daily labor, participate in nonfarm activities, borrowing from neighbors, food for work participation and asset selling are the common ones. However, decreasing food intake and engaging in daily labor are the major ones.

Number of meals the households take per day also partially reflects the food security status of households. Most households eat three times a day regardless of its nutritional content (Table 8). About 64%, 79% and 47.5% of HH in Atsbi Wonberta, Kilte Awlaelo and Saesie Tsaeda Emba woreda households respectively eat three times per day; whereas, only 2.2% of HH in Atsbi Wonberta and 1.7% of HH in Saesie Tsaeda Emba woredas eat four times per day.

Table 8: Number of meals eaten per day within each district

	Atsbi Wenberta	**Kilte Awlaelo**	**Saesie Tsaeda Emba**
Once	3.4%	5.7%	3.4%
Twice	30.7%	15.4%	47.5%
Three times	63.6%	78.8%	47.5%
Four times	2.2%	-	1.7%

The major expenditures of HH are consumption (3087 ETB), education (335 ETB), farm tools (107 ETB), cultural and religious ceremonies (364 ETB), fertilizer (366 ETB), seed (117 ETB) and health-related expenses (188 ETB). HH in Saesie Tsaeda Emba woreda had higher annual costs (6,218 ETB) than HH in Atsbi Wonberta (4,977 ETB) and Kilte Awlaelo (3,967 ETB). The total average expenditure for the three districts was 5,054 ETB per year.

Awareness of *Acacia saligna*

Almost every farmer knows of *A. saligna* (Table 9). The farmers knew of the tree 14 years before, and they pointed out that they received information about the tree from the regional Bureau of Agriculture & Rural Development (around 70%), other farmers (11%), NGOs and neighbours.

Table 9: Awareness on *Acacia saligna*

		Atsbi Wenberta	Kilte Awlaelo	Saesie Tsaeda Emba
Do you know the tree *Acacia saligna*?	Yes	98.9%	100.0%	100.0%
	No	1.1%	-	-
For how many years did you know *Acacia saligna* (mean)		13.4	14.9	15.3

***Acacia saligna* plantation**

The majority of households (62%) have planted *A. saligna*, mostly around their homestead (86.6%) and a few also on their farm land (4%) and communal land (4%) (Table 10). About 60% of respondents observed variability among species of *A. saligna*, 24% did not and 16% did not know. Based on the study findings, about 71% of the households thought *A. saligna* had better performance qualities as compared to trees of other species in terms of survival rate, growth rate and drought resistance. This indicates the tree can survive in drought prone and rainfall deficit areas with low investment and less management.

Table 10: Experiences of households in planting *Acacia saligna*

		Atsbi Wenberta	**Kilte Awlaelo**	**Saesie Tsaeda mEba**	**Total**
	Yes	65.9%	60.2%	60.0%	62.1%

Did you ever plant *Acacia saligna*?	No	34.1%	39.8%	40.0%	37.9%
bIf so, where did you plant *Acacia saligna*?	Homestead (1)	86.8%	79.3%	91.9%	86.6%
	Farm land (2)	3.8%	3.4%	5.4%	4.2%
	Irrigable land (3)	.0%	3.4%	-	.8%
	1&2	1.9%	10.3%	2.7%	4.2%
	Communal land	7.5%	3.4%	-	4.2%
does *Acacia saligna* have best qualities compared to other trees	Yes	57.1%	80.0%	83.0%	70.6%
	No	26.0%	12.5%	9.4%	17.6%
	I don't know	16.9%	7.5%	7.5%	11.8%

***Acacia saligna* for feed**

The increase in the world population and high cost of conventional animal feed ingredients and low protein intake in most developing countries has led farmers to search for sources of feed that are cheap and readily available. Optimum growth performance can be obtained by feeding leguminous forages with or without concentrates in their diets. Leguminous (or nitrogen-fixing) forages contain appreciable amount of protein, oil, minerals and carbohydrates that can support animal production. *Acacia saligna* can be recommended for use in Tigray for lamb production which should reduce the cost of meat production. During the dry season, Acacia remains green. In the pilot woredas there is an experience of using *Acacia saligna* as animal feed in the seasons where there is no enough feed/dry seasons. Overall, 63.7% of the sample HH use the leaf for their animal feed. A larger proportion of Atsbi Wonberta (76%) and Saesie Tsaeda Emba (82%) HH utilize *Acacia saligna* as feed whereas, only 19% of Kilte Awlaelo HH have experienced using *Acacia saligna* as feed. The majority of the farmers (84%) use this feed during March, April and May as these months are feed scare periods in the area (Table 11). There is no experience of supplying *Acacia saligna* feed by treating or processing they simply provide the green leaf of the tree as well as around 75% of the sample households whom use acacia saligna feed respond as they use green/fresh leaf.

Table 11: Use of *Acacia saligna* as feed according to district (in percentage of farmers)

		Atsbi Wenberta	**Kilte Awlaelo**	**Saesie TsaedaEmba**	**Total**
		Column N %	Column N %	Column N %	Column N %
Do you use *A. saligna* as feed	Yes	75.6	19.1	81.7	63.7
	No	20.9	78.7	18.3	34.2
	I don't know	3.5	2.1	0	2.1
If so, then when do animals consume *A. saligna*	December- February	7.3	12.0	10.0	9.8
	March-May	89.3	78.0	86.0	84.4
	June-August	3.4	10.0	4.0	5.8

We wished to know the perception of farmers on the effect of *Acacia saligna* feed on body weight, milk yield and health of their animals after feeding the tree leaf. With regard to milk yield, 50% of them did not observe any change, 38% observed a positive effect on milk yield and 10% responded that the feed had no effect on milk yield. About 56% of total respondents pointed out that *Acacia saligna* feed increased the body weight of their animals; 17% had not observed whether it had a negative or positive effect on body weight. We also tried to know the farmers' attitude on toxicity of the feed; around 31% responded that it had a positive effect, and 3% responded that it had a negative effect on animal health. The rest of the respondents did not observe any change in the health of their animals.

Acacia saligna and bee keeping

Acacia saligna is evergreen throughout the year and can survive during drought periods. As there is a critical bee forage problem in the study districts, we evaluated the importance of this tree flower for honey bee forage and the household awareness of this importance. Around 56% of the sample farmers recognize *Acacia* as an important source of bee forage, 23% believe that the flower is not important for bee production and the rest (21%) did not know (Table 12). This calls for evaluation of content and use of the flower for bee forage based on laboratory results.

Table 12: *Acacia saligna* and bee keeping according to each district

		Atsbi Wenberta	Kilte Awlaelo	S/tsaeda emba	Total
do you think *A. saligna* is important for honey bee production	Yes	56.0%	62.2%	50.0%	55.7%
	No	35.7%	4.4%	17.9%	22.7%
	I don't know	8.3%	33.3%	32.1%	21.6%

Use of *Acacia saligna* as human food

Acacia saligna appears to have a good potential as a fodder plant. Moreover, the majority the households has no awareness that *Acacia saligna* can be used as human food. Households are ready to use the tree for human food in the future if they get enough skill and training by the project (Table 13). Based on the survey results, about 97% of HH did not know *Acacia saligna* can be used for human food, and none of the HH had consumed the pods before. The reasons for households not usinge this tree for food is lack of awareness (97.7%) and cultural barrier (2.3%). About 93% of HH were interested in using *Acacia saligna* as human food in the future if they get trained. Generally, households evaluate the tree as very important (41.6%), important (54%) and harmful (0%). *Acacia saligna* thus is seen asvery important for the community from different perspectives, and households have a positive attitude towards the tree.

Table 13: *Acacia saligna* for human food

		Atsbi Wenberta	Kilte Awulaelo	Saesie Tsaeda Emba	Average
Do you know that *A.saligna* can be used as food	Yes	4.1%	2.5%	1.9%	2.8
	No	95.9%	97.5%	98.1%	97.2

Conclusion and recommendations

We conclude that while the households in the area generally experience periods of food deficit, the awareness of possible uses of *Acacia saligna* is low.

We recommend the following:

- Awareness creation and capacity building;

- As the majority of the farmers are less capacitated and skilled with regard to nature, quality and use of *A. saligna* for different purposes, capacity building on how to utilize the tree as feed, food, bee forage, environmental rehabilitation and other purposes is urgent;
- Field demonstration of *A. saligna*;
- Demonstration of *A. saligna* as feed, food, bee flora and environmental importance through integrated manner supported by frequent training and capacity building starting from plantation up to final utilization at farmers level;
- Establishment of effective producers and marketing cooperatives;
- Even if producers' cooperatives exist in the study areas these are not functional due to many reasons. Establishing strong and sustainable cooperatives will strengthen farmers bargaining power over their resources and products, expectedly leading to improved livelihoods;
- Supply of improved agricultural technologies;
- Since the majority of the existing production inputs of crop, livestock and soil fertility management are less productive and traditional, these need to be replaced with improved and more efficient technologies like seed, fertilizer, improved breeds, better management practices and farm implements; and
- Strengthen the existing institutional support services.

Acknowledgement
We forward our great appreciation to World Vision Australia and World Vision Ethiopia for providing necessary finance and logistics. Thanks to all respondent farmers for their time and information.

Acacia saligna in Chile: a forage resource with potential for human functional foods

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Introduction

Acacia saligna is an exotic species in Chile that mainly occurs in the semi-arid Coquimbo Region, particularly where reforestation has been promoted with the objective of recovery of degraded soils, production of fodder for livestock, fuel wood and control erosion (Perret and Mora 2001) as seen in the work done at the Hacienda Huentelauquén of the Province of Choapa (Figure 1). *A. saligna* was introduced in the north of Chile in 1960 (then known as *Acacia cyanophylla)* in dry areas with rainfall varying between 100-200 mm/year. Since those days the species has been planted mainly for livestock fodder (goats and sheeps) with a total estimated surface of 7,500 ha (Gonzalez 2014).

Figure 1. Dune control with *Acacia saligna* (left) and plantations in Coquimbo Region (right)

Recently a research and development project was funded by the Foundation for Agricultural Innovation (FIA) since 2013 to prospect functional properties of the seeds and flowers. The *A. saligna* resource represents an important potential food because the seeds of the trees could be harvested and processed for the production of breads and biscuits with functional and nutraceutical properties (Yates 2014).

Other species like *A. melanoxylon, A. dealbata, A. decurrens, A. armata, A. melanoxylon* and *A. eburnea* were introduced previously in 1908 for erosion control in coastal dunes in the south and central zone of Chile. Most of this work was done by Federico Albert, one of the pioneers of silviculture in the country at the beginning of the twentieth century.


Figure 2. ***Acacia dealbata*** **experimental plantation in the temperate zone of Chile**

Plantations were established in the semi-arid zone as a result of Decree Law 701 enacted the State of Chile in 1974 and implemented by CONAF[5], that subsidized up to 75% of the total cost of establishing forest plantations (Figure 2). Currently it is estimated that an area of 7,500 ha of *Acacia saligna* plantations exists in the Coquimbo Region. This law was intended to stimulate forestry activities on soil suitable for forestry, on degraded soils and to encourage afforestation, especially by small landowners.

A. saligna is considered to be a fast-growing species for semi-arid regions, reaching 8 meters height at 4-5 years; in irrigated trials in northern Chile the species has an average annual increase in height between 30-71 cm. For fuel wood, production varies between 1.5 to 10 m^3 per ha per year according to site conditions and using coppice management with rotations of 5 to 10 years.

Diversity and adaptation

A. saligna is a native species of the semi-arid Western Australian wheat belt and it is adapted to extremely dry conditions through their physiological mechanisms, i.e. form and distribution of stomata and a deep root system that allows the tree to access subsurface aquifers and withstand long periods of drought (McDonald *et al.* 2007). Plantations near the coast in the Region of Coquimbo allow the species to minimize evapotranspiration and survive on coastal moisture. As a pioneer species in plant succession, *A. saligna* can fix atmospheric nitrogen improving the physical and chemical properties of soils, allowing increased fertility, restoration of degraded soils and possible reforestation with native species in a second rotation (McDonald *et al.* 2007).

A. saligna is extremely polymorphic in phenotypic characteristics such as phyllodes, growth habit cortex and also in ecological and biological attributes. It is endemic to south-western Australia where it occurs in areas with annual rainfall between 250-1200 mm. Taxonomic research indicates that polymorphic

[5] Corporación Nacional Forestal. Chilean Forest Service.

variation in *A. saligna* fits four sub-species (McDonald *et al.* 2007): (1) the variety *saligna* "cyanophylla", (2) the variety *pruinescens* "Tweed River ", (3) the variety *lindleyi* as "typical" and (4) the variety *stolonifera* "forest”. This taxonomy offers a range of morphological and growth habits among sub-species and provenances that may yield specific advantages that are adaptable to specific production purposes.

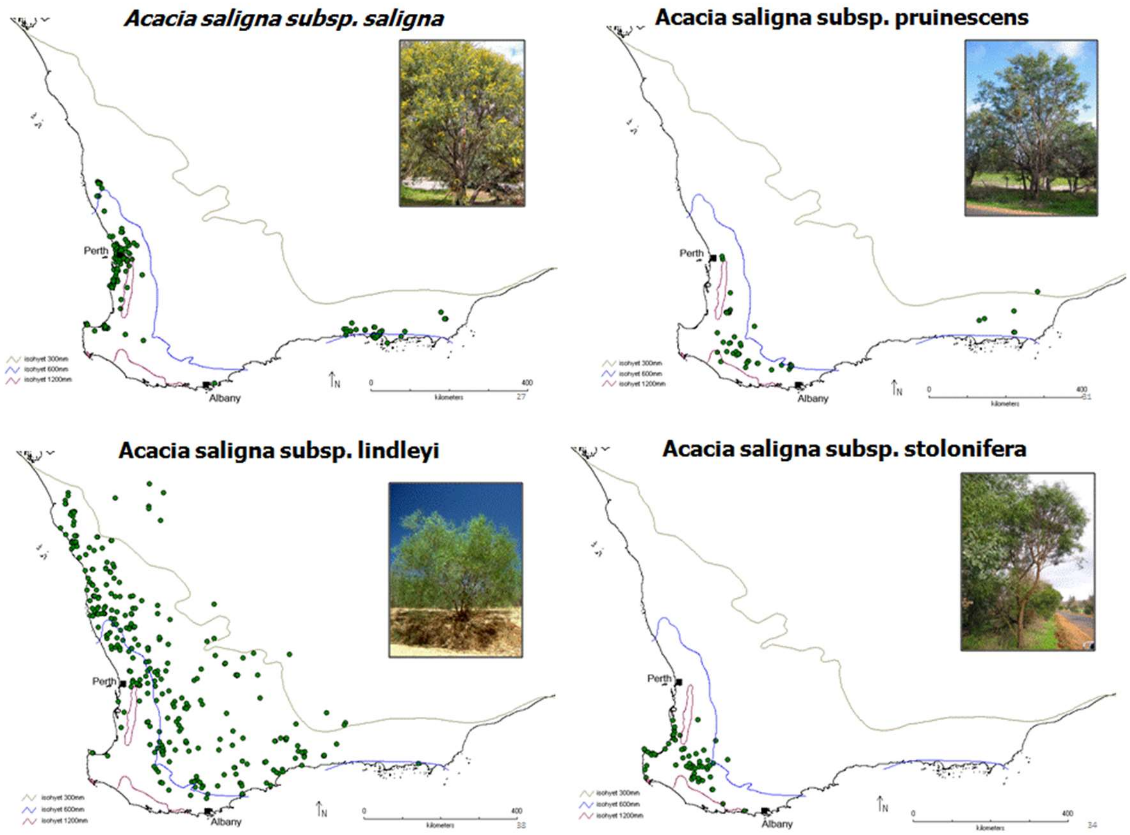

Figure 3. Geographic distribution of *Acacia saligna* in Western Australia (from Maslin *et al.* 2011)

As an example, those subspecies with a tendency to vegetative propagation such as stolonation (suckering) may not be suited to wood production since they will produce multiple stems of small diameter, however this characteristic may be highly desirable if the goal of production is fodder for animals and might further the available phyllode biomass. Field observations in native distribution show that the sub-species *saligna pruinescens* have low occurrence of propagation by stolon, however this feature is very common in *saligna* sub-species *stolonifera.*

Figure 3. Different habit growth of *Acacia saligna* in Coquimbo plantations

Genetic variation

Fourteen provenances of *Acacia saligna* from Australia were evaluated at two sites in the Region of Coquimbo, Chile. Collection sites in Australia ranged in latitude from 27° 20'S to 34° 26'S, and in elevation from 10 m to 320 m above sea level (Figure 4).

SEEDLOT	LOCATION	LAT	LONG	ALT
P1-17971	Ravensthorpe 1	33° 35′	120° 08′	150
P2-15193	Kelmscott	32° 07′	116° 02′	150
P3-15789	Sanford River	27° 20′	116° 24′	320
P4-15791	Greenough River	28° 42′	115° 02′	175
P5-15794	Geraldton	28° 35′	114° 37′	200
P6-15795	Murchison River	27° 51′	114° 37′	180
P7-15797	Mingenew	29° 12′	115° 26′	180
P8-15798	Lake Indoon	29° 52′	115° 39′	100
P9-15800	Moora	30° 34′	116° 01′	200
P10-15803	Muntadgin Rock	31° 45′	118° 35′	320
P11-15806	Lake Muir	34° 26′	116° 40′	170
P12-15810	Boyatup Hill	33° 14′	123° 02′	183
P13-15822	Lancelin	31° 01′	115° 20′	10
P14-15828	Ravensthorpe 2	33° 35′	120° 03′	234

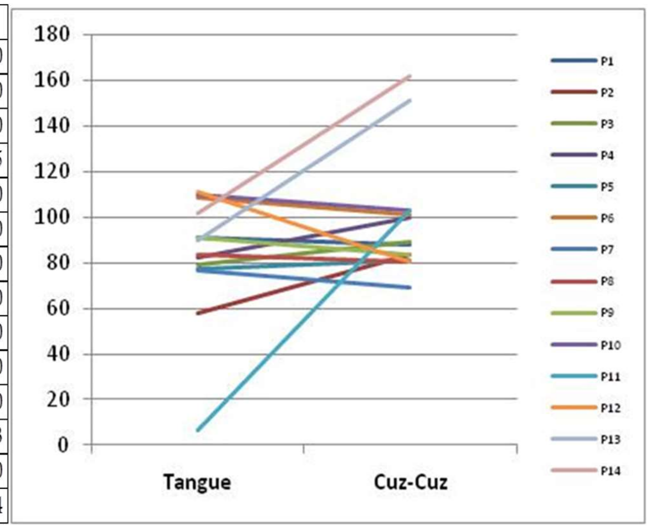

Figure 4. Provenances of *Acacia saligna* x site interaction. Overall height (cm) at 15 months. (Adapted from Mora, 2004)

The average height growth at 15 months of provenances varied significantly between the two sites, showing more growth in Cuz-Cuz located in the southern part of the Coquimbo region. The best provenance in Cuz-Cuz trial were Ravensthorpe 1 (P14) and Lancelin (P13). In Tangue, the two best performing provenances came from latitudes between 27° and 28° S, longitude between 114° and 115° W, and altitude between 175 and 180m. In turn, in Cuz-Cuz best provenances were Ravensthorpe 2 and Lancelin, from latitudes 33° and 31°S, respectively, located in the southern area of the natural distribution of the species in the state of Western Australia.

Forage resource

Acacia saligna is considered a fast-growing species, reaching 8 meters high at 4-5 years at planting sites with limitations like low rainfall and poor fertility. In dry lands of northern Chile annual increases in height between 30 -71 centimeters have been observed. Tree growth is lower in prolonged drought conditions, so that production varies between 1.5 to 10 m^3 ha^{-1} y^{-1}according to site conditions in rotations of 5 to 10 years and coppice management. In rural arid and semi-arid production systems, *Acacia saligna* are generally planted to provide supplemental or emergency food for prolonged periods of drought, shade for small livestock and protection and stabilization of degraded soils (Perret and Mora 2001). However, there are large variations in the nutritional value of this legume species (Maslin *et al.* 2007), probably because of their genetic variability and /or ignorance of this subspecies in plantations in Chile (W. O'Sullivan, pers. comm. 2005).

Normally farmers use this resource to feed sheep and goats, especially during summer and autumn. They harvest Acacia leaves and stems from young and mature trees during the dry season to provide a daily supplement to grazing (Meneses *et al.* 2012). Other farmers permit sheep and goats to also eat directly on the shrubs without any silviculture management.

The recommended planting density for livestock systems is 4 x 3 m (833 trees ha^{-1}). A greater distance between rows, such as 6-10 m may allow for greater production of perennial grasses, herbs and crops under some conditions. The incorporation of silvicultural treatments such as pruning, and thinning improves crop productivity. In arid areas the primary purpose is not to produce high quality wood, but rather to create and adapt the tree architecture to maximize the production of forage for livestock (Vita pers. comm.). Pruning and tree management differ from traditional forestry methods. Crop management for fodder purposes may be accomplished by in situ grazing, managed to create a stump of 25-50 cm high after the third year, or by topping trees when they reach two meters in height. The cutting intervention should be done in the time before the summer growth (Serra 1997). Bratti (1996) concluded that the trees cut to 50 cm height performed significantly better in vigor and growth than other cutting heights.

The fresh foliage is palatable to animals and can be used as a food supplement for livestock (sheep and goats) containing up to 21% crude protein in dry weight. Serra (1997) reported that phyllode material contains 10-19% protein by dry weight, 24-27% crude fiber and 20 to 26.48% digestible organic matter in vitro. Plantations established by INFOR in the arid interior of the province of Choapa showed that forage production can reach a value between 0.8 and 2.2 Mg DM (dry material) ha^{-1} of dry forage at 3 and 4 years after planting (Perret and Mora 2001). Meneses *et al.* (2012) concluded that *Acacia saligna* fodder has limitations as feed for goats. In pregnancy its acceptability as the sole forage, represented 65% of that of alfalfa hay, but during lactation the intake was higher than alfalfa hay. Blood urea is affected with 50% of acacia inclusion. The response of albumin is inconsistent and the other blood components did not present effects from acacia consumption. For this Acacia fodder should not represent more than 26% of diet during the last third of pregnancy, according to body and birth weight.

During lactation, Acacia should not represent more than 25% of diet to avoid affecting milk production, although the regression equation determined that it should not represent more than 7.3%. A higher percentage in the diet would affect animal productivity and more than 50% would affect body weight. Maximum DM intake is obtained with 24.8% of Acacia in the diet (Meneses *et al.* 2012).

The food potential of the seeds, "Wattle Seeds" with functional properties

The seeds of some species of the genus *Acacia* are a traditional food in Australia and these are processed in the "bushfood" industry to create flavoring agents in confectionery, sauces and ice cream and flour for bread, pasta and biscuits. There is interest in the “functional food” potential of Acacia seed in Australia due to the high-protein, low glycemic index meal that can be produced (Yates 2014). The glycemic index (GI) is a system for comparing the relative rapidity with which an energy containing food enters the bloodstream as sugars after consumption. A high glycemic index indicates rapid sugar (and thus energy) availability, which requires a relatively robust response from the insulin-endocrine system. Excessive, long-term exposure to foods with a high glycemic index has been implicated in diseases such as type II diabetes.

A research and development project was conducted by INFOR[6] since 2014 to prospect functional foods in *Acacia saligna* seeds and flours. The main objective is to produce a multicereal bread and a biscuit with 5% of *A. saligna* pre-mix flours. Main specific objectives of the R & D are:

a) Determine the technical and economic feasibility of the production of functional flours of *A. saligna* for the mill and to generate a business plan. This new raw material will allow differentiation and positioning of the flour mill La Estampa in the domestic and international market. A new functional flour product in pure form or in mixture with conventional flours will also contribute to a social contribution to communities and rural producers as seed suppliers.
b) Characterize the current resource of *A. saligna* in terms of existing plantation size and estimate seed yield per tree and per hectare for the supply of raw material for La Estampa Mill.
c) Analyze commercial viability with primary field validated information.
d) Define physical, nutritional and functional characteristics of the seeds of *A. saligna*.
e) Establish processes for obtaining a bread and biscuits of *A. saligna*, and other commercially valuable intermediate products with nutritional, functional, nutraceutical properties.

First results show that there are enough seeds to supply the flour mill (1.2 Ton/year) with the following assumptions: average of seed production of 14.83 Kg/ha/year x 7,500 ha. Analyses of *A. saligna* seeds from five farms in the Coquimbo region confirm the seed as being high in protein and that their fiber content is suitable for use in baking in combination with other flours (Quitral 2012). Studies are currently underway to ascertain whether *A. saligna* seed may have any beneficial effects on diabetes related illness (Yates 2014).

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Population distribution and structure of *Acacia saligna* trees in eastern Tigray, Ethiopia

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Abstract
Acacia saligna, or the Port Jackson willow, is a very adaptable and fast-growing tree native to Western Australia. These attributes have led to its widespread distribution as an important species used extensively for soil stabilization, animal fodder, and a source of fuel wood in many countries around the world. This study was conducted in three districts in eastern Tigray Woreda with the objective of determining the distribution, abundance and structure of existing *Acacia saligna* stands. Transect lines with 100m spacing and 20 by 20 m sample plots were taken from rehabilitated area closures. In total 134 plots were sampled in the three districts. Different parameters of *Acacia saligna* such as DBH, plant height, number of plants per plot, crown height, crown diameter and other species found in the plot were collected from three (3) representative stands of *Acacia saligna*. The average number of *Acacia saligna* trees per hectare in Kilte-Awlaelo, Atsbi Wenberta and Saesie Tsaeda Emba was 385, 635 and 866 respectively, with only Kilte Awlaelo being significantly different from Saesie Tsaeda Emba and Atsbi Wenberta. The mean number of trees per hectare of mature, sapling and seedlings of *Acacia saligna* were 362, 70 and 88 respectively and was not different between the three districts. Differences between districts may be due to the variation in plantation or soil and geographicfactors.

Introduction
Acacia saligna, or the Port Jackson willow, is a very adaptable and fast-growing tree native to Western Australia (Midgley and Turnbull 2003). These attributes have led to its widespread distribution as an important species used extensively for soil stabilization, animal fodder, and a source of fuel wood in many countries around the world. *Acacia saligna* has been identified as one of three priority multipurpose species for arid and semi-arid zones with an estimated 300,000 ha planted globally (Midgley and Turnbull 2003). In some areas, *A. saligna* has gone on to become an invasive species with a wide range of impacts. This is especially apparent in the unique South African fynbos systems, where *A. saligna* has displaced native species mainly through altering the fire regime (Musil 1993; Holmes 2002). *Acacia saligna* is a difficult species to manage, with control methods having to deal with its ability to resprout from its roots and the large, persistent seed banks it creates (Hadjikyriakou and Hadjisterkotis 2002). Furthermore, there are often conflicts of interest over the desire to control Acacias whilst continuing to exploit commercially (Impson *et al.* 2009). However, little is known on the impacts of this exotic tree on plant communities, its abundance and distribution in Tigray.

Acacia saligna is a fast-growing tree and is seen as an important option for rehabilitation of degraded areas within a short period of time. Moreover, the seed of the tree is an important source of human food through mixing with the local meals to enhance nutritional values and even the leaves are useful for animal forage, particularly in dry land areas where scarcity of animal feed is a limiting factor. Therefore, investigating the average number of trees per hectare, its distribution and population structure is very important for estimating the potential merits of these trees for human food, livestock feed and others. As *Acacia saligna* trees are exotic species to Ethiopia and the wider region, studies regarding the above issues are limited.

The general objective of this study was to investigate the population distribution and structure of *Acacia saligna* in eastern Tigray. Specifically, we aimed to determine for each of three districts the

- Average number of *Acacia saligna* trees per hectare in enclosures and population structure of the populations;
- Determine the distribution of the species across the different elevations; and
- Identify the effect of *Acacia saligna* tree on diversity of the other indigenous tree species.

Materials and Methods

Study area

The study was conducted in three woredas in Eastern Tigray Woreda: Saesie Tsaeda Emba, Atsbi Wenberta and Kilte-Awlaelo woreda. In Tigray and specifically in these areas the introduction of *Acacia saligna* is assumed to have occurred more or less at the same time and hence, regardless of the number of trees per hectare, tree parameters such as DBH, tree height and other parameters are expected to be similar. Possible variation could be due to site quality and other environmental factors.

Sampling

From the above three Woreda's, all Tabias, villages and watersheds which have *Acacia saligna* were identified first through communicating with the woreda experts, development agents and inhabitants of the local area. Having this information, boundary GPS (elevation, longitude and latitude) readings was taken for each watershed that has *Acacia saligna.* To determine the population structure, abundance and distribution of *Acacia saligna* in each watershed a transect line with a hundred meter (100m) spacing were used and 20 by 20 m sample plots were taken on the transect lines at random distances between plots. The number of plots to be taken per transect line were determined by the homogeneity of *Acacia saligna* distribution. If the distribution of the species appeared to be heterogeneous across the transect line, more sample plots (20m x20m) were taken to make the sampling as representative as possible. From Kilte-Awlaelo, Atsbi Wenberta and Saesie Tsaeda Emba the number of sample plots taken were 80, 34 and 20 respectively (total 134 sample plots).

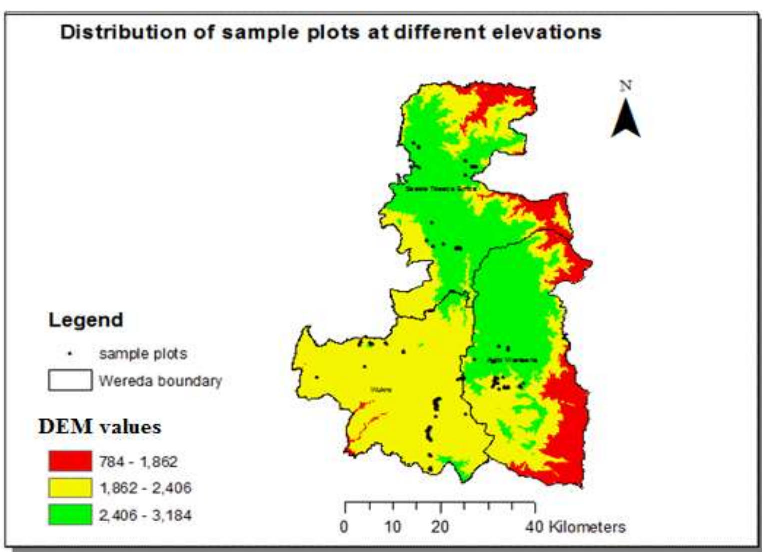


Figure 1. Distribution of sample plots at the study districts (Kilte Awlaelo, Atsbi Wenberta and Saesie Tsaeda Emba)

The plot elevation ranged from 1862 to 3184 m above sea level (Fig. 1). In each plot, all the different parameters of *Acacia saligna* such as diameter at breast height (DBH), plant height, number of plants per plot, crown height, crown diameter, other species found in the plot, soil sample, estimated percentage of land cover under plot and under *Acacia saligna* were collected. Types of woody species in each plot were recorded; for the other parameters, three representative stands were selected, measured and averaged. Crown size measurements were taken in two directions (east to west and north to south) and averaged to calculate the crown diameter of the tree. For tree height, a long *Bamboo* stick was used to stretch the meter upwards and take readings at the base of the tree. This total tree height can be divided into bole height (the height from the base of the tree till branch) and crown height. During the inventory, species were assigned into three categories: (1) mature (> 1.5m); (2) saplings (1 - 1.5m); or (3) seedlings (< 1m) to determine their population structure.

Data analysis

The collected data was analyzed by SPSS computer soft ware version 20 and specifically analysis of variance (ANOVA) tool was used to test for statistically significant differences in the number of trees per ha between the different study sites. Moreover, ANOVA was also used to evaluate group differences in DBH between sites. Tukey test was used to determin which sites were different. Apart from this, DBH and plant height were correlated to evaluate their relationship. Before proceeding to any analysis, the normality and homogeneity of variance (distribution of the data) was checked first, for deciding whether parametric or non-parametric test to be used. To compute if there is statistically significant difference in number of trees per hectare between the different sites, Ln transformation of the data was done first before statistical analysis. Shapiro Wilk test was used to check the normality (distribution of the data) and Levene's test for equality of variance.

Results and Discussion

Species composition, distribution and abundance of *Acacia saligna* trees

Many different trees and grasses living in harmony with *Acacia saligna* have been observed in all of the study sites. Highest number of plant species composition were recorded in Atsbi-Wenberta while the most frequent tree species were *Dodenia angustifolia* and *Acacia etbaica*.

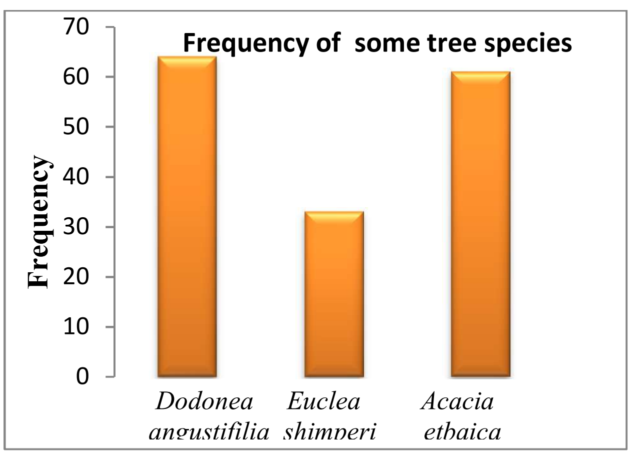


Figure 2. Frequency percentage of dominant tree species in the study area.

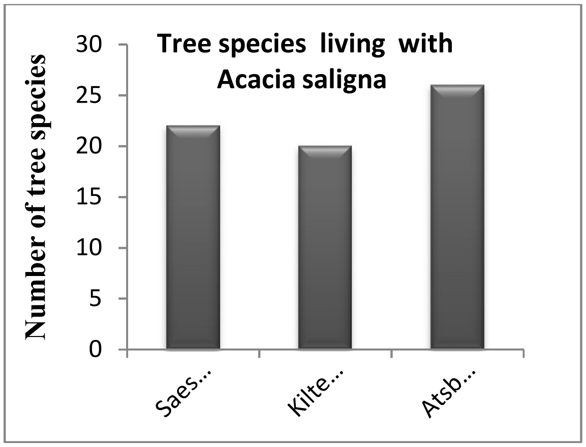


Figure 3. Number of tree species in the study sites

Distribution and abundance of *Acacia saligna* trees

Computing the number of *Acacia saligna* trees per hectare is crucial for different planning purposes. For instance, it helps to estimate what amount of seed per tree and hence per hectare could be obtained, biomass availability and even it gives a clue to what extent the area has been rehabilitated. The average number of trees (including adults, saplings and seedlings) per hectare in Kilte-Awlaelo, Atsbiwenberta and Saesie Tsaeda Emba was 385, 635 and 866 respectively. However, the standard deviation was very high, indicating that there is a high possibility of being above or below these values.

Population structure of Acacia saligna trees

Across the whole study area, the mean number of trees per hectare of mature, sapling and seedlings of *Acacia saligna* were 362, 70 and 88 respectively.

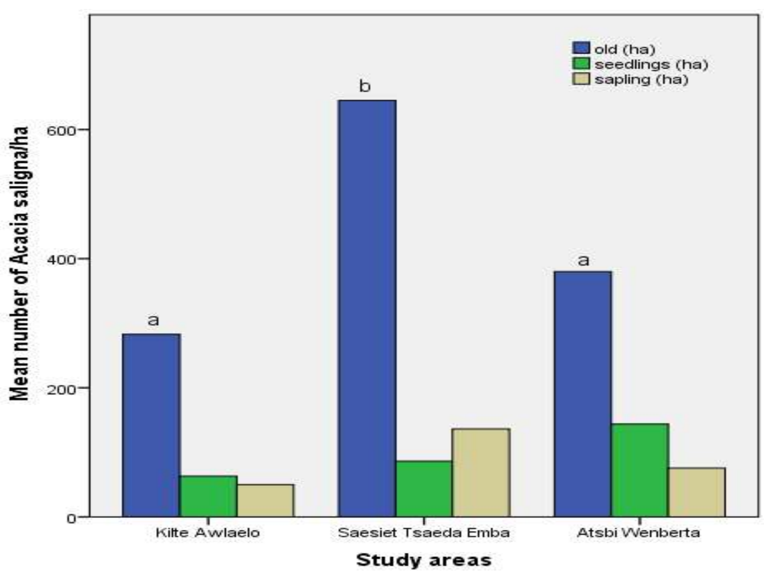


Figure 4. Age structure (tree, sapling and seedlings) of *Acacia saligna* in the study areas

Relationship of *Acacia saligna* DBH with height
The three sites did not differ in mean DBH (Figure 5).

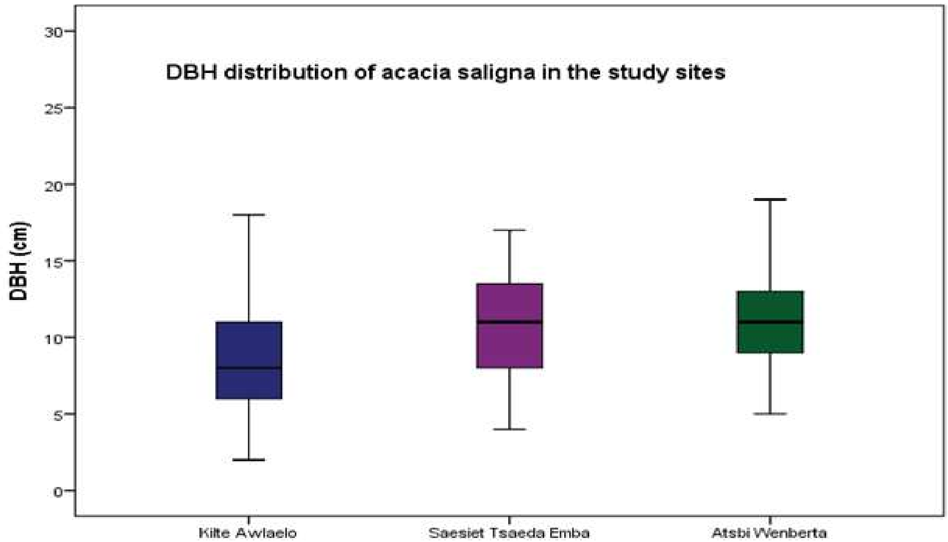


Figure 5. Mean DBH values of the study sites

This could possibly be used as an evidence for the analogue of plantation time of the stands in the different watersheds. The average DBH of old (mature) *Acacia saligna* obtained in *Kilte Awlaelo, Saesie Tsaeda Emba and Atsbi Wenberta* are 7.5, 12.5 and 12 cm respectively (Figure 5).

Relationship of *Acacia saligna* canopy cover with undercanopy land cover
Crown diameter and land cover % of herbs and grasses under *Acacia saligna* was negatively correlated (Pearson r= -0.83, P< 0.001).

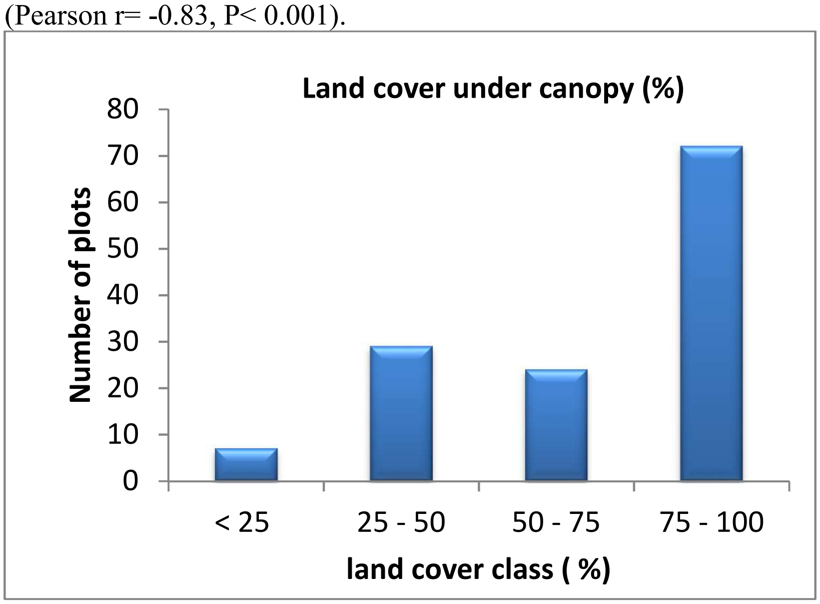


Figure 6. Number of plots with classes of cover of herbs and grasses

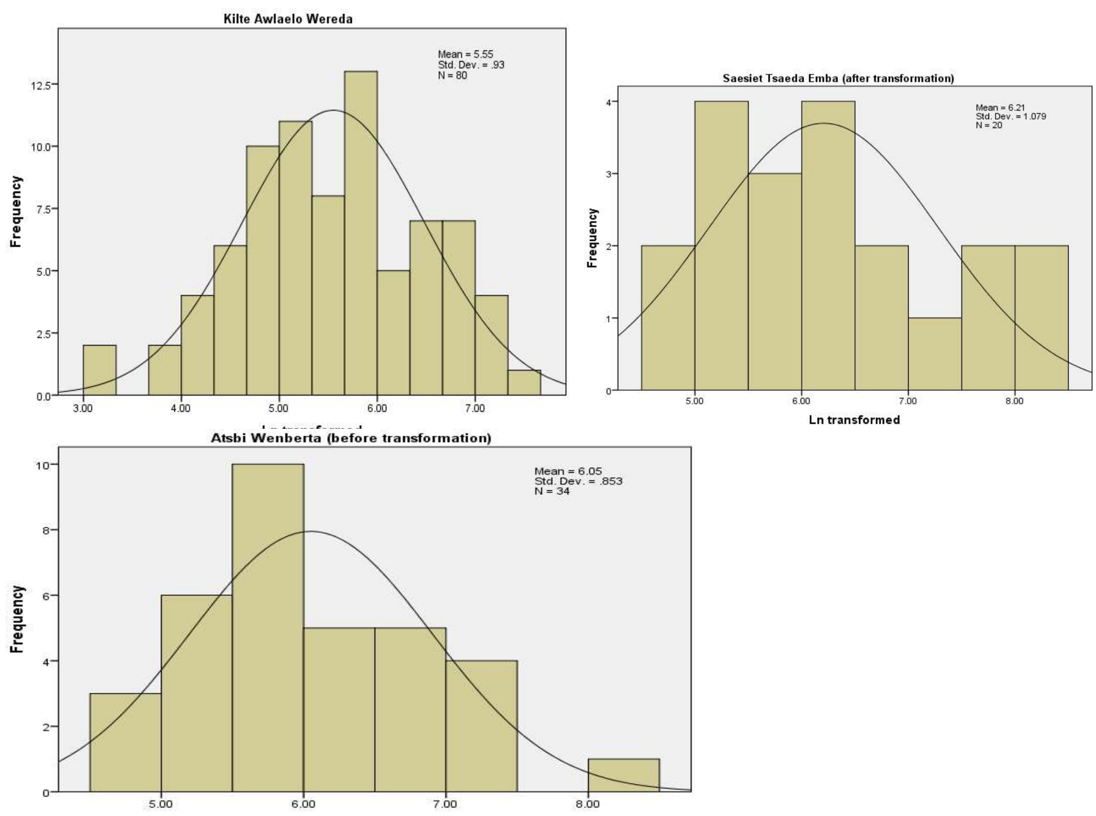
Conclusion

The field survey showed there is a significant variation in number of *Acacia saligna* trees per hectare between study sites. As these tree species are planted artificially, the variation in number of trees per hectare between sites could be due to the variation in survival rates of seedlings. Other factors such as soil type, elevation, animal trampling and browsing could also be responsible for the variability in the number of stands per hectare. Some old trees died due to not being pruned and some died due to wind damage. No evidence was found that suggests invasiveness of *Acacia saligna* in the study areas. *Acacia saligna* actually encourages the undergrowth of grass, herbs and indigenous trees like *Olea europea* var. *africana.*

Acacia saligna should therefore be encouraged to be planted at different land uses (gullies, homestead, enclosures, institutions and others) for many different purposes. In addition, for sustainable utilization and to make the tree long lasting it needs silvicultural applications like pruning of the tree in enclosures.

Further research should be done in introduction and evaluation of this tree as agro forestry/mixed with farm land. Other multipurpose and pole type *Acacia* species that could adapt the ecological condition of the region should also be introduced and popularized. Since there are some literatures that declare *Acacia saligna* as an invasive plant regular follow up should be undertaken to maintain the diversity of the ecosystem. Further research requires on wood quality of the tree in this region for timber, chip wood and charcoal.

Annex 1. Distribution of *A. saligna* trees per hectare in Kilte Awlaelo, Saesie Tsaeda Emba and Atsbi Wenberta sites after Ln transformation of density respectively.



Acknowledgement

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Flowering season and seed yield of *Acacia saligna* in Tigray, Ethiopia

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Abstract
Acacia saligna is a hardy, fast-growing species that tolerates drought, water logging, light frost, alkalinity and salt. It is a multi- purpose tree with a relatively short life span of 10–20 years. *A. saligna* seeds have high protein content and may be used for poultry feed and human supplementary food to avoid malnutrition. Hre we eavluate flowering and seed production of *A. saligna.* In each of four enclosures (Adshihu, Enderta, Atsibi-Wembert, and Bizet) the average annual seed yield per tree of *Acacia saligna* was determined in December 2011 and 2012. Seed yield was determined from mature pods harvested manually from 18 randomly selected trees in each site that were 6-10 years old, and had an average diameter of 9.8 cm, an average height of 4.8 m and a crown width of 4.9 m. The flowering and fruiting period of the tree were also assessed. *A. saligna* flowers two times a year: from early September to late October and from early February to March. Seeds of *A. saligna* mature between early December and mid-January. Overall mean annual seed yield of *A. saligna* is 633 gm per tree ranging between 606 and 656 gm, and without significant differences between sites not years. This seed yield is good compared to other areas. As large areas in northern Ethiopia are in enclosure and many enclosures harbor *A. saligna*, the potential production of seeds is large.

Keywords: *Acacia saligna,* enclosure, seed yield, tree phenology,

Introduction
The search for suitable sub-tropical dry zone acacia species for use as human food for sub-Saharan Africa has been ongoing for almost 40 years. These acacias were originally introduced to semi-arid regions of Africa for use as windbreaks, land rehabilitation and fuel wood (Cossalter 1987). Certain dry zone acacias were identified to have high potential for human food in West Africa (Thomson 1989). The first significant efforts to develop Australian acacias as human food for semi-arid regions of Africa followed the recommendations of a workshop in Central Australia in 1991. A range of invited papers on species selection, traditional Aboriginal use, nutritional composition of acacia seed, seed collection and some preliminary performance results from the Sahelian zone of sub-Saharan Africa were presented (House and Harwood 1992). *A. saligna* is introduced to Northern Ethiopia for rehabilitation purpose more than three decades ago. Except in western Tigray it is found in almost all parts of the region (homesteads, schools, religious areas and especially on area closures). The potential of the region in terms of seed yield of *A. saligna* is not yet known.

A. saligna seeds can be used for livestock and poultry feed, as well as for human supplementary food especially for infants as protein source (Devitt 1992, Cunningham *et al*. 2008, Cunningham 2012a,b). Currently the seed production capacity of *A. saligna* plantations in enclosures of Eastern Tigray is unknown. Here we wished to:

- determine average seed yield of *A. saligna* trees in Tigray;
- describe the flower and fruiting phenology of *A. saligna* trees in enclosures of Tigray; and
- investigate the subspecies level and its origin of the introduced *A. saligna* tree.

Methods

In each four enclosures (Adishehu, Absiterha-we-Atsbha, Hayqemeshal and Bizet) and one Research center (Mekelle Agricultural Research Center), 20 permanent sample trees (total 100) of *Acacia saligna* were marked. Leaf samples of all trees were taken for identification to Australia, and flowering and seed setting was monitored during 2011 and 2012 for each tree. Dried pods were collected, trashed by hand and put into coded plastic bags.

Figure1. Coding and sampling for seed and phyllodes of *A. saligna*

Results and Discussion

The mean seed yield of *A. saligna* in eastern Tigray enclosures is 0.633 kg/tree (Table 1). Adishu and Hyqmeshal enclosures have highest mean seed yield per tree per year (655 gm). From a survey made by TARI in 2012 the population of *A. saligna* in enclosures of Eastern Tigray was 362 trees per ha which, based on a mean of 0.633 kg/tree may produce 229 kg of seeds /ha.

Table 1. Seed production of *Acacia saligna* trees in four enclosures for two years

Site	N	Mean Seed weight/tree (g)	Std. Deviation	Minimum	Maximum
Hayqemeshal 2010	19	655.8	434.9	105.3	1646.7
Hayqemeshal 2011	16	655.1	524.8	28.2	1669.2
Elala-Marc 2011	16	605.7	462.4	32.6	1317.4
Bizet 2010	17	583.4	459.9	25.5	1533.9
Bizet 2011	16	638.5	755.0	31.1	2804.1
Adshihu 2011	18	655.6	344.0	97.9	1221.0
Total	102	633.0	495.2	25.5	2804.1

Observations over time indicate that in Tigray, *A. saligna* trees flower twice a year: from early September to late October and from early February to March. Seeds of *A. saligna* mature between Early December and mid-January. The provenances of the sub species are *A. saligna* subsp. *saligna* and *A. saligna* subsp.

Lindleyi are from west and south-west Australia. In Australia this species flowers from late July to October.

Mature seeds are present between Early December to mid-January and March to late April in the study area. Pod formation occurs in November and seed maturing /pod drying/from early to late December in the rainy season and March to April in the dry season with few seeds. The twice-per-year flowering and seed formation is unique compared to other trees and on its native ecology Australia. Flowers produced in the dry season could meet a fodder-gap for bees. However, we noted high variability on seed yields per tree, even in the same site, potentially due to the high genetic phenotypic diversity of *Acacia saligna* in the enclosures of east Tigray. Mean yield between sites is narrow with no significant difference (P=0.05). Trees with maximum seed yield, such as those in Bizet enclosure which produced 2.8 kg/tree, should be used as mother trees if objective is for seed multiplication.

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SECTION B: NUTRITIONAL VALUE OF *ACACIA SALIGNA* LEAVES

Nutritional quality of different botanical fractions of *Acacia saligna* for ruminants in northern Ethiopia

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Abstract
In Tigray, *Acacia saligna* was introduced in the 1980s for the purpose of environmental rehabilitation and soil and water conservation. However, limited information is available on the utilization of the plant as livestock feed. Here, we assessed the chemical composition of *Acacia saligna* leaves, soft twigs and pods that could be a potential livestock feed source in the region. Plants were differentiated based on physical differences on leaves and seed-bearing ability. Samples of *A. saligna* leaves, twigs and pods were collected from Illala, Mekelle and Atsbi districts. The tree accessions had similar leaf production; however broad-leafed and narrow-leafed had higher ash contents compared with Barka A and Barka B (<5% vs >6% respectively). NLU-1 and NLU-2 accessions had lowest ash contents (3.05 % and 3.65% respectively). All accessions had higher crude protein (19.36%-23.32%) above that considered to be the 6% crude protein maintenance requirement for ruminants. The ash content of the twig part of the different varieties ranged from 4.73 % to 6.14%; twigs of Barka A and Barka B had higher crude proteins compared to others, and below the minimum crude protein requirement for ruminants. Crude protein of pods from the narrow-leafed and broad-leafed accessions were 13.43% and 14.08% respectively. The two varieties had similar NDF (42.57% and 40.83%) and ADF (23.84% and 23.06%) and had a lignin content of 6.89% and 6.16% respectively. The tanning content was higher in twigs followed by the leaves and pods. Generally, all the accessions and botanical fractions of *A. saligna* are potential sources of protein supplements to ruminants, though leaves would be considered optimal.

Keywords: botanical fractions, crude protein

Introduction
Acacia saligna is a dense bushy shrub or small tree that grows 2-8 m tall. It has long straggling branches that are grey to reddish brown in colour. The foliage varies in colour, either green or blue-green, with long phyllodes (up to 20 cm) that are either curved or straight (Gutteridge 1994, Simmons 1988). During spring, it is usually characterised by drooping branches that contain an abundant number of yellow flowers (NAS 1980).

Browse species play a major role in providing feed for ruminants in arid and semi-arid regions, particularly during the dry season when poor quality roughage and crop residues prevail (Kibon and Orskov 1993, Ahn *et al*. 1989). During dry periods forage trees remain green and maintain a relatively high crude protein (CP) content (D'Mello 1992). Their foliage may be used as a protein and energy supplement when animals are given low quality roughage (Reed *et al*. 1990). However, legume trees and shrubs contain a wider range of anti-nutritional factors than more conventional fodder species (D'Mello 1992). Hence, although they may contain adequate concentrations of nutrients, the presence of secondary plant compounds may constrain their use (Dzowela *et al*. 1987).

In Tigray, *Acacia saligna* was introduced in the 1980s for the purpose of environmental rehabilitation and soil and water conservation. The plant was planted in different locations like area closures, gullies and homesteads and it is green even during the long dry season. However, limited information is available on the utilization of the plant as a livestock feed. Hence, the objective of this study was to assess the chemical composition of the *Acacia saligna* leaves, soft twigs and pods as a potential source of livestock feed in the region.

Materials and Methods

Samples of *A. saligna* leaves, twigs and pods were collected from Illala, Mekelle and Atsbi districts in Tigray region, from sites being utilized by the Acacia food security project. Plants were differentiated according to their physical differences in leaves, bearing seed or not, and other morphological features. Hence, the *A. saligna* plants collected in the region were categorized as narrow-leafed unique 1 (NLU-1 or Accession 1), narrow-leafed unique 2 (NLU-2 or Accession 2), narrow-leafed (NL or Accession 3), broad-leafed (BL or Accession 4), Barka A (Accession 5) and Barka B (Accession 6). Samples of leaves, soft twigs and pods were collected from each plant aged 3-4 years and sent to Holleta Agricultural Research Center for chemical analysis. Analysis of tannin was done at the Ethiopian Health and Nutrition Research Institute, Addis Ababa. Dried samples were milled by pestle and mortar to pass through a 1 mm sieve screen size. Nitrogen (N) content was determined according to AOAC (1990). Crude protein (CP) was calculated as N×6.25. Dry matter (DM), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), and digestible organic matter (DOM) were determined according to Van Soest *et al.* (1991). The condensed tannin (CT) content was analyzed as described by Burns (1971).

Results and Discussion

The chemical composition of leaves varied between the different varieties (Table 1). Whilst all varieties had a similar leaf DM, ash content varied considerably from 3.1% (NLU-1) up to 6.5% (Barka-B). All varieties had a level of CP (19.36%-23.32%) well above the CP maintenance requirement of 6%, as suggested for tropical legumes (Minson 1990). The CP contents observed were also far higher than the 5.6% value reported by Tamir and Asefa (2009), potentially due to different agro-ecology and stage of maturity. Barka A and Barka B varieties had higher NDF and ADF contents than other varieties, as well as higher lignin contents (13.24-13.58% vs 10.44-12.99%). In addition to this, they had higher DOM (65.37% and 63.23%) than the others.

Table 1. Chemical composition of *Acacia saligna* leaf sampled from Tigray, northern Ethiopia

s/n	Variety	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	Lignin (%)	DOM (%)	Tannin (%)
1	NLU-1	93.3	3.1	19.36	32.64	24.24	10.96	58.94	1.38
2	NLU-2	93.5	3.7	19.63	34.09	24.5	10.44	60.64	1.89
3	NL	93.3	4.3	21.75	36.32	27.1	12.95	58.45	2.00
4	BL	93.0	4.7	22.01	37.11	27.4	12.99	59.08	1.66
5	Barka A	93.4	6.2	22.86	40.83	28.3	13.24	65.37	-
6	Barka B	93.0	6.5	23.32	41.54	29.0	13.58	63.23	-

NLU-1= narrow leaved unique 1, NLU-2= narrow leaved unique 2, NL= narrow leaved, BL= broad leaved, DM= dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, DOM= digestible organic matter

The chemical composition of *A. saligna* twigs also varied between varieties (Table 2). Dry matter only varied slightly (88-91%) whereas the ash content varied more considerably (4.73-6.14%). Barka A and Barka B varieties had higher CP (9.12 and 10.11%) respectively compared to the other varieties which had CP values below the minimum requirement of CP (7%). As expected, twig values for NDF, ADF and lignin were all higher than those for leaves, presumably due to their woody content. For example, lignin content ranged from 16.67 % (NL) to 20.32% (Barka A). NLU-1 and NLU-2 varieties had a lower DOM (58.89% and 51.32%) than the other varieties. Tannin content varied by only 0.5% among all varieties.

Table 2. Chemical composition of *Acacia saligna* twig sampled from Tigray, northern Ethiopia

s/n	Variety	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	Lignin (%)	DOM (%)	Tannin (%)
1	NLU-1	90.6	4.73	6.32	56.48	42.06	17.67	58.89	2.71
2	NLU-2	88.9	4.96	6.44	67.43	44.80	19.10	51.32	2.55
3	NL	89.5	5.3	6.69	60.47	46.56	16.67	66.08	2.31
4	BL	89.5	4.84	6.04	64.89	49.40	18.08	61.70	2.20
5	Barka A	89.3	6.14	9.12	65.39	38.27	20.32	66.27	-
6	Barka B	91.1	5.86	10.1	60.63	46.75	17.35	64.61	-

NLU-1= narrow leaved unique one, NLU-2= narrow leaved unique two, NL= narrow leaved, BL= broad leaved, DM= dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, DOM= digestible organic matter

The chemical composition of *A. saligna* pods differed from both leaves and twigs (Table 3). CP tended to be more similar to leaves than twigs, with contents ranging from 12.53% to 15.03%; ranking between varieties for pods CP was the same as for leaves with highest pod and leaf CP values found in the Barka B sample. However, tannin contents varied considerably with a range of >5%.

Table 3. Chemical composition of *Acacia saligna* pods

s/n	Variety	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	Lignin (%)	DOM (%)	Tannin (%)
1	NLU-1	92.6	4.89	12.53	44.56	33.15	9.31	69.7	5.6
2	NLU-2	93.05	5.12	12.6	50.76	34.65	8.77	65.2	8.9
3	NL	91.29	4.97	13.43	42.57	23.84	6.89	71.28	6.62
4	BL	90.93	5.4	14.08	40.83	23.06	6.16	69.6	10.29
5	Barka A	91.3	6.8	14.62	53.11	33.295	5.76	73.2	4.62
6	Barka B	92.22	6.33	15.03	51.85	37.85	5.36	71.42	5.06

NL= narrow leaved, BL= broad leaved, DM= dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, DOM= digestible organic matter

Conclusion

Apart from twigs of NLU-1 and NLU-2, all accessions and botanical fractions of *Acacia saligna* are potential sources of supplementary protein for ruminants in Tigray, Northern Ethiopia. However, higher CP content is generally found in the leaf component, followed by the pod and then twigs. Variability in chemical composition exists among the different plant types. The leaf component of all plant types are rich in CP.

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Effect of feeding treated *Acacia saligna* leaves on chemical composition, growth performance and digestibility in goats

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Abstract
A study was conducted to evaluate the effect of air drying, water and wood ash solution soaking of *Acacia saligna* leaves in deactivating the condensed tannin content and assessing nutrient intake, live body weight gain, and digestibility in Abergelle goats. The goats were grouped according to their initial body weight (16 ± 2.47 kg) in a randomized complete block design into four treatments. Treatments included only grass hay as a control (T1), 300 g head^{-1} day^{-1} air dried *A. saligna* leaves (T2), 300 g head^{-1} day^{-1} water-soaked *A. saligna* leaves (T3), and 300 g head^{-1} day^{-1} wood ash-soaked *A. saligna* leaves (T4). Dry matter intake was measured daily, while live weight gain was recorded weekly. A 7-day digestibility trial followed the feeding trial where faeces and urine were collected. Proximate analysis showed that crude protein content was 12.1, 10.6 and 11.2 and 7.9% for the air dried, water soaked, wood ash-soaked leaves and grass hay, respectively. Condensed tannin contents for the air dried, water and wood ash solution-soaked leaves were 18.7,11.2 and 8.2 g kg^{-1}, respectively. Average daily weight gain for the supplemented goats ranged from 21.9-34 g day^{-1}, the highest being recorded in goats provided with the air-dried leaves. The highest nutrient digestibility was measured in the supplemented goats and ranged from 47.4 to 68%. Goats fed on air-dried and wood-ash solution-soaked leaves had a positive N balance whereas goats maintained on native grass hay alone or those supplemented with water-soaked *A. saligna* leaves had a negative N balance. Results show that air dried *A. saligna* leaves can be effectively used as a protein supplement for goats due to higher body weight gain and economic important.

Keywords: weight gain; N balance; tannin.

Introduction

Acacia saligna (Labill.) H.L. Wendl is a drought resistant and evergreen multipurpose tree or shrub introduced and now widely grown in the Tigray region of northern Ethiopia. The presence, however, of secondary plant compounds could be a major constraint to its wider use as a ruminant feed especially during the dry season when other forage options are scarce. The primary anti-nutritional agents in *Acacia* species are condensed tannins, which reduce the digestibility of dry matter, organic matter and crude protein (Reed 1995, Ben Salem *et al.* 1998). Digestibility will be low when tannin contents range from 47 to 55 g/kg DM (Ben Salem *et al.* 1998). They also added that other than the condensed tannin, the fibre quality in *A. saligna* can also affect its utilization as fodder for livestock. Tannins can reduce the nutritive value of feedstuffs more than lignin and they can also affect the health of the animal (Ben Salem *et al.* 2005). However, tannins can be either adverse or beneficial for the animal depending on their concentration and chemical structure (Makkar 2003). The condensed tannin in *A. saligna* foliage were reduced after two days of drying under shade or sun by 22.6 and 11.3% for drying and wilting respectively, as compared to fresh leaves (Van Thanh *et al.* 2005). Ramirez *et al.* (1991, 1992) reported that calcium hydroxide and wood ash solutions, being highly alkaline compounds (pH >10), could improve the nutritive value of cereal straws, sorghum and maize stover. Water and wood ash solution soaking of *A. saligna* leaves reduced the phenolic compounds such as total phenols, total tannin and condensed tannins (Ben Salem *et al.* 2005). However, calcium hydroxide solution is potentially hazardous, and unavailable for use in smallholder situations. The use of wood ash solutions can be promising as the traditional cooking method produces large quantities of wood ash, which is locally available, cheap and safe to utilize in treating tannin-containing feeds. Drying and water soaking techniques are also easily transferred, safe to utilize and cost-effective. Therefore, the general objective of this study was to increase the feeding value of *A. saligna* leaves as a dry season supplement for small ruminants by reducing the condensed tannin content of the leaves.

Materials and Methods

Description of the study area

The study was conducted in Tanqua Abergelle district which is located in the central zone of Tigray Regional State of northern Ethiopia (13° 14' 06" N, 38° 58' 50" E). The climate is hot to warm sub-moist. Altitude of the area ranges between 1300 and 1500 m.a.s.l and can be categorized as low land. Mean annual rainfall ranges from 400 to 600 mm, and annual temperatures can vary from 28 to 42°C. The dominant soil type includes Vertisols and silt loam soils with dwarf shrub vegetation dominated by *Acacia* species.

Experimental feed

The *A. saligna* leaves used in this experiment were harvested from a stand of 3-5 year old trees growing in an exclosure on the property of Abergelle Agricultural Research Centre in Tanqua Abergelle district. A total of 473 kg leaves excluding twigs and petioles were harvested by hand plucking. Leaves were mixed thoroughly, divided into three equal parts (air dried, water soaked and wood ash solution soaked leaves). For the wood ash soaked leaves, every kg of dried leaves was soaked in 6 L of wood ash (derived from ash of *A. etbaica*) solution for 48 hours. The leaves were then rinsed with water to remove the dusty materials and alkalinity. For the water-soaked leaves, about 158 kg fresh leaves were soaked in water for 48 hours. The remaining 158 kg of fresh leaves were air-dried. Finally, before feeding the leaves to the experimental goats, the leaves of all treatments were air dried for 4 to 5 days.

Animals and dietary treatments

Before conducting the experiment, experimental goats were de-wormed using albendasol 300 mg/head on two occasions, the first to kill adult internal parasite and two weeks later to kill matured hatched eggs. The goats were also sprayed with diazinone against external parasites and vaccinated against anthrax, pasteurellosis, pest des petits ruminants (PPR) and foot and mouth disease which are common disease of the area. Two vaccinations at a time were given with a ten days interval. Twenty Abergelle intact male goats aged 14-18 months and weighed 16.1 ± 2.47 kg were used. The goats were assigned to five blocks of four goats in a randomized complete block design. Initial body weight was measured after overnight fasting of the experimental goats at the end of the two weeks adaptation period. The treatments comprised of native grass hay alone provided on *ad libitum* basis (T1); grass hay and 300 g DM air dried *A. saligna* leaves (T2); grass hay and 300 g DM water-soaked *A. saligna* leaves (T3); and grass hay and 300 g DM wood ash solution soaked *A. saligna* leaves (T4). The inclusion of a fixed amount of *A. saligna* leaves was based on previous recommendations (Tamir and Asefa 2009, Mousa 2011)

Measurements and Laboratory Analysis

Dry matter (DM) intake and body weights were recorded during a 90-day feeding trial. Daily feed offeredand feed refusals were recorded throughout the experimental period. Weekly live body weights were taken in the morning before feeding and watering with the help of a spring balance. Feed conversion efficiency was calculated as the proportion of daily live weight gain to daily DM intake.

The digestibility trial was carried out for 7 days following the feeding trial for the determination of nutrient digestibility and N balance. Total feces were collected in a canvas harness attached to the goats. Daily faecal material from each goat was weighed and ten percent of it sub-sampled, stored in a plastic bag in a freezer (-4°C). At the end of the digestibility trial the collected feces was pooled and mixed thoroughly and stored in a freezer (-4°C). DM digestibility (DMD), organic matter digestibility (OMD) and digestible organic matter in DM (DOMD) were computed according to MAFF (1975).

Urine was collected in plastic containers and preserved by adding 10% H_2SO_4 in the 100 ml urine sample to maintain pH <3 (Osuji *et al.* 1993). Urine was collected twice a day in the morning and evening for a period of seven consecutive days. One-tenth of the collected urine was sub-sampled and stored frozen at -4°C.

The left over and uneaten feed sample was taken randomly for nutrient analysis according to ILCA (1993) procedures. Nitrogen (N) content of feed, feces, urine, and leaves were determined according to AOAC (1990). Crude protein (CP) was calculated as N×6.25. Dry matter, ash, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al.* (1991). The condensed tannin (CT) content was analysed as described by Burns (1971). The pH value of *A. etbaica* wood ash was analysed according to Van Reeuwijk (1992) procedure.

Statistical model and data analysis
The collected data were subject to analysis of variance using JMP-5 software (SAS Institute 2002). Treatment means were compared using Turkey HSD (Sokal and Rohlf 1981). The Statistical model was $Yijk=\mu+\alpha i+\beta j+\varepsilon ijk$, where Yijk = K^{th} observation subjected to j^{th} block effect and i^{th} treatment effect, μ = Overall mean, αi = i^{th} treatment effect (i=1-4), βj =j^{th} block effect (j=1-5) and εijk = random error term.

Results and Discussion

Chemical composition of feed ingredients
The chemical composition of native grass hay and the treated *A. saligna* leaves are presented in Table 1. The CP content of the native grass hay used in this study was 7.9% which was higher than the value reported by Tamir and Asefa (2009). But it was comparable to the value reported by (Bruh 2008). The NDF, ADF and ADL contents of the native grass hay were 65.9, 3.8 and 36.2%, respectively. These values were lower than the values reported by Solomon and Simret (2008); the differences might be attributed due to the tree variation and environmental factors such as moisture content and soil fertility. But dry matter (DM) content of native grass hay used in this trial was 92.9% which was almost the same with the values reported by Solomon and Simret (2008). Dry matter (DM) and phosphorus (P) content of the treated *A. saligna* leaves were almost similar among the treatments. The NDF, ADF and ADL contents were lower in the air-dried *A. saligna* leaves than in the water and wood ash-soaked leaves. The lower content of fibre content in air dried *A. saligna* leaves resulted in better feed consumption and digestibility compared to the other treatments. Crude protein content of air dried, water and wood ash-soaked *A. saligna* leave*s* were 12.1, 10.6 and 11.2%, respectively (Table 1). The CP content of air-dried *Acacia* leaves in this study were similar to those reported by Tamir and Asefa (2009), who found a content of 12.6, 12.6 and 12.5% CP in fresh, wilted and air-dried *A. saligna* leaves respectively. The CP content of the water soaked and wood ash-soaked *A. saligna* leaves were relatively lower than the air-dried *A. saligna* leaves. This might be due to the fact that soaking of leaves with water can leach the protein content of the leaf. Ben Salem *et al.* (2005) reported that soaking plant material in water or *A. saligna* wood ash solution decreased OM and CP contents by no more than 70 g kg^{-1} DM compared to unsoaked *Acacia* leaves. The CP content of air-dried *A. saligna* was lower than the 18.3% reported by Boland (1989). This difference might be due to variations such as rainfall, temperature, soil nutrient content and age of the plants. The condensed tannin content for the air dried, water and wood ash-soaked *A. saligna* leaves were 18.7, 11.2 and 8.2 g kg^{-1}, respectively. Water and wood ash-soaked A. *saligna* leaves had lower CT compared to air dried *A. saligna* leaves. The type of wood ash and duration of soaking can affect the level of condensed tannin (Ben Salem *et al.* 2005). They also reported that condensed tannin content of *A. saligna* leaves soaked with water and wood ash solution ranged from 10.3-

18.5 g kg^{-1} DM but the decreasing effect of wood ash solution on total phenols (TP), total tannin (TT) and CT concentration was slightly stronger than that of water. The level of condensed tannin can vary substantially with season and area of plantation (Ben Salem *et al.* 2005). The more the plant is stressed the more it produces tannin as a self-defence mechanism (Makkar 2003).

Table 1: Chemical compositions of the experimental feeds

	Treatments			
Parameter	**T1**	**T2**	**T3**	**T4**
DM (%)	92.9	90.8	91.1	90.9
OM (%)	91.2	93.9	94.9	94.4
CP (%)	7.9	12.1	10.6	11.2
NDF (%)	65.9	49.0	54.3	65.7
ADF (%)	36.2	29.5	37.1	45.6
ADL (%)	3.8	12.5	13.6	16.5
P (%)	--	0.3	0.2	0.3
CT (g kg^{-1})		18.7	11.2	8.2

DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; P = Phosphorus; CT = condensed tannin; T1 = control (hay only); T2 = grass hay + 300 g air dried *A. saligna* leaves; T3 = grass hay + 300 g water soaked *A. saligna* leaves; T4 = grass hay + 300 g wood ash soaked *A. saligna* leaves.

In vivo trial

The average daily dry matter intake (DMI) in goats that received *A. saligna* leaf ranged from 238.2 to 251.5 g $head^{-1}$ day^{-1} (Table 2). This is similar with the value reported by Krebs *et al.* (2007), but higher than that reported by Tamir and Asefa (2009). The variation is likely to be caused by differences in the experimental animals because goats are more browsers than sheep. Goats have also strong adaptation to tanniniferous feeds than sheep (Narjisse et al. 1995) due to their constant secretion of proline-rich proteins compared with sheep that secrete only when consuming tannin rich plants (Austine et al 1989). Age and body weight can also affect the dry matter intake. Lower DMI of *A. saligna* leaves was observed in this study compared with Ben Salem *et al.* (2000), which might be due to the fact that *Acacia* leaves were not offered free of choice in the present study. Supplementation with treated *A. saligna* leaves significantly (P<0.01) increased total DMI of goats. The increased total DMI observed in the supplemented goats may be due to the fact that higher CP intake results in a large number of microflora in the rumen that can facilitate the digestibility of fibrous feed (Van Soest 1994).

Table 2: Nutrient intake of Abergelle goats supplemented with air dried, water and wood ash soaked *Acacia* leaves.

Parameter	**Treatments**				**SEM**	**Prob>F**
	T1	**T2**	**T3**	**T4**		
Hay DMI (g $head^{-1}$ day^{-1})	529.3^{a}	450.5^{a}	443.9^{a}	475.4^{a}	25.6	0.1249
Supplement intake (g $head^{-1}$ day^{-1})	0.00	251.5^{a}	245.9^{a}	238.2^{a}	9.8	<0.0001
Total DMI (g $head^{-1}$ day^{-1})	529.3^{b}	702.0^{a}	689.8^{a}	713.6^{a}	33.26	0.006
Total OMI (g $head^{-1}$ day^{-1})	519.5^{b}	702.2^{a}	691.8^{a}	713.9^{a}	33.13	0.004
Total CPI ($head^{-1}$)	44.7^{b}	71.5^{a}	66.3^{a}	69.5^{a}	3.15	0.002
Total NDFI ($head^{-1}$)	375.4^{b}	455.2^{ab}	461.5^{ab}	509.4^{a}	23.22	0.012

^{abc} Means within a row not bearing a common superscript letter are significantly differ (P<0.05); Prob>F = Probability value; DMI = dry matter intake; SEM = standard error of mean; OMI = organic matter intake; CPI = crude protein intake; NDFI = neutral detergent fibre intake. T1 = control (hay only); T2 = grass hay + 300 g air dried

A. saligna leaves; T3 = grass hay + 300 g water-soaked *A. saligna* leaves; T4 = grass hay + 300 g wood ash soaked *A. saligna* leaves.

Live body weight and feed conversion efficiency

The initial and final live weights as well as the daily live weight gain are presented in Table 3. There was a significant difference (P<0.001) in daily live weight gain between supplemented and non-supplemented goats. Goats fed on grass hay alone showed lower live weight gain (5% increment) than supplemented goats throughout the experimental period due to low DM and CP intake. This is in sharp contrast with the report of Bruh (2008) who observed a loss of 21.9 g head^{-1} day^{-1} in Abergelle goats fed on grass hay alone. This suggests that the native grass hay used in this experiment was dominated by *Cynodon dactylon* grass which has better quality and is more palatable than other local grasses. The crude protein content of the native grass hay used in this experiment was 7.9 % which was slightly higher than other reports (eg. Tamir and Asefa 2009), and this fact may have helped the goats maintain their body weight. The increased weight gains recorded in the supplemented goats ranged from 14-16%. The highest average daily live weight gain (34 g head^{-1} day^{-1}) was recorded in goats that received the air-dried *A. saligna* leaves. Similarly, lambs fed on dried *A. saligna* leaves showed a daily body weight gain of 22 g head^{-1} day $^{-1}$ which was higher than lambs fed on fresh leaves (Tamir and Assefa 2009). Feed conversion efficiency (FCE) was significantly higher (P<0.01) for the supplemented goats than for the control group. Relatively higher feed conversion efficiency was observed in T2 and T3 than in T1 and T4. This could be due to the fact that higher crude protein intake creates a more favourable rumen ecosystem. Goats supplemented with water-soaked *A. saligna* leaves (T3) were taken lower crude protein than goats supplemented with wood ash (T4) but lower feed conversion efficiency was observed in T4. This might be due to the fact that lignin and silica in wood ash can reduce digestibility. Goats supplemented with air dried *A. saligna* leaves exhibited a higher (P<0.001) body weight gain than the control group.

Table 3: Live weight change and feed conversion efficiency of Abergelle goats supplemented with air dried, water and wood ash soaked *A. saligna* leaves.

Parameter	Treatments				SEM	Prob>F
	T1	T2	T3	T4		
IBW (kg head^{-1})	16.2^{a}	16.2^{a}	16.1^{a}	15.8^{a}	0.212	0.997
FBW (kg head^{-1})	17^{b}	19.3^{a}	18.9^{a}	18.4^{ab}	0.38	0.006
ADBWG (g head^{-1} d^{-1})	8.2^{b}	34^{a}	30^{a}	21.9^{ab}	0.341	0.002
FCE (%)	0.02^{b}	0.05^{a}	0.05^{a}	0.04^{ab}	0.01	0.01

^{ab} Means in the same row with different superscript differ significantly (P<0.05); IBW= Initial body weight; FBW= final body weight; ADBWG= average daily body weight gain; FCE= feed conversion efficiency. T1 = control (hay only); T2 = grass hay + 300 g air dried *A. saligna* leaves; T3 = grass hay + 300 g water-soaked *A. saligna* leaves; T4 = grass hay + 300 g wood ash soaked *A. saligna* leaves.

A regression equation was fitted between average daily weight gain, total dry matter intake and total crude protein intake (Figure 1). The variation in body weight gain was best explained by total dry matter intake (R^2 = 0.62).

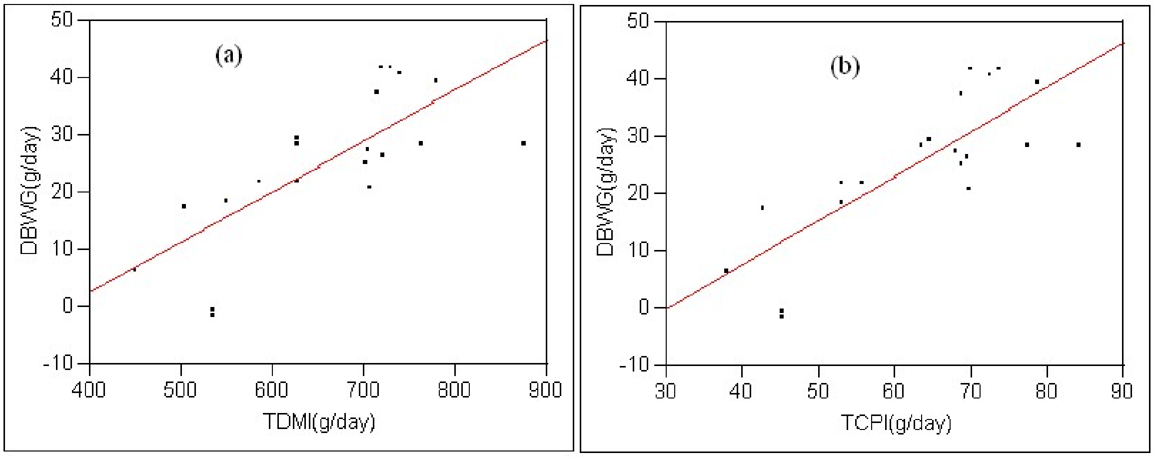

Figure 1: Relationship between daily body weight gain (DBWG) and intake of total dry matter (TDMI) and total crude protien (TCPI).

(a); Daily body weight gain = -32.9+0.09 total dry matter intake, $R^2 = 0.62$.

(b) Daily body weight gain = -23.6+0.8 total crude protein intake, $R^2 = 0.53$.

Apparent nutrient digestibility

Digestibility of DM, OM, and CP in the diets containing air dried, water-soaked, and wood ash-soaked *A. saligna* leaves were significantly ($P < 0.001$) higher than grass hay alone (Table 4). The higher digestibility of DM, OM and CP in goats supplemented with treated *Acacia* leaves might be due to higher crude protein intake and lower tannin content (8-19 g kg^{-1} DM). Tannin levels in excess of 50 g kg^{-1} dry matter can lead to low palatability, reduce digestibility, lower intake, inhibit digestive enzymes and can be toxic to rumen micro-organisms (Kumar and Vaithiyanathan 1990). Similarly, Terrill *et al.* (1992) and Barry and McNabb (1999) suggested that tannin content from 2-4% in the diet did not reduce protein digestibility in the rumen so that can increase the absorption of essential amino acids whereas 4-10% tannin content can cause digestion problems and depress voluntary feed intake. The condensed tannin content in the present study ranged from 8.2-18.7 g kg^{-1}. Ahn *et al.* (1989) reported that in most species, drying will decrease tannin content and increase N degradability. According to Van Thanh *et al.* (2005), the level of condensed tannins in *A. cyanophylla* leaves were reduced after two days of drying under shade or in the sun. However, Ben Salem *et al.* (1998) suggested that field drying had no effect on nutrient digestibility of *Acacia* leaf in sheep. In this study 11 g kg^{-1} and 8 g kg^{-1} of the condensed tannin was decreased by soaking of *A. saligna* leaves in *A. etbaica* wood ash and water, respectively. The deactivation efficiency of the wood ash solution might be due to the high pH value of the ash content. High alkalinity of wood ash solution is considered to be the main reason for the reduction of tannin content (Ben Salem *et al.* 2005*). A. etbaica* wood ash solution used in this study had a pH of 12.8. Others (e.g. Ben Salem *et al.* 2005, Ramirez *et al.* 1992) also observed similar increases in the final pH.

Table 4: Nutrient digestibility of Abergelle goats supplemented with air dried, water and wood ash soaked *A. saligna* leaves.

Nutrient (%)	Treatments				SEM	Prob>F
	T1	T2	T3	T4		
DMD	51.3^c	62.5^a	56.6^b	58.8^{ab}	1.25	0.000
OMD	57.7^c	68.0^a	63.1^b	64.9^{ab}	1.07	0.000
DOMD	56.6^c	68.0^a	63.3^b	64.9^b	1.07	<0.0001
CPD	45.3^c	66.7^a	58.8^b	61.6^b	1.19	<0.0001

NDFD	54.4^{b}	62.4^{a}	57.9^{ab}	62.4^{a}	1.23	0.002
ADFD	40.2^{c}	52.1^{ab}	47.4^{b}	54.3^{a}	1.61	0.000

^{abc}Means within a row not bearing a common superscript letter significantly differ (P<0.05); DMD = dry matter digestibility; OMD = organic matter digestibility; DODM = digestible organic matter in dry matter; CPD = crude protein digestibility; NDF = neutral detergent fiber; ADF = acid detergent fiber digestibility. T1 = control (hay only); T2 = grass hay + 300 g air dried *A. saligna* leaves; T3 = grass hay + 300 g water-soaked *A. saligna* leaves; T4 = grass hay + 300 g wood ash soaked *A. saligna* leaves.

Nitrogen balance

The largest N intake was recorded in goats supplemented with air dried *A. saligna* leaves while the lowest was measured in the control group (Table 5). Higher total N was voided in goats fed on air dried *A. saligna* leaves. This was due to higher condensed tannin content in air dried leaves than the other treatments relatively which can bind proteins. N voided in feces was lower in goats fed on grass hay alone. This might be due to low N intake and digestibility. A negative N balance was observed in goats fed on grass hay alone and those supplemented with water-soaked *A. saligna* leaves while goats that received the air dried and wood ash-soaked *A. saligna* leaves had a positive N balance. The main target of feeding air dried, water and wood ash-soaked *A. saligna* leaves was to minimize the condensed tannin content and bitter taste of the leaf and then to improve N utilization. Tannin content from 2-4 percent in the diet does not pose any difficulty in protein digestibility in the rumen, allowing for normal absorption of essential amino acids (Terrill *et al.* 1992; Barry and McNabb 1999).

Table 5: Nitrogen balance in Abergelle goats supplemented with air dried, water and wood ash-soaked *A. saligna* leaves.

Parameter	Treatments				SEM	Prob>F
	T1	T2	T3	T4		
Total N intake (g head^{-1} day^{-1})	6.7^{b}	13.6^{a}	11.7^{a}	12.8^{a}	0.55	<0.0001
N voided in feces (g head^{-1} day^{-1})	8.0^{b}	10.2^{a}	10.2^{a}	10.4^{a}	0.49	0.017
N voided in urine (g head^{-1} day^{-1})	2.4^{a}	2.4^{a}	2.3^{a}	1.6^{a}	0.15	0.007
Total N voided (g head^{-1} day^{-1})	10.4^{a}	12.6^{a}	12.4^{a}	12.0^{a}	0.56	0.647
N retention (g head^{-1} day^{-1})	-3.8^{c}	1.0^{a}	-0.7^{b}	0.8^{a}	0.16	<0.0001

^{abc}Means in the same row with different superscript differ significantly (P<0.05).

Conclusions

The major nutritional limitation of *Acacia saligna* leaves is the presence of condensed tannin and its astringent taste. Soaking *A. saligna* leaves in wood ash and water effectively reduced the detrimental effects of condensed tannin compared to air drying. Condensed tannin content of wood ash and water-soaked *A. saligna* leaves decreased by 11 g kg^{-1} and 8 g kg^{-1}, respectively, compared with air dried *A. saligna* leaves. Goats supplemented with air dried and wood ash soaked *A. saligna* leaves demonstrated better performance in terms of dry matter intake, body weight gain, digestibility and N balance than the other treatments. Lower crude protein content was observed in water-soaked *A. saligna* leaves as compared to air dried and wood ash-soaked leaves. This might be due to the fact the water can leach the protein content of the leaf.

Therefore, it is recommended to assess this leaching effect by comparing different soaking times. *A. saligna* has different provenances and these provenances should be characterised for their nutritional value, anti-nutritional value and palatability for utilization as small ruminants feed. In this experiment, the level of wood ash was based on recommended amounts, but wood ash contains lignin and silica which may cause digestion problems. Therefore, the effect of wood ash on digestibility of *A. saligna* feed should also be further investigated.

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Body weight change and carcass characteristics of Abergelle goats supplemented with treated *Acacia saligna* leaves

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Abstract
A study was conducted to evaluate the effect of feeding fixed level of treated *Acacia saligna* leaves (ASL) on feed intake, live body weight change and carcass characteristics of Abergelle goats. The experiment was conducted at the Abergelle Agricultural Research Centre goat farm in northern Ethiopia. Four treatments were used to provide supplementary diets: grass hay as a control, 300 g head^{-1} day^{-1} air dried ASL, 300 g head^{-1} day^{-1} water soaked ASL, and 300g head^{-1} day^{-1} wood ash solution soaked ASL. Feed intake was measured daily and live weight gain was recorded weekly. Measurements were taken on empty body weight (EBW), hot carcass weight (HCW), dressing percent (DP) and rib eye muscle area (REMA). Body weight gain and HCW were higher for supplemented goats compared to non-supplemented goats. However, DP on a slaughter weight basis, EBW and REMA were not significantly different among the treatments. Generally, goats supplemented with air-dried ASL showed higher body weight gain and carcass value compared with the other treatments. In this treatment, goats fed on diets supplemented with air dried ASL provided higher economic benefits than the other treatments due to a higher body weight gain and lower cost of the feed.

Keywords: supplementary diets, carcass weight

Introduction

Animal feed shortages occur in arid and semi-arid areas especially during the dry season. In those areas, animals are fed commonly on crop residues and free graze on plants with low nutritional value and digestibility. Woodward and Reed (1989) reported that phyllodes are valuable seasonally when other forages are scarce. The presence of condensed tannins may also limit feeding and contribute towards their low or moderately low digestibility at least in some situations (Michaelides 1979) which results low body weight gain. *A. saligna* appears to have fairly good potential as an animal fodder plant if the phyllodes, young shoots, pods and seeds, are selected and either fresh or dry, are protein-rich and non-toxic and palatable to both sheep and goats (Maslin 2014). Replacement of *A. saligna* leaves up to 40% in growing lambs diet improved growth performance traits and dressing percentage (Mousa 2011). Feeding of *A. saligna* leaves in the dried form could increase the utilization of nutrients with the increasing of growth performance of lambs as compared to fresh leaves (Tamir and Asefa 2009). To increase the feed intake of animals, different feed improvement mechanisms such as urea and molasses treatment, ensiling process, calcium hydroxide and wood ash soaking, chopping and drying should be practiced to decrease the anti-nutritional factors. These pre-treatments ways are not only to increase feed intake but also to increase palatability, digestibility and nutritional value of the feed. Sheep consumed *A. saligna* leaves treated with polyethylene glycol were gained better weight than those fed untreated (Ben Salem *et al.* 1998). Therefore, this study was aiming at evaluating the effect of feeding fixed level of treated *Acacia saligna* leaves (ASL) on feed intake, live body weight change and carcass characteristics of Abergelle goats and fed grass hay as basal diet.

Materials and Methods

Description of the study area

The study was conducted in Tanqua Abergelle district (13° 14' 06" N, 38° 58' 50" E) in the central zone of Tigray Regional State in northern Ethiopia. The study area is categorized as hot to warm sub-moist lowland (SM1-4) sub-agro ecological zone with an altitude of 1300-1500 m.a.s.l. The mean annual rainfall ranges from 400 to 600 mm and annual temperature ranges from 28 to 42°C. The dominant soil type includes vertisols and silt loam soils with dwarf shrub vegetation dominated by Acacia species. The area has a large population of livestock especially goats.

Preparation of experimental feeds

A. saligna leaves used in this experiment were harvested from 3-5 year old stands growing in an enclosure on the property of Abergelle Agricultural Research Centre. A total of 474 kg leaves was harvested by hand plucking and the leaves excluding twigs and petioles were harvested from all branches of the plant and mixed thoroughly.

The collected leaves were mixed thoroughly and divided into three equal parts by weight. One part (158 kg) was soaked in wood (*A. etbaica*) ash solution for 48 hours at a rate of 1 kg fresh leaf per 6L solution (Ben Salem *et al.* 2005). Leaves were then rinsed with water to remove the remaining ash and alkaline material. A second part of fresh leaves (158 kg) was soaked in water for 48 hours. A third part (158 kg) was spread out and allowed to air-dry.

Experimental animals and treatments

A total of 20 healthy Abergelle male goats aged 14-18 months and that weighed 16.11 ± 2.47 kg (mean±standard deviation) were purchased from Yechilla town and nearby areas. Ages of the experimental goats were estimated by asking the owners and by their dentition. The goats were grouped according to their initial body weight such that block one ranged from 17.7-19 kg, block two 16.6-17.5 kg, block three 15.5-16.5 kg, block four 14.8-15.4 kg, and block five 13.5-14.4 kg. Four goats were assigned to each block in a randomized complete block design. Initial body weight was measured after overnight fasting of the experimental goats at the end of a two weeks adaptation period. Following this, goats began their experimental phase with the following diets: native grass hay alone provided on *ad libitum* basis (T1); grass hay plus 300 g DM air dried *A. saligna* leaves (T2); grass hay plus 300 g DM water-soaked *A. saligna* leaves (T3); and grass hay plus 300 g DM wood ash solution soaked *A. saligna* leaves (T4).

The inclusion of a fixed amount of *A. saligna* leaves was based on previous recommendations (Tamir and Asefa 2009, Mousa 2011).

Measurements of animals

Live weights of the experimental goats were measured in the morning time before feeding and watering using a spring balance. The live weight gain (LWG) was recorded every week during the 90 days experimental period and calculated as follow;

$$\text{Live weight gain (LWG)} = \frac{(Final\ weight\ - Initial\ weight)}{Number\ of\ days}$$

The feed conversion efficiency was calculated as the proportion of daily live weight gain to daily DM intake.

Carcass parameters

From each treatment group, five goats were taken and fasted overnight and weighed before slaughtering. During slaughtering, goats were suspended head down; the oesophagus tied off to cease the blood flow, the jugular vein severed and then the blood was collected in a container and weighed with an electronic balance. The skin was flayed cautiously to avoid adherence of fat and muscle tissue to the skin. The skin with legs below the four fetlock joints, head (with horn, and ear), tongue, testicles, penis, lung (with oesophagus and trachea), heart, liver, gall bladder, spleen, pancreas, abdominal fat, gut fill and empty gut were separately measured. The entire gastro-intestinal tract content (gut) was removed and divided into the following sections, namely oesophagus, reticulum, rumen, omasum, abomasums, small and large intestine and each part was weighed and once the internal contents were emptied, the weight of the empty gut was recorded. The hot carcass weight was measured with a spring balance to the nearest 0.5 kg after head and offal were removed. The empty body weight is the weight of the goat excluding the gut contents.

The carcass was divided into two parts: hind and fore quarter between 9^{th} and 10^{th} ribs. The four ribs from (10^{th} to 13^{th}) were chilled overnight in deep freezer and the rib eye muscle (*longissimus dorsi*) area was measured at the 11^{th} and 12^{th} rib site (Jones and William 1993). The rib-eye area value was taken as the mean of the left and right sides. The cross-sectional area of the rib eye muscle area was marked out first on transparent plastic paper after it was cut at the 11^{th} and 12^{th} ribs perpendicularly to the backbone. The transparent plastic paper was attached to 0.25 cm^2 square paper, which was used to calculate the number of squares within the traced transparent plastic paper manually. The area of the squares that fell within the tracer paper was then counted on both sides and the average of the two sides was used to calculate the rib-eye muscle area.

The empty body weight is the weight of the goat excluding the gut fill and was calculated with the following formula;

$$Empty\ body\ weight = Slaughter\ weight - Gut\ contents$$

Dressing percentage was calculated as the proportion of the hot carcass weight or empty body weight to the slaughter body weight;

$$Dressing\ percentage\ (1) = \frac{Hot\ carcass\ weight}{Slaughter\ body\ weight} \times 100$$

$$Dressing\ percentage\ (2) = \frac{Empty\ body\ weight}{Slaughter\ body\ weight} \times 100$$

Statistical model and data analysis

The collected data were subject to analysis of variance (ANOVA) using JMP-5 software (SAS Institute 2002). Treatment means were compared by using Tukey HSD test. The following statistical model was used to analyze the data. $Y_{ijk}=\mu+\alpha_i+\beta_j+\varepsilon_{ijk}$, where Y_{ijk} = Dependent variables, μ = Overall mean, α_i = i^{th} treatment effect (i=1-4), β_j = j^{th} block effect (j=1-5) and ε_{ijk} = random error term.

Results and Discussion

Live body weight change

Supplemented goats had significantly higher daily live weight gain than non-supplemented goats (Table 1). The increased weight gains recorded in the supplemented goats ranged from 14-16%. The highest average daily live weight gain (34 g $head^{-1}$ day^{-1}) was recorded for goats that received the air-dried *A. saligna* leaves (T2). Elsewhere, lambs fed on dried *A. saligna* leaves showed a daily body weight gain of 22 g day^{-1} which was higher than lambs fed on fresh leaves (Tamir and Assefa 2009). The average daily weight gain observed in goats supplemented with air dried *A. saligna* leaves was nearly the same gain (27.8 to 33.4 g day^{-1}) as sheep fed on teff straw as basal diet supplemented with sesbania and leucaena (Melaku 2001). Moreover, Tamir and Assefa (2009) also reported that lower daily weight gain (16.8 and 19 g day^{-1}) exhibited in lambs supplemented with fresh and wilted *A. saligna* leaves, respectively compared to the present study. Goats fed on grass hay alone showed lower liveweight gain than supplemented goats throughout the experimental period. This is in sharp contrast with the report of Bruh (2008) who observed a loss of 21.9 g $head^{-1}$ day^{-1} for Abergelle goats fed on grass hay alone. This might be due to nutritional value difference of the grass hay. But the native grass hay used in this experiment had better quality which was 7.85% CP content as compared to Bruh (2008) which was 6.6% CP or below the body maintenance requirement of goats.

Table 1: Live weight change and feed conversion efficiency of Abergelle goats supplemented with air dried, water and wood ash-soaked *A. saligna* leaves fed grass hay as a basal diet

	Treatments				
Parameters	**T1**	**T2**	**T3**	**T4**	**Prob>F**
IBW (kg)	16.18[a]	16.2[a]	16.1[a]	15.84[a]	0.9968
FBW (kg)	17.0[b]	19.26[a]	18.92[a]	18.42[ab]	0.0064
ADBWG (g/d)	8.2[b]	34.0[a]	30.0[a]	21.91[ab]	0.0024
FCE (gLWG/g DMI)	0.018[b]	0.05[a]	0.046[a]	0.038[ab]	0.0065

[ab]Means in the same row with different superscript differ significantly ($P<0.05$); Prob>F= Probability value; IBW= Initial body weight, FBW= Final body weight, ADBWG= Average daily body weight gain, FCE= Feed conversion efficiency, T1=Control (hay only), T2= Grass hay + 300 g air dried ASL, T3= Grass hay + 300 g water soaked ASL, T4= Grass hay + 300 g wood ash soaked ASL

Carcass characteristics

Dressing percentage on slaughter weight base and empty body weight base, and rib eye muscle area did not significantly vary ($P>0.05$) among the treatments (Table 2). The highest hot carcass weight and dressing percentages in slaughter weight base was observed in goats supplemented with air-dried ASL. In contrast, the lowest hot carcass weight was observed in goats fed on the grass hay alone even though there was not any statistical difference with goats fed on wood ash-soaked *A. saligna* leaves. Lowest dressing percentage in slaughter base was seen in goats supplemented with wood ash treated leaves. Dressing percentage is a major parameter to describe meat production performance of an animal. Devendra and Burns (1983) reported that dressing percentage can be influenced by many factors such as age, sex and plane of nutrition. Hot carcass weights of Abergelle goats were ranged from 34-38 percent which was similar result with Bruh (2008) reported on same breed but incomparable to Boer goats' breeds of the South Africa with hot carcass weight of 48-60 percent (ESGPIP 2008). It was also dissimilar with the report of Melaku and Betsha (2008) on Somali goats both in dressing percent based on slaughter weight and empty body weight. This difference might be due to the difference in genetic potential of goat breeds and feed type provided to the experimental goats**.**

The rib eye muscle area ranged from 4.49 to 5.64 cm^2 and supplement type did not significantly influence the size (Table 2). Melaku and Betsha (2008) reported similar values for the Somali goat, Bruh (2008) on Aberglle goats and Mulu (2005) on Wogera sheep. Rib eye muscle area decreases with the increase in metabolizable energy level (Kirton *et al.* 1995). However, Chestnut (1994) reported that plane of nutrition had no effect on rib eye muscle area. Similarly, Kirton *et al.* (1995) reported that breed and plane of nutrition did not influence rib eye muscle area and its depth. Contrary to the above reports, Hagos and Melaku (2008) reported that rams supplemented with wheat bran have significant different with the non- supplemented in the rib eye muscle area.

Table 2: Carcass characteristics of Abergelle goats supplemented with air dried, water and wood ash soaked *A. saligna* leaves fed grass hay as a basal diet

	Treatments					
Parameters	**T1**	**T2**	**T3**	**T4**	**SE**	**Prob>F**
Hot carcass weight (kg)	6.14[c]	7.06[a]	6.90[ab]	6.50[bc]	0.13	0.0009
Empty body weight (kg)	11.94[b]	13.54[a]	13.22[a]	12.91[ab]	0.23	0.0023

Dressing percentage						
Slaughter weight base (%)	35.94	36.24	36.02	35.27	0.51	0.2338
Empty body weight base (%)	51.37	52.13	52.22	50.29	0.53	0.0808
Rib eye muscle area (cm^2)	4.49	5.47	5.64	5.04	0.31	0.0926
Brisket fat thickness (cm)	1.06	1.28	1.26	1.32	0.06	0.0596

^{abc}Means in the same row with different superscript differ significantly; SE = standard error; Prob>F = probability value. T1=Control (hay only), T2= Grass hay + 300 g air dried ASL, T3= Grass hay + 300 g water soaked ASL, T4= Grass hay + 300 g wood ash soaked ASL

Edible offal components such as liver, genital fat and blood of the supplemented goats were exhibited a significance difference (P<0.05) as compared to the control group (Table 3). In contrast, kidney, visceral fat (kidney fat, omental fat and intestinal fat), empty gut (reticulum-rumen, omasum and abomasums) did not show any significance difference (P>0.05) among the treatments. Similar results were also reported by Melaku and Betsha (2008) and Regasa (2010). The weight of offal components with low metabolic activity varied slightly with diet (Atti *et al.* 2004). Similarly, in this experiment treatments did not show any significant (P>0.05) effect in most of the offal components.

The non-edible offal components such as skin, testicles and penis, gut fill, feet, gall bladder and urinary bladder did not differ (P>0.05) among the treatments. The highest gut fill (5.7 kg) was recorded in T2 and lower gut fill (5.1kg) was recorded in T1. But statistically, there was observed not any significant variation (P>0.05) among the treatments. This was because *A saligna* leaves by itself can be used as a basal diet and so that the more they fed the *A. saligna leaves*, the more gut fill they have. Animals on poor feed are forced to fill their gut with less digestible roughage and have proportionally bigger gut content as a consequence (Hagos and Melaku 2008). However, in the current study goats fed on grass hay alone were almost similar with goats fed on the supplement in their gut fill.

Table 3: Edible and non-edible offal components of Abergelle goats supplemented with air dried, water and wood ash soaked *A. saligna* leaves fed grass hay as a basal diet

	Treatments					
Variables	**T1**	**T2**	**T3**	**T4**	**SE**	**Prob>P**
Lung, trachea and oesophagus (g)	301	333	319.8	308.4	11.05	0.225
Heart (g)	66.2	72.2	69.2	68.8	2.88	0.555
Liver (g)	225^{b}	262.6^{a}	259.6^{ab}	248.8^{ab}	8.37	0.034
Kidney (g)	45.6	53.2	47.8	49.6	2.56	0.248
Empty gut (kg)	1.099	1.245	1.17	1.196	0.056	0.369
Ret-Rum (g)	485	513.2	512	502	9.816	0.201
Oma-abom (g)	172.6	175.4	160.4	164.6	14.53	0.874
Small intestine (g)	375.6^{b}	507.2^{a}	399^{ab}	460^{ab}	27.24	0.0203
Large intestine (g)	66	70	77.2	90	8.74	0.279
Kidney fat (g)	39.6^{b}	70.2^{a}	62.8^{ab}	65.2^{ab}	6.3	0.022
Omental fat (g)	54	96	123.8	111	18.3	0.089
Intestinal fat (g)	48.4	85	110.8	96.8	24.66^{a}	0.360

Genital fat (g)	41[a]	64.6[ab]	73[a]	67.2[ab]	6.84	0.029
Tail (g)	73	86.6	70.4	72.8	4.095	0.061
Blood (g)	630.2[b]	713[a]	663.6[ab]	636.4[b]	0.02	0.022
Tongue (g)	43.8	48.4	46.8	47.2	3.56	0.823
Head (kg)	1.172	1.214	1.17	1.136	0.032	0.428
Total EOC (kg)	3.846	4.351	4.192	4.109	0.12	0.067
%Total EOC	22.61	22.62	22.15	22.4	0.353	0.752
TUP (kg)	5.21	5.64	5.54	5.67	0.164	0.093
TUP %	30.64	29.36	29.31	30.75	0.73	0.356
Skin (kg)	1.363	1.291	1.352	1.353	0.041	0.569
Testicle & penis (g)	145.6	161.8	164.2	161.4	8.286	0.403
Gut fill (kg)	5.1	5.71	5.7	5.51	0.196	0.116
Gall bladder (g)	6.2	5.6	4.4	6.4	1.06	0.557
Urinary bladder (g)	12.6	11.8	13.8	14.6	2.281	0.827
Spleen and pancreas(g)	43.6	53.2	50.8	47.2	2.39	0.068
Feet (kg)	0.415	0.457	0.429	0.442	0.016	0.315
Total NEOC (kg)	1.985	1.981	2.016	2.232	0.11	0.365
%Total NEOC	11.7	10.33	10.67	12.07	0.6	0.185

[ab] Means in the same row with different superscript differ significantly; SE = standard error; prob>F = Probability value; EOC = edible offal components; NEOC = Non-edible offal component. T1=Control (hay only), T2= Grass hay + 300 g air dried ASL, T3= Grass hay + 300 g water soaked ASL, T4= Grass hay + 300 g wood ash soaked ASL

Conclusions

Higher body weight gain, hot carcass and empty weight were observed for goats supplemented with air dried *A. saligna* leaves as compared to non-supplemented goats. In this experiment most of the edible offal and the non-edible offal components did not vary among the treatments. Therefore, it can be concluded that treatments have not had any effects in most of the offal components.

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Utilization of wheat bran and dried *Acacia saligna* leaves by highland rams

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Abstract
This study was conducted to evaluate body weight gain, feed intake and digestibility of highland rams supplemented with wheat bran and dried *Acacia saligna* leaf. Five treatments namely grass hay as a control (T1), 100 grams per day *A. saligna* (T2), 200 grams per day *A. saligna* (T3), 300 grams per day *A. saligna* (T4) and 400 grams per day *A. saligna* (T5) with a fixed amount (200 grams per day) of wheat bran was provided to the supplemented groups. Rams in the control group gained 7.8 g/day while rams placed under T2, T3, T4 and T5 gained 42.8, 63.9, 62.2 and 57.8 g/day respectively. Thus, supplementation of 200 g/day dried *A. saligna* and 200 g/day wheat bran appears to be more efficient and more profitable than alternative diets and is then recommended for highland ram fattening.

Keywords: digestibility, grass hay, highland sheep

Introduction
Acacia saligna is a leguminous shrub which provides large amounts of fodder for ruminants in arid and semi-arid regions (Ben Salem *et al.* 1999). *A. saligna* is one of the introduced browse shrub or tree species, which is widely grown and evergreen in different agro-ecological zones of Tigray (Shumuye and Yayneshet 2011). *A. saligna* leaves have reasonably large amount of crude protein (Moujahed *et al.* 2000), which has the potential to supplement the predominantly poor-quality fibrous feeds widely used by smallholder farmers. As with other acacia species, the major limiting factor in the use of A. saligna is the presence of high concentration of tannins (Shumeye and Yayneshet, 2010; Moujahed et al 2005). The low protein digestibility of A. cyanophylla in sheep was due to the high level of condensed tannins (CT) in its foliage (Degen *et al.* 1995). Although the use of polyethylene glycol (PEG) to deactivate tannin has been recommended (Ben Salem *et al.* 1997; Moujahed *et al.* 2000; Ben Salem *et al.* 2005b), its wider use under smallholder farmers is constrained not only by its cost (Moujahed *et al.* 2005) but also its availability in the market. Air drying improves palatability, intake and digestibility (Shumuye and Yayneshet 2011). Sun-drying was slightly more efficient in reducing CT levels in the acacia foliage (Ben Salem *et al.* 1999).

Like other tropical forages, *A. saligna* is deficient in energy and could be provided to ruminants with other energy sources (Silanikove *et al.* 1997; George *et al.* 2007). With the flourishing of agro-processing plants (Yayneshet 2010), the availability and price of wheat bran make it one of the best energy sources under the smallholder socioeconomic context. Beside to improving the feeding value of *A. saligna* the appropriate level to supplement sheep is not yet studied in Ethiopia. Hence, the objectives of this study were to: (1) evaluate the nutrient contents of the experimental diets; (2) measure body weight gain, feed intake and digestibility; (3) evaluate the nitrogen balance in highland rams fed wheat bran and *A. saligna* in different proportions.

Materials and Methods
Study Area Description
The study was conducted at Mekelle Agricultural Research Center (MARC) 13°31'N and 39°58'E. Average annual rainfall is 475.5 mm and altitude is 2000 m.a.s.l.

Experimental Feeds
A. saligna leaves were collected from 2-3 years old stand by hand plucking. The harvested leaves were air dried for five days. A total of 500 kg dried *A. saligna* leaves were collected and packed in waterproof sacks. Native grass hay (*Cynodon dactylon*) was harvested from MARC's experimental fields at 50% heading. Wheat bran was purchased from a private flour milling industry and mixed with *A. saligna* leaves.

Experimental Animals and their Management
Twenty yearling highland sheep rams with an average initial body weight of 21.9+1.86 kg were purchased from the local market in Atsbi district in the study region. Age was estimated from the presence of milk tooth. The experimental animals were tagged for identification and treated against internal and external parasite using anti-helminthic drugs (Albendazole and Ivermaectin, respectively). The housing was made of concrete floor, aerated from the sides, roofed with corrugated sheet and with drainage for ease of cleaning. Clean water and salt were provided freely throughout the experiment period on an individual basis.

Experimental design and treatments
A randomized complete block design (RCBD) with four blocks and five treatments/block was used. The experimental treatments were (1) T1: Grass hay ad libitum; (2) T2: T1+ 100 g of air-dried *A. saligna* leaves + 200 g wheat bran; (3) T3: T1+ 200 g of air-dried *A. saligna* leaves+ 200 g wheat bran; (4) T4: T1+ 300 g of air-dried *A. saligna* leaves + 200 g wheat bran and (5) T5: T1+ 400 g of air-dried *A. saligna* leaves + 200 g wheat bran. The supplementation was scheduled during each day at two equal portions (8:00 am and 16:00 pm).

Measurements
The amount of feed offered and refused for each sheep was measured every day for the whole 90 days of the experimental period. The feed intake was calculated by subtracting the refusal from the offered feed. Feed conversion efficiency was calculated by dividing daily live weight gain by daily feed intake.

Live body weight record was taken every Friday for each animal for the whole experimental days. The live weight change and daily live weight gain were calculated initial body weight subtracted from the final live weight and the daily live weight gain was a result of final body weight minus initial body weight divided by the 90 days the trial undertaken.

Feces and urine were collected for 7 days following 3 days of adaptation. The daily fecal excretion of each ram was mixed thoroughly according to their treatment and 10% was sampled and kept in air tight plastic containers and stored at -4ºC refrigerator. About 100 ml urine was mixed with 10% H_2SO_4 to maintain pH value below 3.0 (Osuji *et al.* 1992). Urine was collected twice a day in the morning and evening. Out of the total collected urine 10% of urine was sampled from each sheep and stored frozen for each treatment prior to determine N yield (Chen *et al.* 1990).

Nitrogen (N) content of the feed, feces and urine were analyzed according to (AOAC 1990). The CP was calculated N x 6.25. The apparent nutrient digestibility coefficient (DC) was calculated as the total amount of nutrients in feed less the total amount of nutrient in feces divided by the total amount of nutrient in the feed. Digestibility of the dry matter (DDM), digestibility of the organic matter (DOM) and digestible organic matter in dry matter (DODM) was analyzed according to MAFF (1975). The fiber content (dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and Ash) of the experimental feeds was examined according to (Van Soest *et al.* (1991) and the condensed tannin content was determined according to Burns (1971).

Statistical model and data analysis
The following statistical model was used in analyzing the data.

$$Yij= \mu + \tau i + \beta j + \epsilon ijk$$

Where; Yij = the overall response; μ = overall mean; τi = ith treatment effect (i= 1,2,3,4,5); βj = jth block effect (j= 1,2,3,4); ϵijk = overall treatment and block effect

Data on the nutrient and dry matter intake, nutrient digestibility, nitrogen balance and live weight change were subjected to analysis of variance (ANOVA) using JMP5 (SAS Institute Inc. 2002) and mean comparison was done using Tukey's HSD test at $P<0.05$ (Sokal and Rohlf 1981).

Results
Chemical composition
The chemical composition of *A. saligna*, wheat bran and grass hay varied. Wheat bran contained the highest CP content followed by *A. saligna* and grass hay. The NDF content of *A. saligna* was lower than wheat bran and grass hay. The CT content of treatment feeds rose progressively from T2 to T5.

Dry matter and nutrient intake
The highest total DMI (1226.88 g/d) and OMI (1105.95 g/d) were recorded for rams placed under T5. Total DMI and OMI significantly ($P<0.001$) higher in the supplemented rams than the control rams. The daily grass hay dry matter intake was not affected by supplementation and showed no significant difference ($P>0.05$) between the supplemented and control group.

Nutrient digestibility
Nutrient digestibility in rams supplemented with wheat bran and different levels of *A. saligna* leaves were significantly ($P<0.001$) higher in nutrient digestibility from the control group. DCP values were significant ($P<0.0001$) higher at supplemented rams and pronounced at rams assigned to T4. *A. saligna* supplementation did not impose any negative effect on digestibility as the supplemented groups had higher digestibility than the control group.

Nitrogen balance
Nitrogen (N) intake and retention was efficiently utilized in T4 rams as that group had a significantly ($P<0.05$) higher N intake and retention, but not for the other supplemented group and control group. Rams assigned to T3 and T5 responded with a significant higher ($P<0.05$) excretion of N, whereas in contrast T2 rams tended to excrete less N ($P>0.05$).

Live weight changes
Rams of the supplemented group (T3, T4 and T5) had better ($P<0.05$) in their final weight and daily live weight gain (DLWG). However, the DLWG increase till T3 and start to decline even with an increase level of *A. saligna* in the highest supplemented rams (T4 and T5). This implies rams satisfy their requirement with supplementing 200 g/d *A. saligna* and 200 g/d wheat bran. Adding more *A. saligna* means they excrete either in the form of urine or feces. Even the feed conversion efficiency (FCE) also varied significantly ($P<0.05$) between T1 and T3 and T5. For economic reasons T3 was best suited to the rams.

Discussion
Chemical composition
DM, OM and CP of *A. saligna* used in this study contained 92.03%, 84.91% and 14.84%, respectively. The OM content found in this study is comparable with other authors (Ahmed 2007, Moujahed *et al.* 2000, Mousa 2011, Shumuye and Yayneshet 2011). The CP content of *A. saligna* was comparable to 13.8% CP (Krebs *et al.* 2007) and higher than the value reported by others (e.g. Shumuye and Yayneshet 2011, Moujahed *et al.* 2000, Ahmed 2007, Mousa 2011). This variation arises from age and species of the

Acacia plant, soil fertility where the Acacia plant was grown, and the season of the leaf harvest. Different authors also suggested that differences in CP content between these browse plants are due to differences in protein accumulation in them during growth (Ben Salem *et al.* 2006). Some differences might also have been due to stage of plant growth and/or season of collection (Ben Salem *et al.* 2005a). Nutritive value difference in *A. saligna* were primarily the result of change in maturity (Abdel-Fattah 2005). Inconsistencies could also be due to sampling site and climatic influences on foliage growth and plant nutrient accumulation (Ben Salem *et al.* 2006). Abdel-Fattah (2005) also showed that the season of production affects the CP content of *A. saligna*; CP content was lower in summer compared to autumn, winter and spring. Overall, plant characteristics are highly affected by the environment where it grows, and Abdel-Fattah (2005) also insisted soil type, fertility and water supply affect nutrient concentrations in plants.

The NDF, ADF and ADL content was less than the value reported by Shumuye and Yayneshet (2011). Similar to the CP content of *A. saligna* its fiber content also affected by different factors like that of production season and soil type, age of the plant and the like. In agreement with this (Abdel-Fattah 2005) reported NDF, ADF and ADL content of *A. saligna* had lower in winter compared to other seasons. The Acacia leaf used in this study was at the young age this may contribute to low fiber content. As the plant get older the fiber content rise and vice versa. Abdel-Fattah (2005) suggested the variation in nutritive value of Acacia leaves was primarily a result of differences in leaf maturity.

Condensed tannin content of dried *A. saligna* found in this study was lower than the value reported by (Abdel-Fattah 2005) 63 g/kg DM to 113 g/kg DM in summer and winter, respectively for fresh *A. saligna* (Krebs *et al.* 2007) 24.6 g/kg DM CT for *A. saligna* and 18.67% of condensed tannin for *A. saligna* reported by (Shumuye and Yayneshet 2011). The variability in condensed tannin content contribution of many factors. Abdel-Fattah (2005) reported that soil type, soil fertility, and water supply affect tannin concentrations in plants. Beside to the above variation treatment effect also one of the main factors in reducing the condensed tannin content of *A. saligna*. Drying of foliage under shade or sun reduced their CT content (Ben Salem *et al.* 1999). Season of harvest, which collected in spring for this study also contributed in reducing tanning effect. (Abdel-Fattah 2005) also explains the high temperature effect in summer contributes to the concentration of tannin that change because of physiological maturity.

Dry matter intake

The daily total DM, OM, CP and NDF intake in this study showed 24%, 23.6%, 44% and 14%, respectively in the highest supplemented group (T5) compared to the control group. Similar to this study, Tamir and Asefa (2009) and Shumuye and Yayneshet (2011) reported that different forms of *A. saligna* supplementation significantly increased the total DMI, OMI and CPI.

When animals are exposed to tannin-rich feeds, animals tend to restrict their intake which may reduce the growth of the animal (Ben Salem *et al.* 2005a). The negative effects of tannin in *A. saligna* leaves may be reduced by pre-treating the intake. Ben Salem *et al.* (2006) found that PEG treatment of *A. saligna* leaves increased intake of DM in sheep and goats. Ben Salem *et al.* (1999) found brief treatment of *A. saligna* with PEG increased DCP intake. Similarly, Moujahed *et al.* (2000) reported 195 g DM intake improvement when sheep were fed with dried *A. saligna* and supplemented with a mineral block. In this study, the diet with the highest intake of *A. saligna* (T5) contributed 22% to the total DM intake. This diet was less than the 46% share of *A. saligna* contributed towards the total DM intake of sheep fed on lucerne hay based diet (Ben Salem *et al.* 1997). This variation may arise from the supplemental effect of wheat bran and the basal diet grass hay. Moujahed *et al.* (2000) insisted Acacia intake is somewhat related to the associated forage. Different forms of *A. saligna* intake were high when mixed with good quality roughage (Ben Salem *et al.* 1997). Sheep appear to be more resistant to tannin-rich feed, and Abdel-Fattah (2005) suggested it may be possible to use sheep as models for cattle to characterize tanniniferous feeds.

Nutrient digestibility and nitrogen balance
In this study, nutrient digestibility increment were observed when moving from control to the supplemented groups. Similar to this result, Ben Salem *et al.* (1999) and Krebs *et al.* (2007) reported treatment of *A. saligna* with PEG improves DM and OM digestibility compared to feeding fresh *A. saligna* (Ben Salem *et al.* 2005(b)) also insisted wood ash treatment did not affect intake and OM digestibility of the diet but increased crude protein and NDF digestibility. Both Acacia and wheat bran supplement improved digestibility in this study. The DCP value found in this study at the supplemental group 73.81 to 77.38% was comparable to 72.8% DCP reported for sheep fed *A. saligna* treated with PGE (Ben Salem *et al.* 1999). Further mineral block supplementation on Acacia based diets had a positive effect on DCP (Moujahed *et al.* 2000).

N intake was higher by 20% to 33% in the supplemented group than the control group. Similarly, N retention was higher in the supplemented group by 32% to 36% of the control group. However, the total N voided was not significantly different between the supplemented and control group. This result agreed with Ben Salem *et al.* (1999) who observed increased urinary N excretion, though not significant. This implies the N consumed was converted to a desired product rather than voided through the wastes. Ben Salem *et al.* (1999) explained, although sheep ingested equal amounts of nitrogen (N), N excretion in feces and urine was similar in sheep fed fresh or air-dried *A. saligna* foliage. Hence, *A. saligna* treatment with shed drying had a significant impact in reducing the protein binding tannin as the supplemental group displayed a higher N intake but similar in voided N. This may arise from the early adaptation of the rams to the *A. saligna* as the digestibility trial undertaken following to the growth evaluation trial. In agreement to this idea, Ben Salem *et al.* (2005a) reported animals exposed to tannins early in life exhibited retained more N than the inexperienced lambs. Overall in this study the N balance was positive, and this has likely helped all the rams in this study to display weight gain. The positive N balance in this study may arise from the treatment applied to *A. saligna* as Ben Salem *et al.* (1999) reported PEG treatment of *A. saligna* had positive effect on N balance. Ben Salem *et al.* (2005b) also insisted feeding untreated acacia resulted in negative N balances but with treatment, N balance resulted in positive N balance.

Live weight changes
The daily live weight gain was increased as level of *A. saligna* increased to 183.8 g/day DM in T3 and declined gradually when the level of *A. saligna* was increased to 267.3 and 344.4 g/day DM in T4 and T5, respectively. *A. saligna* leaves could be best included in the grass hay based feeding in dried form at the rate of 183.8 g/day DM for improved nutrient utilization and growth performance of yearling rams.

Live weight gain found in this study was comparable to 73 g/day gain for Barbarine and Queue Fine de l'Ouest sheep fed on ad libitum dried *A. saligna* and supplemented with 400 g barley and 30 g mineral and vitamin supplement (Ben Salem *et al.* 1999). Similarly, Ben Salem *et al.* (2005a) also reported 50 g/day gain for Barbarine lambs exposed early to dried *A. saligna* leaf. Unlike this finding, Mousa (2011) reported daily weight gain of 186.31 and 19.28 g/d for Awassi fed ad libitum dried *A. saligna* supplemented with concentrated ration. However, Ben Salem *et al.* (2005a) reported weight loss of Barbarine lamb inexperienced to dried *A. saligna* leaf. The daily live weight gain found in this study was the result of the supplemental feed of wheat bran and the treatment applied to *A. saligna* leaf. Ben Salem *et al.* (1999) described an increase in the rate of gain for growing sheep given PEG-treated acacia reflects the positive effect of PEG on the availability of nutrients, mainly proteins, in the diet. Ben Salem *et al.* (2005b) also insisted higher growth performance of lambs probably results from the higher intake and better provision of available nutrients to these animals.

In conclusion, these results demonstrate that supplementation of highland rams with wheat bran and air-dried *A. saligna* leaves had a positive effect on the feed intake, live weight gain and digestibility. The effects were relatively more pronounced for rams supplemented with 183.8 g DM day dried *A. saligna*.

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Farmer-based feeding of dried *Acacia saligna* leaves for sheep fattening

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Abstract
A study was conducted to evaluate the best supplementary practice of dried *A. saligna* leaves on growth performance of rams and its economic importance. The study was carried out at Atsbi-Wenberta, Wukro Kilte-Awlaelo and Saesie-Tsaeda Emba districts of Tigray. In each district one peasant association (PA) was selected except two PAs participated in Atsbi-Wenberta. A total of 120 farmers with 240 highland sheep rams participated in the on-farm study. Randomized Complete Block Design (RCBD) was applied. Farmers were considered as a block and rams of each farmer were randomly assigned to each treatment. Two treatments were used; farmer's practice (CTL) and farmers practice supplemented with 200 g d^{-1} dried *A. saligna* leaves and 200 g d^{-1} wheat bran (AS-WB). Average daily live weight gain (ADLWG) of rams fed on AS-WB was 50% higher than the CTL group. The highest ADLWG (86.76 g d^{-1}) of supplemented rams was achieved at Abrha-Atsbeha followed by 70.29 g d^{-1} at Hayelom while rams in Mariam-Agamet and Barka-Adi-Sibuh exhibited a weight gain of 46.14 and 35.45 g d^{-1}, respectively. *A. saligna* leaf is locally available, cheap in price and has comparable crude protein content with wheat bran. Hence, supplementation of highland rams with dried AS-WB is economically important for smallholder farmers than free grazing.

Keywords: Browse tree, Industrial byproduct, on-farm trial, weight change

Introduction
Currently, in Tigray region, there is a tendency to rehabilitate the degraded area by constructing water harvesting structures, exclosures, reseeding and seedling plantation and other conservation activities. This forces farmers to confine their animals at home as free grazing is not allowed in these areas. The available feeds at farmers' compounds include crop residues and poorly prepared hay. These feeds are not in a position to support the maintenance requirement of animals. Alemu (2008) reported that ruminant diets in Ethiopia are generally based on fibrous feeds that have low digestibility and are deficient in protein, minerals and vitamins. *Acacia saligna* is the predominant shrub that grows readily in rehabilitated areas of Tigray, northern Ethiopia. Shumuye and Yayneshet (2011) reported that it is an introduced browse shrub or tree species, which is widely grown and distributed in different agro-ecological zones of Tigray region. This plant is utilized as a windbreak, for fuelwood, and in soil and water conservation. The leaves may also be a source of fodder, particularly for small ruminant production (Maslin and MacDonald 2004).

The major limiting factor in using *A. saligna* as ruminant feed is the presence of high concentration of tannins (Moujahed *et al.* 2005). Similarly, the low protein digestibility of *A. saligna* in sheep was due to the high level of condensed tannins (CT) in its foliage (Degen *et al.* 1995, Ben Salem *et al.* 2005). Although the use of polyethylene glycol (PEG) to deactivate tannin has been recommended (Ben Salem et al. 1997; Moujahed et al. 2000), its wider use under smallholder farmers is constrained not only by its cost (Moujahed et al. 2005) but also its unavailability in the local market. Air drying improves palatability, intake and digestibility (Shumuye and Yayneshet 2011). Sun-drying was slightly efficient in reducing CT levels in the acacia foliage and simplifies protein complexes (Ben Salem et al. 1999). Like other tropical forages, *A. saligna* is deficient in energy and could be provided to ruminants with other energy sources (George *et al.* 2007, Ben Salem et al. 2002). Due to the presence of CT in *A. saligna* which binds protein and other compounds, a liquid-based nutrient supply should be practiced in sheep feeding to increase microbial growth and improve intake (Ben Salem et al. 2002). *A. saligna* could be better, if it is provided to ruminants with other energy sources as it contains potentially beneficial protein sources (Gebreslassie 2013). Wheat bran is one low-cost feed resource that contains good sources of energy and protein and is easily accessible from mills.

Furthermore, wheat is the main crop produced throughout Tigray and wheat bran is used as ruminant feed. This makes the wheat residue or wheat bran readily available for local producers. In addition to accessibility, wheat bran contains both protein and energy to support ruminants (Gebreslassie 2013). Therefore, this research work was designed to demonstrate best supplementary practice of dried AS-WB, and to evaluate the growth performance of the rams and assess the economic importance of the feed for different locations.

Materials and Methods

Area description

The research was carried out at three Acacia project sites, namely, Kilte-Awlaelo, Atsbi-Wenberta and Saesie-Tsaeda Emba districts. The altitude of these three districts ranges from 1940-2160, 918-3069 and 2256-2954 m.a.s.l, respectively. Mean annual rainfall is 639.2, 642 and 350-500 mm, respectively. The annual mean temperature of Wukro Kilte-Awlaelo ranges from 14°C - 20°C and 12°C to 28°C for Saesie-Tsaeda Emba. Four Peasant Associations (PA) of the project areas were selected, namely Abrha-Atsbeha from Kilte-Awlaelo district, Barka-Adi-Sibuh and Hayelom from Atsbi-Wenberta district and Mariam-Agamet from Saesie-Tsaeda Emba district. Mixed crop-livestock farming is the feature of the areas.

Chemical composition of feed ingredients

Nitrogen (N) contents of the *A. saligna* and wheat bran (WB) provided were analyzed according to standard procedures (AOAC 1990). The CP was calculated as N x 6.25. The dry matter content (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and Ash of the experimental feeds were examined according to Van Soest *et al.* (1991) and the condensed tannin content was determined according to Burns (1971).

Farmers selection

The feeding trial was conducted with the active participation of farmers. A total of 120 farmers were selected which included 38 farmers from Wukro-Kilte-Awlaelo district (Abrha-Atsbeha PA), 62 farmers from Atsbi-Wenberta district (38 from Barka-Adi-Sibuh and 24 from Hayelom PA), and the remaining 20 farmers from the Saesie-Tsaeda Emba district (Mariam-Agamet PA). Each farmer was provided with two rams at an age of 8-12 months. These 240 rams were randomly divided into two groups; the first group of 120 rams was assigned as the control group, and the remaining 120 rams were the supplemented group. Farmer Research Groups (FRGs) were established by the Acacia project before starting the feeding trial, and results from the sheep-feeding trial were discussed with the FRGs. Female headed households (FHH) were encouraged to participate in the feeding trial. As a result, 41% of the farmers were FHH.

Preparation of the feeds

A. saligna leaves were collected by hand from farmers' backyard, exclosures and other communal areas that have good potential to *A. saligna* leaves. The collected leaves were air dried for 4 to 6 days then crushed by hand, kept in sacks and stored in a place where not exposed to moisture and sunlight. Each farmer collected 11 kg of dried *A. saligna* leaves before the experiment. Wheat bran (WB) was purchased from flour mills in Mekelle city and delivered to each site before commencing the trial.

Experimental design and treatments

A Randomized Complete Block Design (RCBD) was used. Farmers managed the experimental rams in a similar manner. Each farmer was considered as a block. The rams were divided into two groups randomly among farmers with 120 replications. The first group kept their rams on free grazing only (CTL) while the second group practiced free grazing plus 200 g d^{-1} dried *A. saligna* leaves and 200 g d^{-1} wheat bran (AS-WB) provided when they returned to home from grazing.

Management of experimental rams

Experimental rams were tagged for identification purpose. They were treated with anti-helminthic drugs (Albendazole) and anti-external parasite drugs (Ivermectine), respectively, as per recommended dosages before starting the experiment. The shed for the rams was constructed from locally available materials in each farmers' house compound.

Feed intake measurements

The amount of supplemental feed offered and refused was measured every day for 60 consecutive days. Refusal feed was collected in a sack for a week; then the total amount of refusal was divided by the number of days. The experiment was carried out for about 60 days following two weeks of adaptation period. Rams were grazed in the pasture equally and considered to be managed in the same way from farmer to farmer. The feed intake of the supplemented group was calculated by subtracting the refusal from the offered feed using the formula:

Feed intake = Amount of feed offered – Amount of feed refused

Live weight gain measurements

Weight gain (kg) was taken every ten days for both treatments as farm measurements were very difficult to undertake every week. The measurement was taken using a spring balance for the whole 60 days excluding the adaptation period of two weeks. The live weight gain was calculated with the formula;

$$\text{Live weight gain (LWG)} = \frac{\text{Final weight - Initial weight}}{\text{Number of days}}$$

Cost benefit analysis

The initial price of the rams (by estimating the current price of the rams) and all feed costs (supplemental feed) were recorded and considered as expenditure. After completion of the trial, selling price of rams was estimated according to the market estimation at that time. In addition to this, expenditure related to all weight change was recorded and evaluated to determine the benefit or loss. Finally, the net income and the marginal rate of return was calculated.

Partial budget measures profit or losses, which are the net benefits or differences between gains and losses for the proposed change. The net income (NI) was calculated by subtracting total variable cost (TVC) from the total return (TR):

$$NI = TR - TVC$$

The change in net income (ΔNI) was calculated as the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC), and calculated as follows:

$$\Delta NI = \Delta TR - \Delta TVC$$

The marginal rate of return (MRR) was determined as the increase in net income (ΔNI) associated with each additional unit of expenditure (ΔTVC).

$$MRR = \Delta NI / \Delta TVC$$

Data analysis

The collected data on live weight change was subjected to analysis of variance (ANOVA) using JMP5 (SAS Institute Inc. 2002) and mean comparison was done using Student's t test for the comparison of AS-WB and CTL groups at $P \leq 0.05$ for comparison of means by PA.

A statistical model for body weight gain was

$$Yijk = \mu + \tau i + \beta j + \epsilon ijk$$

Where; Yijk = the overall response; μ= overall mean; τi = ith treatment effect (i= 1,2); βj = jth block effect (j= 1,2,3,....,120); ϵijk = overall treatment and error effect.

Results and Discussion

Chemical composition and nutrient intake of supplemented feed

A. saligna used in this experiment had a CP of 14.8% (Table 1) which is higher than 12.7% reported by Mojahed *et al.* (2005), comparable with that of 13.6% reported by Ben Salem *et al.* (2005) but less than 18.2% reported by Abdel Fattah (2005). The variation in CP may be due to variations in soil nutrients, plant age, and/or the leaf to twig ratio. The NDF and ADF of the feed are measures of the energy and fiber source for the ruminants, which stimulates readily available energy source in the rumen and facilitate digestion. The NDF and ADF of *A. saligna* values found in this study were 43.4% and 30.7%, respectively (Table 1), which were similar to values reported by Ben Salem *et al.* (1997) (43.7% and 29.2% respectively) and Moujahed *et al*. (2005) (46.2% and 34.9% respectively). CT content of *A. saligna* (13.8%) found in this study was less than that found by Ahmed (2007) (17.7%) but higher than 11.3% reported by Abdel-Fattah (2005). CT content may vary by treatment method, plant age, and season, and is an attribute of soil type and season of production (Ben Salem *et al.* 2005). Treating *A. saligna* with polyethylene glycol is reported to result in a reduced CT content of the leaf (Ben Salem *et al.* 1999). Variation in chemical composition of *A. saligna* was likely to have been determined by the combination of soil type, tree or leaf age, treatment application and season of production. In agreement to this, Abdel-Fattah (2005) reported that chemical composition of *A. saligna* varied as a result of change in maturity.

Table 1: Chemical composition of the experimental feeds and nutrient intake by the experimental rams

Parameters	Wheat bran (%)	*Acacia saligna (%)*	Dry matter / nutrient intake by rams
DM	93.6	92.0	371
OM	93.7	84.9	357
CP	16.2	14.8	62.1
NDF	48.0	43.4	183.
ADF	15.5	30.6	92.2
ADL	3.52	8.04	23.1
Ash	6.27	15.1	42.7
Soluble matter[a]	52.0	56.6	217
Hemicelluloses[b]	32.5	12.8	90.6
Cellulose[c]	5.73	7.43	26.3
CT	-	13.8	25.3

DM= dry matter; OM= organic matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; [a] = 100%-NDF; [b] = NDF-ADF; [c] = ADF-(ADL+Ash); CT= Condensed tannin

Body weight change

The ADLWG of rams fed the supplementary AS-WB feed gained 59.2 g d^{-1} (Table 2), which was consistent with the reports of 63.89 g d^{-1} by Gebreslassie (2013) for highland rams fed on grass hay supplemented with 200 g d^{-1} dried *A. saligna* leaf and 200 g d^{-1} WB, and within the range of 42.8 - 72.2 g d^{-1} found when Farta sheep were fed on grass hay supplemented with concentrated feed (Asmare et al. 2010). However, the result was lower than that reported by Ben Salem *et al.* (1999) of 73.2 g d^{-1} for sheep fed on field dried *A. saligna* and nearly 40 g d^{-1} higher than that reported by Tamir and Asefa (2009) for lambs fed on basal diet of grass hay and supplemented with 300 g d^{-1} dried *A. saligna* leaf. In our study, rams gained 19.5 g d^{-1} $head^{-1}$ over the rams fed the CTL diet. Tamir and Asefa (2009) reported a loss of 4 g d^{-1} for lambs fed on grass hay only. The higher ADLWG of the rams in AS-WB could be due to the bypass protein in AS and fermentable N in WB which ensures optimum microbial biomass. As the tannin content protects the protein allowing it to digest in the rumen, small amounts of these tannins in the animal feed are not harmful but rather prevent the protein from being broken down in the rumen and to then be absorbed in the small intestine (Ben Salem *et al.* 1999).

Table 2: Average live weight change of highland rams supplemented (AS-WB) or control (CTL)

Parameter	Treatment			
	CTL	AS-WB	SEM	P value
Initial weight (kg)	21.6	21.6	0.29	0.99
Final weight (kg)	22.8[b]	25.2[a]	0.33	0.0001
DLWG (g d-1)	19.5[b]	59.2[a]	2.04	0.0001

DLWG = Daily live weight gain; SEM = Standard error mean; P= P Value; values in a row with different letters are significantly different

In brief, the ADLWG of the AS-WB rams across the PAs ranged from 40 to 80 g d^{-1} (Table 3). Rams in Barka-Adi-Sibuh had the lowest gain compared to Abrha-Atsbeha rams which was highest whereas the Mariam- Agamet and Hayelom rams were found to be intermediate. Overall AS-WB supplemented rams on Abrha-Atsbeha PA performed better than supplemented rams in other PAs. The ADLWG found in Abrha-Atsbeha PA (80 g d^{-1}) was consistent with Ben Salem *et al.* (2005) which reported 85 g d^{-1} for sheep fed on an *A. saligna* concentrate of 300 g d^{-1}. Similarly, Ben Salem et al. (1999) reported a weight gain of 73.2 g d^{-1} for sheep fed with *A. saligna* field-dried foliage fed ad libitum plus 400 g d^{-1} barley plus 30 g d^{-1} commercial mineral and vitamin supplement. This suggests that local feed resources can replace commercial feed resources at the farm level. However, the browse feeds should be supplemented with other best fit feeds to ensure a healthy microbial environment in the rumen may result in better weight gain. In the CTL group, rams in Hayelom PA gained 6.4 g d^{-1}, lower than other PA rams, while rams in Abrha-Atsbeha PA gained the highest (33 g d^{-1}). The lowest ADLWG found in the CTL rams indicate that supplementing rams with available feed sources is important for higher weight gain. Dried *A. saligna* leaf and WB may be suitable at the farm level because of accessibility and complimentary. The research finding by Abdel-Fattah (2005) has suggested to use *A. saligna* as supplemental feed to low quality feed.

Table 3: Body weight change of Highland rams supplemented and control at different Peasant associations

Parameters	Peasant associations				SEM	P-value
	Barka-Adi-Sibuh	Abrha-Atsbeha	Mariam-Agamet	Hayelom		
Initial weight (kg)						
Supplemented	21.8	21.2	21	21.3	0.19	0.43
Control	20.8	21.4	22.3	19.1	0.32	0.07
Final weight (kg)						
Supplemented	23.1[b]	26.4[a]	25.9[a]	22.2[b]	0.36	0.001
Control	22.6	23.2	22.1	21.7	0.2	0.05
DLWG (g)						
Supplemented	40[c]	78.9[a]	60[b]	55.2[bc]	3.67	0.001
Control	12.2[b]	32.9[a]	18.1[b]	6.41[c]	1.73	0.001

DLWG = Daily live weight gain; SEM = Standard error mean; P= P Value; B/A/Sibuh = Barka-Adi-Sibuh; A/Atsbeha = Abrha-Atsbeha; M/Agamet = Mariam-Agamet; values in a row with different letters are significantly different

Partial budget analysis

A partial budget analysis was conducted to determine the feasibility of the study and for further utilization. Income, or return obtained, was calculated from the difference between the variable cost and the return obtained from the sale of the rams (Table 4). The financial rewards obtained from the AS-WB and CTL were positive but even higher returns were obtained from the AS-WB. The AS-WB supplemented rams in PA Barka-Adi-Sibuh, Abrha-Atsbeha, Mariam-Agamet and Hayelom were fetching 2.66, 11.85, 8.65 and 5.08 USD, respectively. The MRR for the AS-WB rams were 0.04, 0.19, 0.14 and 0.08 USD for PAs of Barka-Adi-Sibuh, Abrha-Atsbeha and Hayelom, respectively. This explains for every spending of 0.05 USD farmers can generate the money described in MRR. Even higher return obtained at Abraha-Atsbeha, the return obtained in the other PAs was also magnificent. MRR in AS-WB brought a higher economic return to the farmers.

Conclusion

Acacia saligna and wheat bran (AS-WB) are easily accessible at the farmers' level and may provide alternative small ruminant feed which has been shown to improve the rate of fattening of highland rams and may also provide a higher return to the farmers compared with free grazing.

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Table 4: Partial budget analysis

Description	Control (CTL)				Supplement (AS-WB)			
	Barka-Adi-Sibuh	Abrha-Atsbeha	Mariam-Agamet	Hayelom	Barka-Adi-Sibuh	Abrha-Atsbeha	Mariam-Agamet	Hayelom
Purchase price of sheep, USD/head	27.5	26.5	27.4	27.5	30.4	28.0	28.2	27.1
Total variable (feed) cost	0.0	0.0	0.0	0.0	3.2	3.2	3.2	3.2
Gross income, USD/head	20	33.1	42.7	40.2	36.1	41.9	59.2	52.826
Total return, USD/head	5.6	16.1	12.8	8.8	11.5	31.2	24.7	17.0
Net return, USD/head	5.6	16.1	12.8	8.8	8.3	28.0	21.474	13.8
Δ NI	-	-	-	-	2.7	11.9	8.7	5.1
Δ TVC	-	-	-	-	3.2	3.2	3.2	3.2
MRR(Ratio)	-	-	-	-	0.8	3.7	2.7	1.6

USD =United States Dollar; Δ NI= change in net income; Δ TVC= change in total variable cost; MRR= Marginal rate of return; B/A/Sibuh= Barka Adi-Sibuh; A/Atsbeha= Abrha-Atsbeha; M/Agamet= Mariam-Agamet

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Effect of *Acacia saligna* leaves on milk and milk composition of dairy cows

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Abstract
Acacia saligna leaves have been suggested as an alternative feed for dairy cows. We evaluated the effect of *Acacia saligna* (AS) feed on dry matter intake, milk yield and milk composition of crossbred dairy cows using four treatments with the increasing level of AS leaves. Levels of AS leaves did not affect daily dry matter intake and milk composition, but cows fed 2.5 kg AS leaves and 3 kg wheat bran daily produced more milk than cows fed on the other treatments. Supplementation of dried AS leaves for lactating cows did not affect the total feed intake and milk composition. Thus, AS leaves can be included in dairy cow rations up to 2.5 kg dry matter per day in association with 3 kg wheat bran.

Keywords: dry matter intake, feed intake, milk quality, supplementation.

Introduction
Ethiopia, with a herd size of approximately 48 million (56% female) cattle (CSA 2008) with conducive agro-ecologies to support cattle-raising, has a huge potential for dairy production (Ahmed et al. 2004; Staal et al. 2008). A large potential market exists for dairy products, which is expected to grow with the growing population, urbanization and a rising per capita income. In particular, market-oriented smallholder dairy development presents a promising option to boost rural incomes, improve food and nutrition security, and to achieve sustainable rural poverty alleviation with a positive impact on women and landless rural households; on-farm as well as off-farm employment could be also generated along the dairy value chain (Bennett et al. 2006).

A crucial issue in Ethiopia that affects dairy production is provision of timely and low-cost livestock feed, and this limitation has meant that dairying has not been fully exploited in the country. Despite the huge numbers, the livestock sector in Ethiopia is low in production in general, and compared to its potential, the direct contribution it makes to the national economy is limited. A number of fundamental constraints underlie these outcomes, including traditional technologies, limited supply of inputs (feed, breeding stock, artificial insemination and water), poor or non-existent extension services, high disease prevalence, poor marketing infrastructure, lack of marketing support services and market information, limited credit services, absence of effective producers' organization at the grass root levels, and natural resources degradation (Berhanu and Hoekstra 2006). In addition, policy decisions on milk and milk product marketing are taken in the absence of vital information on how they affect dairy producers, traders, exporters and consumers. Similarly, current knowledge on dairy products market structure, performance and price is poor for designing policies and institutions to overcome the perceived problems in the marketing system (Ayele et al. 2003).

In addition, population pressures harm the potential feed sources like pasture or grazing land. These resources provided feed for livestock for centuries. Currently, these resources are deteriorating because of overuse. As reported in Tawila *et al.* (2008), chronic feed deficiencies constrain animal production in many developing countries due to population increase and allocation of available land for cereal production, thereby reducing the availability of cultivated land for animal fodder production. This situation demands the use of non-conventional feed resources in the livestock ration, especially from the industrial by-products. Migongo and Hansen (1987) reported that in semi- arid and tropical ecosystems, the quality of forages decreases greatly during the dry season, leading to substantial weight loss of animals. This phenomenon requires the alleviation of nutrients deficiency in animals through implementing different feed utilization strategies. These may include maximization of livestock productivity through improving the efficiency of utilization of local feed resources (Seyoum et al. 1996). There is, therefore, a need for an alternative feeding strategy which could alleviate the livestock feed problem, particularly providing locally available supplementary protein for livestock during the dry season.

Of the locally available feed options, *Acacia saligna* (AS) is one of the best plants as it has multiple uses for the farmer in terms of feed for livestock, food for human, fire wood, and other uses. This plant is well adapted to this region having been introduced in degraded areas as a means of rehabilitation, but it is not widely used according to its potential. AS was introduced decades ago to Ethiopia and was subsequently planted around homesteads and in degraded areas for the purpose of rehabilitation, but this plant has significant potential as a protein-rich livestock feed. Browse species such as AS play a major role in providing feed for ruminants in arid and semi-arid regions, particularly during dry season when poor quality roughage and crop residues prevail. During dry periods forage trees remain green and maintain a relatively high crude protein (CP) content. Results from a study by Abdulrazak et al. (2000) on Acacia species showed that CP of Acacia foliage is high enough to use as a supplement to low quality diets and the leaves are rich in minerals.

In Tigray, the potential use of AS as a livestock fodder has been neglected. Research results show that utilization of dried AS leaf as small ruminant feed increases body weight gains of sheep and goat (e.g. Shumuye and Yayneshet 2011, Gebru 2012). However, the feeding value and its effect on dairy cow and its products are not yet known. Therefore, we evaluated the feed intake, milk yield and milk composition of crossbred dairy cows supplemented with different graded level of dried AS leaf meal.

Materials and Method

Study area

This on-station research was conducted at Illala, which is located at 39° 30'E, 13° 30'N near the northern end of Mekelle city, and 1970 m above sea level. The annual mean precipitation is 521.4 mm and mean maximum and minimum temperatures are 26.6°C and 11.6°C, respectively.

Experimental animals and management

Four animals (Holstein-Friesian crossbred milking cows) which gave birth once or were at first parity were bought from Mekelle private farms. The experimental animals were tagged for identification and watered (*ad libitum*) each day with drinking water. They were synchronized through hormone treatment to come on heat at a similar time and then inseminated concurrently to give birth at a similar time and to be appropriately prepared for the feed treatments. The housing for the cows was in Mekelle Agricultural Research Center's dairy farm. Cows were housed in pens with a concrete floor, well aerated, roofed with corrugated sheets and good drainage. The amounts of hay, wheat bran and dried AS leaf offered and refused were measured and recorded daily.

Experimental design

The design for this experiment was a cross over design with four periods, four treatments and four dairy cows circulating at each period. The four crossbred dairy cows were assigned randomly to each treatment with a period of time and then circulated. As a result, every cow received every treatment during the full period of the experiment.

Feed preparation

AS leaves were collected from trial sites at Mekelle Agricultural Research Center and air dried under sheds (3-4 days) till the desired dry matter content (20% moisture) was achieved. The grass hay was also collected and prepared in Mekelle Agricultural Research Center while wheat bran was purchased from the Mekelle flour mill.

Treatments
T1: Hay + 3.00kg/day wheat bran (control)
T2: Control + 2.50kg/day dried AS leaf
T3: Control + 3.75kg/day dried AS leaf
T4: Control + 5.00kg/day dried AS leaf

Feeding experimental animals
The experimental cows were made to adapt with both the dried AS leaf and wheat bran for about ten days and then fed accordingly; cows fed grass hay *ad libitum* and 3.00 kg/day wheat bran control/ (T1), cows fed control and supplemented 2.50 kg/day dried AS leaf (T2), cows fed on control and supplemented with 3.75 kg/day dried AS leaf (T3) and cows fed control and supplemented 5.00 kg/day dried AS leaf (T4). Each experimental feed was offered for twenty days at each period. After the period, a ten days' adaptation period of the new feed was provided prior to the commencement of the next experimental period. Overall, the experiment lasted for a total of eighty experimental days and forty days of adaptation.

Feed intake
The amount of feed offered and refused for each cow was recorded daily. The experimental animals were not allowed to graze in pasture for controlling biasing factors for the whole experimental period. Feed intake was expressed with the following formula;

Feed intake = Amount of feed offered – Amount of feed refused

Milk sampling
Milk samples were taken twice; at the mid and at the end of each experimental period. Each milk sample was collected in a plastic container, covered with a lid, put on ice and transported to Adimeskel milk cooperative (in Adigrat) and analyzed using a Lacto scan milk analyzer to determine the composition (total solids, non-fat solids, fat, protein, lactose, density, ash, specific gravity) of the milk samples.

Chemical analysis
Dried samples of each feed were ground and passed through a 1 mm screen to determine their chemical composition. Dry matter percentages of the different samples were determined by oven drying the samples at 105ºC for 24 hours. Total ash and CP content were determined according to the procedure of AOAC (1990). Ash was also determined by complete burning of the feed samples in a muffle furnace at 500°C overnight. The structural plant constituents, neutral detergent fibers (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL), were analyzed using the detergent extraction method (Van Soest *et al.* 1991). Hemicellulose content was calculated by subtracting ADF from NDF and the cellulose fraction calculated as the difference between ADF and ADL.

Statistical analysis
Data on milk yield and quality were subjected to analysis of variance (ANOVA) using the statistical software JMP5. Chemical compositions were also analyzed using the general linear model (GLM) procedure (SAS 1998). Treatment means were determined to be significantly different when separated by the least significant difference (LSD).

Results and Discussion

Chemical composition of the experimental feed ingredients
The dry matter (DM) content of grass hay used was 94.7%. The organic matter (OM) and crude protein (CP) of the grass hay were 91.71% and 6.55%, respectively. The neutral detergent fiber (NDF), Acid detergent fiber (ADF) and Acid detergent lignin (ADL) of the grass hay were 76.15%, 50.62% and 10.43%, respectively (Table 1).

Crude protein content of the grass hay was greater than 5.64% reported by Brhan and Getachew (2007), similar to 6.6% and 6.56 reported by Bruh (2008) and Simret (2005), respectively but, less than 7.8% reported by Shumuye (2011). The NDF is comparable to 76.8 and 77.94 % reported by Matiwos (2007) and Mulu (2005) but, greater than 65.88% reported by Shumuye (2011).

Dry matter, OM and CP of wheat bran used in this study were 93.58%, 93.73% and 16.20%, respectively. Genet (2011), Simret (2005) and Asnake (2005) reported 21.23%, 20.1% and 19.55% CP, respectively for wheat bran. The result found in this study were lower than those findings but higher than 14.90% and 13.8% reported by Mulat (2006) and Tesfaye (2009), respectively while it was similar to the finding of Zemicael (2007), Takele and Getachew (2011) and Hagos and Melaku (2008), reported 16.66%, 16.0% and 16.82% CP content for wheat bran, respectively.

Dry matter, OM and CP of AS used in this study were 92.03%, 84.91% and 14.84%, respectively. The CP content of AS was higher than 11.40 %, 12.06 %, 12.50 % and 12.70 % reported by Krebs (2011), Shumuye (2011), Getachew (2005) and Moujahed et al. (2000), respectively and comparable to that of 13.11% and 13.07% reported by Ahmed (2007) and Mousa (2011), respectively. NDF, ADF and ADL content of AS used in this study were 43.39%, 30.56% and 8.04%. The NDF content is comparable to 45.2% and 46.2 % reported by Getachew (2005) and Moujahed et al. (2000), respectively. However, this result is higher than 38.7% reported by Ahmed (2007) and less than 48.99% reported by Shumuye (2011). The ADF content of this study is similar to the 29.48% reported by Shumuye (2011) but higher than 25.9% and 24.7% reported by Getachew (2005) and Ahmed (2007), respectively and less than 34.9 % reported by Moujahed et al. (2000). The ADL content of AS used in this study is very minimal than 11.3% 12.54 % and 17.6 % reported by Getachew (2005), Shumuye (2011) and Moujahed *et al.* (2000), respectively.

CT content is lower than 18.67% reported by Shumuye (2011) for dried AS and comparable to 11.46% reported by Getachew (2005). The differences in AS composition were likely to be due to differences in plant age, collection season, soil composition and type, storage period, time of exposure to sun or duration during drying, leaf to twig ratio and others.

Table 1: Chemical composition of experimental feed ingredients

Composition	Grass hay	Wheat bran	*A. saligna* leaf
DM (%)	94.7	93.6	92.0
OM (%)	91.8	93.7	84.9
CP (%)	6.55	16.2	14.8
NDF (%)	76.2	48.0	43.4
ADF (%)	50.6	15.5	30.6
ADL (%)	10.4	3.52	8.04
Ash (%)	8.23	6.27	15.1
Soluble matter (%)	23.9	52.0	56.6
Hemicelluloses (%)	25.5	32.5	12.8
Celluloses (%)	32.0	5.73	7.43
CT (%)	-	-	13.8

DM= dry matter; OM= organic matter; CP= crude protine; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; AS= AS; CT= Condensed Tannin; - = value not found

Dry matter intake

There was difference in hay and dried AS leaves daily dry matter intake. However, there was no difference in daily wheat bran and daily total dry matter intake among experimental cows (Table 2). Hay intake was higher in experimental cows not supplemented with dried AS leaves. Cows supplemented with higher level (5.00 kg/day/head) of dried AS leaves showed higher daily dry matter intake than cows supplemented with lower level (2.50 kg/day/head). This implied that increasing the level of *AS* leaves does not affect intake or the tannin level is affordable by dairy cows.

The findings were similar with the review of Steinshamn (2010) in which lactating dairy cows provided with grassland legumes had an increased dry matter intake than when fed with grass silage alone. Similarly, these results were in line with the studies of Anbarasu *et al.* (2001) and El-shaer (2010) who found that Acacia foliage fed as a supplement, in the presence of other feeds, can minimize the problems of low palatability and toxicity of Acacia foliage. In our study, feeding of AS leaves did not reduce the total DM intake, hence it can be used as dairy cow feed.

Table 2: Dry matter intakes (DMI) (kg/day) of dairy cows supplemented with different levels of air-dried AS leaves with grass hay as a basal diet

Parameters	Treatments				SEM	SL
	T1	T2	T3	T4		
Hay DMI	11.7^{a}	9.98^{b}	9.35^{b}	9.31^{b}	1.72	***
Acacia DMI	0.00	2.22^{c}	2.68^{b}	3.02^{a}	0.46	***
Wheat bran DMI	3.00	3.00	3.00	3.00	-	-
Total DMI	14.7	15.2	15.0	15.3	1.89	Ns

a, b, c, d; means within a row not bearing a common superscript letter significantly differ; ***= (p<0.0001); SEM= Standard error mean; Ns; not significant at 5%; SL= Significance level; T1= Control treatment (feeding grass hay *ad libitum* and 3 kg of wheat bran); T2= T1 and 2.5 kg of air-dried *A. saligna* leaves; T3= T1 and 3.75 kg of air-dried *A. saligna* leaves; T4= T1 and 5.0 kg of air-dried *A. saligna* leaves.

Daily milk yield and milk composition

There was a significantly higher daily milk yield for experimental cows assigned to T2 than the other treatments. Similarly, cows assigned to T4 were higher in milk yield than cows assigned to T1 and T3. However, there was no difference in milk yield between cows assigned to T1 and T3 (Table 3).

Milk fat content was not significantly different between treatments but milk fat content from cows supplemented with AS leaf tended to be lower than the control (T1). Density, lactose content, solids not fat, protein content and mineral content of the milk from experimental cows had no significant differences between treatments. Feeding AS leaf did not have a positive effect on the composition of milk, which suggested that AS can be a source of feed for dairy cows. Similarly, with increased level of AS leaves, milk yield can be increased but the appropriate level is T2. Similarly, milk yield was higher for ewes fed higher levels of AS leaves (Maamouri et al. 2011) whereas it was not in line with the report that milk fat and protein decreased with the inclusion of leaves in the diet.

Table 3: Milk yield and composition of milking cows fed on AS basis

Parameters	Treatments				SEM	SL
	T_1	T_2	T_3	T_4		
Milk yield (kg/head/day)	6.26^{c}	6.61^{a}	6.26^{c}	6.56^{b}	0.05	**
Milk fat	5.20	4.24	5.10	4.60	0.81	Ns
Density of the milk	28.4	29.2	29.5	29.1	1.44	Ns
Lactose content of the milk	4.49	4.58	4.61	4.58	0.21	Ns
Solids not fat	8.20	8.47	8.48	8.34	0.33	Ns
Protein content of the milk	3.00	3.97	3.10	3.06	0.54	Ns
Mineral content of the milk	0.68	0.70	0.78	1.31	0.45	Ns

a, b, c, d; means within a row not bearing a common superscript letter significantly differ; Ns; not significant at 5%; SL= Significance level; T1= Control treatment (feeding grass hay *ad libitum* and 3 kg of wheat bran); T2= T1 and 2.5 kg of air-dried AS leaves; T3= T1 and 3.75 kg of air-dried AS leaves; T4= T1 and 5 kg of air-dried AS leaves.

Conclusion

Under the study conditions, supplementation of air-dried AS leaf did not affect the daily dry matter intake and milk composition of crossbred dairy cows. It also increased the milk yield than feeding grass only. Hence, AS leaf of up to 2.5 kg DM/head/day can be included in dairy cow rations.

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SECTION C: NUTRITIONAL VALUE OF *ACACIA SALIGNA* SEEDS

Effect of soaking and roasting on *Acacia saligna* seed

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Abstract
An experiment was conducted to determine the chemical composition and anti-nutritional content of *Acacia saligna* seeds subjected to soaking and roasting. Each seed processing method was compared with raw seed. There was a significant ($P<0.05$) difference in dry matter (DM) content. The highest DM content was observed in roasted seeds (93.73%) followed by soaked (91.3 %) and raw seeds (90.8 %). However, there was no significant ($P>0.05$) difference between treatments in the levels of crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE), and ash content. Crude protein averaged 28.3%, CF averaged 14.3%, and NFE averaged 37.1%. Similarly, the tannin and phytate contents did not significantly change as a result of the seed treatments. The average tannin and phytate contents were 0.525, 0.498 and 0.322 mg/g and 0.828, 0.816 and 0.132 mg/g for raw, soaked and roasted seeds, respectively. Highest reduction of tannin (38.7%) and phytate (84.1%) was observed in roasted seeds as compared to raw and soaked seeds. *A. saligna* seeds have a potential chemical composition (crude protein and energy) but have some anti-nutritional factors like tannin and phytate. Hence, seeds can be incorporated in animal feeding with proper processing methods.

Keywords: phytate, seed treatment, roasting, soaking, tannin

Introduction
Acacia saligna, known as the Golden Wreath Wattle or Port Jackson willow (Midgely and Turnbull 2003) is a dense and multi-stemmed thornless, spreading bushy shrub (Gutteridge 1994; Orwa *et al*. 2009), or a small tree that grows 2-8 m tall (Simmons 1988), very adaptable and fast-growing tree native to Western Australia (Simmons 1988; Midgely and Turnbull 2003). Its fruits are very narrow, 8-12 cm long and 4-6 mm wide, straight and flattened. There are 6 to 10 beanlike seeds, each 5-6 mm long x 3-2.5 mm wide, dark brown to black, shiny (Orwa *et al*. 2009). The adaptable nature of the tree led to its widespread distribution as important species used for soil conservation, animal fodder and source of fuel wood in different countries of the world (Midgely and Turnbull 2003). It has been introduced into other regions of Australia, and also into many other countries (Gutteridge 1994), including Uruguay, Mexico, Israel, Iran, Iraq, Jordan, Syria, Greece, Cyprus and North African countries (NAS 1980). In northern Ethiopia, especially Tigray region, *A. saligna* was introduced in the 1980s for the purpose of environmental rehabilitation, soil and water conservation to gullies, watersheds and homesteads (personal communication). The tree is the most adaptable, evergreen and easily distributed to almost all parts of the region than any other fodder plants and found widely distributed in six zones out of seven zones of the region. According to Ee and Yates (2012), whole wattle (*A. saligna*) seeds were comprised of 27.6-32.6% proteins, 30.2-36.4% carbohydrates, 12-14% fat and 13-15% crude fibre. Its palmitic, stearic, oleic and linoleic acid contents were also 9.6 %, 2 %, 20 % and 64.3%, respectively. Besides, the anti-nutritional content of the seeds were (0.2%) phenolic, (2.2-3.4%) oxalate and (2.6-3%) saponin which were fairly high but low (0.1%) phytate content. However, it contained high level of trypsin inhibitor ranged between 2474.3-3271.4 trypsin inhibitor units per gram (TIU/g). Wattle seeds (acacia spp.) have been used as a food sources by Australian Aboriginal people for thousands of years (Maslin *et al*. 1998) and are highly nutritious in terms of its protein and carbohydrate contents (Yates 2010). However, according to Ee and

Yates (2012), roasting/heating of wattle seed before consumption is crucial to eliminate anti-nutritional factors like protease inhibitor, lectins, alkaloids, saponins and oxalates which interfere in the digestibility and absorption of nutrients. Similarly, roasting improves the nutritive value of *Jack beans* (Borchers and Ackerson 1950), reduces 89.82% of trypsin inhibitor in *Cajanus cajan* (Onu and Okongwu 2006). In addition, soaking reduces trypsin inhibitor activities in wattle seeds (Ee and Yates 2012), tannin and cyanides (Ayenor 1985; Marfor and Oke 1988; Ahamefule and Odemelam 2008) and oxalate and its toxicity (Cheeke 1995).

In Tigray region, the value of *A. saligna* seeds as animal feed was neglected for almost two decades due to limited information on chemical composition, anti-nutritional content and its method of seed treatment. Therefore, this study was designed to determine the chemical composition and anti-nutritional content with different seed processing methods of *A. saligna* seeds.

Materials and Methods

Study area

The study was conducted in 2013 at Mekelle Agricultural Research Center, Illala site. It is located north east of Mekelle at an elevation of 2250 meters above sea level at 13°28'N and 39°29'E.

Seed collection and processing methods

A. saligna seeds were collected from Mekelle city and its surroundings in February 2013 from trees aged 3- 4 years. Three methods of seed processing (raw, soaking and roasting) were used. A sample of about 500 g of seeds was used for the laboratory analysis of each treatment. For the soaking treatment, about 500 g of sample seeds were soaked overnight, washed with clean water, boiled for 5 minutes in water and dried in the sun for two days. For the roasting treatment, about 500 g sample seeds were roasted at 100°C for 3-5 minutes until the seed coats were broken.

Proximate analysis

The raw and processed seeds were grounded to pass through a 1mm sieve. Seed samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash according to the methods of AOAC (2005). Phytate was determined using the method of Reddy and Love (1999) while tannin was determined using the method of Trease and Evans (1978).

Data analysis

The data were analyzed using one-way analysis of variance (ANOVA) and mean comparison among treatments was done using Least Significant Difference (LSD) at $P<0.05$ .The data were analyzed using the Statistical Package for Social Sciences (SPSS) software version 16.

Results and Discussion

There was a difference among the treatments on the dry matter content of *A. saligna* seeds (Table 1). Roasted seeds had the highest DM content (93.7%) than the soaked and raw seed. In the case of roasted seeds, heat application has removed much of the moisture and resulted in a high DM content. However, there was no significant variation in crude protein, ether extract, crude fiber, nitrogen free extract, and ash content between treatments (Table 1).

The CP content of raw *A. saligna* seeds were in agreement with the findings of (28.6-32.6%) (Ee and Yates, 2012) but higher than the results of *A. colei* (22.3%) and *A. tumida* (22.6%) (Falade *et al*., 2005). Whereas, the CP content of *A. saligna* in comparison with other legume seeds, the raw seeds of *A. saligna* had lower CP content than raw Moringa seeds (31.1%) (Babiker 2012), but similar to *Detarium microcarpum* seeds (26.5%) (Obun *et al.* 2011) and *C. cajan* seeds (27.2%) (Onu and Okongwu 2006) while, it was higher than *F. albida* seed (20.6 %) (Hassen *et al*. 2007), sorrel seeds (21.0%) (Nyameh *et al*. 2012) and *A. africana* seeds (24.0%) (Ayanwale *et al.* 2007). Similarly, the soaked *A. saligna* seeds had higher crude protein content than soaked (21.8%), soaked and boiled (21.5%) sorrel seeds (Nyameh *et al*., 2012) while the roasted *A. saligna* seed was in agreement with roasted *A. saligna* (27.8-32.1%) (Ee and Yates, 2012) and *C. cajan* seeds (26.2 %) (Onu and Okongwu, 2006). The difference in the CP content might be attributed due to the variation in the environment, soil type and species of the plant.

Table 1: Chemical composition of raw and processed *A. saligna* seeds

Treatment	DM (%)	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)
Raw AS	90.8^{b}	28.2	15.5	14.4	36.8	5.10
Soaked AS	91.3^{b}	28.4	14.5	13.3	38.5	5.24
Roasted AS	93.7^{a}	28.3	15.1	15.3	35.9	5.58
SEM	0.56	0.69	0.60	0.86	1.30	0.25
Probability	0.004	0.935	0.315	0.154	0.180	0.227

Columns with different super scripts are significantly different at $P<0.05$, AS= *A. saligna* seed, SEM= standard error of mean, DM= dry matter, CP= crude protein, EE= ether extract, CF= crude fiber, NFE= nitrogen free extract,

The CF content of raw *A. saligna* seeds were in line with the 12.9-14.5% CF findings of Ee and Yates (2012). While comparing with other seeds, it had higher CF than raw seeds of *F. albida* (6.70%) (Hassen *et al*. 2007), *D. microcarpum* (11.1%) (Obun *et al*. 2011), *C. cajan* (7.45%) (Onu and Okongwu 2006) and *A. africana* (7.06%) (Ayanwale *et al*. 2007) but it was lower than the seeds of Moringa (28.5%) (Babiker 2012) and sorrel (19.5%) (Nyameh *et al*., 2012). This implies that *A. saligna* seed has a thinner coat than Moringa and sorrel seeds. Similarly, the roasted seeds of *A. saligna* was in line with the findings of (12.9-13.7%) (Ee and Yates, 2012). When compared with the seeds of other legumes it had higher CF content than roasted *C. cajan* (7.19 %) (Onu and Okongwu 2006), *A. africana* (5.20 %) (Ayanwale *et al*. 2007) which indicates that the seeds of *A. saligna* has a thicker coat than the other seeds listed above. Whereas, the soaked seeds of *A. saligna* had lower CF than soaked (17.5 %) and soaked and boiled (18.0 %) sorrel seeds (Nyameh *et al.* 2012). The difference in the CF content of the seeds may be due to the difference for the duration of soaking or roasting and type of the plant.

The EE content of raw *A. saligna* seeds were in line with the study of (12.8-13.9%) (Ee and Yates, 2012) but higher than raw *A. tumida* (7.80%) and *A. colei* (11.9%) (Falade *et al.,* 2005). When compared with other legume seeds, it had higher EE content than *C. cajan* (1.67%) (Onu and Okongwu 2006), sorrel (5.50%) (Nyameh *et al*. 2012) but lower than Moringa (28.7%) (Babiker, 2012), *A. africana* (21.0%) (Ayanwale *et al.* 2007). However, it was in agreement with *D. microcarpum* (15.2%) (Obun *et al*. 2011) and *F. albida* (13.3%) (Hassen *et al*. 2007). Similarly, the roasted seeds of *A. saligna* had similar results with (13.1-15.7%) EE content (Ee and Yates 2012) but when compared with other legume seeds; it had higher EE content than roasted *C. cajan* (1.58 %) (Onu and Okongwu 2006) while it had lower than roasted *A. africana* (24.4 %) (Ayanwale *et al*. 2007). The soaked seeds of *A. saligna* had higher than soaked (8.50 %), soaked and boiled (9.00 %) sorrel seeds (Nyameh *et al*. 2012). The difference in EE content of the seeds may be due to the difference of environmental, soil type, plant type and treatment duration.

The ash content of raw *A. saligna* seeds were higher than the findings of (3.80-4.20%) (Ee and Yates 2012). This difference may be caused due to the difference in the environment and soil type where it grows. In comparison with other seeds, it had higher ash content than raw Moringa (3.44%) (Babiker 2012), *F. albidda* (3.30%) (Hassen *et al*. 2007), *D. microcarpum* (3.49 %) (Obun *et al.* 2011), *A. africana* (3.22 %) (Ayanwale *et al.* 2007) but lower than sorrel (14.5%) (Nyameh *et al*. 2012). Whereas, it was in line with *C. cajan* (5.31%) (Onu and Okongwu 2006). The roasted seeds of *A. saligna* were also higher than the findings of (4.0-4.2%) roasted (Ee and Yates 2012). In addition to this, when compared with other seeds it had higher ash content than roasted *C. cajan* (4.40%) (Onu and Okongwu 2006) and *A. africana* (3.90%) (Ayanwale *et al*. 2007) whereas, the soaked seeds of *A. saligna* was lower than soaked

(9.00%), soaked and boiled sorrel (10.5%) seeds (Nyameh *et al*. 2012). The difference in the ash content of the seed may be due to environment, soil type and treatment length.

The nitrogen free extract of raw *A. saligna* seeds were higher than the result of 32.0-33.8% (Ee and Yates 2012) whereasit had comparable results with raw *A. africana* (34.2%) (Ayanwale *et al*. 2007) and lower than raw sorrel seeds (39.5%) (Nyameh *et al*. 2012). Similarly, the roasted seeds of *A. saligna* were not far from the result of (33.3-36.4%) (Ee and Yates 2012) on the roasted Australian *A. saligna* seeds and it had a comparable result with roasted *A. africana* (32.0 %) seeds (Ayanwale *et al*. 2007). Whereas, soaked *A. saligna* seed was similar with soaked and boiled (39.9 %) but lower than soaked sorrel (42.7%) seed (Nyameh *et al*. 2012). Generally, the difference in the chemical composition of raw seeds may be due to environment, variety, soil type, season and other genetic factors.

The average tannin content of raw, soaked and roasted *A. saligna* seed was 0.525, 0.498 and 0.322 mg/g, respectively, while the average phytate content was 0.828, 0.816 and 0.132 mg/g, respectively (Table 2). Roasting of seeds reduced the tannin and phytate content by 38.7% and 84.1%, respectively as compared with raw seeds.

The phytate content of raw *A. saligna* seeds (0.828 mg/g or 0.08%) was similar to results of Ee and Yates (2012) (0.10%) but higher published results for *A. colei* (0.09 mg/g) and *A. tumida* (0.03 mg/g) (Falade *et al*. 2005). Raw *A. saligna* seeds had a higher phytate content than *D. microcarpum* (0.255 mg/g) (Obun *et al*. 2011), *C. cajan* (0.240 mg/g) (Yisa *et al*. 2010) while, soaked *A. saligna* seeds were higher than boiled *C. cajan* (0.256 mg/g) (Yisa *et al*. 2010).

The tannin content of raw *A. saligna* seeds were lower than *A. colei* (86.7 mg/g) and *A. tumida* (80.3 mg/g) (Falade *et al*. 2005) but higher than *D. microcarpum* (0.096 mg/g) (Obun *et al*. 2011) and *C. cajan* (0.021 mg/g) (Yisa *et al*. 2010). The soaked seeds of *A. saligna* had higher tannin than boiled *C. cajan* (0.020 mg/100g) (Yisa *et al*. 2010). For sorrel, roasting reduced the tannin content of seeds by 20%, while soaking reduced tannin content by 36% compared with raw seed (Nyameh *et al*. 2012). However, in the current study, roasting of *A. saligna* seed was more effective in reducing tannin as compared to sorrel seeds. In contract, soaking was most effective in reducing the tannin content of sorrel seeds compared with the soaked *A. saligna* seeds of the current findings. The difference in the anti-nutritional content of different seeds may be due to difference in plant type and seed treatment methods.

Table 2: The average tannin and phytate content of raw and treated *A. saligna* seeds

Treatment	Tannin (mg/g)	Phytate (mg/g)
Raw AS	0.525	0.828
Soaked AS	0.498	0.816
Roasted AS	0.322	0.132

AS= *Acacia saligna*, mg/g= milligram per gram

Conclusions

A. saligna seed is a potential source of crude protein and a readily available carbohydrate. However, it contains anti-nutritional factors like tannin and phytate. Roasting and soaking methods have not affected the proximate chemical composition of *A. saligna* seeds. Roasting can considerably reduce tannin and phytate contents of *A. saligna* seed. Therefore, roasted *A. saligna* seeds can be safely used as a livestock feed source. Further research is required to determine effects on those anti-nutritional contents which were not examined in this experiment (oxalate, cyanide, protease inhibitor, saponin etc).

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A sub-acute Acacia seed feeding trial investigating *Acacia saligna*, *Acacia torulosa* and *Acacia colei*

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Abstract
A 14 day sub-acute in-vivo study was conducted to investigate the safety of Australian Acacia seed as a food, and sought to confirm that djenkolic acid is an active toxin in the seed. Ten cohorts of ten rats each were used (n=100). Six cohorts were fed diets supplemented with seed of *A. colei*, *A. torulosa* or *A. saligna*, at either 30% or 60% of diet. Three cohorts were fed a standard rat chow laced with synthetic djenkolic acid at three different levels. A control was fed rat chow alone. Daily observations were made of food and water consumption, weight, and general health. At the conclusion of the trial all animals were euthanised and the liver and kidneys removed for blinded histological examination. No signs of ill health were observed and no significant association was observable between kidney abnormalities in the test cohorts and the control. The study concludes that properly processed Acacia seed at up to 50% of diet causes no health effects over a 14 day period. Further trials including a chronic (90 day) trial, and a human volunteer trial (21 days) will be necessary before Acacia seed can be considered safe for long term human consumption.

Introduction
The seed of some species of Australian Acacia have been shown to have potential as a food source in the semi-arid tropics of Africa. There are over 900 species of Acacia in Australia, and the genus is represented in virtually all ecosystem types on that continent, including semi-arid tropical regions that are climatically quite similar to those found in the Sahel. Several Australian Acacia species have performed well in agroforestry trials in Niger (Cunningham 2009, Cunningham *et al*. 2008, Rinaudo and Cunningham 2007), whilst *Acacia saligna,* with a temperate origin in the south-west of Australia, has been widely and successfully planted as a soil conservation measure in the highlands of Tigray, Ethiopia (Hagazi 2011). Acacia seed has a history of use as food by Australian indigenous people (Devitt 1992, Latz and Green 1995), and following thorough safety testing (Adewusi *et al.*2006, Adewusi *et al.*2011), *Acacia colei* has been used as a food in the Maradi region of Niger for over fifteen years. Acacia seed contains between 18 and 27% crude protein, and is relatively rich in the amino acid lysine, making it an excellent complement to many predominantly cereal diets consumed by the African rural poor (Falade and Adewusi 2013, Harwood *et al.*1999, Adewusi *et al.*2011, Ee and Yates 2013, Yates 2014).

An investigation of the potential of *Acacia saligna* to contribute to the diet of the rural poor in Tigray led the Ethiopian Ministry of Health to conduct a routine animal feeding trial on that seed. Unpublished reports indicated the prescence of a toxin in the unprocessed seed, and a follow-up trial indicated that though certain processing methods could ameliorate the effects, toxicity levels remained unacceptable (unpublished data, Ethiopian Government).

In an effort to identify the toxin, *Acacia saligna* seed was analysed for both cyanide and fluoroacetate by the University of Melbourne, the former occurring at negligible levels, whilst the latter was found to be entirely absent (Yates 2014). A screen for toxic and antinutritional amines showed levels of djenkolic acid sufficient to explain the toxicity observed in the Ethiopian laboratory (Boughton 2015). Further testing revealed that djenkolic acid in Acacia seed can be reduced by over 90% by dry roasting at 180°C for between 6 and 10 minutes depending upon species (Boughton 2015).

In order that Acacia seed be developed as a food in that country, the Ethiopian Ministry of Health, through the Ethiopian Public Health Institute (EPHI) requires a multi-stage toxicity testing process. This process is boadly in line with internationally recognised standards (Sphere Project 2011), and involves an acute or sub-acute trial, a chronic trial run over 60-90 days, and finally a human volunteer trial.

This paper describes the design, conduct and results of a sub-acute Acacia seed feeding trial conducted on behalf of the author by the Florey Institute for Neuroscience and Mental Health, in Melbourne, Australia in June and July 2013, with the aim to determine the safety of processed Acacia seed of three species as food over a 14 day exposure with particular reference to djenkolic acid. Ethics approval was granted by the Florey Institute's Animal Ethics Committee. Our objectives were:

1. To feed groups of rats diets supplemented with processed Acacia seed of three species at varying levels for 14 days and to observe a range of health indicators and at completion, to examine the kidney and liver of the animals to ascertain the health impacts of the feeds at a cellular level.
2. To feed groups of rats a diet supplemented with quantities of synthetic djenkolic acid similar to what would be found in acacia seed diets, but with no acacia seed included for 14 days, and to observe a range of health indicators and at completion, to examine the kidney and liver of the animals to ascertain the health impacts of the feeds at a cellular level.

Materials and Methods

Design

The Acacia species investigated were *A. colei, A. torulosa* and *A. saligna*. Ten cohorts of ten rats (n=100) were fed ad libitum, as follows:

1. Control 100% normal rat chow (Barastock).
2. Feed comprised of 60% *A. saligna* and 40% rat chow.
3. Feed comprised of 30% *A. saligna* and 70% rat chow.
4. Feed comprised of 60% *A. colei* and 40% rat chow.
5. Feed comprised of 30% *A. colei* and 70% rat chow.
6. Feed comprised of 60% *A. torulosa* and 40% rat chow.
7. Feed comprised of 30% *A. torulosa* and 70% rat chow.
8. Feed 100% rat chow supplemented with 378mg djenkolic acid /100g feed offered.
9. Feed 100% rat chow supplemented with 302.4mg djenkolic acid /100g feed offered.
10. Feed 100% rat chow supplemented with 226.8mg djenkolic acid /100g feed offered.

Feed preparation

For the Acacia seed feeds, seed was roasted at 180°C for 6 minutes in (*A. colei* and *A. torulosa*). *Acacia saligna* seed was roasted for 10 minutes at 180°C in line with the djenkolic acid reduction data obtained by Boughton (2015).

After roasting, the seed was allowed to cool to room temperature after which it was ground in a hand operated roller mill. The seed husk was then removed, first by sieving to remove the larger husk particles, and then by winnowing. It is estimated that between 20-30% of the husk could not be efficiently removed. The removed husks accounted for around 25% of the total seed weight.

The Acacia seed needed to be thoroughly mixed with the rat chow so that animals were unable to selectively accept or avoid the Acacia seed in the feeds since this could confound the toxin exposure data. For this reason, the rat chow was ground in the roller mill, moistened, and measured amounts of seed were added and the mix was kneaded into a pliable dough.

The mix was then extruded through a hand operated food mill to form pellets which were dried in a food dehydrator at 40°C for 12-15 hours.

Djenkolic acid feeds

Djenkolic acid feed doses were calculated in reference to the feed measured as containing the highest level of djenkolic acid. This was the *A. saligna* feed given at 60% of diet, which contained 302.4 mg of djenkolic acid/100g of feed. One feed was produced that contained 25% more, at 378 mg/100g feed, and one that contained 25% less, with 226.8 mg/100g feed.

Preparing the feeds

Standard rat chow was ground to a powder. Measured quantities of djenkolic acid were dissolved or suspended in lukewarm water and mixed thoroughly into the ground rat chow. Water was added to make a pliable dough, and the mix was extruded through a hand operated food mill to form pellets, which were dried in a food dehydrator at 40°C for 12-15 hours.

Animal handling and observations

Feed and water taken by each cohort was recorded, and each animal was weighed daily. All animals were handled daily and observed for signs of ill-health or depression. This involved subjective assessments of each animal's responsiveness, activity levels, coat condition and general demeanour by an experienced animal handler. Feed was taken with gusto by all cohorts. No adverse observations were recorded. Bodyweight data was analysed using a two-way ANOVA with repeated measures to examine differences between the control group and the other treatment groups

Results

Bodyweight observations

While the results showed a significant main effect of factors, Treatment ($F(9,90) = 8.8$; $p = 0.0001$) and Day ($F(13,1170) = 143.8$; $p = 0.0001$), a Bonferroni test for multiple comparisons revealed that significant differences in bodyweight were only found between the control group and the rats given the *colei* species at 30% ($p = 0.004$) or 60% ($p = 0.044$) (Figure 1). These data show that the control rats started at a higher bodyweight and steadily maintained this difference throughout the testing period (Figure 1).

A Bonferroni test of multiple comparisons within treatment groups showed steady increases in bodyweight across the 14 days for the control, *colei* 30%, *colei* 60%, *torulosa* 30%, Djenkolic < *saligna* 60%, Djenkolic = *saligna* 60% and Djenkolic > *saligna* 60% groups (Figure 1). While bodyweight in the remaining groups was maintained throughout the 14 days of treatment it did not increase significantly in rats fed *torulosa* 60%, *saligna* 30% or 60% (Figure 1).

Feed consumption observations

A repeated measures ANOVA showed that there was a significant main effect of Treatment ($F(9,90) = 6.3$; $p = 0.0001$) and Day ($F(13,1170) = 14.5$; $p = 0.0001$) for food consumption. A Bonferroni correction for multiple comparisons revealed that the *colei* 30% and 60% groups and the djenkolic < *saligna* 60% group consumed significantly less food than the control group (*colei* 30%: $p = 0.004$; *colei* 60%: $p = 0.032$; djenkolic < *saligna* 60%: $p = 0.025$). The data show that despite differences in food consumption between controls and the aforementioned groups, within treatment groups there is a trend for food consumption to increase toward levels seen in controls during the last few days of testing (Control vs *colei* 60%- Day 11: $p = 0.17$, Day 12: $p = 0.23$, Day 13: $p = 0.06$, Day 14: $p = 0.07$; Control vs *colei* 30%- Day 12: $p = 0.55$, Day 13: $p = 0.33$, Day 14: $p = 0.88$; Figure 2A). A similar trend was recorded in rats from the Djenkolic < *saligna* 60% group compared with control animals (Control vs Djenkolic < *saligna* 60% - Day 11: $p = 0.06$, Day 12: $p = 0.96$, Day 13: $p = 0.44$, Day 14: $p = 0.11$; Figure 2D).

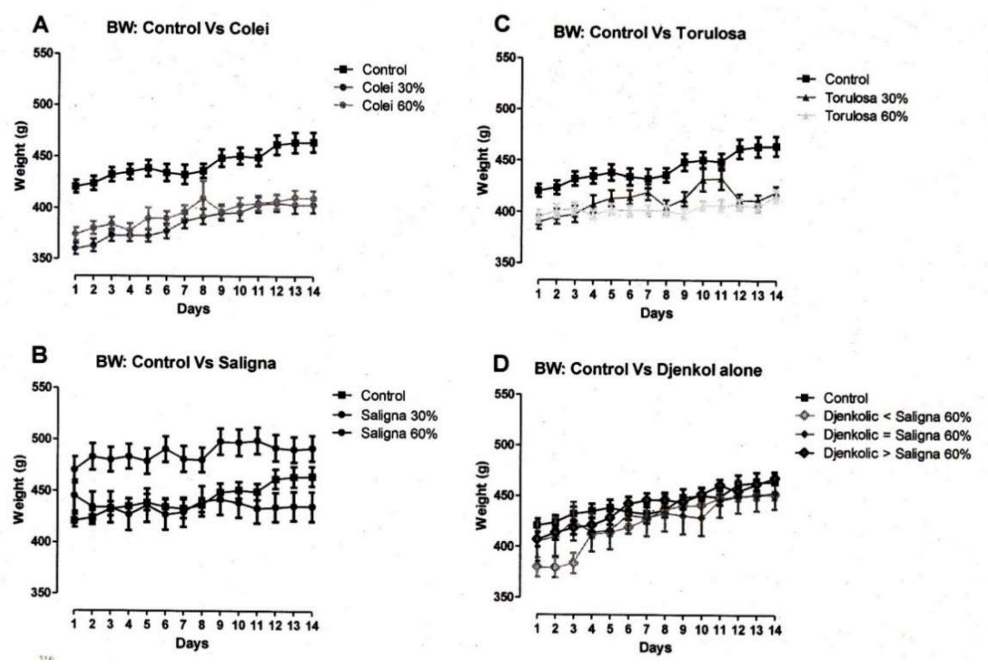

Figure 1: Assessment of rat's bodyweight over 14 days. A = Control feed versus *A. colei* at 30 and 60%; B = Control feed versus *A. saligna* at 30 and 60%; C = Control feed versus *A. torulosa* at 30 and 60%; D = Control feed versus Djenkolic acid fed at an equivalent rate of 25% below, equal to, or 25% above the acid content found in *A. saligna* at 60%. Data is shown as mean ± SEM. Each group contains n=10.

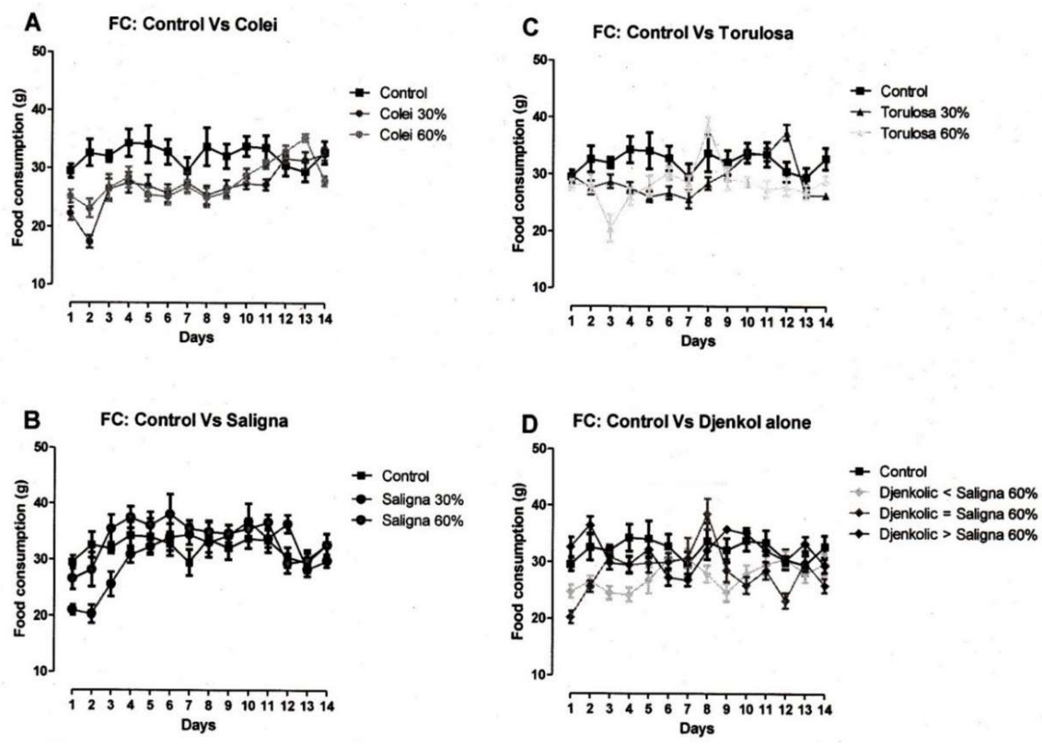

Figure 2. Assessment of food consumption by rates over 14 days. A = Control feed versus *A. colei* at 30 and 60%; B = Control feed versus *A. saligna* at 30 and 60%; C = Control feed versus *A. torulosa* at 30 and 60%; D = Control feed versus Djenkolic acid fed at an equivalent rate of 25% below, equal to, or 25% above the acid content found in the *A. saligna* at 60%. Data is shown as mean ± SEM. Each group contains n=10.

Most treatment groups displayed either stable or increasing food consumption across the treatment period (Figure 2). The control, *torulosa* 30% and Djenkolic > *saligna* 60% groups maintained an average food consumption of 32g ± 1.8g, 28g ± 3.7g.

Water consumption observations

A repeated measures ANOVA showed that there was a significant main effect of treatment (F (9,90) = 3.6; $p = 0.001$) and day (F (13,1170) = 13.6; $p = 0.0001$) for water consumption. A Bonferroni correction for multiple comparisons revealed significant differences between rats fed *colei* 30% versus *torulosa* 30% ($p = 0.018$), *torulosa* 60% ($p = 0.016$) and the djenkolic > *saligna* 60% group ($p = 0.004$). The aforementioned groups all recorded significantly greater levels of average water consumption than the colei 30% group across the 14 day treatment period i.e. 20% greater in *torulosa* 30% and *torulosa* 60%, and 23% greater in the djenkolic > *saligna* 60% group (Figure 3). Of particular note is the fact that none of the treatment groups were statistically different to control rats for water consumption.

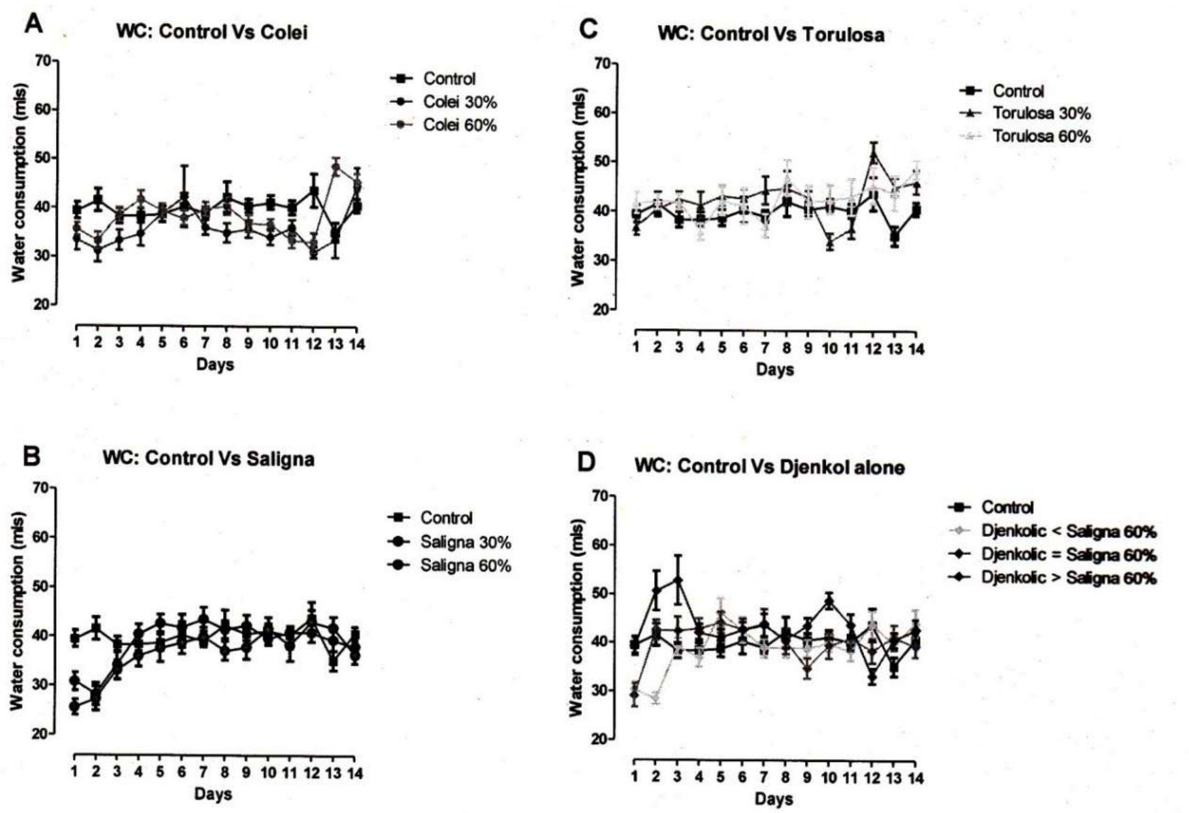

Figure 3. Assessment of water consumption by rates over 14 days. A = Control feed versus *A. colei* at 30 and 60%; B = Control feed versus *A. saligna* at 30 and 60%; C = Control feed versus *A. torulosa* at 30 and 60%; D = Control feed versus Djenkolic acid at an equivalent rate of 25% below, equal to, or 25% above the acid content found in the *A. saligna* at 60%. Data is shown as mean ± SEM. Each group contains n=10.

Histological examination

Rat (n = 100) kidneys and liver lobes fixed in 10% neutral buffered formalin were processed for paraffin embedding, sectioning and haematoxylin and eosin, and PAS (Periodic Acid Schiff) staining. Macroscopically, all submitted samples were unremarkable. Examination of sections, initially conducted blind with regard to cohort groups, demonstrated normal structure with only some minor, focal changes observed in the kidney samples. All liver sections examined demonstrated normal morphology with no areas of inflammation, fatty change, cell vacuolation or parenchymal scarring.

Abnormalities found in the kidneys were considered to be minor, localised and not indicative of toxicity or acute disease. It is likely that many of the lesions observed, particularly those involving scarring in fact pre-existed the trial. Though a relationship between djenkolic acid content of the feeds received and the number of kidney lesions observed appears to exist, this can be discounted since the number of lesions in the control group is in the upper range (5-8) for the high djenkolic acid diets. Far from showing that djenkolic acid causes kidney abnormalities, it could be postulated that low doses of acacia seed and djenkolic acid might actually be protective of the kidney.

Table 1. Number of liver and kidney abnormalities detected for each cohort (n=100).

Cohort feed	Total liver abnormalities detected	Total kidney abnormalities detected
A. colei 30%	0	3
A. colei 60%	0	7
A. torulosa 30%	0	3
A. torulosa 60%	0	7
A. saligna 30%	0	4
A. saligna 60%0	0	8
Djenkolic acid (378 mg/100g)	0	8
Djenkolic acid (302.4mg/100g)	0	5
Djenkolic acid (226.8mg/100g)	0	3
Control	0	6

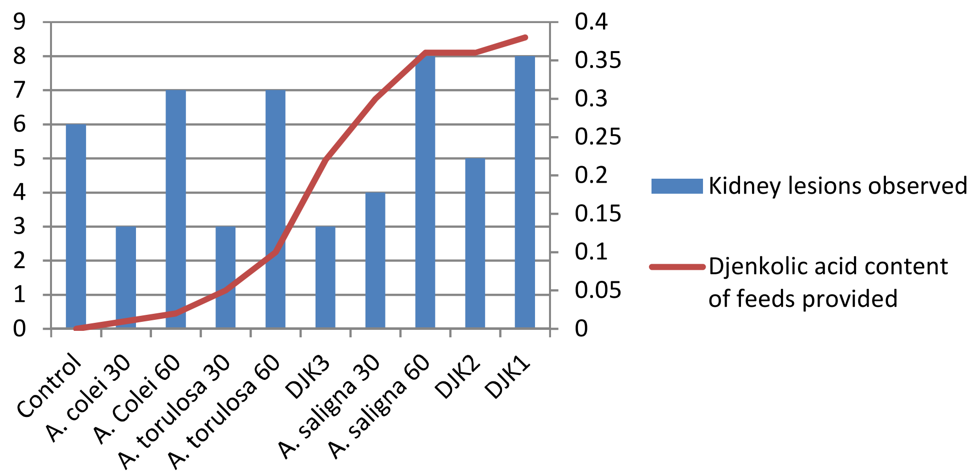

Figure 4. Number of kidney lesions observed compared to djenkolic acid content of feed provided to rats; cohorts are presented in ascending order of djenkolic acid content.

Discussion

This study was designed to expose the subject animals to high levels of Acacia seed, and the presumed toxin found in that seed, djenkolic acid. Of the cohorts fed Acacia seed supplemented diets, those that received 60% *A. saligna* in their diet had the highest levels of djenkolic acid exposure. Assuming a food intake of around 25 g/day, individuals would be consuming 75 mg of djenkolic acid per day. Assuming bodyweights averaging 450 g, this amounts to an exposure of 166 mg/kg of body weight per day. Translated to a human scale, and assuming a body weight of 70 kg, this is equivalent to a person eating 11,600 mg of djenkolic acid per day. Such an amount could be obtained from Acacia seed by eating 630 g of raw *A. saligna* seed, or an unlikely 9.6 kg of appropriately processed (ie. roasted) *A. saligna* seed. For other seed species, the requirements would be even higher.

Exposure to a variety of Acacia – or djenkolic acid alone – supplemented feeds in rats, each with different concentrations of djenkolic acid, had little to no detectable impacts on the body weight and water consumption or liver and kidney tissue architecture, relative to rats fed control feed for 14 days under the parameters of the current study. While the results show rats from the *colei* 30 and 60% groups as well as the djenkolic acid < *saligna* 60% group consumed significantly less food initially, these groups increased their daily food consumption as the trial progressed to levels not significantly different from controls. While a previous study by Shukri *et al.*(2011) found that another djenkolic acid-containing food, the Jering bean, produced an increase in food consumption above control fed rats; this could be due to differences in palatability of the Jering bean formulation used in that study compared with the Acacia seed formulation used in the present study. In addition, and perhaps more likely, differences in food consumption in the present study may relate to rats from the control group being, on average, larger in weight than both the *colei* 30% and 60% groups throughout the study, and therefore consuming less food on average. This behavioural pattern has been observed previously by Thomas *et al*. (2002) and show that rats weighing less (average 239g ± 3g) consume significantly less food than heavier rats (average 479g ± 5g).

While significant differences in bodyweight were detected, in particular, between significantly heavier control rats compared with rats fed *colei* at 30% and 60%; this is primarily due to the fact that rats fed the *A*. *colei* strain began the feeding trial significantly lighter in weight than the control group. Importantly, these animals maintained a steady increase in bodyweight across the 14 days of treatment at much the same rate as controls. Of the 9 different treatment groups constituting varying levels of djenkolic acid, none of them recorded a significant difference in water consumption from the control group. However there were some significant differences between groups, more specifically, the djenkolic > *saligna* 60% group, the *torulosa* 30% and 60% groups all recording significantly greater levels of average water consumption compared with rats fed colei 30% over the 14 day treatment period. The reason for the difference between these groups is not clear; however, it may be better understood in context with a longitudinal study that probes the impact of chronic exposure extending to 3-4 months. A previous study investigating the impact of the djenkolic acid-containing Jering bean, found significant increases in necrotic cells in the heart, kidney, pancreas and liver after 15 weeks of exposure (Shukri *et al.*2011). Although histological observations provided no evidence of necrosis in either the kidney or liver in the current study, the possibility of damage to the kidney after a more pronounced period of exposure should not be ruled out. It should be noted that Shukri *et al.* (2011) merely ground the Jering bean preparation as opposed to the roasted formulation of Acacia seeds in the present study to reduce the concentration of djenkolic acid. As such, the exposure to djenkolic acid in Shukri et al. (2011) is certainly at a higher concentration than the current study. Nonetheless, extended periods of exposure similar to that used by Shukri *et al.* (2011) would provide clarity around the impact of long-term exposure.

In addition to an extended period of exposure to the Acacia species tested in the current study, it would also be prudent to investigate levels of urea and creatinine in the blood and urine (Wannapuk *et al.* 2014). Damage to the filtration units of the kidney, or nephrons, will result in an inability to clear these waste products, resulting in increased circulating levels in the blood.

Conclusion

While prolonged exposure studies are still required to further characterise the impact of chronic Acacia seed supplementation in the rat diet, compared with control rats, it would appear that after 14 days of exposure to the various Acacia seed species at 30% and 60% of the rat diet, and djenkolic acid supplementation in rat chow alone at levels 25% higher, equal to, or 25% lower than that found in the *Acacia saligna* 60% group, there was little to no impact on bodyweight, food and water consumption, or liver and kidney tissue architecture.

Further trials are recommended to ascertain the safety of acacia seed for human consumption. These are:

1. A chronic feeding trial (90 days) to determine long term effects (acacia feed range 40-60%),
2. A 14-day toxin tolerance trial, feeding rats' acacia seed at 10, 20, 30, 40….80% of diet. Animals to be removed for examination if/when signs of ill health are apparent. Objective is to find safe consumption level.
3. Human volunteer trials for all species successfully passing feeding trials.

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Effect of feeding whole *Acacia saligna* seed meal on broilers

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Abstract
The experiment was conducted to determine the productive performance and carcass characteristics of broilers fed graded raw *Acacia saligna* seed meal. A total of 132 Cobb500 unsexed day-old broiler chicks were used for the experiment. The chicks were randomly allocated to four dietary treatments containing 0%, 5%, 10% and 15% raw *A. saligna* seed meal (referred to as T1-T4 respectively). A completely randomized design (CRD) with three replications was used and 33 chicks were allocated for each treatment. The daily dry matter intake showed significant difference ($P<0.05$) between treatments in the starter, finisher and entire period which was higher in chicks fed T2 (66.03 g/chick) and T1 (65.02 g/chick) but lowest for T3 (40.73 g/chick) and T4 (45.54 g/chick) in the entire period. Similarly, the feed conversion ratio (FCR) in the starter, finisher and overall experimental period; final body weight, body weight change and daily weight gain in the starter phase showed significant ($P<0.05$) difference among treatments. The highest FCR was recorded for T3 (0.35) while the lowest was for T2 (0.25). However, there was no significant difference ($P>0.05$) between treatments in the daily weight gain, final body weight, body weight change and carcass parameters in finisher and entire period. Therefore, it can be concluded that raw *A. saligna* seed meal can be incorporated up to 5% level in the diet of broilers for better growth performance and carcass characteristics.

Keywords: Dry matter intake, feed conversion ratio, raw, weight gain.

Introduction
In Ethiopia, the main feed sources for the village chicken, obtained by scavenging, includes household wastes, cereals and their by-products, pulses, roots and tubers, oilseeds and shrubs (Tadelle 1996). According to Solomon (1996), the quality of cereal grain which constitutes the poultry feed is very poor. Shortages of protein and micro-nutrients, which are important ingredients in poultry rations, leads to low production and productivity. The main reason for low productivity of poultry production systems in Ethiopia is the poor feeding system (Alemu 1995; Alemu and Tadelle 1997). Feed costs account for two-thirds of the total cost of poultry production for egg and meat (James 1992; Solomon 2008). However, smallholder farmers and small-scale producers from different corners of the country have limited access to formulated rations. Though some poultry producers can purchase formulated feed, its high cost and transportation expenses have hindered the development of the sector. The demand for animal protein sources is increasing over time. Hence, to make cheap animal protein sources affordable for most people, poultry production costs should be minimized. Thus, it is necessary to formulate balanced poultry rations from locally available and non-conventional feed resources such as *Acacia saligna* seed.

In Tigray region, *A. saligna* is a multipurpose, evergreen and drought-resistant fodder tree introduced in the 1980s for environmental rehabilitation, soil and water conservation of gullies, and homesteads. The tree produces seeds twice per year even during drought and is found in most exclosure areas in the region. Seeds of *A. saligna* were reported to be eaten by poultry (Simons 2007), and the seeds have also been used as human food mixed with other food cereals such as wheat (Maslin *et al*. 1998). According to Ee and Yates (2012), whole wattle seeds of *A. saligna* were found to mainly contain proteins (27.6-32.6%) and carbohydrates (30.2-36.4%), which had approximately 12-14% fat and 13-15% crude fiber. The seeds also contained phenolic acid (0.2%), oxalate (2.2-3.4%) and saponin (2.6-3%) in fairly high levels, but phytate content was low; seeds also contained a high level of trypsin inhibitor. However, the seed was not tested as chicken feed. Therefore, this study was designed to evaluate the effect of feeding raw *A. saligna* seed meal on the growth and carcass characteristics of chick.

Materials and Methods

Study area

The experiment was conducted at the Mekelle University poultry farm, located 783 km north of Addis Ababa, at an altitude of 2250 meters above sea level (13°28'N, 39°29'E). The average annual rainfall is 680 mm and average maximum and minimum temperatures are 26.4 and 8.2°C, respectively.

Experimental ration and treatments

The feed ingredients were maize, *A. saligna* seed, wheat middlings, Noug seed cake (*Guizotia abyssinica*), vitamin premix, salt, limestone, and methionine. *A. saligna* seeds were collected from the surroundings of Mekelle city. The acacia seeds, maize and Noug seed cake were ground to pass a 5 mm sieve size and sent for laboratory compositional analysis which was used for ration formulation. Experimental treatments consisted of different levels of raw *Acacia* seed including: control (C) or 0% *Acacia* (T1), 95% C + 5% *Acacia* (T2), 90 % C + 10% *Acacia* (T3), and 85% C + 15% *Acacia* (T4), were formulated to be nearly iso-caloric and iso-nitrogenous with Metabolizable Energy (ME) content of 12.97 MJ/kg DM and 22% CP for starter phase (1 to 28 days of age), and ME content of 13.39 MJ/kg DM and 19-20% CP for finisher phase (29 to 49 days of age) was formulated using Win feed 2.8 software. The ME of the experimental diets was determined by indirect methods, according to Wiseman (1987) as follows: ME (Kcal/kg DM) = 3951 + 54.4EE - 88.7CF – 40.8Ash.

Table 1: Diet composition of broilers (1-49 days of age)

Ingredients	Starter diet (1-28 days age)				Finisher diet (29-49 days age)			
	T1	T2	T3	T4	T1	T2	T3	T4
Acacia seed	0	5	10	15	0	5	10	15
Wheat md	21.3	16.3	10.3	9.26	23.2	8.21	8.21	8.21
Noug cake	38	38	37	34	30	33	31	30
Maize	37	37	39	38	44	51	48	44
Limestone	1.2	1.2	1.2	1.2	0.8	0.8	0.8	0.8
Salt	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
Vitamin pre	1	1	1	1	0.7	0.7	0.7	0.7
Lysine	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6
Methionine	0.34	0.34	0.34	0.34	0.29	0.29	0.29	0.29
Total (Kg)	100	100	100	100	100	100	100	100
ME	12.97	12.98	13	13.09	13.67	13.57	13.54	13.42
CP %	22	22	22	22	19	19	19.8	19

T= treatment, kg= kilogram, ME= metabolizable energy (MJ/kg DM), MJ= Mega joule, CP= crude protein.

Management of experimental animals

One hundred and thirty-two unsexed day-old Cobb500 broiler chicks with initial body weight of 36.93 ± 0.38 g (mean ± SD) were randomly divided into four dietary treatments with three replications per treatment in a completely randomized design having eleven chicks per pen with the size of 1m x 1.5m. The chicks were vaccinated against Newcastle Disease (HB1 at day 7 with eye drop and Lasota with drinking water at day 21) and Infectious Bursal Disease (Gumboro) at the age of 14 days with drinking water. The house was disinfected with potassium permanganate and formaldehyde two months before the commencement of the experiment. Chicks were given access to a 250-watt heat source, *ad libitum* feed and water in the pen, which contained deep litter covered by wheat straw.

Measurements
The amount of feed offered and refused per pen was recorded daily. Feed intake was determined as the difference between the feed offered and refused. Chicks were weighed weekly as a group per pen and pen average was calculated. Body Weight (BW) change was calculated as the difference between the final and initial BW. Average daily BW gain (ADG) was calculated as the ratio of BW change to the number of experimental days. Feed conversion ratio (FCR) was the ratio of ADG to daily DM consumption.

Carcass parameters and dressing percentage
For determining the carcass parameters, chicks were starved for 12 hrs prior to slaughtering. A total of three chicks were randomly selected and slaughtered from each treatment. Carcass weight measurements were done after de-feathering and removal of feet, head and non-edible viscera. Hot carcass dressing percentage was then calculated by dividing the hot carcass weight by the live body weight of the chicks.

Proximate analysis
Seed samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash (AOAC 2005). Phytate was determined using the method of Reddy and Love (1999) and tannin was determined using the method of Trese and Evans (1978).

Data analysis procedures
The collected data were analyzed using GMP5 software. One-way Analysis of variance (ANOVA) was used to compare the treatment means of the group and significant differences among treatments were determined using the students t-test at 5% significant (P=0.05). The following model was used for the experiment (Gomez and Gomez 1984).
$Yij = \mu + Ti + eij$, where Yij = Overall Responses, μ = overall mean, Ti = i^{th} treatment effect of feeding level (1, 2,…. 4) and eij = random error effect.

Results
Chemical composition of feed ingredients
The chemical compositions of feed ingredients used in the experiment are presented in Table 2. The results showed that there was similar DM content in each of the ingredients. Crude protein ranged from a minimum of 7.43% in maize to 34% in nouge cake. The ME of raw *A. saligna* seed meal was lower compared to maize or wheat middlings but had a higher EE and CF % than the other ingredients except noug cake.

Table 2: Proximate composition of experimental diets fed to broilers

Ingredients	DM (%)	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	ME	Tannin (mg/g)	Phytate (mg/g)
Maize	89.74	7.43	5.09	2.79	83.19	1.5	16.40		
Noug cake	91.94	34	7.09	21.93	27.9	9.08	8.45		
Wheat Middlings	86.76	15.17	3.26	3.69	74.83	3.05	15.38		
Raw acacia	90.83	28.16	15.51	14.43	36.8	5.1	13.83	0.53	0.83

DM= dry matter, CP= crude protein, EE= ether extract, CF= crude fiber, NFE= nitrogen free extract, ME= metabolizable energy (MJ/kg DM)

Dry matter intake and body weight change
The average DMI, BW change, daily gain and FCR performances of chicks are presented in Table 3. The DMI and FCR showed significant difference (P<0.05) in the starter, finisher and entire experimental

period. Similarly, there was a significant difference (*P*<0.05) in final BW, BW change and daily gain among chicks in the starter phase, whereas, there was no significant difference (*P*>0.05) in the finisher and entire experimental period.

Table 3: Average dry matter intake (DMI), body weight change (BWC), average daily gain (ADG), and feed conversion efficiency (FCE) of broilers fed *A. saligna* seed meal based diets

Parameters	T1	T2	T3	T4	LSD (5%)
DMI (g/chick)					
Starter	39.15^{a}	39.75^{a}	32.76^{b}	31.32^{b}	0.007
Finisher	99.52 ^{a}	101.08 ^{a}	51.37 ^{b}	64.49 ^{b}	0.01
Entire period	65.02^{a}	66.03^{a}	40.73^{b}	45.54^{b}	0.003
IBW (g/chick)					
Day old	36.9	36.94	36.9	36.9	1.0
FBW (g/chick)					
Starter	403.00^{a}	373.60^{a}	306.70^{b}	311.67^{b}	0.005
Finisher	861.5	830.77	743.33	743.5	0.384
BWC (g/chick)					
Starter	366.10^{a}	336.66^{a}	269.80^{b}	274.77^{b}	0.005
Finisher	458.5	457.17	436.63	431.83	0.981
Entire period	824.6	793.82	706.43	706.6	0.384
ADG (g/chick)					
Starter	13.08^{a}	12.02^{a}	9.64^{b}	9.81^{b}	0.005
Finisher	21.83	21.77	20.79	20.56	0.384
Entire period	16.83	16.20	14.42	14.42	0.384
FCR					
Starter	0.33^{a}	0.30^{ab}	0.29^{b}	0.31^{ab}	0.01
Finisher	0.23b^{c}	0.22^{c}	0.39^{a}	0.32 ^{ab}	0.01
Entire period	0.26b^{c}	0.25^{c}	0.35^{a}	0.32^{ab}	0.025

Rows not connected by same letter are significantly different at P<0.05, DMI= dry matter intake, IBW= initial body weight, FBW= final body weight, BWC= body weight change, ADG= average daily gain, FCR= feed conversion ratio, T= treatment.

Carcass parameters of broilers

The results showed no significant variation (P<0.05) between treatments for any of the carcass parameters (Table 4).

Table 4: Carcass parameters (g) of broilers fed raw and treated *A. saligna* seed meal based diets

Parameters	Treatments				P<0.05
	T1	T2	T3	T4	
Live Wt.	814	997	783.67	877.33	NS
Head	32.33	34	27.67	33.67	NS
Feather	39.67	43.67	44.67	40.67	NS
Skin	46.67	62	44.67	58	NS
Neck	25.67	34.33	23.67	27.67	NS
Feet	53.33	51.33	41.67	46.33	NS
Wing	32.67	43	29.67	35.33	NS
Thigh	75.33	97.33	70.67	81.67	NS
Drumstick	74.67	94.33	70.67	81	NS
Breast	181	223.67	172.33	194.67	NS
Heart	8.33	8.33	6.0	6.67	NS
Liver	21.33	28	19.67	21	NS
Gizzard	19.33	21.33	18.67	21.67	NS
Tail	4.33	5	3.67	4.33	NS

Gut	41.33	47.67	40.67	44.33	NS
Blood	35	42	34.67	36.67	NS
Crop and pro-ventriculos	16.33	17.67	15.33	16.67	NS
Back	58.67	77.67	53.33	63.67	NS
Carcass wt.	448	570.33	420.33	484	NS
Adjust carcass wt.	543.67	690	509.33	591.33	NS
Dressing %	66.75	69.26	64.99	67.24	NS
Lost wt.	48	65.67	66	63.33	NS

Discussion
The result showed that the ME of raw *A. saligna* seed meal was low compared to maize; whereas, the CP, EE and CF % were high compared to maize and wheat middlings. *A. saligna* seed has comparable CP content with the most commonly used oil cake in Ethiopia, noug seed cake, which indicates that it can be used as both energy and protein sources in poultry ration. The raw *A. saligna* seed meal had similar DM, CP, EE and CF content with the findings of Ee and Yates (2012). The higher CF than maize and wheat middlings may limit the DM intake of the seed. Tannin content was low compared to *A. colei* (86.7 mg/g), *A. tumida* (80.3 mg/g) while the phytate contents were higher than *A. colei* (0.09 mg/g) and *A. tumida* (0.03 mg/g) (Falade *et al.* 2005). However, phytate content was similar to the results of Ee and Yates (2012). The highest DMI was recorded in chicks fed T2 and T1 while the lowest was recorded by T3 and T4. This may indicate that there are anti-nutritional factors that have limited the intake by chicks of these diets. This finding was similar to the report of Obun *et al.* (2011), who found that as the level of raw seed meal increases, the dry matter intake decreases. Duwa *et al.* (2012) and Onu and Okongwu (2006) reported that chicks fed raw roselle (*Hibiscus sabdariffa*) and pigeonpea (*Cajanus cajan*) seed meal during the starter phase performed better than this study result (DMI of 69.45 g/chick and 55.48 g/chick respectively), which might be due to variations in the palatability of the feed and breed of the chicks used. However, DMI in this study was comparable with performance of chicks fed *A. africana* seed meal (37.60- 41.85 g/chick) (Ayanwale *et al.* 2007) and chicks fed cassava root chips (33.83-37.06 g/chick) (Etalem *et al.* 2012). In this starter phase, chicks fed a 5% diet of raw *A. saligna* seeds had a comparable DMI with the control, which implies that the seed can be an alternative ingredient in the starter broiler ration.

In the finisher phase, the DMI was highest in chicks fed T2 and T1 while the lowest was recorded in chicks fed T3 and T4. Chicks in the current study overall had a lower DMI than chicks fed *H. sabdariffa* (120.72-145.14 g/chick) (Duwa *et al*., 2012) while the performance observed in chicks fed 5% *A. saligna* seed meal and control was similar to the findings of Etalem *et al.* (2012) in which chicks fed on cassava root chips (85.58-96.01 g/chick). This difference might be due to variation in the palatability of the feed.

In the entire experimental period, the overall mean DMI was highest for chicks fed T2 and T1 while the lowest was recorded for chicks fed T3 and T4. The DMI of the chicks was lower than the report of 94.78-105.26 g/chick by Duwa *et al.* (2012), while the chicks fed on T1 and T2 performed similar DDMI with chicks fed on cassava root chips (61.34-66.83 g/chick) (Etalem *et al.* 2012). This was also in line with the findings of Onu and Okongwu (2006), in which the higher feed intake of chicks fed raw pigeon pea seed meal indicates that the chicks needed to meet their nutrient requirements from the diet despite it containing anti-metabolites. Similarly, it was also in agreement with the study of Obun *et al.* (2011) on feeding raw *Detarium microcarpum* seed meal and feeding raw jack bean-based diets (Ologhobo *et al.* 1993), stating that as the level of raw seed meal in the ration increases, DMI decreases. The same argument can explain in this study for the decreased DMI with increasing inclusion level. With regard to the effect of tannin and phytate, the result of this study was below the maximum dietary tannin and phytate level stated by Kumar *et al.* (2007) to be 16 g/kg of dietary tannin, which had no effect on N, Ca and P retention. Similarly, Begovic *et al.* (1978) stated that the maximum dietary level that poultry can tolerate is 1%. A diet of 1-6% phytate over a long period reduced the bioavailability of mineral elements in monogastric animals (Oke 1969).

In the starter phase, there was significant ($P<0.05$) difference among chicks fed T1/T2 and T3/T4 in the final body weight, weight change, ADG and FCR, but no significant ($P>0.05$) difference among chicks fed T1 and T2 or T3 and T4. The highest FCR, suggested a low amount of feed is required per body weight gain, was observed in chicks fed T1 while the lowest was recorded in chicks fed T3. However, there was no significant ($P>0.05$) difference among chicks fed T1, T2 and T4 in FCR. or the T1 feed is comparatively higher in nutrition, more digestible, and provides more available nutrientswhereas T3 diet would require a high amount of feed is required per body weight gain. This study was in line with Ayanwale *et al*. (2007), who found for broilers fed raw *A. africana* seed meal significantly reduced daily weight gain (DWG) compared to the control in the starter phase. Broilers in this study had a lower DWG than the findings of Onu and Okongwu (2006) (17.17 - 23.73 g/chick), Ayanwale *et al*. (2007) (19.66 - 20.63 g/chick) and Etalem *et al.* (2012) (15.62 - 17.03 g/chick). The poor performance of the chicks compared to other reports might be related to the effect of cool environmental temperatures (Wideman 1988), feed form, anti-nutrient content, and breed difference.

In the finisher phase, there was significant ($P<0.05$) difference on FCR but there was no significant ($P>0.05$) difference among all treatments in the FBW, BW change, and DWG. However, there was significant ($P<0.05$) difference in FCR among chicks fed T1, T2, and T3/T4, but there was no significant ($P>0.05$) difference among T3 and T4. The highest FCR was recorded by T3 whereas, the lowest was recorded by T2 and T1 (Table 3). This was similar with the findings of Onu and Okongwu (2006) who found that the increased dry matter intake of chicks which did not result in increased weight gain might be to fulfill the nutrient requirement of the chicks or might be related to ascites (Wideman 1988). Similarly, according to Onu and Okongwu (2006), the superior FCR of chicks suggested that there are enhanced availability, digestion, absorption and utilization of the nutrients in the diet.

During the entire experimental period, there was no significant ($P>0.05$) difference among treatments on FBW, BW change and DWG of chicks. However, there was significant ($P<0.05$) difference of the treatment effect on the FCR. Hence, the highest FCR was observed in chicks fed T3 but the lowest was recorded by T2 and T1 (Table 3). This study agrees with Onu and Okongwu (2006) and Wideman (1988). However, it was not in agreement on the BWG studied by Obun *et al.* (2011) and Hassan *et al.* (2013). There was also no significant difference on the carcass characteristics of the chicken implying that it can be used as broiler feed without any adverse effect on the carcass of broilers.

In conclusion, this study confirms that *A. saligna* seed meal is a significant source of crude protein and energy for broilers, and raw *A. saligna* seed meal can be incorporated at a level of up to 5% in their diet.

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SECTION D: VALUE OF *ACACIA SALIGNA* IN BEEKEEPING SYSTEMS

Acacia saligna effects on beekeeping and the importance of bees to seed yield and quality

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Abstract
Ethiopia's climatic and edaphic variability have endowed this country with diverse and unique flowering plants thus making it highly suitable for sustaining large numbers of bee colonies and the long-established practice of beekeeping. Local flowering plants are very good sources of honeybee forage, *viz*. nectar and/or pollen. There are also exotic flowering plants which serve as a source of honeybee forage. Of the exotic honeybee forages, *Acacia saligna* is one which was not recommended by some of the beekeepers and extension workers in the region. Therefore to determine the contribution of *A. saligna* to beekeeping industry and honey production, the Mekelle Agricultural Research Center's Apiculture and Sericulture team conducted research activities. The activities were pollen sorting and counting, pollen nutritional analysis and the contribution of managed honeybees (*Apis mellifera*) for *Acacia saligna* seed yield and quality. Result revealed that for sorting and counting the highest was *Acacia saligna* 42.2% and the lowest were unknown plants 0.25% and sunflower with 0.6%. With the nutritional content, *A. saligna* accounts for 21.21% protein and *Helianthus annuus* is 17.31%. Yield increments of *A. saligna* are: seed weight with coat = 94.81 g, seed weight without coat (g) = 159.5 g, and germination = 2.9%. Therefore, honeybees collect acacia saligna pollen even there is availability of other pollen source. The protein content of the plant is very good and recommended for honeybee. Moreover *A. saligna* pollen is regarded as very good protein source for hive build-up. The results show that utilization of honeybees would effectively increase *A. saligna* seed quantity and quality.

Keywords: Open pollination, caged, germination

Introduction
Ethiopia's climatic and edaphic variability have endowed this country with diverse and unique flowering plants thus making it highly suitable for sustaining large numbers of bee colonies and the long-established practice of beekeeping. Nevertheless, the honeybees and the plants they depend on like all renewable natural resources are constantly under threat from lack of knowledge and appreciation of these endowments. In addition to the local honeybee plants which are very good source of nectar and/or pollen there are also exotic honeybee forages. From the exotic honeybee forages, *Acacia saligna* is one which is not recommended by the beekeepers in the region. Therefore to determine the contribution of *A. saligna* for honeybee development, the Mekelle Agricultural Research Center's Apiculture and Sericulture team conducted research activities.

Flowers of *Acacia* species in the subgenus *Aculeiferum* are usually borne on elongated inflorescences and produce nectar, while those of species in the subgenus *Acacia* are usually presented in spherical inflorescences and without nectar (Graham *et al*. 1998). Male and female flowers of both subgenera mature at different rates, and last for a single day (Graham *et al*. 1998). *Acacia saligna* has spherical inflorescences without nectar. Honey bees require a balanced diet of sugar, protein, vitamins and minerals, along with sufficient water. Honey bees also need the same 10 amino acids as other animals (e.g. humans). These amino acids are obtained from pollen only, because honey bees do not have any other sources of protein.

The quantity and quality of pollen collected by honeybees affects reproduction, brood rearing and longevity, thus ultimately the productivity of the colony. Apart from small quantities in nectar honeybees obtain all the proteins, lipids, minerals and vitamins they need for brood rearing, adult growth and development from pollen. *Acacia* and other pollens are utilized by honeybee colony for colony buildup. Our research then focused on collecting pollen samples to determine the nutritional content.

Some beekeepers and extension workers believe that honeybees are collecting *A. saligna* pollen at the time when other pollen is not availabile. Therefore, this research was implemented to check whether the honeybees are collecting *A. saligna* pollen during this period or they will collect even if other pollen sources are available.

Materials and Methods

This study was conducted at the experimental site of Mekelle Agricultural Research Centre, Illala during September 2012 (located at 13º 5'N, 39º 6'E and altitude 1970 m above sea level). The annual average rainfall is 547.5 mm and mean maximum and minimum temperatures are 26.5°C and 11.8°C, respectively.

The experiment was designed into three treatments. Each treatment was replicated eight times. The treatments were: (1) *Acacia saligna* accessible to all flower visitors in which branches of trees with 10-15 flower buds were left exposed for natural pollination as a control treatment; (2) *Acacia saligna* not accessible to any insects, in which branches of trees with 10-15 flower buds were covered with an insect proof mesh cage (before the ray florets started opening) (Fig. 1); (3) *Acacia saligna* accessible only to honeybees, in which branches of plants with 10-15 flower buds were covered with an insect-proof mesh cage and a honeybee colony with five frames was placed inside the cage during the *Acacia saligna* flowering peak period (i.e. 50% florets open) (Fig. 2).

Insect-proof mesh was made using wooden poles covered with a 20% shade cloth, then erected around the appropriate branch and tree. All insects were removed from all the cages before blooming, to exclude unwanted pollinators. Honeybee colonies used in this experiment received supplementary feeding (dissolved sugar) and water before and after they were placed in the cages.

The seed yield increment of the plant was calculated using the formula.

$$\text{yield increment }(\%) = \frac{(\text{yield from honeybee pollinated} - \text{yield from insects excluded})}{\text{Yield from open pollinated}}(100)$$

Three honeybee colonies having a queen of the same age were selected for pollen collection. A pollen trap was fitted at the entrance, and the collected pollen was sorted and counted by plant source. A sample of the collected pollen was used for further nutritional analysis and for re-feeding to the honeybee.

Pollen samples from four different flowering plants, which included *Acacia saligna*, sunflower (*Helianthus annuus*), Tebeb (*Bacium grandiflorum*) and Kancha Dumu were collected and analyzed at the Paster nutritional laboratory, Addis Ababa. The fresh samples were air-dried to obtain water content as a percentage of fresh weight. Crude protein content (%), fatty acids (%), fiber (%) and ash (%) content of the different pollen types was determined using the standard procedures.

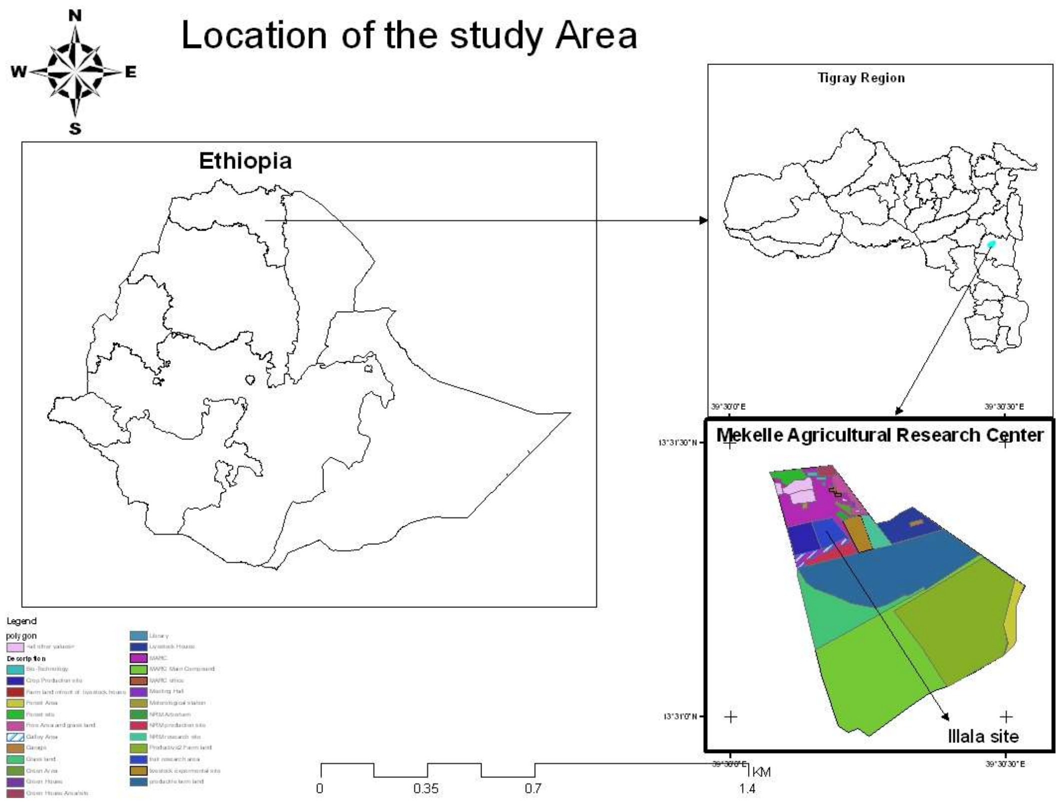

Figure 1: Map of Mekelle Agricultural Research Center Experimental Site, Illala, Tigray Region, Ethiopia

Results and Discussion

Nutritional contents of the test samples (Table 1) are presented below (Table 2). The comparative efficiency of each treatment was evaluated on the basis of seed weight with coat, seed weight and germination percentage (Table 2). The seed yield increment, as a result of honeybee pollination, was 94.8% for seed weight with coats, 59.5% for seed weight and 2.9% for germination (not significant). There were significant differences among the three pollination treatments leading to differences in seed weight with coat (P = 0.0001) and seed weight (P = 0.0001), but not for germination (P = 0.6461).

Table 1. Number of different plant pollen types sorted and counted

S/N	Local name	Scientific name	Number of pollen grains counted	%
1	Sunflower	*Helianthus annuus*	29	0.6
2	Adri	*Brassica abyssinica*	1,643	32.5
3	Tselim Berbere	*Schinus molle*	43	0.85
4	Acacia saligna	*Acacia saligna*	2,143	42.2
5	Tselim Kemem	*Nigella sativa*	196	3.9
6	Kurbah		500	9.9
7	Awhi	*Cordia africana*	400	7.9
8	Shewit hagay		98	1.9
9	Unknown plants		13	0.25

Table 2. Different pollen nutritional content of *Acacia saligna*, Sunflower (*Helianthus annuus*), Tebeb (*Bacium grandiflorum*) and Kancha Dumu

S/N	Name	Moisture content (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)
1	*Acacia saligna*	9.19	21.21	8.32	0.35	2.83
2	Sunflower (*Helianthus annuus*)		17.31			1.93
3	Tebeb (*Bacium grandiflorum*)		20.84			3.24
4	Kancha Dumu		22.78			3.41

Table 3. Mean values for *Acacia saligna* seed weight with coat (g), seed weight (g) and germination percentage of the Caged without bees (NI), Caged with bee (HB) and Open pollination (CTL).

	CTL	NI	HB	*P*
Seed weight with coat (g)	3.325	1.735	4.8875	0.0001
Seed weight (g)	1.175	0.65	2.525	0.0001
Germination %	8.625	9.375	9.625	0.6461

Figure 2: Caged without bees (NI) treatment

Figure 3: Caged with bees (HB)

Pictures were taken before and after the cage was erected to observe if there was any physical colour change in the honeycomb. No change was observed (Figs 4,5).

Figure 4: Before the colony was caged

Figure 5: After the colony was caged

Bees obtain pollen from flowers or from pollen stored in the combs. Honeybees can draw on body-protein when they are protein-stressed, such as occurs in a spring build-up in temperate areas or a heavy honey flow. They consume body protein to create royal jelly to feed their brood. This is similar to a cow using body tissue to produce milk for a calf. Pollen is the bees' main source of protein and is required for muscle growth in brood and young adult bees. The ideal food source is pollen which contains more than 20% digestible crude protein and honeybees need pollen with at least 20% protein. Acacia tree pollen, Tebeb (*Bacium grandiflorum*) pollen and Kancha Dumu pollen were consisting 21.21%, 20.84% and 22.78% protein respectively (Table 2). Therefore, these species should be regarded as very good protein sources for hive build-up. Sunflower (*Helianthus annuus*) pollen is 17.31% protein, so has less protein compared to those above.

Conclusion

Acacia saligna and other pollen are utilized by honeybee for colony buildup. The plant is important in areas where shortage of honeybee forage (pollen) occurs. The plant can flower two times a year and it has pollen with good protein source (21.21%). Honeybees are important to pollinate the plant and produce a good quantity and quality seed.

Effect of *Acacia saligna* on honeybee health and honey quality

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Abstract
Honey production is by far the preponderant management objective of beekeepers in the country whether that production is for home consumption or for sale. A quality product will go a long way to developing the confidence that encourages return customers and efficient production of a product to any marketing scheme. Some beekeepers and extension workers in Tigray region had negative attitudes on the contribution of *Acacia saligna* trees to honey quality. There were complaints raised from the farmers and extension workers on the immediate death of the honeybee in relation to the plant (*Acacia saligna* flower). To verify this, honey quality analysis (acidity, mineral ash content, water insoluble solids, moisture content, conductivity, total reducing sugar, sucrose content, ph and hydroxymethylfurfural (HMF)) was done at Dimma Beekeeping and Honey Processing company. Moreover, honeybee colonies with eleven frames were caged in the *Acacia saligna* trees at the 50% flowering stage to see the effect of *Acacia* on bee health. Field days were arranged to discuss with the farmers and extension workers at the two districts (Atsebi Wonberta and Wukro Kilte-Awulaelo). The average contents of Acidity, Mineral ash content, Water insoluble solids, Moisture content, conductivity, Total reducing sugar, Sucrose content, PH and HMF of honey samples were determined as 27.7 meq kg^{-1}, 0.2%, 0.0%, 18.1%, 0.4 mS/cm, 70.1%, 2.7%, 4.0 and 14.4 $mgkg^{-1}$ respectively. The results indicate that each biochemical component of the honeys from different origin were generally appropriate to European, Indian and Ethiopian standards in terms of all biochemical components. There were no observed mass honeybee deaths due to the *Acacia* flower and no color change in the honeycomb.

Keywords: beekeepers, Dimma, Tigray region, Field day

Introduction

Honey production is the focus of beekeepers, whether that production is for home consumption or for income generation. A quality product will go a long way to developing the confidence that encourages return, customers and efficient production of a product to any marketing scheme. Although thousands of tons of honey are produced every year in the country, it is usually poorly managed and unattractive in appearance. Moreover, traditional hive honey is of good quality as long as it is in the hive. Faulty handling, from the time of its harvest until it reaches to market is responsible for its inferior quality. The type of hive and the method of harvesting and storage of honey play a vital role in the quality of honey. Water content is also important to the quality of a honey; to minimize the growth of naturally occurring yeasts and subsequent fermentation, moisture content should be below 19%. Since honey is hygroscopic, it can absorb moisture from the air unless it is kept in a sealed container. If it is left exposed in humid environments, the moisture content rises and leads to fermentation. Due to a number of factors, the properties of honey will vary considerably from place to place, and it is difficult to get two identical honeys.

Beekeeping in Tigray, as one of the agricultural sub-sector, is playing a significant role in supplementing the annual income of the beekeepers through the sale of honey and bee colonies and is serving as a healthy food for the rural farming communities. This intern indicates that beekeeping as an agricultural activity would contribute a lot to the food security and income generation. These days however improved beekeeping practice is fast expanding and modern beehives acceptance by the farming community is growing in Tigray region. This supplies quality honey known as Tigray white honey to the local and export markets thus serving as source of foreign exchange earning to the country. Tigray white honey is one of the best and highly valued types in Ethiopia and it often valued more highly than others. The colour and taste of the honey is a function of the forage types used by the honeybees. Many experts and researchers agree to the contribution of bee forage species locally known as Girbia *(Hypoestes forskaosolii)*, Tebeb *(Bacium grandiflorum)* and Shewa- Kerni *(Lucas abysinica)*. The region is characterized as moisture deficit area and this also an opportunity to the contribution of quality honey. The newly introduced bee plants, mainly *Acacia saligna* were not treated as honeybee forage in the region. Complaints were raised from some farmers and extension workers on the immediate death of the honeybees in relation to the *Acacia saligna* flowers.

Honey production is the objective of beekeepers whether that production is for home consumption or for sale. A quality product will go a long way to developing the confidence that encourages return, customers and efficient production of a product to any marketing scheme. Honeybees have been observed to be foraging on flowers of *Acacia saligna*. Honey fermentation caused an increase of acidity and because of this a maximum acidity value has proven useful. The less HMF in honey is the better honey quality. Also effects of HMF in honey depend on heat process after harvesting, pH of honey and storage time and temperature. Honey diastase activity is a quality factor influenced by honey storage, heating and thus, an indicator of honey freshness and overheating. Conductivity is a good criterion of the botanical origin of honey and today it is determined in routine honey analysis instead of the mineral content.

We undertook this study to

- Observe if any mass bee deaths occurred due to foraging on *Acacia saligna* flowers;
- Determine the effect *Acacia saligna* plant on the quality of honey;
- Evaluate quality difference between woredas (districts) and Kebeles.

Materials and Methods

Ninety (90) honey samples were collected from three (3) districts/Woredas (Atsibi-Wenberta, Saeie-Tsaeda Emba and Wukro-Kilte Awulaelo) where the Acacia project was implemented, and the following parameters were analyzed.

Honey quality analysis (Acidity, Mineral ash content, Water insoluble solids, Moisture content, conductivity, Total reducing sugar, Sucrose content, PH and HMF) was done at DIMMA BEE KEEPING DEVELOPMENT & HONEY PROCESSING PLC**.**

Figure 1: Honey sample purchased and labelled (left) and honey sample labelled and sent to the laboratory (right) for quality analysis

To check whether *Acacia saligna* flowers affect observable bee mortality, honeybee colony was caged under insect proof mesh cage around the *Acacia saligna* trees. This experiment was implemented at Atsebi-wonberta (Hayelom), W/kilte-Awulaelo (Abrha-Atsbeha) and Elala. Continuous observation was done on the forager honeybee to see the effect of *Acacia saligna* on bee health.

Figure 2: Arbeha-Atsbeha W/kilte-Awulaelo field day (left) and Atsbi-wenberta (Hayelom) field day (right)

Results and Discussion

The means for each quality parameter of the honeys from different origins (Table 1) were similar to those of European and Ethiopian standards (Table 1, Table 2).

There was no significant difference between woredas or between kebeles on moisture content or mineral ash content ($P<0.10$). In all cases, the honey had the same characteritics among kebeles and woredas, probably because the vegetation types in each location are more or less the same.

Table 1: Results of honey derived from *Acacia saligna* in comparison with the Ethiopian standard

Parameter	Mean of 90 samples	Standard
Acidity, meq/kg	27.7	Limit ≤ 40 meq/kg
Mineral ash content, %	0.2	Limit ≤ 0.6 %
Water insoluble solids, %	0.0	Limit ≤ 0.1 %
Moisture content, %	18.1	Limit ≤ 21.0 %
Conductivity, ms/cm	0.4	Limit ≤ 0.8 ms/cm
Total reducing sugar, %	70.1	Limit ≥ 65 %
Sucrose content, %	2.7	Limit ≤ 5 %
pH	4.0	Limit (3.4 - 6.1)
HMF, mg/kg	14.4	Limit ≤ 40 mg/kg

Table 2. Comparison between means of quality parameters of Tigray honey with the national, regional and international standards

Country	Moisture content, %	Total reducing sugars, %	Sucrose content, %	Acidity, meq/kg	Mineral content, %	HMF
EU	21	65	5	40	1	40
Ethiopia	20.6	65.6	3.6	39.9	0.23	32.4
Tigray	18.1	70.1	2.7	27.7	0.2	14.4

HMF is 5-hydroxymethylfurfural, a recognized indicator of honey quality

There was no observation of honeybee deaths from inside the mesh cages, suggesting feeding on *Acacia saligna* pollen was not a problem; furthermore, no color changes in the honey comb were observed. Both results were confirmed with joint field visits by honey producers from nearby farming communities and extension officers.

Conclusion

The honey quality of Acacia pollen is good in comparison to Ethiopian and international standards. But toxicity analyses need to be done to be sure about minor compounds. The local impressions of honeybees dying because of Acacia pollen is found not to be based on facts.

Annex 1: List of Project Members and Participants

S. No	Name	Responsibility	Position	Email
1.	Dr. Eyasu Abraha	General Director	General director	eysuabraha@yahoo.com
2.	Niguse Hagazi	Project coordinator	Natural resources research Directorate Director	niguse.hagazi@yahoo.com
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4.	Kinfe Mezgebe	NRM Team Leader	Mekelle Agr. Research center director	Kinfemez2@yahoo.com
5.	Tesfay Hagos	Conference organizer	Livestock Research technical coordinator	eytesfay@yahoo.com
6.	Gebreamlak Beazabih	Team member	Apiculture researcher	gbtesfay@gmail.com
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19.	Dr. Abadai Girmay	Organizing Committee	Natural resources research technical Coordinator	abbadigirmayreda@gmail.com

Annex 2: Number of conference participants with their respected organizations

- 5 from World Vision Australia (WVA), Australia
- 3 from Ethiopian Institute of Agricultural Research (EIAR), Ethiopia
- 3 from Ethiopian Health and Nutrition Research Institute (EHNRI), Ethiopia
- 1 from Drylands Coordination Group (DCG), Ethiopia
- 11 from World Vision Ethiopia (WVE), Ethiopia
- 3 from Mekelle University (MU), Ethiopia
- 9 heads and expets from Tigray Bureau of Agriculture and Rural Development (BoARD), Ethiopia
- 1 from German Technical Cooperation (GIZ), Ethiopia
- 2 from Relief Society of Tigray (REST), Ethiopia
- 1 from local NGO MUMS for MUMS, Ethiopia
- 1 from Tigray Bureau of Finance and Economic Development (BoFED), Ethiopia
- 1 from Tigray National Regional State Parliament Representative, Ethiopia
- 2 from International livestock Research Institute (ILRI), Ethiopia
- 1 from Centre for International Potato (CIP), Ethiopia
- 1 from World Agroforestry Centre (ICRAF), Kenya
- 1 from Beyond Subsistence, Uganda
- 1 from Chile Forest Institute INFOR, Chile
- 22 from Tigray Agricultural Research Institute including researchers from 9 research centers
- 3 farmers from project implemeting sites, FRG members

Annex 3: Concluding Remarks by Eight Panelists

At the end of the conference day, eight senior scientists, researchers and experts representing their respective organizations provided their overall reflection and feedbacks on the conference as well as their final concluding remarks. Thus, the final concluding remakes provided by each panelist has provided as indicated below. They all happy by the conference and forwarded their appreciation to the organizing organizations, TARI and World Vision.

1. Dr. Yaynishet, Scientist from ILRI

Dr. Yaynishet said "I have totally changed my mind regarding Acacia saligna. I knew it in elementary school. At that time it was growing in nurseries and then planted in degraded areas. Very grateful to TARI and its partners including WVA, the funding organization for working on nutritive value of Acacia saligna for animals and for changing people's view".

2. Dr. Joy Tukuhirwa, Beyond Subsistence, representative for east Africa, Uganda

Dr. Joy provided a speech with regard to her personal feeling, and also for her organization and country as indicated below.

a. **Personally:** "I bave been impressed by the power of teams. When we collaborate, we have changed landscapes and it shoud go outside Ethiopia".
b. **Speaking for Beyond Subsistence:** "Beyond Subsistence is a Christian organization to do what God wants this earth to be. Want to see how earth can come back and feed us. Need to listen to God and do his will. Definitely doing his will when we see water and green. Look forward to working in partnership with communities and organizations like TARI".
c. **Speaking for Uganda:** "Uganda has a lot to learn from here. Hope that WV or ICRAF will facilitate an exchange visit here. Uganda has some dry areas which need Acacia species".

3. Mr Tony rinaudo, Principal Advisor, Natural Resources, Food Security & Climate Change Team, WVA

"I have been waiting for this kind of event for 30 years. We will look back and see this conference as a turning point – the start of scale up. Butterfly story. A boy had reached the age where he thought he was smarter than his father. He caught a butterfly, cupped it in his hands and asked his father if it was dead or alive. The father knew that if he said it was dead, the boy would open his hands and the butterfly would fly away. If he said it was alive, the boy would crush it. The wise father said "the answer is in your hands". Will farmers adopt recommendations from here? The answer is in our hands".

4. Dr. Ramni Jamnadass, Kenya, ICRAF Global Leader - Science Domain 3 (Diversity, Domestication, Delivery Trees for Food, Nutrition & Health, Energy, Environment & Wealth)

Dr. Ramni started with appreciating World Vision and Tony rinaudo as "Thank WV and Tony for the opportunity to come here and participate in this interesting conference". She also added as "I am very happy I came here. Just 2 weeks ago, researchers put proposals at ICRAF and I wasn't sure where I would work. I have seen a great site here in Tigray like Abreha We Atsbeha".

5. Mr. Kissi, Researcher, EHNRI

Mr. Kissi started with his happiness with regard the results presented and comments provided during the conference. He also stressed with what he sow good result in Abreha We Atsbeha and finally concluded by saying thank you and keep it up".

6. Mr. Haileselassie Desta, WVE, MPrO Program Manager in Tigray region

Mr. Haileselassie put the following points during his concluding remarks.

a. "This is a turning point for us".
b. "Not surprised that Acacia saligna would be for Food Security as I have seen Macaroni made with Acacia saligna and drank soup made of it. Also bread and Injera. I am still alive".
c. The land is hungry and the chickens, climate and people. There is a famine beyond drought even beyond 1984. This seed may make a contribution. We need a supplement to what we have and our collaboration is vital".

7. Mr. Patricio Rogas, Researcher, Chile

Mr. Patricio started by saying "Some years ago, an Australian visited our plantation in Chile and I did not think it could be used for food but I heard of Tony Rinaudo. I was invited to "Wattle we have for dinner" in Alice Springs in Australia. Now, deeply happy to be here. You are very wise people in the way that you manage your environment. I feel very at home here. I will try to finish my research successfully. I promise to continue. I can offer you any results we obtain. I will not forget the beautiful days I have spent with you".

8. Dr. Abbadi Girmay, Senior Researcher and Research Coordinator, TARI

Dr. Abbadi started by saying "Words are not enough to express my thanks". This has been very inspirational especially for TARI. A good platform and a golden opportunity to see people gather from every corner of the world. Now we will not stop. We will continue with your very good support. This is the end of the beginning. Our message is "beyond the horizon". We stand together for a better world. I hope we will do many things together. I wish you a very fruitful future collaboration".

Annex 4: Closing remarks by World Vision Australia and Tigray BoARD delegate

Christine Fellner
Country Program Manager, International Programs Africa Team, World Vision Australia

Representing the World Vision Australia as the Funding orgnazation and her close follow-up with the project, Christine Fellner, started by saying *"2 years ago, I started my World Vision career with a trip to Tigray. I now have the opportunity to come back and see all the progress".* She gave a high emphasis on the next steps by saying *"What's next"? "Abreha We Atsbeha was the example then and still is now. We can look for funding but you are on the ground. We need the good stories from the field. I need a strong evaluation, proof that we have a good partnership. I encourage you here to not just look to World Vision but to take the work in your own hands. Don't stand and wait for the next thing. You can continue to promote the work before next grant comes".* She also said *"Donors are always ready to scale up a good project but they also want to see innovation. Let's think about how we can bring in other things such as cactus. I hope when I return that you will be feeding me Acacia".*

Mr. Haftu Kiros
Regional BoARD Delegate, Mekelle, Tigray, Ethiopia

Mr. Haftu started by saying "I want to thank the conference organizers and participants for such a successful event where we learnt a lot about the Acacia species in general and *Acacia saligna* in particular

Mr. Haftu started by saying "I want to thank the conference organizers and participants for such a successful event where we learnt a lot about the Acacia species in general and Acacia saligna in particular". He also provide important comments and directions on future activities of the project and integration of different stakeholders including funding organizations. He indicated that "development should be our common goal and took as a tool in the MDGs where partnership for development is observed as a key element". "The partnership between TARI and WV could be as an examplinary as an effective partnership where it also extends with the joint work they have on FMNR with different districts/Woredas that have a potential to lead the Tigray region in to sustainable development and restoration of degraded landscapes". He also gave emphasis and gave a direction to consider climate change and assessing and find a way to access carbon market as a cross-cutting issues in our project endeavors. Finally, Mr. Haftu closed the conference by saying "On behalf of myself and the regional Bureau of Agriculture and Rural Development, I appreciate all these partners and we will work together towards our common goals".