

Livestock Technologies/information User's Manual

Series 2

Prepared by: Tesfaye Alemu Aredo, Mekonen Diribsa, Alemu Lema, Samuel Tufa, Girma Chalchisa, Tura Barake, Mathios Hailu, Tolera Kumsa, Amsalu Bezabeh, Dawit Abate



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P Program

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Tel: +251 114707102/18, Fax: +251 114707126/27, P.O. Box: 81265, Email: info@iqqo.org,
Website: <http://www.iqqo.org>, Addis Ababa, Ethiopia

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Preface

As per the mandate given to it the livestock research directorate of the Oromia Agricultural Research Institute is conducting various research activities in areas of dairy, meat, apiculture, fisheries, poultry and feed resources and rangeland improvement. From the research activities conducted every year, a good number are completed and published in different channels such as journals and proceedings. However publishing the research findings in such a way only would not guarantee the wider use and application of the research outputs. Being cognizant of this fact, the livestock research directorate of the institute has started availing its published research findings in the form of technologies/information user's manual. To this end, from the research works completed till 2015, it has produced its first series manuals one on dairy and meat, one on apiculture, one on fisheries and one on feed resources and rangeland improvement technologies/information in 2018. These manuals were distributed to different organizations in a way they could reach even district agricultural offices for wider utilization at grass root levels.

From feed backs obtained from those who got the manuals, the importance of such manuals in simplifying the application and use of technologies/information generated is so immense that it necessitated the preparation of the second series of the manual. The first series of the manual was prepared only in English hoping to translate it in to Oromiffaa in the course of the time and in collaboration with other institutions such as the Oromia Livestock Resources Development Agency. However, this was not materialized because of various reasons. Learning from this lesson, it is now intended to prepare this second series of the manual both in English and Oromiffaa languages. Though the Oromiffaa version is not yet finalized, the English version is finalized and given in this manual.

The manual encompasses technologies/information generated from selected findings obtained from research works completed in 2016 and 2017. The manual contains six parts, namely dairy, meat, poultry, feed resources and rangeland improvement, fishery and apiculture technologies/information. In each part, technologies are described first, followed by information. While technologies are for direct application and use by users, information are more useful for different organizations and policy makers for them to take some measures based on the information availed.



Tesfaye Alemu Aredo (PhD)
Director, Livestock Research
Oromia Agricultural Research Institute

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Part one: *Dairy Technologies/information User's Manual*



Composite breed development work by Adami Tulu Agricultural Research Center

I. Technologies

1. Formulation of dairy rations from locally available feed resources for lactating crossbred cows

1.1. Background information

Urban and peri-urban dairy producers depend substantially on commercial concentrate feeds to supplement lactating crossbred cows. However, the high cost and lack of knowledge in providing balanced ration is a limiting factor in urban and peri-urban dairy production systems of the country. Previous studies indicated that dairy cows in urban and peri-urban production systems do not meet their energy and protein requirements and hence perform below their genetic potentials. Strategic formulation of different ingredients in a manner to furnish the cows with nutrients in a balanced proportion and to reduce the cost of milk production is desirable. Accordingly, formulation of balanced dairy rations from local feed resources for crossbred cows was conducted in East Shewa zone Dugda district by Adami Tulu Agricultural Research Center starting from October 2015 to March 2016.

1.2. Inputs required to apply the technology

- ❖ Early lactating crossbred cows of 50-62.5% exotic blood level and body weight of 350-395, wheat bran, wheat straw/teff straw, cotton seed cake, *atela*, water and common salt.

1.3. Steps and procedures to apply the technology

- ❖ Check the availability of feed types in the area
- ❖ Assess the prices of each feed types
- ❖ Measure/estimate body weight of early lactating crossbred cows if Possible.
- ❖ After confirming the availability of the feeds, mix them as indicated in Table 1.

Table 1. Amount of feed ingredients to be mixed (in % and Kg)

Feed ingredients	feed ingredients to be mixed	
	%	Weight
Wheat bran	68	4.5 Kg
Cotton seed cake	15	1 Kg
<i>Atela</i>	16	3liters
Salt	1	66 gram
Total	100	6.5 Kg
CP%	21.5	1.4 Kg
Wheat/teff straw	40	5 Kg

NB: *Atela* = residue of locally produced beverage

- ❖ The amount of feeds indicated are as feed base/not in dry matter base
- ❖ *Atela* should be offered separately
- ❖ Deliver 5kg of wheat/teff straw/cow/day
- ❖ Provide pure and sufficient water 3 times a day
- ❖ Feed animals individually
- ❖ Use stall feeding
- ❖ The total feed amount indicated should be divided into three equal parts and offered three times/cow/ day.

1.4. Scope of using the technology

- ❖ This technology can be used under all agro-ecologies and for lactating crossbred cows provided that all feed types are locally available and cheaper than other feed mixtures
- ❖ The palatability should be checked regularly

1.5. Important data to be recorded/calculated

- ❖ Daily feed offered
- ❖ Daily feed leftover
- ❖ Daily milk yield
- ❖ Milk price
- ❖ Milk consumed by household and calves
- ❖ Total costs for feed and others
- ❖ Daily feed intake is calculated as daily feed offered minus daily feed refused
- ❖ Net daily/monthly income = Daily/monthly income from milk sale minus total costs

1.6. Precautions needed

- ❖ Including more than 30% of cotton seed cake to daily ration of cows might cause toxicity (gossypol) to animals

1.7. Benefit of using the technology

- ❖ Formulating balanced supplementary feeds from locally available and cheap feed resources improves the net income of dairy farms (up to 73 ETB/cow/day).
- ❖ Formulating and supplementing dairy cows ration from locally available feeds improves daily milk yield (from 7.8 liters/cow/day to 9.5 liters/cow/day)

1.8 Reference

Girma Chalchissa and Estifanose Tadesse. 2017. Assessing feed quality and evaluating milk yield and economic profitability of dairy rations formulated from locally available feed resources in Dugda district. Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

2. Feeding value of Urea Treated Maize Stover along with concentrate feeds for Crossbred Cows

2.1 Background information

The major feed resources in Ethiopia for ruminants are natural pasture and crop residues; which are categorized as poor quality roughage with low intake, poor digestibility and nutrient deficiency. The importance of natural pasture as source of feed resource is gradually declining as a result of the expansion of crop production and land degradation. The problem of feed shortage in dry season has directed research efforts towards harnessing and enhancing the utilization of abundant crop residues. Maize stover is one of such residues commonly used as livestock feeds. Maize stover consists of the leaves, husks, stalks and cobs of maize plants left in a field after harvest of cereal grain. Because of its poor nutritional value, maize stover is usually treated with urea to enhance its nutritional quality by increasing microbial biomass thus contributing significantly towards higher crude protein content. In countries where dairy industry is well developed, a huge work has been done and is being done on maize to increase the protein content of the crop. The addition of protein rich concentrates or chemicals when feeding maize crop residue or its silage are being worked out. Feeding trial of urea treated maize stover to crossbred cows was conducted at Bako Agricultural Research Center, starting from December, 2015 to March 2016 to determine the improvement in chemical composition due to urea treatment of maize stover as compared with the untreated stover and to determine the potential of urea treated maize stover for milk yield and milk composition of dairy cow during dry season.

2.2 Inputs required to use the technology

- ❖ Early lactating crossbred cows (7 days after delivery)
- ❖ Maize stover, Urea, pure water
- ❖ Chopper/can be chopped manually for small scale
- ❖ Water sprinkler, plastic/metal bucket, fork
- ❖ 1m² area of land for underground pit (This can accommodate up to 400 Kg treated stover)
- ❖ Maize grain, noug seed cake, salt

2.3 Steps and procedures to be followed

- ❖ Collect maize stover and chop into the size of 2-3 cm using chopper/manually
- ❖ Dissolve 5 kg of urea in 100 liters of water
- ❖ Sprinkle the mixed solution uniformly over 100 kg of chaffed maize stover by using sprinkler and buckets
- ❖ Mix the treated maize stover by fork
- ❖ Pack the mixtures firmly by trampling to remove air and seal the silo
- ❖ Ensilage the treated maize stover for 30 days

- ❖ Keep the cows under stall feeding and treat them against internal and external parasites
- ❖ Prepare concentrate mix from 49.5% maize grain, 49.5% noug seed cake and 1% salt
- ❖ Give the concentrate mix to milking cows at the rate of 0.5kg/liter of milk yield daily
- ❖ Offer about 6 kg of ensiled maize stover/day by dividing into 3 equal parts to be offered three times

2.4 Scope of the recommended technology

- ❖ This technology can be used for all breeds of dairy cows, in all agro-ecologies provided that there is excess maize stover in the area and all other ingredients are available.

2.5 Important data to be recorded or calculated

- ❖ daily milk yield per cow
- ❖ Amount of feed offered and feed refused
- ❖ Milk price
- ❖ Amount of milk sold, consumed by calf and used at home
- ❖ Feed consumed is calculated as amount of feed offered minus amount of feed refused
- ❖ Net benefit/cow/day = Total variable cost/cow/day minus gross income (income from milk sale)/cow/day

2.6 Precautions needed: Feeding too much urea might cause bloating to dairy cows

2.7 Benefits of feeding urea treated maize stover to lactating cows

- ❖ Improves crude protein content of maize stover (from 6 % to 10 %)
- ❖ Improves the digestibility of maize stover (from 37 % to 58 %)
- ❖ Improves voluntary intake of maize stover (from 4 kg/cow/day to 6 kg/cow/day)
- ❖ Improves the metabolizable energy content of maize stover (from 5.8 MJ/kg DM to 9.2 MJ/kg DM)
- ❖ Increase milk yield of cows (from 6 liter/cow/day to 8 liters/cow/day)
- ❖ Increase the net benefit obtained from dairy cows (from 48 ETB/cow/day to 67 ETB/cow/day)

2.8 Reference

Tesfaye Mideksa, Habtamu Abera, Sisay Eshetu, Tesfaye Marsha, Temesgen Jembere and Dereje Bekele. 2017. Effect of Urea Treated Maize Stover on Voluntary Feed Intake, Milk Yield and Milk Composition of Crossbred Dairy Cows Supplemented With Concentrate Diet. Proceedings of Review Workshop on Completed Research Activities

of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

3. Supplementation of crossbred cows with Alfalfa or cowpea hays

3.1 Background information

The dominant livestock feed resources in Ethiopia are crop residues. But they are characterized by high fiber (>55%) and low crude protein (<7%) contents. Thus, their intake level is limited and they barely satisfy even the maintenance requirements of animals. Currently, the larger proportion of livestock products is produced by smallholder crop-livestock mixed farmers operating under such poor quality feeds in mixed farming systems. In order to efficiently exploit the genetic potential of crossbred cows under tropical environment, there is a need to look for biologically and economically sound supplementary feeds. Currently supplementation with agro-industrial by-products is becoming costly which necessitates searching for other options. Thus, integration of low cost feed technologies that are easy and suitable and within the limits of the resource poor farmers needs to be considered. Supplementation of crop residues with plant protein sources such as leguminous forage crops may alleviate protein deficiency as these contain medium to high levels (12 – 25%) of CP. This suggests the need for conducting research on the level of substituting commercial protein supplements with such feeds as alfalfa or cowpea hay in the diet of crossbred dairy cows. Cowpea (Fig. 1) is annual legume commonly cultivated and used as livestock and human feed/food. It is a warm-season crop that is mainly produced in semi-arid areas. It is well adapted to areas below 2200m.a.s.l. and it can grow under 400 mm of annual rainfall. It performs well in areas of sandy soils and drought conditions. Cowpea produces average herbage DM yield of 5-7 t/ha, 14-29% CP and 10.5 MJ of energy per kg DM at different areas.



Fig1. Cowpea forage at early (left) and matured (right) stages

Alfalfa (Fig. 2) is a perennial forage legume known for its high forage quality and it is well adapted in different agro-ecologies (1500 to 3000m.a.s.l.) both under rain fed and irrigation conditions. Alfalfa produces average herbage DM yield of 4-5 t/ha, 18-19% CP and 13 MJ of energy per kg DM. It was also reported to withstand long periods of water deficit by impeding its vegetative growth and accessing water from depth through its deeper root system. The current and projected decrease of agricultural water resources further necessitates the persistently

growing interest for water saving forage production strategies through introducing drought tolerant forage legumes such as alfalfa.



Fig 2. Alfalfa forage at early (left) and matured (right) stages

A study on substitution of conventional protein supplements with cowpea hay or alfalfa hay in the feeds of crossbred cows was conducted at Adami Tulu Agricultural Research Center from May to October, 2017. Basic procedures and benefits of applying the recommended supplementation levels from this study are summarized below:

3.2. Inputs required to apply the technology

- ❖ Cow pea or alfalfa hay, wheat bran, maize stover/natural pasture, common salt and pure drinking water
- ❖ Land for forage production/irrigated or rain fed
- ❖ Lactating crossbred cows with 50-62.5% exotic blood

3.3. Steps and procedures to use the technology

- ❖ Sow the cowpea and alfalfa seeds according to their production system given in Feed resources and rangeland improvement technologies user's manual series 1 (Tesfaye *et al*, 2018)
- ❖ Store the harvested and dried forages separately under dry shed
- ❖ Give the forages and other concentrate to lactating cows as indicated in Table 2.

Table 2. Recommended ratio of concentrate and forage hays for lactating cows

No.	Option 1			Option 2		
	Feed types	%	Amount	Feed types	%	Amount in kg
1	Wheat bran	60	4 kg	Wheat bran	61	4 kg
2	Alfalfa hay	39	4 kg	Cowpea hay	38	4.5 kg
3	Salt	1	70 gram	Salt	1	70 gram
4	Maize stover/natural pasture		<i>Adlibitum</i>	Maize stover/natural pasture		<i>Adlibitum</i>
5	Pure water		<i>Adlibitum</i>	Pure water		<i>Adlibitum</i>

NB: Feed amount indicated in table 2 is as feed base (not on dry matter base) and it includes the maintenance requirement of animals. *Adlibitum*= whole day

3.4. Scope of using the feeding technology

- ❖ Cow pea and alfalfa hays can be supplemented for lactating cows provided that the cowpea and alfalfa forages can be adapted in the area and wheat bran is available
- ❖ This specific ration is recommended for dairy cows with body weight ranging from 220 to 290 kg and milk yield of 7-10 liters/cow/day.
- ❖ If there is no feed leftover, give 1kg wheat bran and 1kg alfalfa/cowpea hay additionally until leftover is observed

3.5 Important data to be recorded or calculated

- ❖ Initial body weight and daily milk yield
- ❖ Amount of feed offered, feed consumed and feed refused
- ❖ Milk price
- ❖ Amount of milk sold, consumed by calf and used at home
- ❖ Net benefit/cow/day is calculated as: Gross income (income from milk sale)/cow/day minus total variable cost/cow/day

3.6 Precautions needed

- ❖ Feeding too much fresh alfalfa and cowpea forages might cause bloating to cows
- ❖ Alfalfa is perennial forage. It needs supplementary moisture during dry season

3.7 Benefits of using the technology for lactating cows

- ❖ Improves the total daily dry matter intake (from 5kg/cow/day for maize stover +wheat bran + noug seed cake to 7kg/cow/day for maize stover + wheat bran + cowpea hay and also 6.5 kg/cow/day for maize stover + wheat bran + alfalfa hay)
- ❖ Helps to produce milk with high fat content without affecting milk yield of cows (4.5% for linseed and noug seed cakes Vs 5.4% for alfalfa and cowpea hays)
- ❖ Increases the benefit of dairy farms (from 40-50 ETB/cow/day for linseed and noug seed cakes to 55-60 ETB/cow/day for alfalfa and cowpea hays)

3.8 Reference

Girma Chalchissa, Estifanos Tadesse, Alemayehu Arega and Sisay Eshetu. 2018. Evaluation of Replacement of Conventional Protein Supplements with Cowpea (*Vigna Unguiculata*)

and Alfalfa (*Medicago sativa*) Hay on Milk Yield and Milk Composition of Lactating HF x Arsi Crossbred Cows fed maize stover as basal diet. Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

Tesfaye Alemu Aredo, Dawit Abate and Bikila Negasa (eds.) 2018. ***Feed Resources and Rangeland Improvement Technologies User's Manual***, Oromia Agricultural Research Institute (IQQO), Finfinnee, Ethiopia

II. Information

1. Performance of Borana Cattle under Rangeland Conditions of Borana zone

1.1 Background information

Growth and milk production performance of animals directly influence their profitability. The expression of these traits is dependent on the animal's inherent production ability, means of selection and production environment. Borana cattle are originated in Borana rangeland and have unique traits which make them suitable for the harsh environment in the low lands. The climate condition of Borana zone is characterized by semi-arid with annual rainfall range of 500 mm in the South and 700 mm in the North, the altitude ranges from 1000m in the South to 1500m in the Northwest. The rainfall is bimodal but erratic in distribution. Fifty –nine percent (59%) of the annual precipitation occurs from March to May and 27% from September to November, annual mean daily temperature varies from 19 to 24°C. There are four major seasons in Borana plateau. These include: (1) Ganna (March-May), the long rainy season; (2) Adoolessa (June–August), the cool dry season; (3) Hagayya (September- November), the short rainy season; and (4) Bona (December-February), the warm dry season.

Performances of Borana cattle breeds have been evaluated in different research stations and ranches in different times. However, Borana cattle breeds have never been evaluated for its performance in its own environmental condition. Therefore, this study was conducted in Borana zone at Yabello Pastoral and Dry land Agriculture Research Center by collecting data for 10 years (2007 to 2017). Useful information regarding performance of the breed and suggestions given with respect to their appropriate husbandry practices are summarized as follows:

1.2 Methods followed to generate the information

Data was collected from 176 Borana cattle. The Dams were allowed to mate by different sires so as to assure that the experimental animals are not relatives. Natural grazing was the main feed sources for the experimental animals. Supplementation with concentrate and common salt was used during critical drought periods. The animals were allowed to graze freely during the daytime from 8:00 AM to 4:00 PM and sheltered in the barn during night time. The source of water was pipe water. Mating system was natural mating in which one bull was assigned to an average of 15-20 identified cows during breeding time. The bulls were allowed to run with the cows they were assigned to for two months. Mating was designed to have births during the main rainy season (March/April) and short rainy season (September/October) when there is enough forage. Experimental animals were vaccinated against major diseases, de-wormed and sprayed against internal and external parasites, respectively. Milking procedure was partial suckling.

1.3. Major information obtained from the study

1.3.1 Growth Performance

- ❖ The average birth weight of the Borana calves was 22 kg (23 kg for males and 21kg for females) and the birth weight recorded in the area is less than the previous results reported on this breed in different parts of the country (23 – 26 kg). This might be related to the management differences.
- ❖ Calves average weaning weight at 7 months of age based on partial suckling regime was 98 kg (102 kg for males and 94 kg for females). This result is higher than the previous studies (79 to 94 kg) conducted in different research stations and ranches on the breed. The variation in weaning weight of the calves might be attributed to the difference in weaning age (6 months in previous studies), weaning season, agro-ecological zone, and production objective of the breeds.
- ❖ The average yearling weight of the Borana calves was 134 kg (142 kg for males and 126 kg for females).
- ❖ The average weight at 24 months of age for the breed was 194 kg (203 kg for males and 185 kg for females).

1.3.2 Reproductive Performances

- ❖ Average age at first calving was 48 months (4 years). This age at first calving is long compared to the previous reports of 45 months for the same Ethiopian Borana cattle breed. Seasonal breeding system applied under the current study and poor nutritional quality in the area might contributed to this long age at first calving
- ❖ Calving interval of Borana cows was 18 months, which is within the estimated calving interval for zebu cattle which ranged from 12 to 26.6 months. Short calving interval of 15-16 months were reported at Abarnossa ranch for the same breed. The difference in calving interval for the same breed might be due to the variation among the different locations in feed resource availability
- ❖ The calving rate of Borana cattle in six years breeding time was 70% (calving rate = number of cows that calved divided by the number of cows mated times 100).

1.3.3. Milk yield

- ❖ The average 210 days (7 months) milk yield for Borana cows under Borana rangeland management condition was 441 liters/cow (2.1 liters/cow/day). In the current study, the average lactation milk yield of Borana cows was less than the previously reported 3-5 liters of milk/cow/day for the same cattle breed managed under optimum management conditions.

1.4. Suggested husbandry practices for the breed

- ❖ As shortage of feed during dry season (December to February) is the major constraint to animal performance (less milk production and low body weight), annual calving season for cows should be adjusted to main rainy season (March to May) in order to manage the animals and reduce feed shortages for lactating cows and calves.
- ❖ Dry season feed supplementation and health related management issues deserve careful considerations for the breed to express its production and reproduction potentials.

1.5 Benefits of knowing this information

- ❖ The information will enable Government, NGO, Investors and pastoralists to take appropriate intervention measures to make use of the potentials of the breed.
- ❖ Improves the awareness of pastoralists and extension workers to design schedules as to when to breed and supplement their herds

1.6 Reference

Birhanu Bekele and Beshir Husien. 2019. On-station Performance Evaluation of Borana Cattle under Rangeland Conditions of Borana Zone, Southern Oromia, Ethiopia. Proceedings of review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

Part Two: *Meat Technologies/information User's Manual*



On-station fattening at ATARC: 2 years old Arsi bull (Top left), Young Kereyu bull (Top right) and on-farm goat fattening (Bottom)

I. Technologies

1. Feeding option for fattening Kereyu-Bulls to attain local/export market weight

1.1 Background information

Improving the growth performance of fattening animals is one of the most important targets to obtain the required export market weights. To this effect evaluation of different feeding options for animals of different breeds and ages has been envisioned to be of a paramount importance in improving the foreign earning which the country can get by exporting meat and live animals. Moreover conducting beef cattle fattening activities for export market would bring a significant change in the income of those who undertake the activities. Technologies on feeding different feed options were developed at Adami Tulu research center in the year 2016/17 for Kereyu bulls of two age categories (yearling and two years). The technologies were demonstrated to farmers and produced comparable results to the on-station findings with good acceptance by the users. Guideline for application of the feeding options for both age categories are indicated below.

1.2 Inputs required to use the technology

- One and two years old Kereyu-Bulls
- Rhodes hay or Natural grass hays
- Concentrate feed ingredients (molasses, wheat bran, noug cake, and maize grain, cotton seed cakes and salt)

1.3 Steps and procedures to apply the technology (for both age groups)

After purchasing the above mentioned concentrate feed ingredients and the animals, formulate three different feeding options as follows:

Option 1= Rhodes hay +20% molasses+ 40% wheat bran+ 40% Noug cake

Option 2= Rhodes hay +20% maize grain+45% wheat bran+35% Noug cake and

Option 3= Rhodes hay + 65% wheat bran+ 35% cotton seed cakes) were evaluated.

The three different concentrate feed rations are mixed and prepared to make a 100 kg of the mix. 1 kg common salt is added to each 100 kg mix of each ration. Natural grass or Rhodes hay is provided *ad libitum* for all the animals. Every day, all bulls need to be supplemented with the concentrate feeds at the rate of 2.5% of their body weight throughout the fattening period. For these particular technologies for fattening yearling Kereyu bulls on average feeding can range from (3.68-7.10 kg) and for fattening the two years old Kereyu Bulls it can range from (7.37-8.53 kg) based on their body weight. All animals must be fed individually with their corresponding rations for 14 days adaptation and 179 days actual feeding periods for yearling

Kereyu Bulls and 14 days adaptation and 168 days actual feeding periods for two years old Kereyu bulls to reach the export market weight. Provide them two times (half in the morning and the remaining half in the evening).

1.4 Scope of using the technology

These three feeding options/rations can also be fed to other local breeds of cattle found in any agro-ecology provided that the feed ingredients are available and their intake by the animals is adjusted to their body requirement.

1.5 Important data to be recorded or calculated

- Purchase price of animals to be fed,
- Initial and final weight of the animals,
- Price of all feed ingredients,
- Amount of feed eaten,
- Veterinary costs,
- Selling price of the fattened animals,
- Labor cost (when necessary)
- Net benefit is calculated as: *Total variables cost – Final selling price of the animals*

1.6 Expected benefits of using the technologies

From the work done to generate this technology, the biological benefits obtained in terms of weight gains of the fattened animals and the economic benefits obtained are given in Table 1 for yearling Kereyu Bulls. Even if there are numerical differences, there are no statistically significant differences in daily weight gain (DWG), total weight gain (TWG), final body weight (FBW) and even in carcass characteristics among the bulls received the three different dietary rations for 179 fattening days. Economic analysis of feeding the three different dietary feeds also showed that, all the three feeding rations are profitable for fattening growing Kereyu bulls and to obtain the required export market weight. For yearling Kereyu bulls; Numerically bulls fed on Option 1 are more profitable than bulls fed on Options two and three Therefore, any beef cattle fatteners can preferably use feeding Option one to fatten yearling Kereyu bulls for local markets. However, as there were no significant differences in major parameters among the treatments, any of the feeding Options can be used depending on availability of the feed ingredients in the area. The animals could attain the weight of 250-300 kg within 179 days of feeding.

The results obtained from fattening two years old Kereyu bulls fed on three different feed options for about 168 days for export market weight gain is indicated in Table 2.

Feeding of two years old Kereyu bulls with ration 2 and ration 3 for 168 days is less profitable as compare to feeding of the bulls with ration 1. Hence, feeding on ration 1 is very feasible both economically and biologically as compare to feeding on ration 2 and ration 3. Therefore beef cattle fatteners can use ration 1 for fattening of two years old Kereyu bulls for export/local market weight gain.

Table 1.Fattening yearling Kereyu Bulls on different feed options

Sr no	List of Items	Ration 1	Ration 2	Ration 3
1	Number of bulls	8	8	8
2	Purchasing price/ bull(Birr)	2144.75	2069.75	2125
3	Transportation/ animal	300	300	300
4	Cost of concentrate/ animal(Birr)	6439.23	6722.83	7271.16
5	Labor cost per animal(Birr)	787.5	787.5	787.5
6	Veterinary cost/animal(Birr)	59	59	59
7	Total cost per animal(Birr)	9730.48	9939.08	10542.66
8	Gross return per animal(Birr)	14543.48	14460.31	14180.96
9	Gross margin per animal(Birr)	4813.00	4521.23	3638.30

Table 2. Fattening two years Kereyu Bulls on different feed options

Sr no	List of Items	Ration 1	Ration 2	Ration 3
1	Feeds costs per bull	5933	6605	6479.96
2	Purchasing price and transportation coats per bull	2400	2400	2400
3	Labor cost per bull	294	294	294
4	Vet cost per bull	35	35	35
5	Total variable costs per animals	8662	9334	9208.96
6	Total gross output per bull	14000	14000	14050
7	Total gross margin (8 bulls)	42704	37330.25	38728.3
8	Gross margin per bull	5338	4666.3	4841

1.7 Reference

Ashebir Worku, Tesfaye Alemu, Mieso Gurru, Aman Gudeto. Genet Dadi and Firehiwot Messele 2018.Evaluation of different feeding options for one year old Kereyu-Bulls to attain local/export market weight. Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia.338 pp.

2. Feeding Options for Arsi Bulls to Attain Export Market Weight

2.1 Background information

Improving the growth performance of fattening animals is one of the most important targets to obtain the required export market weight. To this effect evaluation of different feeding options for animals of different breeds and ages has been envisioned to be of a paramount importance in improving foreign earnings which the country can get by exporting of meat and live animals. Moreover conducting beef cattle fattening activities for export market would bring a significant change in the income of those who undertake the activities. A technology on feeding options were developed at Adami Tulu Agricultural Research Center in the year 2016/17 for 2 years old Arsi bulls. The technology was demonstrated to farmers and produced comparable results to the on-station findings with great acceptance by the users. Guideline for application of the feeding options is indicated below.

2.2 Inputs required applying the technology

Two years old Arsi bulls, grazing, concentrate mixture from molasses, wheat bran, noug cake or cotton seed cakes, maize grain and salt.

2.3 . Steps and procedures to apply the technology

After purchasing the above mentioned concentrate feed ingredients, prepare three different concentrate mixtures (feeding options) as follows: Option 1=grass hay + 20% molasses + 40% wheat bran + 40% noug seed cake; option 2=grass hay + 20% maize grain + 45% wheat bran + 35% noug seed cake and option 3=grass hay + 65% wheat brain + 35% cotton seed cake. Add one kg common salt to each 100 kg of this concentrate mixture. Allow all animals to graze for 8 hours per day and give them grass hay *ad libtum*. Every day, all bulls have to be supplemented with the concentrate feeds at the rate of 2.5% of their body weight throughout the fattening period. This will be an average equivalent of 3.71-7.59 kg/bull/day (excluding allowance for left-overs). All the animals have to be fed individually with their corresponding rations for a 21 days of adaptation and 195 days fattening periods. Provide the daily requirements of the animals in two times (half in the morning and half in the evening)

2.4 Scope of using the technology

These three feeding options/rations can be fed to 2 years old local breeds of cattle found in any agro-ecology provided that the feed ingredients are available and their intake by the animals is adjusted to their body requirement.

2.5 Important data to recorded or calculated

- Purchase price of animals to be fed,
- Initial and final body weights of the animals,
- Price of all feed ingredients including grass hay
- Amount of feed eaten,
- Veterinary costs,
- Selling price of the fattened animals,
- Labor cost (where necessary)
- Net benefit is to be calculated as: *Total variables cost–Final selling price of the animals*)
- *Growth performance* is to be calculated as:

$$ADW = \frac{(FBW-IBW)}{D},$$
$$TWG = FBW - IBW$$

Where: ADG = Average daily weight gain, TWG = Total weight gain, FBW = Final body weight, IBW = Initial body weight and D = Total of fattening days)

2.6 Expected benefits of using the technology

Generally, while evaluating the three feeding options mentioned above, there were no significant differences in major parameters (Tables 3) such as feed intake, live weight change and feeding costs. Numerically bulls fed on ration one attained better body weight and registered higher gross margins than the other two feed options. Therefore, any one who want to fatten a 2 years old Arsi bulls can preferably use feeding options one, but can also use the other options depending on availability of the feeds. The gross margins from feeding feed option two is lower than that from feeding feed option 3 which could possibly be because of the relative expensiveness of feed option two than 3. Similarly, as there is no significant difference in major parameters among the three feeding options, any of the feeding options can be used depending on availability of the feed ingredients in the area.

Table 3. Fattening two years old Arsi Bulls on different feed options

No	Parameters	Option ₁	Option ₂	Option ₃
1	Initial body weight (kg)	148	148	148
2	Final body weight (kg) overall	303.44	298.44	299.44
3	Average daily live weight gain (g)	795	772	777
4	Total variable cost per bull (Birr)	11310.44	11583.79	12291.44
5	Total gross return per bull (Birr)	14817.58	14246.33	14890.55
6	Gross margin per bull (Birr)	3507.15	2662.54	2599.11

2.7 Precautions needed:

Feeding concentrate before provision of some roughage in the morning might cause bloating or other problems. Therefore, it is recommended to provide them with some roughage before providing them with their morning share of the concentrate every morning. The animals should be drenched and sprayed against internal and external parasites before they go to fattening.

2.8 Reference:

- Aman Gudeto, Tesfaye Alemu Tucho, Tesfaye Alemu Aredo, Mieso Guru, Ashebir Worku, Genet Dadi and Frehiwot Mesele 2018. Evaluation of Different Feeding Options for Yearling Arsi Bulls to Attain Export Market Weight. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu*, Ethiopia, and 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp
- Tesfaye Alemu, Ashebir Worku, Genet Dadi, Mieso Gurru, and Aman Gudeto 2018. Evaluation of different feeding options for growing two years old Arsi-Bulls to attain export market weight. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, and 01-04 October 2018*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp

3. Supplementation of two years old Arsi-Bale rams with mixture of molasses and atella

3.1 Background information

It is a well-known fact that the critical issue for livestock production and productivity is availability and/or the method of utilization or formulation of the available feed resources. Supplementation of animals fed on fibrous feeds with locally available materials is one among many alternatives to achieve better utilization of fibrous feeds. The conventional energy feeds for fattening animals are mainly grains, molasses, brewery dry grains, flourmill by products; and the main protein sources are forage legumes, noug cake, urea, soybean meals. This being the case, due to lack of appropriate formulated fattening rations and the high cost of grains, it is wise to formulate alternative cheap sources of energy and protein rations. Formulation of fattening rations, comparing and replacing wholly or partly energy and protein sources with alternative sources in appropriate levels will serve to increase animal growth performance and farmers income; it also helps as a sound and appropriate use of farmers' feed resources, and in reducing feed expenses and using industrial by products. Live weight gain of our sheep is affected by the availability of feeds. To alleviate this, using different feed mixtures is of paramount importance in increasing meat production in our country. However, there is limited information on the use of different mixtures for fattening, particularly, for our local sheep. Hence, a technology on feeding two years old Arsi Bale rams with different feed mixtures was developed at Adami Tulu Agricultural Research Center in the year 2017/18. Descriptions of the recommended technology are summarized below:

3.2 Inputs required to apply the technology

- Two years old Arsi-Bale rams
- Molasses
- Atella
- Wheat bran
- Grazing
- Noug seed cake
- Salt

3.3 Steps and procedures to apply the technology

After purchasing the above mentioned concentrate feed ingredients and the animals different feed resources are mixed and prepared to make a 100 kg of the mix. One kg of common salt is added to each 100 kg mix of each ration. After 14 days of adaptation period, rams are provided with their respective supplementary feed according to their requirements at the rate of 2.5% of their body weight. This will be an average equivalent of 91.6 g per day (excluding allowance for

left overs). The amount of feed given to each animal is adjusted every two weeks during the fattening period. Each dietary treatment is offered twice daily (half in the morning and half in the afternoon after 8 hours grazing) for the respective groups of animals. All the experimental rams are individually fed on their corresponding feed mixtures for the fattening period.

Accordingly the following four options (Option 1 = Grazing + 10% molasses + 40% wheat bran + 50% noug seed cake Option 2 = Grazing + 30% atella + 50% wheat bran + 20% noug seed cake Option 3 = Grazing + 10% molasses + 40% atella + 25% wheat bran + 25% noug seed cake Option 4 = Grazing + 65% wheat bran + 35% noug seed cake) were tested at Adami Tulu Agricultural research center

3.4 Scope of using the technology

These feed mixtures can be fed to local breeds of sheep found in any agro-ecology provided that the feed ingredients are available and their intake is adjusted to their body requirement.

3.5 Important data to be recorded or calculated

- Initial/purchase price of animals to be fed,
- Initial and final weight of the animals,
- Price of all feed ingredients,
- Amount of feed eaten,
- Veterinary costs,
- Selling price of the fattened animals, Labor cost (when necessary)
- Net benefit is to be calculated as: ***Total variables cost – Final selling price of the animals***)

3.6 Expected benefits of using the technology

On average the rams which had received dietary Option₁, Option₂, Option₃ and Option₄ had attained 30.3 kg, 29.7 kg, 28.4 kg and 31.00 kg body weight, respectively at the end of the fattening period. The partial budget analysis indicates that all groups of Arsi-Bale rams had positive gross margin. Therefore, fatteners can use one of the Option₄, Option₂ and Option₁ based on the availability of the feed resources in the area to fatten two years old Arsi-Bale rams for local markets.

3.7 Reference

Aman Gudeto, Mieso Guru, Girma Debele, Tesfaye AlemuTucho, Ashebir Worku, Genet Dadi and Frehiwot Mesele 2018. Effect of different mixture of molasses and atella on growth

responses of two year old Arsi-Bale rams. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, and 01-04 October 2018.* Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp

4. Improved Forage Legumes (*Cajanus cajan* and *Lablab purpureus*) supplementation for fattening yearling Horro rams

4.1 Background information

Different studies indicated that fodder crops improved the intake of basal diet and enhanced better nutrient utilization of sheep. It is also suggested that high quality feed for ruminants in developing countries can be achievable through intensive utilization of multipurpose trees and shrubs as they are easily produced and managed by livestock producers and have better nutritional quality nearly equivalent to grain based concentrates. Nevertheless, the adoption rate and wider use of multipurpose trees by livestock keepers in Ethiopia is not significant probably because of paucity in information regarding the feeding value and less dissemination of these fodders. Hence, a technology on feeding **forage legumes** (*Cajanus cajan* and *Lablab purpureus*) for yearling Horro rams was developed at Bako Agricultural Research Center in the year 2014/15. A description of the recommended technology is summarized below:

4.2 Inputs required to apply the technology

In order to use/apply the technology, the following inputs are required: Yearling Horro rams, wheat bran, *Cynodon dactylon*, *Lablab purpureus*, *Cajanus cajan* and salt.

4.3 Steps and procedures to apply the technology

Purchasing the above mentioned concentrate feed ingredients and the animals; and preparing all other feed resources, the following five feed options (Option1:*Cynodondactylon* + 125gm wheat bran(WB),Option 2:*Cynodondactylon* + 125gm WB + 236gm*Cajanuscajan*, Option 3:*Cynodondactylon* + 125gm WB + 199.8gm *Lablab purpureus* + 94.4gm*Cajanuscajan*, Option 4:*Cynodondactylon* + 125gm WB + 133.2gm *Lablab purpureus*+141.6gm*Cajanuscajan* and Option 5:*Cynodondactylon* + 125gm WB + 333gm *Lablab purpureus*) will be prepared by mixing to make a 100 kg of the mix. One kg of common salt will be added to each 100 kg mix.

Rams have to be provided with their respective supplementary feed for 14 days adaptation and 90 days fattening period. The provision is at the rate of 2.5% of their body weight with adjustment being made every two weeks during the fattening period. This allowance will be on average 87.4per day (excluding allowance for left overs).The daily feed was offered twice daily (half in the morning and half in the afternoon after 8 hours grazing). All the rams have to be fed individually on their corresponding feed mixtures throughout the fattening period.

4.4 Scope of using the technology

It was seen that supplementation with forage legumes can enhance the utilization of poor quality roughages under smallholder mixed farming systems for better growth of Horro sheep. These feed mixtures (fodders) can also be fed to other local breeds of sheep found in any agro-ecology provided that the feed ingredients are available and their intake by the animals is adjusted to their body requirement. Thus this feeding system can be recommended for small scale sheep production

4.5 Important data to be recorded or calculated

- Purchase price of animals to be fed,
- Initial and final weight of the animals,
- Price of all feed ingredients including grass hay
- Amount of feed eaten,
- Veterinary costs,
- Selling price of the fattened animals,
- Labor cost (where necessary)
- Net benefit is to be calculated as: *Total variables cost–Final selling price of the animals*)
- Growth performance is to be calculated as:

$$ADW = \frac{(FBW-IBW)}{D},$$

$$TWG = FBW - IBW$$

Where: ADG = Average daily weight gain, TWG = Total weight gain, FBW = Final body weight, IBW = Initial body weight and D = Total of fattening days)

4.6 Precautions needed

Care should be taken not to over feed *Cajanus cajan* and *Lablab purpureus* since it may result in bloating and toxicity.

4.7 Expected benefits of using the technology

Better utilization of nutrients and animal performance are attained in rams supplemented with 333 gm *Lablab purpureus* (Option 5), followed by 94 gm and 200 gm (option 3) of *Cajanus cajan* and *Lablab purpureus* mixture. Therefore, fatteners can use one of the Option4, Option 2 and Option 1 based on the availability of the feed resources in the area to fatten two years old Horro rams for local markets

4.8 Reference

Mekonnen Diribsa, Mengistu U, Gemed D., 2016. Effects of Supplementation with *Cajanus* *Cajan*, *Lablab Purpureus* or Their Mixture on Feed Utilization and Growth of Horro Sheep Fed A Basal Diet of Natural Grass Hay. *Journal of Biology, Agric. Health Care*. Vol.6, No.17, 2016.

5. Supplementation of vetch hay for fattening of Arsi-Bale sheep Fed a basal diet of Fodder oat hay

5.1 Background information

Shortage of feed resources both in quantity and quality as well as poor feeding systems were repeatedly reported as major constraints hampering livestock production and productivity in different parts of the country. One of the alternatives to improve livestock feeding, and thereby their productivity could be the cultivation of improved forage crops to offer animals during critical periods in their production cycle and when other sources of feeds are in short supply. Forage species such as vetch and fodder oat are feed sources of high potential to fill the gap of feed shortages. Therefore; a study on evaluation of different varieties of vetch using yearling Arsi-Bale rams was conducted at Sinana Agricultural research center in the year 2016/17. Guideline for application this recommended technology is given bellow.

5.2 Inputs required to apply the technology

Arsi-Bale rams Fodder oat hay Vetch hay varieties (Gebisa, Lalisa, Abdetta and Vicia sativa)
Common salt block

5.3 Steps and procedures to prepare/use the technology

After purchasing the above mentioned feed ingredients and the rams; and preparing the vetch varieties, formulate the recommended rations as follows:

Ration1: Fodder oat sole + Vetch hay (Gebisa 350 Kg)

Ration2: Fodder oat sole+ Vetch hay (Lalisa 350 Kg)

Ration3: Fodder oat sole+ Vetch hay (Abdetta 350 Kg)

Ration4: Fodder oat sole+ Vetch hay (Vicia sativa 350 Kg) were evaluated

Provide the basal diet (fodder oat hay) *ad libitum* to all rams. The supplementary feeds must be offered in two equal meals at 8:00 AM and 4:00 PM in separate feeding troughs. Drinking water and common salt block need to be freely available to all rams throughout the 90 days feeding period.

5.4 Scope of using the technology

These different varieties of vetch can be fed to local breeds of rams found in any agro-ecology provided that vetch and oat can be grown in the area and their intake by the animals is adjusted to their body requirement.

5.5 Important data to be recorded or calculated

- Purchase price of rams to be fed,
- Initial and final weight of the rams
- Price of all feed ingredients,
- Amount of feed eaten,
- Veterinary costs,
- Selling price of the fattened rams
- Labor cost (when necessary)
- Net benefit is to be calculated as: ***Total variables cost – Final selling price of the rams***

5.6 Expected benefits of using the technology

Vetch varieties in terms of feed intake, digestibility, and body weight gain, and feed conversion efficiency and carcass characteristics of sheep. Supplementation of Gebisa vetch variety (option2) induced highest growth performance and carcass characteristics than all other feeding options. Based on these findings Gebisa can be recommended as the best variety for use as supplementary feeding roughage based ruminant diets. The dietary feeding options used in this study induced outstanding biological performance in terms of feed intake, digestibility, body weight gain, feed conversion efficiency and carcass characteristics of sheep, suggesting that fodder oat and vetch hay based feeding is explicitly a feeding strategy of high potential and effort should be made to introduce and scale up the production of these forages in the farming system. In general fattening of yearling Arsi-Bale rams using different vetch hay for 90 days after 21 days of adaptation period; is economical and advantage as supplementary feeding roughage based ruminant feeds

5.7 Reference

Berhanu Tassew, Adugna Tolera and Mengistu Urge 2018. Effect of Different Varieties of Vetch Hay Supplementation on Feed Intake, Digestibility, Body Weight Change and Carcass Characteristics of Arsi-Bale Sheep Fed a Basal Diet of Fodder Oat Hay. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, and 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp*

6.. Feeding options for yearling Arsi-Bale sheep to attain export market body weight

6.1 Background information

The small ruminant meat demand of foreign countries particularly Arab countries has increased and forced them to import from Africa. Ethiopia has relative opportunities for live animals and meat export since it is found in the entrance of Asia countries. Currently, the country has more than nine standard livestock slaughtering abattoirs. However, the earning from export of live animals and processed meat is very small as compared to the potential the country has. Moreover, the red meat currently produced from livestock production in the country could not satisfy the high demand for animal protein.

The standard export market live weight for yearling small ruminants is 25 – 30 kg per individual. However, yearling live weight for our sheep is estimated to be 15 to 17 kg per individual. To improve this scenario improving the animals' growth performance, one of the most important traits to obtain the required export market weight demand, is essential. Different feed options plays a significant role to enable animals attain export market weight demand at different length of fattening period. In addition to the effect of dietary feeds, various fixed effects have their own role on growth performance and carcass characteristics of animals kept under a given environmental conditions. Evaluation of different feeding options for yearling Arsi-Bale rams to attain export market weight demand was conducted at Adami Tulu Agricultural Research Center in the year 2017/18. Description of as to how to apply the resulting technology and its advantage are described as follows.

6.2 Inputs required applying the technology

- Yearling Arsi-Bale rams
- Wheat bran
- Maize grain
- Noug seed cake
- Cotton seed cakes
- Grazing
- Salt

6.3 Steps and procedures to apply the technology

After purchasing the above mentioned concentrate feed ingredients and the rams, prepare the recommended feed options as follows: option1 = grazing + 50 % wheat bran + 50 % noug seed cake, option2 = grazing + 45% wheat bran + 20% maize grain + 35% noug seed cake and option3

= grazing + 65% wheat bran + 35% cotton seed cake. The different feeds must be mixed to make 100 kg. One kg of common salt should be added to each of the 100 kg mixture.

Then provided the rams are with their respective supplementary feed according to their requirements at the rate of 2.5% of their body weight for 14 days adaptation and 75 days fattening periods. The amount of feed given to each ram must be adjusted to their body weight every two weeks during the fattening period. This allowance will be on average 109.17g per day (excluding allowance for left overs). Feed the rams individually and the feeds must be offered twice daily (half in the morning and half in the afternoon after 8 hours grazing).

6.4 Scope of using the technology

These recommended feeding rations can be fed to local breeds of rams found in any agro-ecology provided that the feed ingredients are available and their intake by the rams is adjusted to their body requirement.

6.5 Important data to be recorded or calculated

- ❖ Purchasing price of rams to be fed,
- ❖ Initial and final weight of the rams
- ❖ Price of all feed ingredients,
- ❖ Amount of feed eaten,
- ❖ Veterinary costs,
- ❖ Selling price of the fattened rams
- ❖ Labor cost (when necessary)
- ❖ Net benefit is to be calculated as: *Total variables cost – Final selling price of the animals*)

6.6 Expected benefits of using the technology

Feeding the yearling Arsi-Bale rams on any of the three feeding options for 75 days enabled them to attain the minimum export market weight demand of 25 kg (Table 5). Feeding option 1 incurred more variable cost than the other feeding options. The partial budget analysis indicated Arsi-Bale rams allocated to all treatments have positive gross margins (Table 5). Feeding maize grain (Option2) is more profitable than feeding the other two feed options (option1 and option3). This may be related to the price of maize grain which was lower than that of the noug seed cake and cotton seed cake in that particular area. Therefore fattener or exporters can choose option 2 to fetch more profit. However, based on accessibility and availability of the feed ingredients, they can use the other two options as well as there was no significant difference among the three feeding options.

Table 5. Fattening of yearling Arsi-Bale rams on different feed options

No	Parameters	Option ₁	Option ₂	Option ₃	Grand mean
1	Initial body weight (kg)	18.85	16.85	17.0	17.57
2	Final body weight (kg) overall	25.3	25.1	24.8	25.07
3	Average daily live weight gain (g)	113.3	109.5	104.7	109.17
4	Total variable cost per ram (Birr)	1283.5	1253.5	1270.5	1269.18
5	Total gross output per ram (Birr)	1650	1650	1650	1650.00
6	Gross margin per ram (Birr)	366.5	396.5	379.5	380.83
7	Total gross margin (Birr)	2565.5	2775.5	2656.5	2665.83

6.7 Reference

Aman Gudeto, Mieso Guru, Girma Debele, Tesfaye Alemu Tucho, Ashebir Worku, Genet Dadi and Frehiwot Mesele 2018. Evaluation of different feeding options for yearling Arsi-Bale sheep to attain export market body weight. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, and 01-04 October 2018*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp

II. Information

1. Prevalence of gastrointestinal parasites of cattle in pastoral Areas

1.1 Background information

Parasite is an organism that lives in another organism, called the host for survival. Gastrointestinal parasites are a world-wide problem in livestock as well as in agricultural sector and are responsible for major economic losses. The impact is greater in Africa in general and Ethiopia in particular due to the availability of a wide range of agro-ecological factors suitable for diversified hosts and types of helminthes. The most serious economic consequences of gastrointestinal parasites are based on the overall number of worms, number of genera and species present, general levels of pathogenicity and wide spread distribution. Recent study indicated that parasitic infection of cattle is the major factor responsible for economic losses through reduction in productivity and increased mortality in heavily parasitized animals. Especially parasitic nematodes (roundworms) are extremely important in both human and animal diseases. A study was conducted during the period of October 2016 to June 2017 in selected districts of Borana zone of Oromia Regional State to identify the major species of cattle GIT parasites and determine their prevalence, and the associated risk factors.. It was conducted on a total of 383 cattle of different age groups and both sexes were included. The animals were maintained under traditional extensive management system, where they foraged in communal pastures and have no history of de-worming at least for three months prior to starting the study. Useful information regarding this study is summarized below.

1.2 Outputs obtained from the information

- Prevalence of the gastro intestinal parasites investigated of the gastrointestinal parasites investigated in the area, 29.60, 23.28, 11.78, 9.48 and 4.31% are strongyle, Eimeria Oocyt, Ascaris, Strongloides, and fasciola species, respectively. Mixed infections account for 14.37% of the infestations.
- Highest prevalence was determined for strongyles type species (29.6%), Eimeria Oocyte (23.28%) and lower levels in trematodes and cestodes.
- Overall prevalence of GIT parasites was 218 (56.92%). The prevalence was higher in Moyale (71.65%), followed by 52.76% and 46.51% in Yabello and Arero respectively

1.3 Associated risk factors with prevalence of the parasites

Some associated risk factors (age, body condition, sex and location) and their association with prevalence of the parasites is indicated as follow:

Age: The prevalence of GIT parasite was higher in young animals (66.85%) than in adult ones (47.74%).

Body condition: The prevalence rates observed in cattle of poor, medium, and good body conditions were 77.33, 57.14 and 47.62%, respectively.

Sex: The study revealed the parasites infestation seems more prevalent in male (62.86%) than in female (54.68%) cattle

Location: The prevalence was higher in Moyale (71.65%), followed by 52.76% and 46.51% in Yabello and Arero districts, respectively

1.4 Benefit of knowing the information

Having this information policy makers and other Gos, NGos, cattle producers, regional and district level livestock agencies can seasonally arrange their calendar to de-worm their cattle with appropriate anti-helminthic drugs. In addition, cattle keepers or producers can apply appropriate management practices such as housing, feeding, grazing system (eg. rotational and zero grazing) and health care (eg. acaricide spray).

1.5 Reference

Dereje Teshome, Gizachewu Gemechu and Bantayehu Muluneh 2018. Prevalence of gastrointestinal parasites in cattle kept under pastoral management system in selected districts of Borana zone, Ethiopia *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

2. Epidemiological study of contagious caprine pleura pneumonia

2.1 Background information

Contagious caprine pleura pneumonia is a severe and distressing respiratory disease with high morbidity and mortality in goats. Contagious caprine pleura pneumonia (CCPP) caused by *Mycoplasma capricolum* subspecies *capripneumoniae* (Mccp) The disease is causing considerable economic losses. It occurs in many countries in Africa, Asia and Middle East and is a classical trans-boundary animal disease. Moreover, the disease is included in the list of noticeable diseases of the World Organization for Animal Health (OIE) as it threatens a significant number of goat populations throughout the world and has a considerable socioeconomic impact in infected territories. Though the disease is confined to goats, subclinical cases were reported in sheep and some wild ruminant species.

Therefore, a study was conducted to determine the sero-prevalence of caprine contagious caprine pleura pneumonia (CCPP) from November 2016 to April 2017 in selected districts of Borana zone, Southern Oromia, Ethiopia. to investigate the epidemiology and characterize the causative agent using molecular techniques. Useful information regarding this study is summarized below.

2.2 Outputs obtained from the information

Generally, the following prevalence was recorded in the area:

- Out of a total of 789 sera samples examined, 246 (31.2%) were found positive for anti-*MCCP* antibodies.
- The highest prevalence (36.70%) was observed in Moyale district, followed by Yabello (32.7%) and Elwoya (22.6%) (Table 6).
- Higher sero-prevalence was recorded in female goats (32.1%) than males (29.1%) although this difference was not statistically significant.
- Similarly sero-prevalence of CCPP was 34.3%, 32.2% and 28.8% in small, medium and large flock size, respectively

2.3 Associated risk factors with Sero-prevalence of CCPP in Goat

Association of the different risk factors (location, sex, age and flock size) with parasites prevalence is indicated as follow in the Table 6:

Table 6. Identified risk factors of sero-prevalence of CCPP in goats in Borana Zone

No	Risk factors	Number	Test Positive	Prevalence (%)
1	District			
	Elwoya	252	57	22.6

	Moyale	332	122	36.7
	Yabello	205	67	32.7
2	Sex			
	Female	535	172	32.1
	Male	254	74	29.1
3	Age			
	Adult	405	151	37.3
	Young	384	95	24.7
4	Flock Size			
	Small	175	60	34.3
	Medium	267	86	32.2
	Large	347	100	28.8
Overall		789	246	31.2

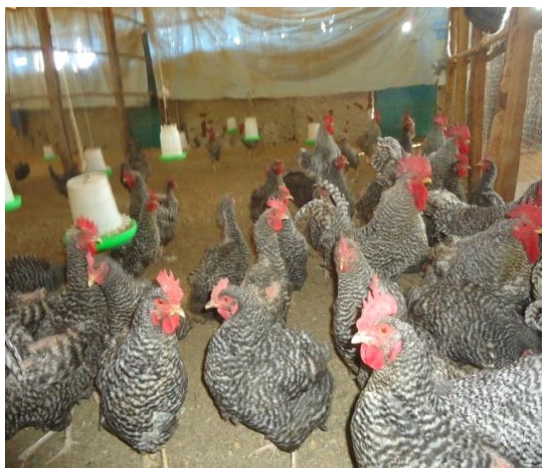
2.4 Benefit of using the information

Having this information policy makers and other Gos, NGos, Goat producers, regional and district level livestock agencies can seasonally arrange their calendar to vaccinate their Goat with appropriate Vaccines. In addition, goat keepers or producers can apply appropriate management practices such as housing, feeding, grazing system (eg. rotational and zero grazing) and health care.

2.5 Reference

Dereje Teshome, Teshale Sori and Barbara Wieland 2017. Epidemiological investigations of contagious caprine pleura pneumonia in selected districts of Borana Zone, Southern Oromia, Ethiopia. *Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

Part three: *Poultry Technologies/information* *User's Manual*



Koekoek chicken breed at BARC (left) and Fayoumi chicken production at ATARC (right)

I. Technology

1. Substituting Soybean meal with fish meal for feeding Fayoumi chickens

1.1. Background information

Fayoumi chickens originated from Egypt and are one of the egg producing breeds introduced to Ethiopia. They are, hardy and very precious in being early maturing. They mature at a very young age of 4-5 months, lay a good number of white cream eggs, have excellent resistance to viral and bacterial diseases, can cope with hot conditions and are excellent foragers.

Considering its production traits, the breed was brought to mid rift valley of Ethiopia to distribute for farmers. However, according to the previous studies conducted on poultry production systems in Mid-rift valley of Ethiopia, chicken rearing is characterized by inadequate feeding system which resulted in low growth rate and low egg production performance. There are no surplus grains rich in protein source to feed chickens in order to satisfy their nutrient requirements. It is, therefore, not advisable to develop a wholly grain-based feeding system because of socio-economic reasons. Identifying locally available feed resources to formulate diets are the recommended approach for chickens feeding. Soybean is one of the good protein sources for chicken feeding. It contains 40 to 48% crude protein depending on the amount of hulls removed and the oil extraction procedures. However, in mid rift valley area it is not possible to use soyabean for layers ration as it is not extensively cultivated. Instead, it is possible to use fishmeal as layers ration as it is highly available in the area. Nutritionally it has been widely used as a supplemental protein source for many years primarily for mono-gastric animals. Fish meal is an excellent source of protein with high levels of essential amino acids such as methionine and lysine. It also has a good balance of unsaturated fatty acids, certain minerals (available phosphorus), and vitamins (A, D, and B-complex). It is produced from clean dried and ground tissue of un-decomposed fish residues remaining after processing for human food or industrial purposes. Considering its availability and nutritional value, it is worthwhile to observe if it could be used instead of soybean in ration of layer fayoumi chickens. An experiment with four different feeding rations was conducted at Adami Tulu Agricultural Research Center to determine the amount of fish meal used as a substitute to soyabean meal in layers ration and to identify the economic benefits of using fish meal in layers diet. Description of how to prepare and utilize the recommended feeding and its benefits are indicated as follows:

1.2. Inputs required to apply the feeding technology

- Fish waste/offal, fish box, clean water, barrel, fire wood, plastic sheet/lamera (for drying), mesh wire (for decanting), grinding material and sacks.
- Concrete floor house

- Feeder, waterer
- Maize grain, wheat bran and noug seedcake
- Egg laying chicken/Fayoumi breed of 24 weeks of age

1.3 Housing and health management of chickens

- Keep the chickens in open house with concrete floor and saw dust/wheat/barley straw bedding at thickness of 5 to 7cm.
- The recommended stocking density is 4 chicken/m².
- Use bulbs with ultra violet light
- All chickens must be vaccinated at appropriate age against major poultry diseases

1.4 Steps and procedures to apply the technology

1.4.1 Feed preparation and feeding

A layer needs 100 grams of mixed ration daily. In order to prepare the recommended daily ration for a layer, mix and use the following ingredients indicated below (Table 1):

Table 1. Appropriate amounts of fish meal and other feed ingredients to be mixed

Feed ingredients	Amounts in gram
limestone	0.5
Salt	0.5
Premixes	1
Wheat bran	28
Fish meal	3.5
Soybean	11.5
Maize	32
Noug cake	23
Total	100

The recommended soybean meal to be used is 15 gram in layers ration. In this case 24% of the soybean meal is substituted with fish meal

The preparation of fish meal involves the removal of water and oil from press cake to give a high protein content and low moisture product which is stable in distribution and storage. In case fish meal is to be prepared by one self, the detail procedures of preparing it can be referred from “**Fishery technologies user’s manual**” first series (Tesfaye *et al.* 2018). It is also indicated in short as follows:

Collection of raw materials

- Fish offal consists of fish visceral, head, trimmings and intestine

- Purchase/obtain the fish offal from fish caught for the sole purpose of fishmeal production, by-catch from other fisheries or from fish processing operations.
- Fish offal can also be purchased at low cost from Fish Production and Marketing Enterprise when operational.
- Wash the bulk offal/waste using clean water and hash into smaller pieces for the cooker to ensure even processing although small fish can be fed whole into the process.

Heating (cooking)

- Heat the fish offal is to coagulate protein and disrupt fat deposits to release oil and physico-chemically bound water. Coagulation of the proteins and rupture of the fat cells can be completed quickly at temperatures below 100°C.
- Heating above 75°C for long periods is unnecessary. If the cooking time and temperature are too low the fluid (oil and water) will not be released from the protein and pressing will be difficult. However if the offal are over cooked the fish will become a soft mush and sufficient pressure will not build up in the press to expel the liquids.
- The offal and wastes are cooked in a barrel divided into two equal parts. The lid at the top can be made from sheet metal. The barrel which has a capacity of cooking 50 kg offal is quite enough.
- The offal must be stirred gently at intervals and be cooked for 35-40 minutes at a 70-75°C.
- The cooked offal must be left over night to settle in the barrel.

Pressing

- Press the cooked offal to separate the bulk of the liquid fraction (press liquor) from the solid parts (press cake). The main purpose of pressing is to squeeze out as much liquid (water and oil) as possible from the solid phase.
- This can be attained by pressing tightly the lid and tilting barrel containing cooked offal, so that the liquid fractions drain out.
- This helps to accelerate the drying process. If the cooked offal has not settled, it is possible to squeeze the maximum amount of liquid fraction from the solid fraction by pouring cooked offal on 0.5 mm mesh wire.

Drying

- The purpose of the drying process is to convert the wet and unstable mixture of press cake and concentration into a dry and stable fish meal.
- The pressed product is spread on the laminated tin on rack for drying.
- Drying is done by direct sun drying to the temperature where the rate of evaporation of the water is considered satisfactory.
- Increasing the temperature will speed up the drying process.
- The drying temperature under Zeway condition is 28°C.

Grinding (milling)

- Before milling the meal, it is necessary to remove or check extraneous matter like pieces of wood, clothe, fish hooks and nails, which might be present.
- The dried fish meal is ground using bone miller or mortar and pestle or any grinding material.

Storage and utilization

- Once fish meal grinding process is over, a powdered new fish meal product can be stored using polyethylene laminated sacks.
- This sack prevents the rapid movement of oxygen and water.
- It protects the meal from rodents and insect attack.
- Fish meal is a high protein feed supplement which can be mixed with other feed supplements to produce a balanced diet for livestock.
- The final product can be packed in 50 kg capacity paper or polyethylene laminated sacks and can be stored for one year in a cool and well ventilated areas.

1.5 Scope of using the technology

- This feeding technology can be applied anywhere provided that fish offal from which fish meal can be prepared and all other ingredients are available in the area in the area

1.6 Important data to be recorded

- Price of different feeds
- Amount of egg produced daily
- Total costs (feed, medicine, labor if any, cost of pen construction mesh wire, poles and bedding materials)
- Net income can be calculated as: $\text{Net income} = \text{Total return} - \text{Total variable cost}$

1.7 Precautions needed

- Fish meal must be kept in a cool dry place protected from rodents and birds.

1.8 Expected benefits of using the technology

Substituting soybean meal with 24% fish meal to layers ration has the following benefits:

- Improves feed intake by 9% (from 86 gram/chicken/day for soybean to 95 gram/chicken day for fish meal substituted)
- Improves egg production by 23% (from 52 egg/chick/6months for soybean to 64 eggs/chick/6months for fish meal substituted)
- Increases the income obtained by 3 folds (from 0.07 ETB/bird/day to 0.30 ETB/bird/day).

1.9 Reference

- Tesfa Geleta and Usman Abdulkadir. 2018. Systematic substitution of Soybean meal with fish meal in the diet of Fayoumi chickens. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.
- Tesfaye Alemu Aredo, Alemu Lema, Megerssa Endebu and Getachew Senbete (eds.) 2018. ***Fishery Technologies User's Manual***. Oromia Agricultural Research Institute (IQQO), Finfinnee, Ethiopia.

II. Information

1. Performance of dual Purpose *Koekoek* Chicken Breed

1.1 Background information

Ethiopia 97% of the total poultry population are reported to be indigenous breed. These breeds are managed under scavenging system and their egg and meat production potential is low. On the other hand there are improved breeds of chicken developed in different parts of world. These breeds needs to be managed under high input system and are known by high egg and meat production potential. *Koekoek* is a dual purpose (meat and egg production) chicken breed developed in Lesotho. Hence in order to fill the gap in egg and meat production in Ethiopia, it important to introduce and evaluate the production potential of improved chicken breed under prevailing management conditions. Accordingly, *Koekoek* chicken (Fig. 1) was introduced and its growth and egg production potential evaluated at Bako Agricultural Research Center over the past years. From the evaluation study, valuable information regarding its management and performance is summarized as follows:



Figure 1. Koekoek chicken breed

1.2. Housing and feeding management

- Keep the chickens in open house with concrete floor and saw dust/wheat/barley/teff straw bedding at thickness of 5 to 7cm.
- The recommended stocking density is 4 birds/m²
- The use bulbs with ultraviolet light
- Vaccinate chickens against major chicken diseases
- The house, feeders and waterers should be kept hygienic
- At the age of 18 weeks, prepare nest from local carton and provide them in the ratio of 1 nest to 8 layers.
- Purchase feed from commercial feed producers or retailers and offer according to different age groups indicated below (Tables 2 and 3):

Table 2. Recommended daily feed allowance for *Koekoek* chicken during the first 8 weeks (g/bird/day) for both sexes

Weeks	Feed required (g/bird/day)
Week1	9
Week2	15
Week3	23
Week4	28
Week5	38
Week6	41
Week7	55
Week8	59

Table 3. Recommended daily feed allowance for *Koekoek* chicken during 12 to 48 weeks (g/bird/day) for both sexes

Weeks	Feed required (g/b/day)	
	Female	Male
Week12	66	70
Week13	70	75
Week14	72	77
Week15	76	69
Week16	83	77
Week17	84	78
Week18	84	77
Week19	74	77
Week20	97	83
Week 21-27	119	-
Week 28-48	848	-

1.3 Growth performance and mortality rate of *Koekoek* chicken

These parameters are indicated for chicken of different age groups in Tables 4 and 5 bellow.

Table 4. Weight gain (g/bird/week) and mortality (%) of female and male *Koekoek* breed during starter phase (0 to 8 weeks)

Week	Av. Weekly weight (g/b/week)	Mortality(%week)
Week1	52	10
Week2	90	4
Week3	97	0.50
Week4	116	0.00
Week5	136	0.20

Week6	190	0.00
Week7	217	2
Week8	309	10

Table 5. Weight gain (g/bird/week) and mortality (%) of female and male Koekoek breeds during 12- 48 weeks

Weeks	Average weekly weight (g/b/week)		Mortality(% week)	
	Female	Male	Female	Male
Week12	592	612	2	0.5
Week13	657	698	0.95	0.9
Week14	722	764	1.5	1
Week15	616	926	0.98	0.00
Week16	795	1068	0.99	2
Week17	862	1159	2	2
Week18	897	1292	1.5	3
Week19	1120	1568	3	2
Week20	1299	1680	0.00	0.00
Week 21- 48	1792	2542	0.38	0.00

1.4 Egg Production potential of Koekoek

- Egg production potential of the chicken per week is 61%.
- The hatchability rate is 78% (checked by natural breeding)
- Age at first egg is 22 weeks

1.5 Recommendation

The breed has adapted at Bako Agricultural Research Center with very negligible mortality rate. Hence, small scale farmers, NGOs and other beneficiaries can use the breed without any fear in Bako and other areas with similar agro ecologies provided that the above mentioned management practices are followed.

1.6 Reference

Dereje Bekele, Tesfaye Tadesse and Fayera Bodena. 2017. Introduction and Evaluation of Dual Purpose Chicken (Potchefstroom KoeKoek) Breed at BARC. *Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017*. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

Part four: *Feed Resources and rangeland management Technologies/information User's Manual*



Cluster based Maize-*Lablab purpureus* intercropping at Dugda district (left) & on-station Elephant grass multiplication at ATARC (right)

I. Improved forage production and utilization technologies

1. Fodder Oat (*Avena sativa*)

1.1 Background information

Fodder oat (*Avena sativa* L.) is an annual cereal forage crop which is used mostly for animal feeding. Its straw is soft and superior to wheat and barley and its grain is valuable feed for almost all livestock species. Fodder oat is fast growing and produces a significant amount of fresh fodder within short period (80-90 days) with adequate nutritional facts. It contains large amount of digestible crude protein, total digestible nutrients (TDN), vitamin B1, minerals and fat. Use of low yielding cultivars and poor adaptation of management practices are factors responsible for the low forage yield. The improved cultivars of oat can feed double number of animals per unit area as compared to the natural pasture in the region due their higher yield potential of green forages. So far some adapted and released varieties of oat were recommended for fodder production in the region (Tesfaye *et al.*, 2018). Recently new oat variety named as ‘Bate’ or **ILRI 5453** (Fig. 1), which showed high yield performance as compared to oat varieties currently under production was released by Bako Agricultural Research Center. Here under is given the production techniques and utilization of this newly released variety.



Fig.1. Fodder oat (Bate variety) at early growing stage (left) and at dough stage (right)

1.2 production techniques

Bate (ILRI 5453) variety: It is a medium maturing variety released from Bako Agricultural Research Center in the year 2018 G.C.

Suitable agro-ecologies: Bate variety is characterized by having wide adaptation from lowlands to highlands of the region (1200 to 3000m.a.s.l.) with annual rainfall of 800-1200mm.

Establishment methods: Oat is propagated by seed and established in rows or broadcasting. It requires a clean and well-prepared seedbed.

Sowing date: Time of sowing varies according to the climate where oats are grown. Early planting at the start of raining enables the crop to take the full advantage of the main rainy season. Therefore, early to mid-July is the proper sowing time at places like Bako areas.

Seeding rate and spacing: Seeding rate of 80 kg/ha and 20 cm row spacing is required for herbage production. Whereas for seed production, 70 kg/ha with 30 cm row spacing is recommended (Abuye *et al.*, 2019).

Fertilizer rate: The optimum fertilizer levels to get realistic herbage and seed yield is 100 kg/ha DAP and 50 kg urea. Urea need to be applied in split application (half during planting and half after germination)

Weeding management: At early stage of growth, all improved forage crops are less aggressive and hence very sensitive to different weeds and thus need to be kept free from any weed. The most common weed management practices are cultivating, hoeing and hand weeding.

Harvesting stage: For reasonable biomass yield and digestible nutrient concentration, fodder oat should be harvested at 50% heading.

Seed production: Oat seed production is similar with the procedure used for seed production from cereal crops such as barley and wheat.

Nutritional composition: This newly released variety ‘Bate’ has 9.55% crude protein, 67.74% *In vitro* dry matter digestibility (IVDMD) and fiber contents of 32.78% ADF and 54.03% NDF.

Utilization: Fodder oat is mainly used for livestock feeding. It can be fed as green fodder by cut-and-carry system, or it can be made into hay or silage, or it may be grazed (in rare case).

1.3 Benefit of using the variety:

The performance of fodder oats for herbage and seed production varies depending mainly up on the type of varieties, soil, climate and the management practices followed during production. Bate variety has produced 8.56t/ha of herbage yield and 32.99quintals/ha of grains at Bako and similar agro ecologies.

1.4 Reference

Mekonnen Diribsa, Abuye Tulu, Waqqari Keba, Gutu Fekeda and Warku Temesgen, 2019. Registration of Bate, ILRI 5453^{*} Oat (*Avena sativa* L.) variety. In: *Proceedings of Review Workshop on Adaptation and Generation of Agricultural Technologies (Dagnachew Lule, Chemeda Daba, TemesgenJembere, Teshome Bogale, Kamil Ahimed, Girma Mengistu, Ayalew Deme, Kefyalew Asefa, Tesfaye Letta, Tadele Tadesse, KissiWakweya, Tilahun Geleto, Tesfaye Alemu, Dereje Woltedji & Kedir Wako*

(eds.).Oromia Agricultural research institute review workshop on Adaptation and Generation of Agricultural Technologies, 25-27 June 2018, Adama, Ethiopia.. 377 pp.

Tesfaye Alemu Aredo, Dawit Abate and Bikila Negasa (eds.) 2018. Feed Resources and Rangeland Improvement Technologies User's Manual, Oromia Agricultural Research Institute (IQQO), Finfinnee, Ethiopia.

II. Recommended Agronomic Practices

1. Rhodes grass (*Chloris gayana*)-Pigeon pea (*Cajanus cajan*) intercropping

1.1. Background information

Intercropping is a multiple cropping practice, which involves growing two or more crops in proximity. Intercropping forage legumes with grasses presents a potential to increase productivity, herbage nutritive value and resource efficiency. Legumes also improve the nutritive value of the low quality native pastures grown with them and are important component of a farming system since they have high nutritive value and able to rehabilitate nutrient deficient soils. Intercropping exhibits a greater forage production performance than sole cropping and is a feasible option for forage production. Furthermore, the cereal-based intercropping with forage legumes has a yield advantage compared with sole cropping of grasses or legumes. Accordingly, experiments on intercropping of Rhodes grass with pigeon pea genotypes were conducted at Bako Agricultural Research Center and the most compatible combination to improve forage production was identified and recommended. Here under is given the guideline as to how to apply this technology.

1.2. Inputs required to apply the technology

- Rhodes grass variety (Massaba)
- Pigeon pea variety (*Degaga*)
- DAP

1.3. Steps and procedures to apply the technology

Land preparation: This step is important to ensure that the field is ready for planting. It typically involves clearing, plowing, harrowing and leveling the field.

Establishment:

Planting materials should be planted on a well prepared field. Spacing for Pigeon pea is 1 m between rows and 50 cm between plants. Sowing of two seeds per hill for pigeon pea is recommended to secure plant failure. Rhodes grass seeds can be sown either in rows or by broadcasting. Half (50%) of the recommended seed rate for sole Rhodes grass (10-12 kg/ha) should be uniformly drilled between pigeon pea rows. Accordingly, 5-6 kg/ha is the recommended seed rate when Rhodes grass is intercropped with pigeon pea.

Planting date: Planting date of the mixture is generally at onset of the rainy seasons or by using irrigation in areas where irrigation facilities are available. Pigeon pea is sown at the onset of main rainy season (mid-June to early July), whereas Rhodes grass

can be sown 2-3 weeks after planting Pigeon pea (when pigeon pea started to grow).

Fertilizer rate: 100kg/ha of DAP at sowing

Management: Recommended agronomic managements for forage crops should be applied. Hand weeding and hoeing should be started a week after the seed is emerged and thinning is followed in case it is grown in double for pigeon pea. Guarding is the main activity to avoid any risk coming to the crop and must be carried out from sowing to harvesting times.

Harvesting stage: If the target is forage biomass production, the optimum harvesting stage is at pod setting for pigeon pea and at 50% flowering for Rhodes grass. On the other hand, if the purpose is seed production, it should be harvested after the crops attained full maturity stage.

1.4. Scope of using the technology

This intercropping technology is recommended for lowland and mid-altitudes (1300-1900 m.a.s.l.) agro-ecologies with moderate to high rainfall (800-1200 mm). This is mainly in the agro-ecology where pigeon pea and Rhodes grass are adapted and performed well in pure stand.

1.5. Benefit of using the technology

Intercropping of Rhodes grass with Degaga variety produced higher cumulative total herbage DM yield (6.9 t/ha) than both of the sole forage crops. Sole Rhodes grass produced 4.86 t/ha and sole Degaga produced 3.8 t/ha. The intercropping practice also resulted in a yield advantage of 49% over that from an average of pure stands of the species (grass and legume). This implies that 49% more area would be required for a sole cropping system to achieve the yield obtained from an intercropping system.

1.6 Reference

Mekonnen Diribsa, Waqqari Keba, Warku Temesgen, Abuye, Tulu and Gutu Fekeda, 2018. Compatibility Study of *Chloris gana* Intercropped with Different Accessions of *Cajanus cajan* under Bako Condition. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate. (Tsfaye Alemu Aredo, Kebebew Wakjira, Dawit Abate, Alemu Lema, Mekonnen Diribsa, Tsfaye Alemu Tucho, Felekech Lemecha. (eds.). Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

2. Maize - *Lablab purpureus* intercropping

2.1. Background information

Intercropping provides an opportunity to harness available resources by cultivation of two or more crops planted simultaneously in the same land that provides the possibility of yield benefit and minimizes crops failure. The major benefit of intercropping is an increase in production per unit area compared to sole cropping through the effective use of resources (water, nutrients, and solar energy). It also reduces weed competitions and stabilizes the yield. Legumes contribute to maintaining the soil fertility via nitrogen fixation. As a result of this ability of legumes and due to the more competitive character of cereals for soil inorganic nitrogen, the importance of legumes in intercropping with cereals increased. This leads to a complementary and more efficient use of nitrogen sources by the crops in the intercropping system. Intercropping study which targeted to evaluate the influence of such cropping patterns on maize and legumes grain yields and other yield components was conducted at Mechara Agricultural Research Center and the best association was recommended. A guideline as to how to apply this technology is summarized as follow.

2.2. Inputs required to apply the technology

- Maize (Melkasa-4)
- Dolichos lablab
- DAP and UREA fertilizers

2.3. Steps and procedures to apply the technology

Land preparation: This is important step to ensure that the field is ready for planting. It typically involves clearing, plowing, harrowing and leveling the field.

Establishment:

Maize and legumes should be planted on a well prepared filed. Single and double row planting of legumes between maize rows is used. Spacing for maize is 75 cm between rows and 30cm between plants. Dolichos lablab seed can be sown at 20cm space between plants and 37.5 cm between maize and Dolichos lablab in single row. The recommended seed rate for Dolichos lablab (15 kg/ha)is sown between maize rows. Sowing of two seeds per hill for both cereal and legume is recommended to secure plant failure.

Planting date: Maize is sown at the onset of main rainy season and lablab can be sown 35 days after planting maize.

Fertilizer rate: 100kg/ha of DAP at maize planting and 50 kg urea after maize develops two to three ears.

Management practices:

Hand weeding and hoeing should be started a week after the plant is emerged and thinning must be undertaken for sole planting of both maize and lablab following their respective planting time. Guarding should be there from sowing to harvesting time.

Harvesting stage: The optimum harvesting stage for Lablab should be at 20-40% flowering for herbage production. For seed production, harvesting of both maize and lablab should be after the crops attain their full maturity.

2.4. Scope of using the technology

This intercropping system is beneficial in areas with altitude ranges from 1350 to 1750 m.a.s.l. and moderate to high rainfall (900-1300 mm) conditions. Such agro-ecology is where maize and Dolichos lablab are grown and perform well in pure stand.

2.5. Benefit of using the technology:

Intercropping of Dolichos lablab in single row planting at 37.5 cm spacing between maize rows produces comparable maize grain yield (39.16 qt/ha) with sole maize (40.57 qt/ha). The forage fresh biomass production of Lablab obtained from the single row intercropping practice varies from 63.93 to 78.1 t/ha which is considered as an additional advantage of the intercropping practices. In addition to getting quality feed production from Dolichos lablab, such forage legumes have a contribution to improve fertility of the soil. Hence, intercropping lablab in maize with a single row planting pattern is more advantageous than the sole maize production.

2.6. Reference

Birmaduma Gadisa, Tamrat Dinkale, and Muleta Debela, 2018. Evaluation of the effects of Maize-Intercropped with Forage Legumes under Different Planting Patterns on Yield and Yield Components of Maize and Fodder in West Hararghe, Oromia. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate (Tesfaye Alemu Aredo, Mekonen Diribsa, Dawit Abate, Temesgene Jembere, Dereje Teshome, Amsalu Bezabeh, Matheows Hailu, Samuel Tufa, Girma Chalchisa (eds.)). Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

III. Recommended planting date and seeding rate for different forage species

Background information

Germination of tropical grasses and legumes is typically low mostly due to dormancy restriction, which might be improved through application of appropriate cropping practices. Besides other routine cropping practices, planting date, seeding rate and row spacing, play a great role in herbage biomass yield, seed yield and other performances of forage crops. Seeding rates and row spacing are considered as important factors to optimize plant population as the establishment of an adequate and uniform crop stands is critical to achieve high yields. Therefore, it is crucially important to manipulate the level of seeding rate and planting date in order to increase crop productivity. So far, some agronomic studies for different forage species have been conducted by different Research Centers including Bako and Adami Tullu Agricultural Research Centers to identify and recommend appropriate seeding rate and planting date of forage grasses and legumes to the study areas and similar agro-ecologies. Guideline to use recommended technologies from such study is given bellow.

1. Optimum planting date and seed rate for *Brachiaria Decumbens*

1.1. Inputs required to apply the technology

- *Brachiaria Decumbens* seeds
- DAP and Urea

1.2. Steps and procedures to apply the technology

Land preparation: It is important to ensure that the field is ready for planting. Land preparation typically involves clearing, plowing, harrowing and leveling the field.

Planting date: Three weeks after onset of the rainy season is the appropriate planting time.

Seed rate: Depending on the soil fertility of the field and the seed quality, seed rate of 6-8 kg/ha is optimal for biomass production.

Establishment: The seeds should be sown on a well prepared field with 30 cm spacing between rows and drilled uniformly.

Fertilizer rate: 100kg/ha of DAP/NPS and 100 kg/ha of UREA is the recommended fertilizer rate. DAP/NPS can be applied at planting time followed by urea split application (50 kg/ha at planting and 50 kg/ha a month after the planting date).

Management: Since *Bracharia decumbas* delays to emerge, manual weeding should be started before its emergence and must continue until the grass grows fully and dominates the emerging weeds. Hoeing should be started a week after the grass is fully

emerged and must continue. Guarding is the main routine activity to be undertaken till harvesting.

Harvesting stage: The optimum harvesting stage for forage biomass is at 50% flowering stage. For seed yields, harvesting should be after the grass attains full maturity.

1.3 Scope of using the technology

The technology is practical at an altitude ranges from 1300 to 2400 m.a.s.l. with moderate to high rainfall (800-1200 mm) conditions. This is mainly in the agro-ecologies where *Bracharia decumbas* is grown. So, it is favorable for Bako area and similar agro ecologies.

1.4 Benefit of using the technology

Sowing *Bracharia decumbas* at a rate of 6kg/ha at three weeks after commencement of the main rain can produced better herbage DM yield (18.7 ton ha⁻¹) and seed yield (6.37 qt ha⁻¹).

1.5 Reference

Mekonnen Diribsa, Waqqari Keba, Gutu Fekeda, Abuye Tulu, and Warku Temesgen, 2018. Determination of Optimum Planting Date and Seed Rate for *Brachiaria Decumbens* at Bako Condition. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate (Tsfaye Alemu Aredo, Kebebew Wakjira, Dawit Abate, Alemu Lema, Mekonnen Diribsa, Tsfaye Alemu Tucho, Felekech Lemecha. (eds.).Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute, held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia.232 pp.

IV. Forage crops management technologies

1. Napier grass dry season cutting management

1.1. Background information

Napier grass (*Pennisetum purpureum*) is a perennial forage crop with high growth rate and productivity mostly used for cut and carry system. It is an adaptable, vigorous and withstands considerable periods of drought, rapidly recovering from stagnation of growth with the onset of rains after extended dry periods. Moreover, it has the advantage of withstanding repeated cutting and can give high yield from a plot of land. Proper grass management is equally as important as selecting the right species and establishing them correctly in the proper locations. With appropriate management practices, Napier grass could provide a continual supply of green forage throughout the year and hence it suits small scale and intensive farming. Of the management practices, cutting management during dry seasons play an important role in determining yield, quality and longevity of the pasture. Research work on cutting height and cutting interval of Napier grass was conducted at Bako Agricultural Research Center during 2015-2017 cropping seasons with the objective of evaluating the effect of dry season cutting management on subsequent forage yield and growth performance of the grass. Here under is given the mechanism of applying this technology.

1.2. Inputs required to apply the technology

- Napier grass cuttings
- DAP/NPS and Urea fertilizers

1.3. Steps and procedures to apply the technology

Land preparation: Land preparation is important to ensure that the field is ready for planting.

Land preparation typically involves clearing, plowing, harrowing and leveling the field.

Establishment: Napier grass is usually propagated by stem cutting with 3 nodes or via root splitting. In the first case 2 nodes are planted in soil at 45° slanting and in case of root splitting up to 15 cm must be buried in furrows.

Planting date: The planting date of the grass is commonly at onset of the rainy seasons or by using irrigation in the areas where irrigation facilities are available

Fertilizer rate: 100 kg DAP and 100 kg urea per hectare should be used. Urea need to be applied in split application (half during planting and half after germination).

Management: Hand weeding and hoeing can be started a week after emergence and guarding should be continued year round since Napier grass is perennial grass and stays on the field for many years.

Harvesting stage and utilization: The optimum harvesting stage for Napier grass is at 1 to 1.5 m height. The grass can be used in a cut-and-carry system for green forage and conserve as fodder by making silage.

1.4. Scope of using the technology

The technology is suitable at an altitude ranges from 1200 to 2400 meters above sea level with rainfall ranging from 600 to 1200 mm per annum. This is principally in the agro-ecologies where Napier grass is commonly adapted.

1.5. Benefit of using the technology:

Harvesting of Napier grass for green forage at 30 cm cutting height during the beginning of drought period can produce herbage dry matter yield of 24.63 t/ha and resulted in high value (2.40) of leaf to stem ratio than at 20 cm cut above the ground level in the same season which resulted in lower values (1.69 t/ha and 1.6) of herbage dry matter and leaf to stem ration, respectively. Hence cutting at the onset of dry season at 30 cm height above ground level is the optimal level of harvesting for better forage yield and re-growth performance at Bako and other areas with similar agro ecologies.

1.6 Reference

Abuye Tulu, Mekonnen Diribsa, Gutu Fekede, Wakgari Keba, Worku Temesgen, Alemayehu kumsa, 2019. Effect of dry season cutting management on subsequent forage yield performance of Napier grass (*Pennisetum purpureum*) grown under sub-humid climatic condition of western Oromia, Ethiopia. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate (Tesfaye Alemu Aredo, Mekonen Diribsa, Dawit Abate, Temesgene Jembere, Dereje Teshome, Amsalu Bezabeh, Matheows Hailu, Samuel Tufa, Girma Chalchisa (eds.). Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute, held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp

2. Application of cattle manure for Napier grass biomass production

2.1. Background information

Napier grass is one of the most important species and commonly used by many farmers today due to its wide ecological adaptation, ease of propagation, management and its biomass production. However, the yield and quality of Napier grass can be further enhanced by improving fertility of the soil. High cost of inorganic fertilizers is one of the main limiting factors in using them for the production of forage species in general, and Napier grass in particular. On the other hand, farmyard manure is known to have a significant role in maintaining and improving the chemical, physical and biological properties of soils. Farmyard manure prepared from cattle manure is the most important organic fertilizer used to improve soil fertility. A study on the use of this fertilizer to improve the yield and quality of Napier grass was conducted at Adami Tulu Agricultural Research Center. Description as to how to apply this technology is summarized below.

2.2 Inputs required to apply the technology

- Napier grass cuttings
- Cattle manure
- DAP fertilizer

2.3 Steps and procedures to apply the technology

Land preparation: The land should be cleared from unwanted weeds and ploughed two to three times to get a fine seedbed. A well-prepared seedbed favors good germination and growth.

Establishment: Napier grass should be established on well prepared seedbed. The grass is usually propagated by root splitting or stem cuttings. Bury in 15 cm furrows for root splitting and bury 2 nodes in soil at 45° angle for cuttings.

Planting date: The grass should be planted at the start of the main rain

Row spacing: Distance between plants and two adjacent Napier grass rows should be 0.5m and 1 m respectively.

Cattle manure application rate: Applying partially decomposed cattle manure at the rate of 7.48t/ha during the establishment and split applications after each cut is recommended.

Inorganic fertilizer rate: DAP fertilizer at the rate of 100 kg/ ha at planting is essential

Weed management: The newly established Napier grass should be free from weeds. Removing weeds by hand is essential. It is very important to control weed and unwanted plants during the production periods.

Harvesting stage: The optimum harvesting stage is at 1- 1.5 m height

2.4 Scope of using the technology:

Napier grass grows and performs better in areas where annual rainfall is above 400 mm and altitude ranges from 500 - 2400 m.a.s.l.

2.5 Benefit of using the technology:

Herbage total dry matter yield of 9.94 to 11.7t/ha and CP content of 11.3 to 14.3% can be obtained by using cattle manure at a rate of 7.48t/ha in the mid rift valley and similar agro-ecologies. The yield and quality improvement due to the use of cattle manure (7.48t/ha) is comparable to the application of inorganic fertilizer (UREA) at 100kg/ha. Hence, the use of cattle manure as fertilizer offers the best opportunity to improve Napier grass productivity under smallholder farmer's condition. .

3. Forage legumes intercropping in Napier grass

3.1 Background information

The importance of herbaceous forage legumes in increasing herbage production of grasses and quality of feed produced has been well recognized. The inclusion of forage legumes in Napier grass based diet has shown to improve animal performances because of their high nutrient contents. Intercropping herbaceous forage legumes such as Dolcious Lablab and alfalfa in Napier grasses enhance the yield and quality of the mixture crops. Forage legumes benefit Napier grasses by contributing nitrogen to the soil through atmospheric fixation, decay of dead root nodules or mineralization of shed leaves. In line with this, efforts have been made at Adami Tulu Agricultural Research Center in identifying the best forage legumes to be intercropped in Napier grass to improve the yield and quality of Napier grass. Description for such practice is given bellow.

3.2 Inputs required to apply the technology

- Napier grass (*Pennisetum purpureum*)
- Dolcious Lablab (*Lablab purpureus*), Alfalfa (*Hunter river*)
- DAP fertilizer

3.3 Steps and procedures to apply the technology

Land preparation: The land should be cleared from unwanted weeds and ploughed two to three times to get a fine seedbed.

Establishment: Napier grass root splits should be planted on a well prepared seedbed, at 15cm depth and inclined at 45° angle. Forage legumes should be planted in between two adjacent rows of Napier grass.

Seed rate for forage legumes: for *Lablab purpureus* =15 kg/ha, for *Hunter river* =5kg/ha

Type and rate of fertilizer: DAP fertilizer should be applied at 100 kg/ha at the establishment time

Row spacing: Distance between plants and two adjacent Napier grass rows should be 0.5m and 1 m respectively. Forage legumes should be sown in between two adjacent rows of Napier grass

Time of planting: Planting date for Napier grass is at the start of the main rain and forage legumes must be intercropped after Napier grass started growing.

Management: The newly established grasses have to be kept free of weeds. Removing weeds mainly by hand is important. This reduces competition when grasses are weak.

Optimum harvesting stage: The optimum harvesting stage for Napier grass is at about 1-1.5m height while the forage legumes must be harvested at 20 to 50% flowering.

3.4 Scope of using the technology

Suitable agro-ecologies for these forage production ranges from an altitudes of 500 - 2,200 m.a.s.l. with annual rainfall of more than 400 mm

3.5 Benefit of using the technology:

Herbage total dry matter yield of 12.05 to 13.3t/ha and 12.35 to 13.4 t/ha can be obtained from Napier-Lablab and Napier-Alfalfa mixtures respectively. The CP content varies from 13.2 to 13.6% for Napier-lablab and from 12.4 to 16.7 for Napier-Alfalfa mixture. On the contrary the yield of 9.6 to 10.3 t/ha of dry matter and 11.1 to 12.8 % of CP content can be obtained from the sole Napier grass production. Hence, intercropping Napier grass with forage legumes (Lablab and alfalfa) has a significant advantages due to the higher total biomass yield and quality obtained from intercropping system as compared to growing Napier grass in pure stands.

3.6 References:

Usman Semman, Dawit Abate, Lalisa Diriba, Nebi Husein and Meseret Tilahun 2019. Effects of Fertilizer Application Versus Forage Legumes Intercropping on Agronomic Parameters, Yield and Crude Protein content of Napier grass (*Pennisetum purpureum*) at Adami Tulu and Arsi Negele. In: Proceedings of Review Workshop on Completed Research Activities

of livestock Research Directorate (Tesfaye AlemuAredo, Mekonen Diribsa, Dawit Abate, Temesgene Jembere, Dereje Teshome, Amsalu Bezabeh, Matheows Hailu, Samuel Tufa, Girma Chalchisa (eds.). Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute, held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01- 04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia.338 pp.

V. Rangeland technology

1. Appropriate cutting Frequency of reseeded grasses for better Yield and Nutritional Quality

1.1. Background information

Most grasses fed at early stages of maturity are more digestible and are eaten in larger quantities than at more mature stages. Due to increasing pressure on rangelands, which leads to degradation, rangeland restoration has been recommended to enhance rangeland ecosystem services, such as biomass production. To curb the negative consequences of degradation, there are already good practices of forage production in rangelands particularly where perennial rivers flow throughout the year. Such practices have been also envisaged for most rangelands of Ethiopia with anticipated water network development. If this envisaged rangelands development is going to be realistic, there should be an appropriate grass production system fitting to the new paradigm of rangeland production for sustainability. The surplus biomass production of rainy season and/or while using irrigation should be carefully preserved in various forms, such as hay formation for latter use. In Borana rangelands, government and non-government organizations are initiating hay making, particularly from enclosures, but, cutting only once for hay making and/or left as standing hay (*Kelo*) to be grazed by animals each year. However, the various cutting studies with herbaceous vegetation revealed that cutting interval is crucial for growth, yield and persistence of swards. Because cutting at suitable interval promotes tillering and increases the basal area of the tussocks of perennial grasses. It also promotes tillering and more effective seed formation as well as vegetative growth. Therefore, cutting frequencies study of reseeded grasses was conducted at Yabello Pastoral and Dryland Farming Research Center and an appropriate cutting frequency for two common rangeland grasses (*Cenchrus ciliaris* and *Chloris gayana*) was determined. Here under is mentioned the procedure of applying the reseeded technique and the envisaged advantages from such exercise.

1.2. Inputs required for applying the technology

Materials required as input include

- degraded rangeland
- fencing material/locally available bushes
- Sickle or any locally available grass cutting material
- cow dung and
- seeds of the grass species

1.3 Steps and procedures to apply the technology

- i. Select a degraded rangeland and/or site to be reseeded
- ii. Land preparation using simple tillage to only break the soil crust
- iii. Improving the soil fertility status by adding cow dung (10 ton/ha)
- iv. Start reseeding at the beginning of the main rainy season if irrigation is not used (seeding rate: 20-35 kg/ha for *Cenchrus ciliaris* and *Chloris gayana*)
- v. Cutting should be undertaken every fortnightly to monthly period

1.4. Scope of using the technology or its recommendation domain

This technology is important for the management of reseeded grasses in semiarid rangelands, mainly where the two recommended grass species are used for restoration of degraded semiarid rangeland ecosystems reseeded by grasses of the same species. The findings have a paramount importance in the management of rangelands of different ages in areas such as Borana rangelands, where the study species have recently been recommended for reseeding activities.

1.5. Important data to be recorded or calculated

- Grass biomass yield
- Restored land area

1.6. Precautions needed:

Care should be taken because the high biomass production of grasses can only be ensured provided that they are clipped from fortnightly to monthly intervals under good rainfall year or irrigation. Increasing the frequency of cutting to weekly interval reduces biomass production even when the year is good. Further, keeping the grasses without cutting until maturity reduces their nutritional quality.

1.7. Expected benefits of using the technology

The higher biomass under moderate clipping frequencies compared to non-clipping highlights that controlled grazing can strongly enhance biomass in a newly established pasture. This might be attributed to the fact that plants have the capacity to compensate or even overcompensate for herbivory at low levels of grazing pressure. However, weekly clipping significantly stimulated up to 152% higher biomass of newly established grasses. Weekly clipping, further, significantly enhanced grass nutrients (crude protein) in mature grass tufts by up to 82 and 105% in *C. ciliaris* and *C. gayana*, respectively. Generally, the findings provide important information for local decision makers, which might enhance the establishment and management of reseeded rangelands in the Borana and similar agroecosystems. The results from this study will greatly increase the available information on biomass production in *C. ciliaris* and *C. gayana*. It is

recommend that the traditional way of pastoralism, including resting places that exclude grazing (*Kalo*), should be supported.

1.8. Additional information

The long-term practiced enclosures and reseeding of degraded rangelands should be clipped or grazed from biweekly to moderately interval to enhance the overall biomass yield of the rangelands when grasses are young. When the rainfall is below average, i.e., lower rainfall regime, a trend predicted for eastern Africa in the future climate change scenarios, the biomass production reduces to 31 and 40% as water stress leads to reduced daily leaf extension. This result implies that under drought conditions or when irrigation is not used grazing or clipping seems less important for grass biomass production.

1.9. Reference

Samuel Tuffa, Dana Hoag, Anna C. Treydte. 2017. Clipping and irrigation enhance grass biomass and nutrients: Implications for rangeland management. *Acta Oecologica* 81 (2017) 32 – 39.

VI: Rangeland – Information

1. Nutritional Characterization of Feed Resources in Borana Semi-arid Rangelands

1.1. Background information

Boran cattle are known for their high degree of heat tolerance, resistance to specific disease, feeds and water shortage, and high milk and meat production potential. On the other hand, due to different constraints they show correspondingly low performance, low milk yield and long age at first calving and long calving interval. Their low productivity could be attributed to absence of appropriate information to improve feed shortage, poor rangeland management. The Borana rangelands are relegated to marginal land, characterized by climatic variation and frequent drought, which contributes to feed shortage. Moreover, there is little or no conclusive information on feed resource characterization, nutritional aspect and constraints to implement appropriate development strategies for pastoralists and agro-pastoralist in semi-arid Borana rangelands. Likewise, there is no organized information about the utilization pattern of feed sources that may be helpful as a baseline for future development works. To this end, a study which addresses the nutritional characterization of feed resources in Borana rangelands was conducted by Yabello Pastoral and Dryland Agriculture Research Center and the following valuable information was generated.

1.2 Inputs required for generating the information

- Laboratory materials have been used and methods have been followed to generate the information.

1.3. Steps and procedures used to generate the information

A total of four districts, namely, Teltele, Yabello, Arero and Dire were selected. Two kebeles were selected from each respective selected district. And then 15 household heads were selected from each kebele. The structured and pre-structured questionnaire were prepared and pre-tested on some households from the respective study area before the commencement of the actual survey. Then after, appropriate modification and corrections were made to facilitate effective delivery of the needed information. All necessary data including type of feed available, feeding system, condition of the feed, season of feed availability, major constraints of feed production and mitigation to feed shortages were collected using structural and semi-structural questionnaires. In each study sites, all the major feed resources were recorded with inclusion of their usages for respective livestock species. Then the feed types that are similar in usage and character from all sites were merged together. The most prioritized feed samples from grasses and leaves of browse trees were collected during wet (April) and dry seasons (January) from all

districts. The feed samples were evaluated for chemical composition using Near Infrared System (NIRS) at nutritional laboratory of International Livestock Research Institute (ILRI).

1.3 Major information generated

The chemical composition of grasses, particularly crude protein (CP) percentage is lower during dry season than wet season. Although the browse trees have similar chemical composition during both dry and wet seasons, these browse trees are not available in required amount in both seasons. In line to this, there were no improved forages production practices in the area. Hence, it is important to increase available feed resources in terms of nutritional value either by integrating with improved forages resources. The following forage species (Table 1) have been adapted and recommended for end users to improve the nutritionally poor available feed resources.

Table 1: Information generated on chemical composition of improved forage species

Forage species	DM (%)	Ash (%)	OM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	TIVDMD (%)
<i>Chloris gayana</i>	92.13	13.26	86.74	9.67	74.66	46.42	5.87	52.36
<i>Cajanus cajan</i>	91.58	10.81	89.19	24.25	27.95	30.23	8.02	75.40
<i>Lablab purpureus</i>	90.62	10.98	89.05	18.74	43.96	30.88	4.36	75.21
<i>Sesbania sesban</i>	90.56	11.32	88.67	22.29	29.82	28.86	6.94	76.46
<i>Sesbania aculeata</i>	90.86	11.36	88.63	22.48	29.12	28.42	5.99	78.44
<i>Pennisetum purpureum</i>	90.51	14.72	85.28	13.73	75.41	42.2	5.99	78.65
<i>Rhynchosia ferruginea</i>	90.39	10.8	89.2	15.79	52.35	40.0	7.41	64.28

1.4 Precautions needed:

The nutritional quality of supplement feeds should be ensured through appropriate harvesting time and conservation mechanisms. Further, the rangeland should be properly managed for better biomass production and also the total number of livestock grazing or browsing must be balanced with the available resources to avoid degradation of the reangeland.

1.5 Expected benefits of using the information

The nutritive value of grass species, especially crude protein percentage is less than critical value during the dry season. Hence, improving feed sources, mainly through rehabilitation of rangelands and upgrading the nutritive value of feed sources during the dry season through the use of improved forages and proper conservation is required. The benefit of using the information is increasing the availability of quality feed throughout the year that increases animal performance.

1.6 Reference

- Bedasa Eba, Bikila Negasa, Samuel Tuffa, Jaldesa Doyo, Asfawu Ijo, Bantayehu Mulune and Gebayehu Elias. 2016. Inventory of Feed Resources and Nutritional Characterization in Semi-arid of Borana Rangelands, Southern Ethiopia. In: Proceeding of Regional workshop on review of livestock research results (Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh, Alemu Lema and Berhanu Shilema; eds.), held at Adami Tulu Agricultural Research Center, Adami Tulu.
- Bedasa Eba, Bikila Negasa, Jaldesa Doyo, and Asfawu Ijo. 2016. Inventory of Feed Resources and Nutritional Characterization in Semi-arid of Borana Rangelands, Southern Ethiopia. In: Proceeding of Regional workshop on review of livestock research results (Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh, Alemu Lema and Berhanu Shilema; eds.), held at Adami Tulu Agricultural Research Center, Adami Tulu.

2. Boran cattle population dynamics

2.1 Background information

The Boran cattle are more productive than other local cattle breeds, with quite high rates of reproduction, milk yield, and low mortality rates. They are adapted to the arid and semiarid environment of East Africa, particularly to the semiarid Borana rangelands, Ethiopia. Boran cattle strongly contribute to the food security of the pastoral community in areas where other agricultural land use systems would not be ecologically sustainable. However, the total dependency on animals has recently come under threat due to recurrent drought and human population pressure as well as increased occupation and privatization of preferred grazing land use changes. Consequently, Boran cattle have recently undergone drastic population crashes, which highlights the fragility and the lack of knowledge of their persistence within an increasingly unpredictable environment due to climate change. However, little is known about the resilience of Boran cattle and their population dynamics in the face of increasing drought due to climate change. The generated information from modelling the Boran cattle population dynamics sheds light on the population size of this highly threatened but important breed in the Borana rangelands under different drought scenarios. Such information is highlighted below.

2.2 Inputs required for generating the information

- Boran cattle population of consecutive year
- Weather information
- Market information
- Vital rates (birth and death rates)
- Trends in frequency of drought
- Modeling software

2.3 Steps and procedures used to generate the information

- Collection of data on demographic and environmental factors and market values affecting the current and future Boran cattle population from Ethiopian central statistical agency and literature.
- Generating stochastic models under different drought scenarios (scenarios 1- 4 with mean and standard deviation, (μ , SD): (20, 15), (15, 11.25), (10, 7.50) and (5, 3.75), respectively) and the future development of the cattle population was assessed.
- Presenting changes in age- and sex-cohorts of Boran cattle population by randomly disturbing the trajectory at different drought frequencies on vital rates, carrying capacity and marketing.

2.4 Major information generated

- We observed high herd crashes under scenario 4, which is the most likely to happen in the face of climate change.
- Management should focus on lowering herd crashes through increasing sale of mature males that increases feed availability to females during drought years in the Ethiopian Rangelands.
- Drought early-warning systems and market information must be strengthened so that pre-planned selling can be realized for the fair and sustainable use of the animal resource.
- Rangelands should be managed to enhance resilience after drought through marrying scientific and indigenous knowledge.

Generally, cattle sale should be encouraged as it reduces grazing pressure on the rangelands; further, it should be pre-planned and should target males rather than females. In addition, drought early warning systems and market information must be strengthened in drought prone pastoral areas so that the advice of pre-planned selling of cattle can be realized for a sustainable use of the animal resource. Further, rangelands should be managed to enhance resilience after drought through integrating scientific and indigenous knowledge.

2.5 Expected benefits of using the information

The model can aid in devising a proactive drought management for age- and sex-structured Boran cattle population in the face of more prevalent drought. Such strategies can enhance food security as they facilitate off take and prevent the build-up of herds and subsequent die-off of animals during drought, which has been a common phenomenon in eastern African rangelands.

2.6 Reference

Samuel Tuffa and Anna C. Treydte. 2017. Modeling Boran cattle populations under climate change and varying carrying capacity. *Ecological Modelling*, 352:113–127.

3. Effect of Encroaching Acacia Species on Herbaceous Composition, Aboveground Biomass and Soil Nutrient

3.1. Background information

East African rangelands including Borana rangelands are threatened by environmental changes due to drought and encroachment of undesirable woody species, which reduced grass production owing to competition for water, light or nutrient. Encroaching woody species are challenging for pastoral animal productions; because most of the encroaching woody species are thorny or thicket-forming, which make grasses under their canopy inaccessible to animal grazing. Herbaceous layer productivity is lower under encroached canopies than the nearby open grassland. Despite the interest in bush management, it is remarkable that little information is known about the interaction of the two basic components: bushes and herbaceous species. Hence, a study was conducted by Yabello Pastoral and Dryland Agriculture Research Center to investigate the interaction effects of acacia species on herbaceous species composition, above ground biomass and soil nutrient and identify the most noxious species that has negative effects. The information obtained from the study is summarized as follows for use by different stakeholders.

3.2 Inputs required for generating the information

- Axe or any cutting material for thinning
- quadrant
- measuring tape

3.3. Steps and procedures used to generate the information

- Three plants for each acacia species that were almost similar in height, branches and structural form were selected.
- A 15 m transect was extended from the trunks of each of the three species to open zone.
- The transects were positioned as 1 - 2 m for root, 5 - 10 m for canopy and 12 - 15 m for open zones of respective acacia species.
- Four transects were positioned in four direction (north, south, west and east) randomly from each acacia species, avoiding shrubs, termite mounds and other disturbances.
- Samples of basal cover and species composition were taken using a 0.5 m x 0.5 m frame quadrant along each length of the transects for the three acacia species and three zones (three acacia species x three zones x 3 replication).
- Herbaceous species cover, composition and above ground productivity were determined in the three zones (root, canopy and open).

- All plants within the 0.5 m x 0.5 m quadrant along transect were clipped to ground level. Dry matters of herbaceous were determined after oven drying at 105 °C for 24 hours at Yabello Pastoral and Dryland Agriculture Research Center.

3.4 Major information generated

Under all canopies of acacia species studied, *A. mellifera*, *A. drepanolobium* and *A. reficiens*, drymatter yield of herbaceous vegetation significantly decreased along open, canopy and root zone, in that order with the lowest drymatter accumulation in the root zone. Like drymatter yield, species composition and basal cover were highest at open zone. However, the highest percentage of organic carbon and nitrogen in the soil were observed under root zone of *Acacia derpanolopium* and *Acacia reficiens*. Hence, acacia species with encroached condition might have negative effect on aboveground biomass where as positive effect on soil fertility status. And hence, areas encroached with these species need thinning (at least to 35-50%) to minimize the negative effects of the encroached condition.

3.5 Precautions needed:

For sustainable use of the rangeland after thinning or fire there should be a continuous monitoring for controlling encroaching species and balance the livestock density with available feed resource of the area to avoid overgrazing.

3.6 Expected benefits of using the information

This information can be used by different stakeholders who are active in the rangeland management. For example different NGOs in Borana are currently involved in bush clearing. However, according to the findings of the current research, acacia enchroached areas should be thinned instead of clearing to save the benefit of soil fertility and other ecological advantages. Therefore, minimizing the density by thinning rangeland areas encroached by acacia species leads to a positive effect on rangeland productivity, and hence, improves grass production in the rangelands that definitely contributes to food security. Further, improved soil fertility under the canopy could help as “island of fertility” that can promote health of rangeland condition.

3.7 Reference

Bedasa Eba, Bikila Negasa, Samuel Tuffa, Jaldessa Doyo. 2016. Effect of Encroaching Acacia Species on Herbaceous Composition, Aboveground Biomass and Soil Nutrient Status in Borana Rangeland, Southern Ethiopia. In: Proceedings of Regional workshop on review of livestock research results (Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh,

Alemu Lema and Berhanu Shilema; eds.), held at Adami Tulu Agricultural Research Center, Adami Tulu.

4. Effects of the Neglected Encroaching Species on Herbaceous Species Composition

4.1. Background information

Encroaching species can dramatically alter the habitat of native species through changes in structure and function of vegetation, consequently reducing availability of food resources. Therefore, encroaching species are now considered as one of the primary causes of degradation to native species in rangelands and are considered as a major cause of the reduction and extinction of important forage species as well as other important species globally. Encroachment has been among the major threats to the livelihoods of Borana pastoralists and their ecosystems; not only woody or herbaceous plants but also other neglected encroaching species, such *Cissus rotundifolia* (*Cophii kooraa*), *Euphorbia nubica* (*Annoo*), *Sansevieria ehrenbergii* (*Cakkee*), and *Ipomoea hildebrandtii* (*Omborokkee*) are challenges in Borana, reducing the productivity of the rangelands; they are threatening the productivity of the rangeland and hence the livelihood of the pastoral communities. Therefore, areas encroached with these species need to be assessed to understand the negative effects of the encroached condition. Such assessment has been carried out by Yabello Pastoral and Dryland Agriculture Research Centre in the year 2016 and the following useful information has been generated.

4.2 Inputs used to generate the information

- Axe or any cutting material for thinning
- Measuring tape
- Quadrant

4.3 Steps and procedures used to generate the information

- Systematic stratified sampling method was used to collect vegetation data after stratifying the rangeland into encroached and non-encroached by the study species.
- In order to collect vegetation data quadrant was randomly thrown after laying out main plot of 20 m x 20 m size in each habitat of the study species, i.e., in encroached and non-encroached habitats.
- Then four sub quadrants of 1 m x 1 m size was randomly placed in encroached and non-encroached habitats of the encroaching species to determines basal cover, litter cover, soil erosion and compaction, and herbaceous species richness, diversity and dry matter yield of rangelands.

4.4 Major information generated

The *cissus*, *euphorbia*, *sansevieria* and *ipomoea* species have adversely affected rangeland condition and its productivity. Based on pastoralists' perceptions most of these species are less important due to their easy spreading as well as shrinking grazing areas of rangeland. The encroaching species have negative impacts on rangeland ecosystem because they alter the species composition through displacement of productive grass species and favouring less desirable species. Generally, encroachment reduces desirable herbaceous species and increase less desirable and annual herbaceous species (see Table 2 - 5 for *Cissus rotundifolia*, *Euphorbia nubica*, *Ipomoea hildebrandtii* and *Sansevieria ehrenbergii*, respectively).

Table 2: The relative frequency and density (RF and RD, respectively) of herbaceous species in the encroached and non-encroached habitats of *Cissus rotundifolia*

Scientific name	Vernacular name	Family name	Encroached		Non-encroached	
			RF	RD	RF	RD
<i>Sporobolus pellucidus</i>	Salaqoo	<i>Poaceae</i>	9.43	8.73	13.46	15.85
<i>Indigofera spinosa</i>	Qilxiphee	<i>Fabaceae</i>	1.89	0.44	7.69	4.27
<i>Cyperus species</i>	Saattuu	<i>Poaceae</i>	11.32	14.41	9.62	6.10
<i>Digitaria naghellensis</i>	Ilmogorii	<i>Poaceae</i>	0.00	0.00	3.85	2.44
<i>Endostemon kelleri</i>	Urgoo	<i>Lamiaceae</i>	7.55	2.62	5.77	3.05
<i>Aristida kenyensis</i>	Bilaa	<i>Poaceae</i>	3.77	2.18	15.38	26.22
<i>Chrysopogon aucheri</i>	Alaloo	<i>Poaceae</i>	0.00	0.00	1.92	1.22
<i>Commelina africana</i>	Qaayyoo	<i>Commelinaceae</i>	7.55	8.73	3.85	3.05
<i>Cynodon dactylon</i> (L.) Pers.	Sardoo	<i>Poaceae</i>	7.55	6.55	7.69	14.63
<i>Chionothrix species</i>		<i>Amaranthaceae</i>	0.00	0.00	7.69	8.54
<i>Tagetes minuta</i> L.	Suunkii	<i>Asteraceae</i>	1.89	0.87	0.00	0.00
<i>Oxygonum sinuatum</i> (Meisn.) Dammer	Mogoree	<i>Fabaceae</i>	3.77	2.62	7.69	8.54
<i>Chloris roxbargana</i>		<i>Poaceae</i>	0.00	0.00	1.92	0.61
<i>Hibiscus crassinervius</i>	Bungaala	<i>Malvaceae</i>	5.66	3.93	0.00	0.00
<i>Solanum somalense</i> Franchet	Hiddii gaagee	<i>Solanaceae</i>	3.77	1.75	0.00	0.00
<i>Crabbea velutina</i> S. Moore	Qorsa garaa	<i>Acanthaceae</i>	1.89	0.44	0.00	0.00
<i>Indigofera species</i>		<i>Fabaceae</i>	1.89	0.44	0.00	0.00
<i>Chionothrix tomentosa</i> Rendle	Gurbii daalattii	<i>Amaranthaceae</i>	7.55	4.37	0.00	0.00
<i>Zaleyapentandra</i> (L.)C.Jeffrey	Araddoo	<i>Aizoaceae</i>	1.89	0.44	0.00	0.00
<i>Digitaria milanjiana</i> (Rendle) Stapf	Hiddoo	<i>Poaceae</i>	3.77	2.62	0.00	0.00

<i>Indigofera volkensii</i> Taub.	Gurbii hoolaa	<i>Fabaceae</i>	0.00	0.00	1.92	0.61
<i>Justicia odora</i> (Forssk.) Vahl	Agaggaroo harree	<i>Acanthaceae</i>	0.00	0.00	5.77	3.05
<i>Athroism aboranense</i> Cufod.	Gurbii	<i>Asteraceae</i>	7.55	21.83	3.85	1.22
<i>Justicia odora</i> (Forssk.) Vahl	Agaggaroo harree	<i>Acanthaceae</i>	0.00	0.00	1.92	0.61
<i>Pupalia lappacea</i> (L.) A. Juss.	Hanqarree	<i>Amaranthaceae</i>	7.55	8.30	0.00	0.00
<i>Chlorophytum</i> <i>gallabatense</i> Schweinf. ex Baker	Miirtuu	<i>Anthericaceae</i>	7.55	11.35	0.00	0.00

Table 3: The relative frequency and density (RF and RD, respectively) of herbaceous species in the encroached and non-encroached habitats of *Euphorbia nubica*

Scientific name	Vernacular name	Family name	Encroached		Non-Encroached	
			RF	RD	RF	RD
<i>Cenchrus ciliaris</i> L.	Mata guddeessa	<i>Poaceae</i>	0.00	0.00	2.04	0.75
<i>Sporobolus pellucidus</i>	Salaqoo	<i>Poaceae</i>	2.33	1.27	6.12	3.73
<i>Indigofera spinosa</i>	Qilxiphee gaalaa	<i>Fabaceae</i>	9.30	7.59	8.16	5.97
<i>Volkensinia prostrate</i>	Gurbii	<i>Amaranthaceae</i>	6.98	6.33	6.12	2.99
<i>Cyperus species</i>	Saattuu	<i>Poaceae</i>	0.00	0.00	8.16	13.43
<i>Digitaria naghellensis</i>	Ilmogorii	<i>Poaceae</i>	2.33	1.27	4.08	2.24
<i>Endostemon kelleri</i>	Urgoo	<i>Lamiaceae</i>	9.30	6.33	8.16	3.73
<i>Cynodon dactylon</i> (L.) Pers.	Sardoo	<i>Poaceae</i>	6.98	6.33	6.12	3.73
<i>Justicia odora</i> (Forssk.) Vahl	Agaggaroo harree	<i>Acanthaceae</i>	0.00	0.00	2.04	0.75
<i>Pupalia lappacea</i> (L.) A. Juss.	Hanqarree	<i>Amaranthaceae</i>	11.63	8.86	2.04	0.75
<i>Chionothrix species</i>		<i>Amaranthaceae</i>	6.98	6.33	8.16	4.48
<i>Tagetes minuta</i> L.	Suunkii	<i>Asteraceae</i>	4.65	6.33	0.00	0.00
<i>Pennisetum mezianum</i>	Ogoondhichoo	<i>Poaceae</i>	9.30	27.85	8.16	26.87
<i>Ocimum urticifolium</i> Roth.	Hancabbii	<i>Lamiaceae</i>	2.33	1.27	2.04	0.75
<i>Solanum somalense</i> F.	Hiddii gaagee	<i>Solanaceae</i>	2.33	2.53	0.00	0.00
<i>Aristida kenyensis</i>	Bilaa	<i>Poaceae</i>	2.33	2.53	8.16	9.70
<i>Chrysopogon aucheri</i>	Alaloo	<i>Poaceae</i>	16.28	7.59	14.29	14.18
<i>Commelina africana</i>	Qaayyoo	<i>Commelinaceae</i>	6.98	7.59	6.12	5.97

Table 4: The relative frequency and density (RF and RD, respectively) of herbaceous species in the encroached and non-encroached habitats of *Ipomoea hildebrandtii*

Scientific name	Vernacular name	Family name	Encroached		Non-Encroached	
			RF	RD	RF	RD
<i>Sporobolus pellucidus</i>	Salaqoo	Poaceae	11.97	33.61	10.59	27.78
<i>Indigofera spinosa</i>	Qilxiphee	Fabaceae	5.98	3.86	10.59	9.83
<i>Chionothrix tomentosa</i> Rendle	Gurbii daalattii	Amaranthaceae	7.69	5.51	8.24	4.70
<i>Cyperus bulbosus</i>	Saattuu	Poaceae	5.13	4.68	12.94	17.95
<i>Digitaria naghellensis</i>	Ilmogorii	Poaceae	7.69	4.41	3.53	2.56
<i>Endostemon kelleri</i>	Urgoo	Lamiaceae	6.84	3.86	1.18	0.43
<i>Justicia odora</i> (Forssk.) Vahl	Agaggaroo harree	Acanthaceae	6.84	5.51	5.88	2.99
<i>Pupalia lappacea</i> (L.)	Hanqarree	Amaranthaceae	4.27	5.79	3.53	2.99
<i>Oxygonum species</i>		Fabaceae	0.85	0.28	0.00	0.00
<i>Amaranthus thunbergii</i> Moq.	Raafuu	Amaranthaceae	0.00	0.00	1.18	0.43
<i>Hibiscus crassinervius</i>	Bungaala	Malvaceae	1.71	1.38	2.35	1.28
<i>Solanum somalense</i> Franchet	Hiddii gaagee	Solanaceae	0.85	0.28	0.00	0.00
<i>Digitaria milanjana</i> (Rendle) Stapf	Hiddoo	Poaceae	0.85	0.28	0.00	0.00
<i>Indigofera volkensii</i> Taub.	Gurbii hoolaa	Fabaceae	0.85	0.28	0.00	0.00
<i>Heteropogon contortus</i>	Seericha	Poaceae	0.85	0.55	0.00	0.00
<i>Chlorophytum gallabatense</i> Schweinf. ex Baker	Miirtuu	Anthericaceae	0.85	0.28	2.35	0.85
<i>Aristida kenensis</i>	Bilaa	Poaceae	9.40	8.26	12.94	13.25
<i>Chrysopogon aucheri</i>	Alaloo	Poaceae	2.56	0.83	4.71	2.56
<i>Commelina africana</i>	Qaayyoo	Commelinaceae	7.69	9.09	5.88	4.70
<i>Cynodon dactylon</i>	Sardoo	Poaceae	0.00	0.00	2.35	0.85
<i>Indigofera species</i>		Fabaceae	0.85	0.28	0.00	0.00
<i>Tagetes minuta</i> L.	Suunkii	Asteraceae	1.71	0.55	1.18	0.43
<i>Chenopodium opulifolium</i> Schrad ex Koch. & Ziz.	Ononnuu	Chenopodiaceae	3.42	1.93	3.53	1.71
<i>Oxygonum sinuatum</i> (Meisn.) Dammer	Mogoree	Fabaceae	2.56	1.38	4.71	2.99
<i>Dactilostegium species</i>		Poaceae	3.42	5.23	2.35	1.71
<i>Chionothrix species</i>		Amaranthaceae	0.85	0.28	0.00	0.00

Table 5: The relative frequency and density (RF and RD, respectively) of herbaceous species in the encroached and non-encroached habitats of *Sansevieria ehrenbergii*

Scientific name	Vernacular name	Family name	Encroached		Non-Encroached	
			RF	RD	RF	RD
<i>Cenchrus ciliaris L.</i>	Mata guddeessa	<i>Poaceae</i>	2.82	1.27	5.08	2.65
<i>Sporobolus pellucidus</i>	Salaqoo	<i>Poaceae</i>	14.08	25.42	15.25	16.81
<i>Indigofera spinosa</i>	Qilxiphee gaalaa	<i>Fabaceae</i>	8.45	8.05	5.08	1.77
<i>Volkensinia prostrate</i>	Gurbii	<i>Amaranthaceae</i>	4.23	1.69	0.00	0.00
<i>Cyperus species</i>	Saattuu	<i>Poaceae</i>	5.63	10.59	18.64	36.28
<i>Digitaria naghellensis</i>	Ilmogorii	<i>Poaceae</i>	2.82	1.27	1.69	0.44
<i>Endostemon kelleri</i>	Urgoo	<i>Lamiaceae</i>	1.41	0.85	3.39	1.33
<i>Chrysopogon aucheri</i>	Alaloo	<i>Poaceae</i>	7.04	8.05	8.47	7.52
<i>Pupalia lappacea</i>	Hanqarree	<i>Amaranthaceae</i>	1.41	0.42	0.00	0.00
<i>Chlorophytum gallabatense</i>	Miirtuu	<i>Anthericaceae</i>	2.82	1.27	1.69	0.88
<i>Aristida kenyanensis</i>	Bilaa	<i>Poaceae</i>	5.63	6.36	10.17	10.18
<i>Justicia odora</i>	Agaggaroo harree	<i>Acanthaceae</i>	8.45	5.51	5.08	1.77
<i>Chrysopogon aucheri</i>	Alaloo	<i>Poaceae</i>	7.04	8.05	8.47	7.52
<i>Commelina Africana</i>	Qaayyoo	<i>Commelinaceae</i>	12.68	16.53	6.78	12.83
<i>Tephrosia pentaphylla</i>	Darguu	<i>Fabaceae</i>	4.23	1.69	3.39	1.33
<i>Pennisetum mezianum</i>	Ogoondhichoo	<i>Poaceae</i>	5.63	5.93	6.78	4.87
<i>Cissus aphyllantha Gilg.</i>	Cophii soodduu	<i>Vitaceae</i>	1.41	0.42	6.78	0.00
<i>Chloris roxbargana</i>		<i>Poaceae</i>	4.23	2.12	1.69	1.33
<i>Hibiscus boranensis cufod</i>	Bungaalaa	<i>Malvaceae</i>	2.82	1.27	0.00	0.00
<i>Ocimum urticifolium Roth.</i>	Hancabbii	<i>Lamiaceae</i>	1.41	0.42	0.00	0.00
<i>Solanum somalense Franchet</i>	Hiddii gaagee	<i>Solanaceae</i>	1.41	0.42	0.00	0.00
<i>Solanum species</i>	Bosoqqee	<i>Solanaceae</i>	1.41	0.42	0.00	0.00

4.5 Precautions needed

Since the encroaching species are succulent and stay green throughout the year care should be taken while cutting and drying for preparation for firing as the liquid that comes out during cutting can be harmful to human eyes.

4.6 Expected benefits of knowing the information

As shown under section 5.5, all the encroaching species are causing huge damage to rangeland productivity and hence, minimizing the density of these encroaching species would lead to a positive effect on rangeland productivity and improves grass production that consequently contributes to feed improvement. Therefore, government or any stakeholder may be able to design strategy for managing these encroachers, or look for means of using them for different purposes.

4.7 Reference

Asfaw Ejo, Badasa Eba, Jaldesa Doyo, Bikila Nagasa, Samuel Tuffa, Gabayo Elayas and Zerihun Yahannes. 2019. Effects of *Cissus*, *Euphorbia*, *Sansevieria* and *Ipomoea* Species Encroachment on Herbaceous Species Composition in Borana Zone, Southern Ethiopia. In: Proceedings of Completed Research Activities Review Workshop of livestock Research Directorate (Tesfaye Alemu Aredo, Mekonen Diribsa, Dawit Abate, Temesgene Jembere, Dereje Teshome, Amsalu Bezabeh, Matheows Hailu, Samuel Tuffa, Girma Chalchisa (eds.)); held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 8-11 September 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

5. Causes and Effects of Rangeland Degradation in Pastoral areas of Bale Zone

5.1. Background information

Rangelands in Ethiopia occupy about 61% of the national land mass and largely dominate the lowland areas. Out of the total area of Bale zone 63.5% is included under lowland and 39.1% is under rangeland. These areas are characterized by arid and semi-arid environments, endowed with diversified vegetation types, livestock and wild animal species as well as untapped mineral resources. Nowadays the Bale lowland eco-region is characterized by low livestock productivity, leading to declined number of livestock holding per house hold, severe livestock death during dry periods, increasing of cultivated land, increasing number of people vulnerable to food insecurity and considerably higher reliance on food aid. However; detail causes and effects of the declining rangeland condition, which resulted in poor pastoralists' livelihood and pressure on conserved Bale eco-region is not yet studied. Therefore, a study was conducted by Sinana Agricultural Research Center to address the causes and effects of rangeland degradation in the lowland eco-region of the zone. Valuable information obtained from the study is summarized below.

5.2 Steps and procedures used to generate the information

The study was based on primary and secondary data. Primary data related to the socio-economic characteristics of the pastoralists such as educational level, land size, livestock ownership, and livelihood activities were collected using semi-structured questionnaires. The data on cause and effects of rangeland degradation, perception of communities on rangeland condition trend and overall livelihood activity was collected using Focus Group Discussion (FGD) and key informants, respectively. Secondary data about livestock development activities and information on rangeland management and utilization was collected from respective organizations. The status of rangeland condition was judged using field observation, targeting major rangeland and types of grazing, using easily understandable methods such as resource mapping and constraint listing by the local communities.

5.3 Major information generated

The current rangeland degradation of Bale eco-region in particular and south east Ethiopian rangelands in general is caused by human activity. In lowland of Bale-ecoregion, the influx of settlers and illegal settlement and expansion of agricultural land is the main bottle necks to rangeland rehabilitation. Currently, effective rangeland management strategy - mobility of pastoralists, is constrained by influx of settlers, expansion of crop land, and private enclosure “*kalo*”. Another problem of rangelands is privatization; a number of mineral water and mineral soil places are now controlled by private individuals and National parks. This has hindered the

activity of mineral supplementation of pastoralists to their animals. Lack of micro-minerals in animal feeds affects the production and reproductive of livestock in many ways. To fill this gap the exact minerals that pastoralists had been utilizing has to be identified and the way to access these minerals has to be devised.

5.4 Precautions needed:

The feasibility of investment activities planned in lowland areas has to be seriously considered in relation to social and environmental feasibility. The current running soil and water conservation activities by the government lacks coordination or involvement of stakeholders, skilled human power and lacks integration of biological materials in the developed conservation structure. Under such condition the success of rangeland development effort would be a futile exercise. Hence, there must be a clear policy of land uses and livestock development in pastoral areas.

5.5 Expected benefits of knowing the information

Rehabilitation of degraded rangeland has paramount importance in enhancing the livelihood of the pastoral community. If the sustainable rangeland use is supported by policy and already degraded areas are restored, the expected benefit from biodiversity and ecosystem services will be improved and contribute to human well being.

5.6 Reference

Aliyi Kedu, Solomon Dadi and Medakso Sankuro. 2019. Causes and Effects of Rangeland Degradation in the Lowland Districts of the Bale Eco-Region, Southeast Ethiopia. In: Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute (Tefaye Alemu Aredo, Mekonen Diribsa, Dawit Abate, Temesgene Jembere, Dereje Teshome, Amsalu Bezabeh, Matheows Hailu, Samuel Tuffa, Girma Chalchisa (eds.)). Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01- 04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.

6. CO₂ Emission Mitigation in the Rangelands

6.1 Background information

Crop cultivation in former grassland is one of the major threats to rangelands today, both for traditional pastoralists as well as in terms of carbon emission, because it breaks up soil aggregates, which opens up previously unavailable carbon compounds for decomposers access leading to giving off of carbon stock. Herbivory also removes above-ground biomass and changes the belowground biomass and, hence, soil organic carbon stocks in rangelands. Understanding the impact of land use change on soil organic carbon stock following the conversion of a semiarid rangeland into different land use types is essential to devise an appropriate and sustainable rangeland management strategy. However, there is a knowledge gap as to the impact of currently ongoing land use changes and overgrazing on soil organic carbon stock, which is an important rangeland ecosystem service, particularly in the face of climate change. Thus, a study was conducted to assess the effect of land use change on soil organic carbon stock in three land use types, namely, enclosures, communal grazing and cultivated lands in Borana rangeland. The information generated from the study is summarized as follows.

6.2 Inputs used to generate the information

- Soil auger,
- Quadrant and
- Other laboratory materials have been used.

6.3 Steps and procedures used to generate the information

Three land use types (communal grazing, cultivated and enclosure) were purposively selected. The sampling plots were laid out in four blocks, each containing the three land use types. Soil samples were collected from each land use type from 5 m × 5 m plots, which were laid out within 20 m × 20 m at each four corners and center to capture the heterogeneity of soil fertility in the rangeland. The sampling spots were composited within 20 m × 20 m to form a sample at each soil depth (0 - 10 cm, 10 - 20 cm, 20 - 30 cm). Additionally, 36 independent soil samples were collected with core sampler for determination of the soil bulk density. The soil bulk density was collected from five spots within 20 m × 20 m plot and then averaged per depth for later use in soil organic carbon stock calculations. Collected soil samples were dried at a constant room temperature and sieved (2 mm) to eliminate coarse soil particles before analyses. The soil organic carbon was determined according to the Walkley and Black method.

6.4 Major information generated

There were significant interactions between land use types and depths for soil organic carbon stock with mean losses of 60% and 69% in soil organic carbon stock from the surface layer (0 - 10 cm) of communal and cultivated lands, respectively, as compared to enclosure land use type. The results indicated that communal grazing and crop cultivation in the Borana rangeland resulted in significantly decreased soil organic carbon stock (Fig. 2). With increasing population the control of overgrazing and limiting the expansion of unsustainable cultivation under rainfed agriculture in the rangelands is very challenging. There should be a government policy that should clearly reinforce the realization of the appropriate rangeland use.

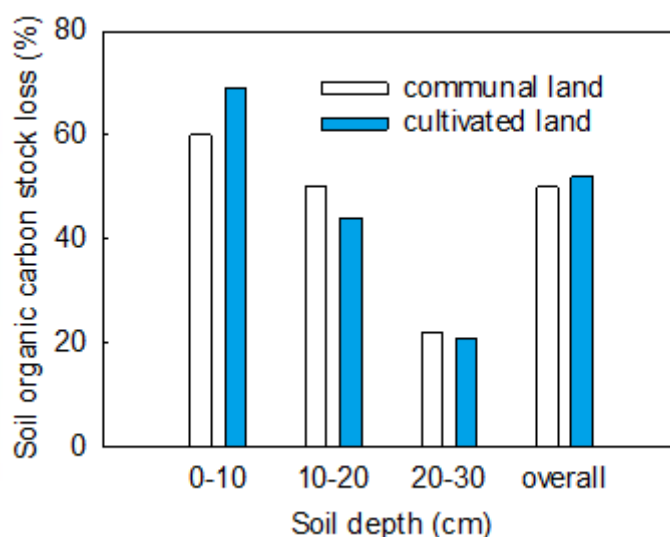


Fig. 2: Soil organic carbon stock loss from communal and cultivated land use types compared with enclosure.

6.5 Precautions needed

Land use change is becoming a chronic challenge in rangelands utilization. Unless any management effort is accompanied by appropriate land use policy the land use change will continue to emit more carbon to the atmosphere, contributing to the impact of climate change.

6.6 Expected benefits of using the information

This information can be used by policy makers to develop an appropriate rangeland use plan in the face of climate change to create resilient and sustainable rangeland ecosystem. In other words, it enables them to devise an appropriate and sustainable rangeland management strategies. As such, if overgrazed communal lands and cultivated lands are managed appropriately by reducing overgrazing and crop cultivation and restoring degraded areas the rangeland ecosystem services will be enhanced; for instance, the carbon sequestration potential of the rangelands as a means of CO₂ emission mitigation options in the face of climate change in the rangelands will be

increased. Mitigating CO₂ emission in the rangelands has a global benefit due to vastness of the rangeland ecosystem globally.

6.7 Reference

Addis Shiferaw, Fantaw Yimer, Samuel Tuffa. 2019. Changes in Soil Organic Carbon Stock under Different Land Use Types in Semiarid Borana Rangelands: Implications for CO₂ Emission Mitigation in the Rangelands. J Agri Sci Food Res 9: 254.

Part five: *Fishery Technologies/information User's Manual*



On lake evaluation of boat constructed from plastic bottles

I. Technologies

1. Common carp (*Cyprinus carpio*) Aquaculture

1.1. Background information

During the last three decades, fish catches have increased rapidly due to construction of various reservoirs in the country. Despite the fact that the total fish production is increasing in the country, there is disparity in availability of fish in many parts of the country. These disparities can be filled through expansion of aquaculture. The term 'aquaculture' involves all forms of culture of aquatic animals. Aquaculture has the same objective as agriculture: to increase the production of food above the level which would be produced naturally.

Fish farming can be combined with agriculture, animal husbandry and irrigation practices which can lead to a better utilization of local resources and ultimately to higher production and net profits. This practice is called 'integrated fish farming' and this subject is extensively dealt with in fishery technologies user's manual series 1 (Tesfaye et al., 2018).

Common carp (*Cyprinus carpio*), next to *Oreochromis niloticus* and *Clarias gariepinus*, is a candidate fish species in the development of Ethiopian aquaculture, which has been started at extensive farming level in earthen ponds among farmers. In pond culture, growth performance of fish is determined by many factors, of which water temperature is among the major ones. Though Carps prefer low temperature for spawning, higher temperature is desirable for good growth. Here under is given the procedure and advantages of establishing aquaculture using Common carp (*Cyprinus carpio*).

1.2. Inputs required for preparation of the technology

Finance: The practitioner should make an estimate which includes the cost of land as well as capital expenditures for fish stock, pond construction, labor, production and harvesting.

Site: The soil must be able to retain water. A good water quality and quantity should be available

Fish fingerling: There should be access to fish fingerlings from nearby farms or through the district's livestock and fishery agency.

Fish feed: Fish farmers must often get assistance with starting up any fish farming enterprise in the form of technical advice from extension services.

1.3. Steps and procedures to use the technology

Site selection:

Proper selection of a site is probably the most important factor in the success of a fish farm. However, the ideal site is often not available, so, one has to compromise. There may also be conflicts concerning land and water use which need to be resolved.

Soil:

The quality of soil influences both productivity and water quality in a pond. However, it must also be suitable for dike construction. To determine soil suitability the two most important properties to examine are soil texture (particle size composition) and porosity or permeability (ability to let water pass through). There are different ways to determine the suitability of the soil for pond construction but the easiest method is the "squeeze method" (Figure 1.) which is described below:

- Wet a handful of soil with just enough water to make it moist,
- Squeeze the soil by closing your hand firmly, and
- If it holds its shape after opening the palm of your hand, the soil is good for pond construction.

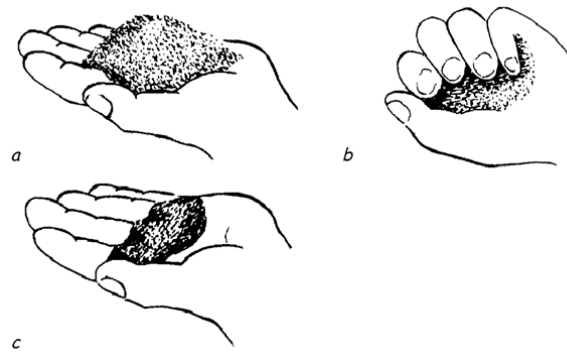


Figure 1: The "squeeze method"

Pond construction:

The guide for pond construction is described in detail in the first fishery technologies user's manual series 1 (Tesfaye et al., 2018). Ponds are usually constructed on land with a gentle slope. They are rectangular or square shaped, have well finished dikes and bottom slopes and do not collect run-off water from the surrounding watershed. It is important that sufficient water is available to fill all ponds within a reasonable period of time and to maintain the same pond water level. You should also be able to drain the pond completely when fish are to be harvested.

Fish stocking and management

The best growth of common carp is achieved with stocking densities of 2 fish per m² of pond surface. Carps prefer a temperature range of 15-32°C, and the optimum requirement in wild is from 20-28°C. Growth of carps was affected significantly by water temperature and water transparency. Mean weight increment observed between 15-40 cm secchi depth which can be measured according to figure 1.



A. Insufficient fertilizer

If you can still see your arm and even your hand then there is not enough algae present in the pond, so it needs more fertilizer.



B. Correct amount of fertilizer

If you can see about half of your arm below the elbow then there is enough natural fish food available and the pond is receiving the right amount of fertilizer



C. Too much fertilizer

If you can hardly see your arm at all in the water then there are too many algae in the water. If this is the case then you should immediately stop fertilizing the pond until the water turns light color

Figure 1. Methods in determination of pond fertilization and turbidity

Yields can be increased by giving the fish extra food. In ponds which are well fertilized, the fish will usually receive more than enough protein. However, they may not obtain sufficient energy which can limit production. By feeding the fish with grains, which is rich in energy you can supplement this deficiency. The by-products from grain production, such as wheat bran, make excellent food supplements for fish ponds which are fertilized using animal dung. Carps are usually harvested by seine nets. The length of nets should be 1.5 times the width of ponds

1.4. Scope of using the technology

Growth of carp can be limited by higher water turbidity, shallower than 12 cm secchi transparency at lowland; lower water temperature of below 16°C and higher secchi transparency. Hence, growth of carp at highland and mid-altitude agro-ecologies can be enhanced by using dipper ponds to maintain water temperature in preferable range during the cold months and fertilizing ponds to enhance water turbidity

1.5. Important data to be recorded

- Stocking date
- Survival =Initial number-final number
- Turbidity or sechi depth (Figure 1.)

1.6. Expected benefits of using the technology

Carp species will yield the first fish for the market after 6 to 7 months, with a total production of up to 60 kg per 100 m² of fish pond.

1.7. Reference

- Megerssa Endebu, Derribew Hailu and DabaTugie (2019). Growth performance of common carp (*Cyprinus carpio*) at different agro ecologies. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne
- Tesfaye Alemu Aredo, Alemu Lema, Megerssa Endebu and Getachew Senbete (eds.) 2018. Fishery Technologies User's Manual. Oromia Agricultural Research Institute (IQQO), Finfinnee, Ethiopia.

2. Complementary recipe formulation from fish and maize

2.1 Background information

Stunting and micronutrient deficiencies are significant health problems among infants and young children in rural Ethiopia. Widespread of under nutrition in Ethiopia continue to exert enormous cost in terms of survival among infants and young children. Chronic under nutrition (stunning) and micronutrient deficiencies are significant health problems among infant and young children in Ethiopia. The use of recipe has been identified as the best way to alleviate malnutrition and chronic under nutrition through producing high-quality nutritious food products. Such recipe can be prepared from a mix of fish and maize.

Fish contains high concentrations of two essential amino acids called lysine and methionine, in contrast to cereal proteins. Maize, a source of starch is major staple food in Ethiopia, serving as a raw material for the production of some staple foods such as unfermented bread, flour and porridge. As the essential amino acids limited in cereals are present in fish, a mix containing fish and maize are considered complementary. The Maize-Fish flour mixes can be used as cereal gruel in breakfast food by vulnerable groups. Maize and fish flour produce acceptable porridge with a greatly improved nutritional quality. Porridge prepared from blend of fish and maize is nutritionally rich, low in anti-nutrients and suitable for local consumption and industrial utilization. Optimum recipe porridge formulated from fish and maize was test at Batu Fish and Other Aquatic Life Research Center. Description as to how to apply this recommended technology is given bellow.

2.2 Inputs required to apply the technology

- Fish fillet (*Barbus gananensis*),
- Maize grains,
- Milling machine
- Electric/charcoal

2.3 Steps and procedures to apply the technology

Fish and maize collection

Fish must be collected, cleaned, descaled, eviscerated and filleted manually using stainless steel knife. Immediately after filleting, semidry thefillet under shade. Then the semi-dried samples can be oven dried or sun dried. Maize grain must also be cleaned with water, dried and then ground into flour.

Grinding

Dried fish fillet is easily ground into powder using local mortar and pestle or analytical laboratory mill. Maize grain can be ground using local milling machine. The ground products must be sieved (Fig 1)



Figure 1. Sieving of ground fish flour

Recipe formulation

Recipe formulation is designed in such a way as to obtain organoleptically most acceptable product which has the highest energy content. With this regards, recipe of maize and fish with 1:1 ratio or 50% maize and 50% fish is found to be an appropriate blend.

Porridge preparation

To prepare porridge, fish flour is added to water with water to flour ratio of 3:1. Before adding blended flour to boiled water, the flour must be sieved and mixed properly until it become uniform. The mixture is stirred continuously during cooking to avoid formation of a product with a lumpy texture. The blended flour is cooked for 10 minutes. Then it must be removed from the stove and allowed to cool at room temperature. The fresh porridge can be consumed outrightly.

2.4 Scope of using the technology

The Maize-Fish flour recipe can be used as cereal gruel in breakfast food by vulnerable groups, child, adult or any age groups of human being. Recipe preparation can be applied where fish and maize are available.

2.5 Important data to be recorded

- Price of fish and maize, weight of fish and maize flour for recipe formulation.

2.6 Expected benefits of using the technology

Combinations of the two flours at equal levels significantly increase the nutrient contents of the blends when compared to maize flour alone. With this regards energy, protein and fat content in recipe porridge is 385.85 ± 0.85 Kcal/100g, 44.71 ± 0.08 g/100 g and 5.25 ± 0.25 g/100 g. Blend

containing 50% fish and 50 % maize had the highest gross energy value as compared to other blending ratio (AlemuLema, 2018).

2.7 Reference

Alemu Lema Abelti. (2018). Fish–maize based recipe formulation and optimization. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

3. Feeding of Nile Tilapia with levamisole incorporated diet

3.1. Background information

Fish disease is one of the major challenges in intensive fish culture. Antibiotics, drugs and chemicals have been used for treating fish disease caused by environmental stress and other factors for years. However, these are often effective for only a short time, enhance microbial resistance, and accumulate in the environment and tissue of the fish. In the past, the immunological approach to prevent fish disease has been by vaccination against specific pathogens. Vaccination is time consuming, labor intensive, costly and protection is often pathogen specific. An alternative approach is incorporation of levamisole into diet of fish to stimulate the innate immune system of cultured fish (GebawoTibesso, 2018). Levamisole is, a synthetic phenylimidazol thiazole, Immuno stimulant, immuno modulator and antihelminthic drug which is widely used in veterinary medicine as an anti-parasitic. Levamisole has been shown to have the ability to up-regulate non-specific immune response in carps, rainbow trout and gilthead sea bream. It has been observed that immuno stimulants enhance nonspecific defense mechanisms of animals and the plasma lysozyme activity. Lysozymal activity is an important defense mechanism in fish, which causes lysis of bacteria and activation of the complement system and phagocytes by acting as an opsonin. Influence of levamisole on the immune enhancement of Nile tilapia (*Oreochromis niloticus*) against potential bacterial pathogens was evaluated at Batu Fish and Other Aquatic Life Research Center. Here under is given a description as to how to apply the technology generated from this work.

3.2. Inputs required

Earthen ponds or concrete tank or PVC tanks for culturing, fish fingerlings, fingerling collecting nets, levamisole, fish feed (fish meal, noug cake and wheat bran), pelletizer/meat mincer, aerator, Dissolved Oxygen meter and thermometer, syringe, pathogenic bacteria (*Aeromonas hydrophila*, *E.coli*, *Staphylococcus aureus* and *Salmonella*).

3.3. Steps and procedures used to apply the technology

i. Fish husbandry conditions

The fish fingerlings can be collected from Koka reservoir, Hara Arsedi or Batu Fish and Other Aquatic Life Research Center. Fish must be disinfected with 3% sodium chloride for 5 min and kept for 2 weeks under observation for acclimatization in water tank. Fish can be cultured in concrete pond, earthen pond or PVC tanks filled with water. Ponds/tanks must be supplied with aerated de-chlorinated fresh water every four days, maintaining the water temperature at $25 \pm 1^\circ\text{C}$ with dissolved oxygen of 8.5 ppm.

ii. Diet preparation

Fish feed is prepared by mixing dry ingredients (Noug cake, wheat bran and fish meal) together for 15 minutes to ensure homogeneity and then adding in hot water. The mixture is steamed for 15 min, allowed to cool and levamisole at 750-1500mg/kg of diet was added to steamed and cooled feed mixture and then palletized. All pellets is separately air dried and stored in tightly sealed plastic bags at 8-10°C until used.

iii. Feeding Nile Tilapia with levamisole incorporated diet

Pelletized fish feed is hand casted at 10% body weight for fingerling stage and 5% of their body weight for juvenile and adult fish. Crude protein content of the feed must be adjusted according to their age. For starter fish (fingerlings) crude protein of feed to be offered is 35-40%, 30-35% for juvenile and 25-30% for finisher (Adult).

3.4. Scope of using the technology

Incorporation of levamisole in fish diet is applicable in pond culture, Aquaponics or Re-circulation system culture or Race way pond culture. It is difficult to apply levamisole to feed of fish in natural water bodies or cage culture.

3.5. Important data to be recorded

Data to be recorded are weight of fingerlings stocked, price of fish feed and levamisole, culturing duration, final body weight of fish and price of whole fish

3.6. Precautions needed

- High doses of levamisole may be toxic and cause immuno-suppression, and under dose may not be efficient.

3.7. Expected benefits of using the technology

The benefits of supplementing levamisole in Nile Tilapia diet is that it increased phagocytic activity, serum bactericidal activity and leukocrit. A dose of 750 mg - 1500 mg levamisole kg⁻¹ diet is the recommended range to stimulate the immune function of Nile Tilapia and confer a high degree of protection against the invading bacterial pathogen. Dietary levamisole supplementation (750-1500 mg levamisole kg⁻¹ of diet) significantly enhanced higher Red Blood Cell (2.22x10⁶/μL), White Blood Cell (3.39x10⁵/μL) and Lymphocytes (94.1 %) as compared with RBC (1.66 x10⁶/μL), WBC (2.94 x10⁵/μL) and Lymphocytes (81.4 %) count of fish fed on control diet. However, dietary levamisole supplementation (750-1500 mg levamisole kg⁻¹ of diet) has significantly decreased percentage of Monocytes (4.6 %) and Granulocytes (1.3 %) as

compared with Monocytes (11.2 %) and Granulocytes (7.4 %) percentage of fish fed on control diet. Percentage monocyte and granulocytes have decreased with the increase of Levamisole levels in fish diet.

Tilapia fed with higher concentration of (750-1500 mg levamisole/kg of diet) showed high survival rate when challenged with *Aeromonashydrophila*, *E.coli*, *Staphylococcus aureus* and *Salmonella*. The Percentage of Relative Protection (PRP) or survival rate is statistically highest (85 %) in fish fed on 1500 mg/kg of diet as compared to control diet. Other benefit of feeding fish with levamisole incorporated diet is that it has statistically enhanced phagocytic rate /bacterial engulfing rate (51.4) and bactericidal activity (0.11). Generally incorporation of levamisole into feed (750-1500 mg levamisole/kg of diet) has a potential for immune enhancement in Nile Tilapia thereby increasing the resistance of the fish to diseases and stress which reduce fish mortality rates and offer economic benefits.

3.8. Reference

GebawoTibesso Bedasso. (2018). A Study of Immune Response in Nile Tilapia (*Oreochromis niloticus*) Fed Levamisole Incorporated Diet. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 232 pp.

4. Longline for catfish harvesting

4.1. Background information

Longline is a commercial fishing technique. It uses a long line called the main line, with baited hooks attached at intervals by means of branch line called snoods. A snood is a short length of line, attached to the main line using a clip or swivel, with hook at the other end. Longline is one of the most commonly used methods for harvesting of carnivorous fish populations like Catfish in lakes, reservoirs and rivers for commercial fisheries. African Catfish (*Clarias gariepinus*) is the second most dominant species which comprises 24 % of the catch next to *Oreochromis niloticus* (31 %) in Lake Zeway (Lemma Abera et al., 2014). The advantages of using longline include ease of use, low cost, and possibility to be set at any depth and in areas with difficult bottom conditions.

It has become a popular method from 1980s. Longline gear is used all over the world, from small scale fishing to modern mechanized longline operations. Longline is very simple fishing gear, but there are many variations in gear construction, fishing method and fishing strategy. Evaluation of different hook sizes and baits for the catch efficiency of *C. gariepinus* was carried out in Lake Zeway during September 2009 to August 2010 by Batu fish and Other Aquatic Life Research Center.

4.2. Inputs required to apply the technology

Mainline rope or Sibago in Oromiffa, Swivel, Branch line (twine or nylon rope), Hooks, Anchor/sinker, floater/Buoys, fishing boat which can be raft, planked or motorized steel based on the investment capacity of individuals. Baits (fish fillet, termite or soap) which are attached to hooks to lure fish.

4.3. Steps and procedures to use the technology

I. Longline construction

Longline fishing activities contain four different components.

1. Mainline:

The mainline is the basic part of longline gear. Branch lines, buoy and sinker are attached to it. The mainline is characterized by the material from which it is constructed and its size. The materials from which mainline can be constructed is multifilament polypropylene with

thickness (diameter size / Ø) = 6 mm and its length can vary based the investment capacity of individuals.

2. Branch lines:

The materials from which branch line are constructed is multifilament nylon with thickness (diameter size / Ø) = 1.02 mm and its length must be less than the spacing between branch line. For instance if the spacing between branch line on mainline is 1m the length of branch line must be less than 0.5m. Swivel joins branch line or snood to the mainline (Fig. 2). Swivel is mounted between two stoppers to avoid sliding.

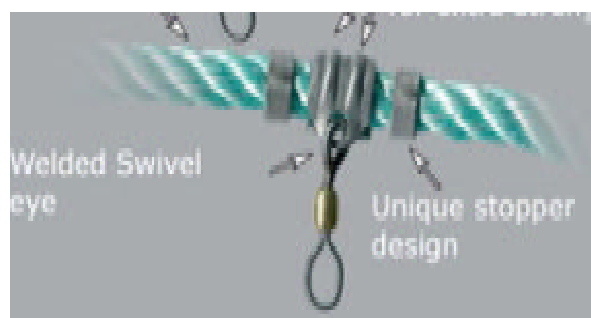


Figure 2. Branch line or snood attached to mainline

3. Hooks:

Hook is the heart of the longline system. The hook mainly consists of an eye, shank, bend, point, gap and throat (Fig. 3). Hook is mounted on branch line which is attached to mainline using swivel. Eventhough different hook sizes are available in the market, hook size no. 9 is appropriate size to maintain fish resources as compared to hook size no. 10, 11 or 12 in Lake Zeway. How to knot the hook to branch line and brach line to swivel is indicated in (Fig.3).

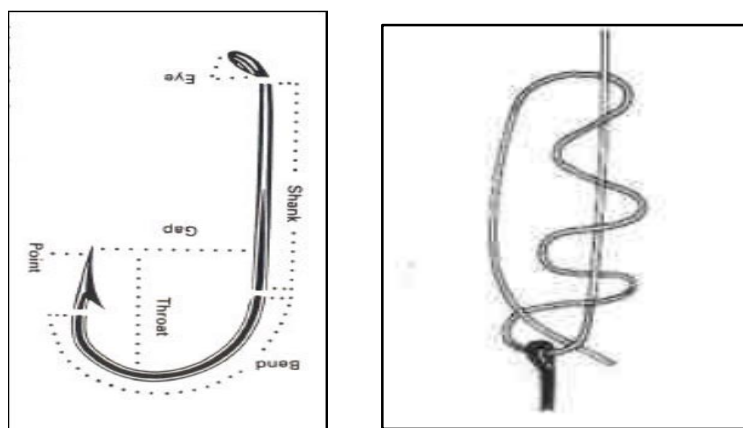


Fig. 3. Basic parts of a J shaped hook made of steel and coated with different metals (leftand) How to knot hook line and branch line to swivel (right)

4. Baits:

The principle of longline fishing is to lure fish to bite the bait. Therefore, bait is one of the most important factors in line fishing. The catch rate depends to a large extent on bait type, quality and size. Fishermen use different types of bait from their experience accumulated over years. The best bait is termite (Lemma Abera and AlemuLema, 2009) as compared to fish fillet, soap and *Barbus paludinosus* (Shilunku). Termite can be collected from decomposed typha or bofoffe.

ii. Longline operation

Once the longline is mounted, it must be handled carefully. The hooks can be twisted and tangled with mainline and branch lines. Hooks must be put on piece of styrofoam or bofoffe logs to avoid tangling. This gives increased safety for the fishermen. On arrival at fishing ground, the line is set perpendicular to water current. The setting depth of the bottom longline is controlled by adjusting the length between the sinker and the mainline. At first, the anchor and buoy are dropped, then consequentially placed hooks are baited manually by hand one after the other. At the end of setting, the marker buoy is set to identify the line. The soaking time depends on the fish density and weather conditions but 24 hours is common. Hauling begins by locating the marker buoy. The lines from marker buoy end is cleaned and de-hooked by hand and fish stored in containers until processed.

4.4. Scope of using the technology

- Longline technology is suitable to catch only carnivorous fish. It is not suitable for water bodies harboring herbivores fish.

4.5. Important data to be recorded or calculated

Important data to be recorded to know the benefit of longline technology is market price of whole fish, fillet fish, gutted fish and other fish products both at landing site and secondary market.

4.6. Precautions needed

In longline fishing, several factors such as the hook, bait, branch line and mainline affect catch ability and selectivity. When using surface longline in shallow water body care must be taken since rock or logs may entangle the lines and break them. Where muddy bottoms are found, the longline are not set to remain on the bottom and are held off the seabed by floats. Longline can be set in such a way that the bait is suspended at any desired distance from the bottom.

4.7. Expected benefits of using the technology

Longline is proven to be a good fishing method for catching large, high quality and high value fish. Longline can harvest catfish which can weigh 7 kg in Lake Babogaya (Lemma Abera *et al.*, 2009) and can catch as huge as 9.25 kg in Lake Zeway (DabaTugie and Masarat Taye, 2004). From a total of 734 (421 female and 313 male) *C. gariepinus* caught during the study, fish which was lured by termite bait was 35 % in number (Lemma Abera and Alemu Lema, 2011). The remaining number of fish was lured by *Barbus paludinosus* (27.5 %), Fish fillet (25 %) and Soap (10 %)

4.8. Reference

- DabaTugie and Meseret Taye. (2004). Reproductive biology and feeding habits of African catfish (*Clarias gariepinus*, Burchell, 1982) in Lake Zeway, Ethiopia. In: *The Role of Agricultural Universities/Colleges in Transforming Animal Agriculture in Education, Research and Development in Ethiopia: Challenges & Opportunities*. Tamrat Degefa and Fekede Feyissa (Eds). Proceedings of the 13th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 25- 27, 2004. ESAP, Addis Ababa. 244 pp.
- Lemma Abera and Alemu Lemma. (2011). Evaluation of different hook sizes and baits for the catch efficiency of African catfish *Clarias gariepinus* (Burchell) in lake zwai, Ethiopia In: Proceedings of the International Conference on Ecosystem Conservation and Sustainable Development (ECOCASD 2011). Natarajan et al., (eds.), 468p. Organized by Ambo University, Ambo, Ethiopia, 10-12, Feb.2011.
- Lemma Abera, Abebe Getahun and Brook Lemma. (2014). Composition of commercially important fish species and some perspectives into the biology of the African Catfish *Clarias gariepinus* (Burchell), Lake Ziway, Ethiopia. *International Journal of Advanced Research* (2014), Volume 2, Issue 1, 864-871.
- Lemma Abera, Demeke Admassu and Zenebe Tadesse. (2009). Length-Weight Relationship, Sex Ratio, Length at Maturity and Condition Factor of African Cat fish *Clarias gariepinus* in Lake Babogaya, Ethiopia. In: *Climate change, livestock and people: Challenges, opportunities, and the way forward*. Zelalem Yilma and Aynalem Haile (Eds). Proceedings of the 17th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, September 24 to 26, 2009. ESAP, Addis Ababa 300 pp.

5. Fish resource dynamics monitoring method

5.1. Background information

The differences in annual fish yield within and/or between reservoirs cannot be easily understood, most likely due to a complex interaction among several variables which influence biological productivity. Several ecologists and fishery managers have attempted to determine the yield and abundance of fish stocks in aquatic ecosystems using physical, chemical and biological characteristics such as surface areas of river drainage basin; lakes; floodplain areas; morpho edaphic index; depth, shoreline development; primary production; etc. The utilization of one or more variables as a management tool, however, largely depends on the nature of the fisheries as well as the available database. Moreover, the variability in fish yield also may be caused by fluctuations in recruitment, and growth and survival rates of the available target species, as well as the fishing effort.

Many studies had shown that changes in fish landings could serve as a suitable ‘indicator’ for monitoring community level responses to both fishing pressures and environmental factors. Variations in species composition of fish in reservoirs and lakes would also reflect the variation in fish yields (i.e. individual large-sized species contribute more weight than a small sized species), although declines in overall fish yield may not be apparent until the complete collapse of the fishery. Thus, temporal patterns of variation in fish species composition are one of the most important topics for fish stock assessment of lake and reservoir fisheries, with long-term studies of fish communities and yields being necessary to establish a baseline for management recommendations.

Sustainability in lake can be achieved by regular monitoring of the fish resource and immediate intervention can be done to sustain the fisheries. Fisheries data collection system, on a regular basis is lacking in the region except those for research purpose. Here is the outline for regular data collection for sustainable fisheries. Data collection format is tested on different lakes and training has been given to selected fisheries experts. This manual is helpful as a reference for routine fisheries data collection and record keeping in day to day activities.

5.2. Inputs required to use the method

- Frame survey data collection sheet (Table 1)
- Catch assessment (CAS) data collection sheet (Table 2). The CAS parameters consist of fishing days, landings (kg) for each species and effort. (Fishing effort is a measure of the activity of the fishing fleet directly aimed at catching fish. It can be rigorously defined as the mortality that the fleet causes in a fish stock of a given size and distribution)
- The catch per unit effort (CPUE, kg per gillnet night) from CAS will be raised by a function of effort from Frame survey.

Table 1. Frame survey format

Sheet code	Lake: _____				Region: _____				Zone: _____								
	District: _____				Kabele: _____				Landing site: _____								
Name of Data collector	No	Name	Social Data			Boats		Gear Code	Number of gill nets and long lines by mesh/hook size								
			Age	Family size	Other source of income (Yes/No)	Boat Type	No of crew		5	6	7	8	9	10	11	12	
Boat type						GEAR CODE				Target Spp							
PB=Planked boat						GN=Gill net				TS= Tilapia							
RB=Reed Boat						LL=long line				CF= Catfish							
						HL=Hook & line				BS= Barbus							
NB: 1 gill net = 50 m																	

Table 2 Catch assessment Format

Landing site _____										Date _____			
Data collector _____													
No of no fishing activity in that month _____													
№	Name of Fishermen	Fishing gear							Weight of fish landed in (kg)				
		No days the boat fished in the last 7 days	Boat type	Gear type	Length /No of hooks	No of setting	1 st mesh	2 nd mesh	Tilapia	Catfish	CC	CR	
Fish price													
Fish type		Tilapia	Catfish	Common carp		Crusian carp							
Price in kg													

Key: LL= Long line, BS= Beach seine, GN= Gill net, CC = Common carp, PB= Planked boat, CR= Crusian carp, RB= Reed Boat

5.3. Steps and procedures

The annual commercial fish catch of a water body can be estimated from annual frame survey and a weekly/monthly catch assessment survey (CAS) conducted on each landing site throughout the year. Frame Surveys involve a complete enumeration of all fishing inputs (fishing effort) at all fish landing sites including the facilities and services. The information generated is used in fisheries management planning and also provides the sampling frame for secondary surveys (CASs). The information recorded in the Frame Survey is used to identify primary and secondary sampling units, and appropriate sampling strata for the Catch Assessment Surveys (CASs). The data generated through CASs provides information on the catch per unit of effort (CPUE) and information on fishing effort from FS provides the raising factors used in the estimation of the quantity of fish landed (tones) and landing site value by species, at temporal and spatial scales (time and space).

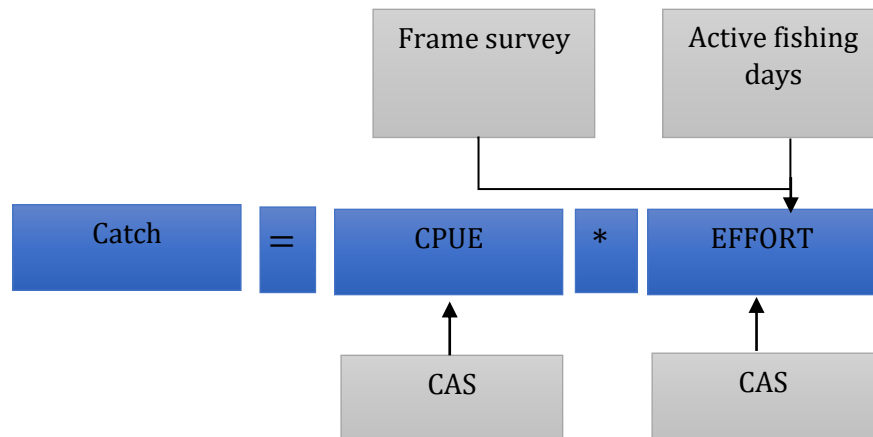
5.4. Scope of using the method

The scope of this method is for major fish production or potential areas, in which fisheries can provide lively hood support and employment for the communities. Besides, both FS and CASs provides information used to guide in determination of appropriate effort and harvesting levels of the exploited fisheries resources and their implications to the sustainable management and utilization of the fisheries resource.

5.5. Important data to be recorded or calculated

- Name of the water body
- Total area of each water body
- Type of harvested fish species
- Name and location of fish landing site
- Number of fishermen (fulltime and seasonal)
- Type and number of fishing gear used by each fisherman
- Price of fish at landing site

- Total catch can be calculated by multiplying CPUE from catch assessment survey by effort, in terms of fishing gear and active fishing days.



5.6. Precautions needed

There is evidence of over or under reporting of the effort (either in terms of fishing gear or fishing effort). The enumerator should clearly indicate the purpose of fisheries data collection to overcome this problem.

5.7. Expected benefits of using the method

By using the above forms and monitoring the fisheries dynamics, appropriate measures in fisheries management can be achieved for each water body. This will help in determining the fishermen number, fishing gear and sustainability of the resource.

5.8. Reference

Mathewos Hailu (2017) Fish stock assessment in Gilgel Gibe Reservoir. Livestock Research Proceeding. Regional workshop on review of livestock research results, held at Adami Tulu Agricultural Research Center, Adami Tulu

6. Gillnet for Tilapia Based fishery

6.1. Background information

Gill-netting is amongst the most important fishing methods, and is used to harvest a variety of species worldwide. The nets are made of synthetic fibers like polyamide forming monofilament or multifilament twines from which the net is knitted. There are several types of twine: twisted multifilament, monofilament, and mono twine. The webbing of gill-nets is made transparent and as invisible as possible because, gill-nets are passive gears, the fish itself moving into the net webbing head on, and trying to push through the mesh opening. Small fish pass through, but the larger ones with a maximum circumference just bigger than the girth of the mesh opening become gilled. The very large fish can entangle themselves or escape capture.

The size at first capture should be greater than the size at first maturity. The smallest size at which tilapia breeds for the first time ranges from 16-21 cm in most of the lakes and reservoirs of the region.

Due to the size-selective nature of gillnets which are widely used by fisheries that target *Oreochromis niloticus*, mesh size regulations can be an effective tool for managing the size composition of catches. Using the SELECT (share each length's catch total) model, the selectivity of appropriate Gillnet mesh size for harvesting tilapia was evaluated in Lakes Fincha, Koka, Elen, Amerti and Chercher. Despite the difference in the lakes the optimum gillnet mesh size for harvesting Tilapia in these lakes is 8 cm mesh size. Therefore, gillnet with mesh size of 8 cm and above can be used to harvest Tilapia in lakes and reservoirs of the region, without damaging the population of tilapia.

6.2. Inputs required to use the technology

Gillnets for fishing with mesh size 8 can be purchased as a ready to use on which the floater, float line, net and led line are mounted together. In many cases the nets with mesh size of 8 cm, appropriate depth and length are rigged with floater, float line and led line are prepared from locally available materials.

6.3. Steps and procedures to use the technology

When making the net the mesh size (the longest distance between two opposite knots in any direction) should be 8 cm (Fig. 4).

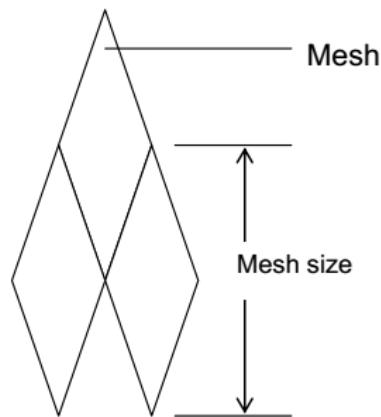


Fig.4. Measurement of mesh size

Parts of a gillnet are shown in Fig. 5. For tilapia fishing the hanging ratio (the length of unmounted net divided by the float line) of the net should be 0.5. In which a 100-meter stretched net is rigged with equal spacing in 50-meter rope. To keep it standing as a rectangular net wall in the water, the net is mounted under a float line with positive buoyancy and a groundline with negative buoyancy. The float line can be made of a floating material like polypropylene, and may have synthetic floats embedded in it or solid floats formed as rings or rectangular pieces can be mounted on it. The groundline can have solid lead pieces mounted externally, or small lead pieces can be embedded in the groundline itself.

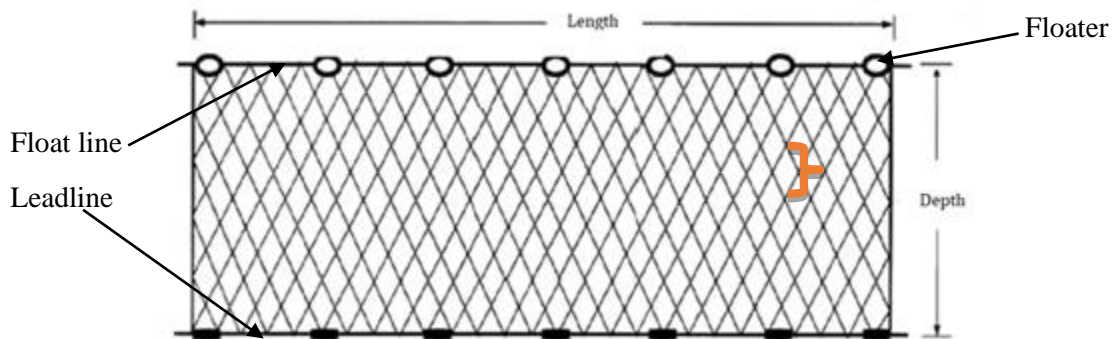


Figure 5. Parts of gill net

The length and depth of a gill net is determined on the fishing area. However, the depth of the net should be always equal or less than the depth of the water. Excess gillnet depth will result in irregularity of the hanging ratio, which results in non-targeted selectivity.

6.4. Scope of using the technology

Gillnets with mesh size of 8 cm can be used both in pelagic and lacustrine environment of lakes and reservoirs to catch appropriate size fish. The gear can be used for Tilapia without damaging the sustainability of the fishery.

6.5. Important data to be recorded

The catch per unit of effort/ the amount of catch in number/ kilogram should be recorded for a standardized unit of gear

6.6. Expected benefits of using the technology

Appropriate market size tilapia can be harvested in a sustainable manner from lakes and reservoirs. Gillnet with mesh size 80 mm most efficiently selects individuals about 17-31 cm in length, and the selection has a sharp peak in about 22 cm length class.

6.7. Reference

- Mathewos Hailu (2014) Gillnet Selectivity and Length at Maturity of Nile Tilapia (*Oreochromis niloticus* L.) in A Tropical Reservoir (Amerti: Ethiopia) Journal of Agricultural Science and Technology A 4:135-140.
- Mathewos Hailu (2017) gear selectivity and abundance of fish in Lake Chercher, West Hararge Zone, Oromia. Livestock Research Proceeding. Regional workshop on review of livestock research results, held at Adami Tulu Agricultural Research Center, Adami Tulu

7. Fishing boat construction from re-cycled plastic bottles

7.1. Background information

Globally 40 million empty plastic bottles are thrown away a day. These wasted plastic bottles pose serious environmental pollutions and health problems in humans and animals. Burning plastics releases toxic and potentially cancer-causing chemicals into the air during burning. The smoke and ash can irritate eyes and lungs, which is especially bad for people with asthma or heart disease.

The trend in the number of waste plastic bottles is increasing over the year in Ethiopia. One of the solutions against the plastic bottle disposal is reusing them for various purposes. Currently, even if the waste bottles are recycled for different purposes, the recycling rate is far less behind the wasted rate. In view of searching for alternative use of waste plastic bottles on the one hand and finding solution for the increasing price of plank boat for fishing on the other hand, the technique of constructing boats from wasted plastic bottles was first designed and constructed at Batu Fish and Other Aquatic Life Research Center. The boat was tested and its preliminary demonstration have created interest among fishermen. Description as to how to construct and use this boat technology is summarized below.

7.2. Inputs required to construct the boat

To construct such boat the following materials are required:

- 2290 pcs of 2 liters capacity cylindrical shape plastic bottles (Polyethylene Terephthalate) are required to construct the boat with the dimension shown in (fig 6). The number of bottles varies based on the size and shape of the Boat.
- Multifilament nylon rope of 3 mm is needed to tie the bottles together.
- Plank for the inside bottom of the Boat.

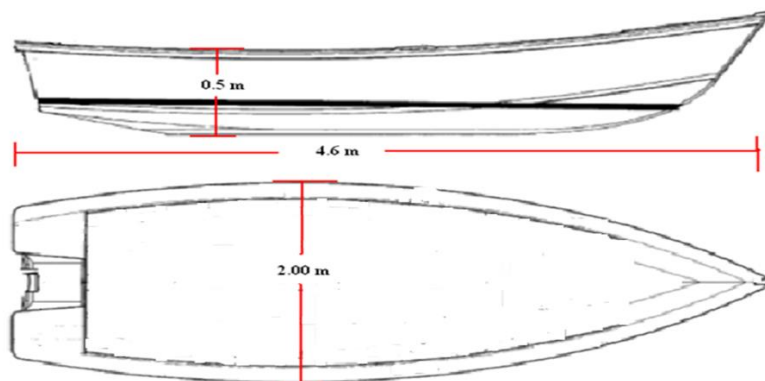


Fig 6. The design of the boat (side view and top view)

7.3. Steps and procedures to construct the boat

To construct the boat, follow the steps given bellow and illustrative figures (Fig.7a to 7f) which follows them.

Step 1: Similar shaped 2 litter capacity plastic bottles should be collected and their labels should be removed (Fig7a)

Step 2: The top and bottom of one bottle is cut in half and used to connect two uncut bottles in order to make large row of plastic bottle. (Fig7b)



Fig. 7a) Plastic bottles collected



7b) cutting and making the bottles in row

Step 3: By using a standard boat as a template the joined plastic bottle rows are tied together using poly filament nylon ropes in two rows (Fig 7c)



Fig 7c) The bottles are tied together by weaving together alternative rows so as the ropes should not fall apart.

Step 5: By flipping over the boat and reinforcing the sides with rope the transom is constructed as of the sides



Fig. 7d) reinforcing the sides with rope

Step 6: Plank is tied with rope to the plastic layer on sitting and footing areas



Fig 7e) tying plank for the sitting area

Step 7: Finally, the boat is ready for fishing



Fig 7f) evaluation of the boat in the lake

7.4. Scope of using the technology

The boat can be used for fishing and transportation. The boat can be constructed in areas where there are excess plastic bottles and shortage or unavailability of other fishing boat construction materials.

7.5. Important data to be recorded

Data to be collected are durability of the boat and efficiency in various climatic conditions.

7.6. Precautions needed:

The plastic bottles should be fastened together tightly so that they do not fall apart in water.

7.7. Expected benefits of using the technology

The cost of plastic bottle can be taken as zero as they can be collected from different areas whereas, the average cost of timber to make one boat according to present market rate reaches up to 4000ETB. Following the rules and guidelines on permissible boat builder, to make a single timber boat requires 4,600 ETB while the cost of plastic bottle boat is 2,400 ETB.

Moreover, use of building materials such as rope for binding one plastic bottle to another and using only few timbers for plastering of the floor again brings a significant reduction in cost in plastic boat production as compared to the conventional timber boat construction that is fully made up of timber. Generally, it was evident from the study that; plastic bottle has the potential to be used in construction and this reduces the total cost of boat construction by at least 25-35%

depending on the availability of resources and type of labor exploited. The boat constructed in this manner is relatively fast and durable than plank boat (Table 3).

Table 3: Speed of plastic bottle boat and wooden boat

Operator	Waste plastic bottle boat		Wooden boat	
	Average speed (km/hour)	Maximum speed (km/hour)	Average speed (km/hour)	Maximum speed (km/hour)
A	4.24 ± 0.34	4.51 ± 0.51	3.93 ± 0.82	4.31 ± 0.65
B	4.92 ± 0.19	5.84 ± 0.27	4.21 ± 0.22	5.22 ± 0.33
Average	4.51 ± 0.11	5.23 ± 0.32	4.04 ± 0.12	4.71 ± 0.12

7.8. Reference

Lemma Abera and Abraham G/Tsaddik (2019). Evaluation of recycle plastic bottles as a fishing boat in Lake Ziway. In: *Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute. Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018*

8. Spirulina production technology

8.1 Background information

Spirulina (*Arthrospira platensis*) is a naturally occurring blue-green micro-algae which grows in alkaline lakes of the tropics. Naturally Spirulina has the ability to thrive in conditions where other algae cannot grow. It is a single celled organism that turns sunlight into micronutrient life energy. It is one of the early life forms which originated more than 3.6 billion years ago, and its spiral shape is what gave it the common name of spirulina.

Spirulina has amazing properties and, in many ways, it can be considered a Super Food. It contains the most remarkable concentration of nutrients known in any food, plant, grain, or herb. It's composed of 60% highly digestible vegetable protein, has extremely high concentrations of beta carotene, vitamin B-12, iron and trace minerals, and the rare essential fatty acid GLA – Gamma-Linolenic Acid. It has a balanced spectrum of amino acids (Gershwin and Belay, 2007). All the essential vitamins and minerals a body requires can be provided by spirulina. These provide a variety of benefits such as nourishment, mental clarity, assisting in cancer recovery, depression help and many others for the human body. Several scientific studies showed that spirulina has the ability to inhibit viral replication. Due to its high quantities of minerals, vitamins and micro-nutrients, Spirulina has mainly been used to combat mal-nourishment. In recent years Spirulina marketing has grown amongst the health and fitness conscious. Its high protein and nutrient contents made it an ideal food supplement and an immune booster. The production of spirulina in small and medium scale farms was tested in outdoor pond at Batu Fish and other Aquatic Life Research Center, using algal culture pond.

8.2 Inputs required to apply the technology

For production of Spirulina the following materials are necessary.

- Production pond (preferably race way pond). spirulina can be produced in open ponds made of polished cement or basins lined with thick polyethylene plastics. The latter are much more cost effective in the short run but have proven to be more expensive in the long run due to the wear and tear of the polyethylene material.
- Electrical or manual driven paddle wheel
- Electronic balance
- Starter spirulina inoculum
- Filtration cloth
- Microscope: for enabling close inspection of the culture
- Chemical for Zarrouk medium preparation (Table 4)

Table 4. Required nutrient

Nutrient	Gram per liter
NaHCO₃	13.61
Na₂CO₃	4.03
K₂HPO₄	0.50
NaNO₃	2.50
K₂SO₄	1.00
NaCl	1.00
MgSO₄ . 7H₂O	0.20
CaCl₂ . 2H₂O	0.04
FeSO₄ . 7H₂O	0.01

8.3 Steps and procedures to apply the technology

- A Spirulina culture is started with a small portion of fresh and mature Spirulina culture. It can be started from a small inoculum, growing it to a large scale through serial scale up cultivation until the desirable quantity is reached depending on the pond size.
- Spirulina strains can be maintained and cultivated in the Zarrouk medium described in Table 4.
- The pond should be cleaned in each growing period before production. Water and bleach are used for cleaning the pool or basin. All tools that come in contact with the culture must be cleaned before and after each use.
- Inoculation of the raceways can be done after filling the race way pond with clean water addition of nutrients as described in Table 1.
- The water level of the race way pond should not be above 15 cm. Covering the pond with green house sheet is helpful to increase/maintain the water temperature at 30-35°C. Spirulina can survive lower (not below 20°C) and slightly higher temperatures (up to 38°C), but it is not advisable as its metabolism will be harmed and it may suffer from a state of 'shock'. Temperatures can be measured with a thermometer.
- Spirulina can live in a pH level that ranges 8.0 to 11.0, but it is at its best at 10.5-11.0, which is the level that needs to be maintained, as below 10.5 it is at risk of being contaminated and over 11 it undergoes chemical changes
- Spirulina tends to gather at the top of the growing culture, where sunlight exposure is maximal. Due to this, Spirulina that cannot reach the top will ultimately die. In order to maximize Spirulina exposure to sunlight, the water in which it is grown must be agitated so that all Spirulina filaments are exposed to sunlight. Agitating can be done manually, using a broom (both must be cleaned before use). This should be done gently, in circular motions that maintain the same direction (clockwise or counterclockwise). In raceway pond should be agitated by a paddle wheel rotating at 20 rpm 12 h per day.
- Spirulina's reproduction is asexual. Given the right conditions (temperature, lights, fertilizers, agitation) it doubles itself approximately every 48 hours.

- When Spirulina is mature and dense (this can be estimated by the dark green color of the culture, the darker green the culture the denser it is and ready for harvest (Figure 8a).
- Harvesting during morning hours is best
- The product can be harvested by using nylon
- Harvesting Spirulina is essentially separating/filtering it from the culture medium in which it grew. Cloth with a density of 30-40 microns in diameter, made of polypropylene, nylon or polyester is good for filtration.
- The Spirulina on the cloth will at this point will still have some residue of the culture medium. In order to bring the Spirulina to a pH level of 7, which is healthy for consumption, these residues need to be eliminated. To do so press the filtering cloth (with the Spirulina in it) evenly and gently. The culture medium, which is transparent, will drain from the cloth. When the water draining through the filtering cloth is no longer transparent but green, stop squeezing. This means that all the culture medium has been squeezed out and the Spirulina is at a healthy pH level (Figure 8c).



Fig. 8. steps in spirulina production (a: cultivation b: filtration c: drying)

8.4 Scope of using the technology

Spirulina is a high-quality product which can be produced as a business venture, targeting, especially, alleviation of infant malnutrition

8.5 Important data to be recorded

The crucial elements that need to be monitored in the process of spirulina production are: temperature (of culture and of air), pH level, culture depth, radiation (amount of light), salinity, density. Besides temperature of air in greenhouse and radiation (which will be the same for all pools or containers in it), these measurements should be taken and kept separately for each pool or container. Measurements should be taken twice a day.

8.6 Precautions needed

Tools that come in contact with culture (thermometer, for instance) should be cleaned between pools, preferably with distilled water if available. It is also advisable to monitor the amount of Spirulina that is harvested at each harvest.

8.7 Expected benefits of using the technology

There's is a growing market by different NGOs to supply spirulina for Malnutrition affected children. A healthy body requires 10 to 12 grams of Spirulina, malnourished children and HIV/AIDS patients require a lot more. In order to maintain this high level of production water is required to fill the ponds and boost production.

8.8 Reference

- Mathewos Hailu and Alemu Lemma (2019). Establishment of medium scale spirulina farm and Determination of Growth rate. In: Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 01-04 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 338 pp.
- Gershwin, M. E. and A. Belay (2007). Spirulina in human nutrition and health, CRC press. pp 328

II. Information

1. Fish postharvest losses in water bodies of Oromia

1.1 Background information

The term post-harvest refers to the period of time when fish is separated from its growth medium. This includes the time a fish enters a net, caught on a hook or in a trap. There are four types of fish post-harvest losses namely: Physical loss, Quality loss, Market force losses and Nutritional loss.

Substantial losses of fish occur at all stages in the chain from capture to marketing of fresh fish. Fish losses are expressed in economic, physical and nutritional terms. The first of these (economic losses) implies a net reduction in potential revenue from a given lot of fish whereas, the physical losses refer to a direct loss of nutrient material. The nutritional losses imply a reduction in nutritional value or increase in toxicity of the product. Although the extent of fish post-harvest loss varies from lake to lake and from species to species, from its eleven water bodies the Oromia region is losing a huge amount of fish (167.25 tons) annually through post-harvest losses. This is a massive economic and nutritional loss for a country like Ethiopia which suffers from protein malnutrition. The main causes for post-harvest losses include inadequate handling, processing and storing facilities, delay between catch, collection and distribution, lack of proper fish market channel, absence of regulations governing quality and standards of fish to be sold for human consumption, poor extension services and lack of knowledge on proper fish preservation techniques (Alemu Lema, 2018). The factors (variables) which contribute to post-harvest fish losses were; spoilage, size discrimination, species preferences, operational loss (fishing gears) and Animal predation (dogs, stork, cormorant and crocodile). Physical loss and quality loss were the two pertinent kinds of losses.

In addition to raw fish lost after harvesting, there is also offals loss which ranges between 50% and 70% during fish filleting depending on the fish size and species. In Ethiopia, total fish offals range between 55% for catfish, 60.2% for Labeo barbus and 68% for tilapia filleting. Wastes include trimming, guts, skins, deteriorated fillet, viscera, roes/eggs, fish maws, heads and scales. Cognizant of this fact, fish postharvest loss assessment in Oromia region of Ethiopia has been conducted in eleven water bodies by Batu Fish and Other Aquatic Life Research Center. These water bodies are Genale river, Finca'a-Amerti reservoirs, Koka reservoir, Belbela reservoir, Lakes like HoraKilole, Hora Aresede, Babogaya, Kuriftu, Beseka and Langano. Information generated from the assessment conducted is summarized as follows.

1.2 Inputs used to generate the information

- Formats to collect data regarding fish catch and Post-harvest loss at every segment of the chain (landing, processing, transportation and marketing).
- Checklist for semi-structured interviews for fishers, fish processors and fish traders,
- Checklist to guide during Informal Fish Loss Assessment Method (IFLAM) observation and information which help to identify key locations for IFLAM
- Tape recorder (Dictaphone) for recording notes and observation,
- Small spring balance, camera to capture losses and observations and water proof clothing.

1.3 Steps and procedures followed to generate the information

There are three loss assessment methods developed in artisanal fishery which are used separately or sequentially to gather losses, basic data on losses or the impact of interventions on losses. These methods are the Informal Fish Loss Assessment Method (IFLAM), Load Tracking (LT) and Questionnaire Loss Assessment Methods (QLAM).

A. Informal Fish Loss Assessment Method (IFLAM):

This is a quick assessment method used to generate qualitative and indicative quantitative data/information. Based on rapid and participatory rural appraisal (RRA and PRA), it helps in identifying opportunities for loss reduction. IFLAM is used under the following scenarios:

- Where very little is known about the post-harvest fish losses at a particular site, area or distribution chain and when a quick assessment is required to identify whether losses are an issue and whether further action is required.
- Where losses are known to be occurring in a particular part of a distribution chain and information is required on the reasons and levels of losses.
- When information on losses occurring in a particular geographical area is required for planning purposes.
- When fishermen, processors or traders request for information which helps them to reduce the losses in their business (reduce wastage and improve income).

B. Load Tracking (LT):

This generates biometric data along the supply (distribution) chain. It is biometric sampling, replication and design to measure change in fish quality and quantity loss between stages in a distribution chain. Statistically it is a valid assessment of loss between two stages in a distribution chain. LT is used under a scenario where an intervention to reduce losses has been identified, but information on its impact on losses is required.

C. Questionnaire Loss Assessment Method (QLAM):

This is a method done by interviewing a population sample in a community (geographical area) using a questionnaire to validate data generated by the informal Fish Loss Assessment Method and Load Tracking.

Generally, the total fish catch and losses at the landing sites were assessed by using the following calculations:-

$$\text{Total monthly fish} = \frac{\text{Sum of sampling day catch} \times \text{Monthly fishing days}}{\text{Number of sampling days}}$$

$$\text{Total monthly fish loss} = \frac{\text{Sum of sampling day loss} \times \text{Monthly fishing days}}{\text{Number of sampling days}}$$

1.4 Scope of using the information

Information generated from fish post-harvest loss assessment is applicable in areas where there is huge losses. However, such loss assessment information may not be required from water bodies like Langano Lake where, landings sites are accessible and hence fish is sold in fresh form. Similarly, substantial fish loss data could not be gathered from fish farming (Aquaculture) as the system is only for subsistence fishery.

1.5 Important data recorded

Important data collected during the assessment of fish post-harvest losses are; information which help to identify key locations for IFLAM, checklist for semi-structured interviews for different groups (fishers, fish processors and fish traders) and checklist to guide during IFLAM observation. Data like fish catches and losses during sampling time must be recorded.

1.6 Fish post harvest losses incurred

Information generated from fish post-harvest loss assessment is to locate water bodies where loss is abundant hence to prepare fish silage or fish meal. In Oromia regional state, the pertinent losses identified in different water bodies are as follows.

In Genale river, 34 % loss in quality of *Bagrus docmak* was observed (Alemu Lema, 2016).

With regard to fish post-harvest loss in other water bodies, the most fish species lost is Common carp (11.18 %) in Fincha-Amerti reservoir, *Labeobarbus* (12.27 %) in Gilgel Gibe reservoir, Common carp (21.01 %) in Koka reservoir. On the other hand, considerable carp species in Belbela reservoir and Hora Kilole, Nile Tilapia in Hora Harsedi, Babogaya and Kuriftuare lost. Any individual who has the potential for fish silage production from waste fish can be benefited without any wading.

1.7 Recommended methods to minimize fish postharvest losses

Fish postharvest losses can be minimized, if fishermen, processors, retailers and whole sellers do the following activities;

- Fishermen who use gill nets should not keep for more than 8 hours in the water. Multi hauling techniques of gill nets ought to be followed to avoid spoilage. Fishermen who use Beach Seine need to increase mesh size to greater than 8 cm to reduce by-catch.
- Postharvest fish losses would be highly reduced if freshly harvested fish are sold readily within 1 to 2 hours after harvest. Unsold fresh fish should be preserved to use during lean season.
- To reduce fish quality loss, fish traders should use ice during transportation of fish from landing site to storage or freezing units.
- Value added fish product should be developed to improve the utilization of non-preferred fish species in the region.
- Lost raw fish as well as by-products are dumped into the lake or consumed by wild birds. However, small scale users can easily convert this loss into fish silage or fish meal using a simple technology which requires a low investment and is economically viable at small scale.

1.8 Reference

- Alemu Lema Abelti. (2016).Post-harvest and nutritional loss assessment of fish at different handling stage from Genale River, Southeastern Oromia. In: Livestock Research Proceedings. Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh, Alemu Lema and Berhanu Shilema (Eds.). Regional workshop on review of livestock research results, held at Adami Tulu Agricultural Research Center, Adami Tulu.
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2. Prevalence of fish parasites in Zeway, Charcher, Elan, Abaya Lakes and Genale River

2.1 Background information

The awareness, knowledge and literature pertaining to fish-borne zoonotic parasites are growing and are now quite substantial. This is partly due to the extensive range of parasites (primarily helminths or ‘worms’) of fish that can be transmitted to humans and due to the world-wide concern over food safety and quality. In Oromia region of Ethiopia, preliminarily fish parasite investigation in Lake Zeway, Lake Elan, Lake Charcher, Lake Abaya and Genale River has shown the occurrence of Nematodes, Cestodes and Trematodes in fish.

Nematodes are long, cylindrical, non-segmented worms enclosed in a cuticle. They are sexually dimorphic and typically have multiple host life cycles, each stage of which is preceded by a molt (4 in total). The group is large, wide spread and common in fish.

Cestodes (tapeworms) are segmented flatworms and are hermaphroditic characterized by a scolex (‘head’) that attaches to the host’s intestinal epithelial lining, and a long tape-like body (strobila) made up of segments containing the reproductive organs and eggs. Cestodes belong to the *Phylum* Platyhelminthes that encompasses a variety of acoelomate organisms that are bilaterally symmetrical, dorso-ventrally flattened ribbon shaped and generally longer than wide. Some of their harmful effects include introducing metabolic by products, acting as vectors of other pathogens, surviving in the expense of the fish (host) food, causing mechanical injury such as irritation; injury; and atrophy of tissues. Sometimes cestodes can negatively affect the health state of cultured fish and cause death to heavily infected; mostly vulnerable young (fry, fingerlings) fish.

Trematodes are non-segmented flatworms or ‘flukes’ (platyhelminths), which are characterized by possession of oral, and usually, ventral suckers and a life cycle requiring one or more intermediate hosts.

2.2 Inputs used to generate the information

- Saline water, scissors, needles, petri dishes, labels, 70 % alcohol, 4% neutral formaldehyde solution and glasses.

2.3 Steps and procedures used to generate the information

The steps that are followed during identification of the most common disease causing parasite in fish are; Fish examination, parasite collection, fixation, preservation and identification of parasites. First the coelom is opened by making a ventral surface cut from the anus forward the

posterior portion of the operculum using standard evisceration technique. The gill filaments and various organs including stomach, intestine, liver, heart, gall bladder and gonads are removed and placed separately in petri dishes containing 0.75% saline solution. All the collected parasites are preserved in 70% ethanol or 4% formalin, fixed using Alcohol Formalin Acetic Acid (AFA) and further identified using appropriate procedure (Gebawo Tibesso, 2014).

2.4 Output obtained from the information

- In Lake Ziway, the infestation was high during the month of July to October (2010) for *Contracaecum* and *Clinostomum* whereas the frequency of Cestodes larva was high in July to August (2010) and in between May and June (2011) (Lemma Abera, 2013).
- A total of 431 specimens of *O. niloticus* (383) and *Tilapia zilli* (48) were examined from Lake Charcher. Out of these, 55 *O. niloticus* and 13 *Tilapia zilli* were infected with one or more species of meta cercariae with overall prevalence rate 15.7%. The major internal parasite identified in the body of fish were *Contra caecum* (3.9 %), *Clinostomum* (8.8 %) and *Eustrongylides* (3 %) in Lake Charcher. (GebawoTibesso, 2014).
- In Lake Elan, a total of 472 fish belonging to four species were examined. From the totally examined, 50(10.6%) fishes were found to be infected with different parasite Six (6) species of parasites comprising two Digenea, two crustacean and two nematodes were isolated. Among the types of fishes examined of which fifty were positive from the total (n: 472) twenty eight (of them were infected by *Contra caecum* larvae (5.93% of the total and 56% of the infected) while thirteen (2.75% of the total and 26% of the infected), and two (0.4% of the total and 4% of the infected) were *Clinostomum* spp and *Eustrongylides* respectively (GebawoTibesso, 2015).
- Out of 216 fish examined in Lake Abay, 26 (12.03%) fish were infected with different internal parasites (Table 6). Out of these infected fishes, 5 were *Synodontis schall*, 15 *Clarias gariepinus* and 6 *Oreochromis niloticus*. Fish species like *Bagrus docmak*, *Latesniloticus*, *Mormyruskannume* and *Labeobarbus intermidus* were not infected with internal parasites. Adult *Contracaecum* (Nematoda), *Eustrongylides* (Nematoda), Metacercariae of *Clinostomum* spp. (Digenea) and *Diplostomum*spp. were the identified internal parasites from Lake Abaya (GebawoTibesso, 2016).

Table 6. Major parasite isolated and identified from fish of Lake Abaya

Species of fish	Fish sampled		Parasite identified	
	Total	Infected	Parasite type	No. (+)
<i>Synodontis schall</i>	111	5	<i>Contracaecum</i>	2
			<i>Clinostomum</i>	2
			<i>Eustrongylides</i>	1
<i>Bagrus docmak</i>	11	0	-	0
<i>Oreochromis niloticus</i>	39	6	<i>Contracaecum</i>	6

<i>Clarias gariepinus</i>	21	15	<i>Diplostomum</i>	15
<i>Lates niloticus</i>	7	0	-	-
<i>Mormyrus kannume</i>	8	0	-	-
<i>Labeobarbus intermidus</i>	4	0	-	-
Total	216	26		26

- In Genale river a total of 319 fishes (77*Bagrusdocmak*, 81*Varicorhinusbeso*, 5 *Anguilla labiata*, 59 *Mormyrus caschive* and 97 *Labeobarbus gananensis*) were examined. From totally examined fish, 37(11.6%) were found to be infected with different parasite. Among the types of fishes examined of which thirty seven were positive, twenty five of them were infected by *Contracaecum* larvae 25(67.56%) while 11(29.73%), and 19(51.35%) were *Clinostomum* sp and *Eustrongylides* respectively. The major parasites identified during the investigation include adult *Contracaecum* (Nematoda), *Eustrongylides* (Nematoda) and metacercariae of *Clinostomum*spp. (Digenea) (GebawoTibesso, 2018).

2.5 Scope of using the information

The information generated from internal fish parasite are applicable in water bodies which are prone to human and animal interference. However, this information could not hold true where the water bodies is pristine (environment which is free of any interference).

2.6 Benefits of using the information

Information which was generated from these activities are beneficial to minimize some risks.

- As there are zoonotic parasites, fishermen and other people who have developed the habit of consuming raw fish are at higher risk of becoming infected by parasites. The generated information implies that, consumers should abstain from consuming of uncooked or slightly cooked fish.
- The surveillance indicates that parasites that detach from the fish host can bite the bare foot of fishermen. This might allow the entrance of other organisms. Hence, it is not recommended for fishermen to walk barefoot.

2.7 References

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3. Bacterial fish pathogens isolated from Lake Zeway

3.1 Background information

Fish are susceptible to a wide variety of bacterial pathogens. Many of these bacteria capable of causing disease are considered to be saprophytic in nature. In Ethiopian water bodies less attention have been given to bacterial pathogens of fish including those which have zoonotic importance. Bacterial fish pathogens reduce fish production by affecting the normal physiology of fish and if left uncontrolled, it can result in mass fish mortality or in some cases, can serve as source of infection for human and other vertebrates that consume fish. A study on major bacterial pathogens of fish from Lake Zeway was carried out from October 2012 to June 2013 by Batu Fishery and Other Aquatic Resources Research Center. Useful information obtained from the study is summarized as follows.

3.2 Inputs used to generate the information

Gillnets, Microbiological media, Saline water, scissors, needles, petri dishes, labels, incubator, vortex, pipette, homogenizer, aluminum foil, distiller, distiller, inoculating loop, test tube, autoclave, colony counter, sampling jar and cotton swab.

3.3 Steps and procedures used to generate the information

Steps and procedures followed during assessment of bacterial fish pathogens are collection of fish, collection of bacterial pathogen, Isolation and Identification of bacteria. A total of 155 fish samples were collected from randomly selected site of water bodies. To collect bacterial fish pathogens, fish are externally examined for lesion then body wall is opened and the samples were taken from kidney, spleen and liver after searing the surface of the organ. Aseptically taken swabs from different organs were inoculated onto blood agar and brain heart infusion agar and incubated for 24-48 hrs at 37°C for isolation (Gebawo Tibesso, 2015).

3.4 Outputs obtained from the information

In Lake Ziway, from a total of 155 fish samples 23(14.8%) were found to be infected, of which 4 fish were *C. gariepinus*, 10 were *O. niloticus*, 4 were *Tilapia zilli*, 1 was Barbus species and 4 were Carp species. Pathogenic bacteria isolated from kidney, liver and in spleen of Nile Tilapia, African catfish, Barbus species and Common carp in Lake Zeway were *Edwardsiella ictaluri*, *Yersinia* spps, *Aeromonas* spps, *Citrobacter*, *Escherichia coli* and *Shigella* spps (GebawoTibesso, 2016).

3.5 Scope of using the information

The information generated from bacterial fish pathogen are applicable in water bodies which are prone to human and animal interference. However, this information may not be important where the water bodies are pristine (environment which is free of any interference).

3.6 Benefits of using the information

Information on bacterial fish pathogens from fish and fish products helps the consumers to take measures that can be taken during harvesting, processing or post processing (e.g. by the consumer) to reduce the risk of infection.

- Fishermen and other people who have developed the habit of consuming raw fish are at higher risk of becoming infected by the zoonotic parasites. Consumers should not eat uncooked or slightly cooked fish and health education should be given for them on the risk of eating raw and partly cooked fish.
- Presence of opportunistic fish pathogens in kidney and the other organ indicates the risk of the occurrence of disease outbreak any time when the fish are succumbed under stress (Gebawo Tibesso, 2016).

3.7 Reference

Gebawo Tibesso Bedasso. (2016). Study on major bacterial pathogen of fish at Lake Ziway. In: Livestock Research Proceedings. Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh, Alemu Lema and Berhanu Shilema (eds.). Regional workshop on review of livestock research results, held at Adami Tulu Agricultural Research Center, Adami Tulu.

4. Hazard in fish and fish products from Lake Zeway

4.1 Background information

Fish being an extremely perishable foodstuff needs careful treatment in handling and processing both from public health aspects and improvement of the welfare of fishing community. In addition to higher water activity (A_w), the poor sanitary practices in local fish processing imposes public/consumer health hazards due to the presence of pathogenic bacteria. It has a paramount importance to explore the quality of different fish products provided for consumers in different hotels, restaurants, recreation areas and shops. Microbes which are of food safety concern include Aerobic Plate Count, Mold, Yeast, *Escherichia coli* (*E. coli*), *Fecal coliform*, *Total coliform*, *Staphylococcus aureus*, *Salmonella* and *shigella* must be investigated in fish products before it is served for consumer. Hazard analysis of different fish products presented to consumers in Zeway town was conducted by Batu Fish and Other Aquatic Life Research Center to analyze microbial load of four different fish products namely Fish Goulash, fish Cutlet, fish fillet and fried fish. Valuable information obtained from the analysis are summarized below.

4.2 Inputs required to generate the information

Microbiological media, Saline water, scissors, needles, petri dishes, labels, 70% alcohol, 4% neutral formaldehyde solution and glasses

4.3 Steps and procedures followed to generate the information

Hazard analysis of different fish products in Zeway was initiated with the objective to analyze microbial load of four different fish products. Accordingly, 8 samples of Fish Gulash, 8 sample of Cutlet, 2 sample of fish fillet and 2 samples of fried fish were collected in triplicate and packed in pre-sterilized glass jars from hotels, fish shops and lake side recreation areas of Zeway town. Microbial load of Aerobic plate count, Mold and yeast, *Staphylococcus* species, *Salmonella* species and *Shigella* species quantity is determined using standard laboratory procedure (Demeke Teklu, 2015). *Escherichia coli* and total coliform were determined using Most Probable Number methods (Alemu Lema, 2013).

4.4 Outputs obtained from the information

The output obtained from the information indicated that, aerobic bacterial counts for 14 samples were categorized as highest microbiological risk, while 6 samples were categorized as moderate risk. Regarding *Staphylococcus*, 7 samples were categorized as highest microbiological risk however 8 samples didn't show any growth while the rest of samples were at moderate risk. 9 samples were shown *Salmonella* species and *Shigella* species count beyond the acceptable limit.

Only 6 samples were shown the highest risk of all total coliform, E-coli and fecal coliform counts. During the hazard analysis of fish products, total coliform and fecal coliform count of twelve samples and *E. coli* count of fourteen samples exceeded the acceptable recommended limit. This implies different fish products (Goulash, Cutlet, Fried fish and fillet) can be bad source of hazards.

4.5 Scope of using the information

The information generated from hazard in fish and fish products are recommended in water bodies which are prone to human and animal interference. However, this information may not be important where the water bodies are pristine (environment which is free of any interference).

4.6 Benefits of using the information

Hazards associated with consumption of different fish products may lead to ingestion of Mold, Yeast, *Escherichia coli* (*E. coli*), *Fecal coliform*, *Total coliform*, *Staphylococcus aureus*, *Salmonella and shigella* (Demeke Teklu, 2016). The recovery of microorganisms, which are potentially pathogenic to humans, in fish fillet suggest that if they are improperly handled, undercooked or consumed raw may cause diseases to susceptible individuals. Hence, consumer should take into account about this information considerable care should be taken during fish processing, preservation and fish food preparation.

4.7 References

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- Demeke Teklu Senbetu. (2016).Hazard analysis of different fish products provided for consumers in Zeway. In: Livestock Research Proceedings. Tesfaye Alemu Aredo, Dawit Abate, Amsalu Bezabeh, Alemu Lema and Berhanu Shilema (Eds.). Regional workshop on review of livestock research results, held at Adami Tulu Agricultural Research Center, Adami Tulu.

Part six: *Apiculture Technologies/information User's Manual*



Beekeeping by community at Ambo district, Dobi kebele (left) and Apiary site at Menagesha



Vernonia amygdalina with flowers (left) and Pot hive for hiving stinglesbee colony (right)

I. Technologies

1. Migratory beekeeping technique for multi-seasons honey harvesting

1.1 Background information

Migratory beekeeping is an important dimension to produce successive honey in a year. The technique is important in Ethiopia to utilize all the advantages of flowering plants in different areas at different seasons to take the advantage of successive nectar flow. It is more economical compared to stationary beekeeping system with its own profitability level. Ethiopia is endowed with bee flora species which provide nectar and pollen with distinct seasonal flowering patterns within a year. With great variety of climatic conditions in the country, several vegetation localities exhibit different flowering phenology.

Beekeepers in the country practice migratory beekeeping from one site to another during the flowering seasons to harvest multiple honey, but the practice is not fully exploited in a planned way. Moreover, migratory beekeeping is important to compensate crop pollination deficit, resulting from the current decline in wild pollinators, however, beekeepers and farmers are not recognizing the crucial importance of honeybees for crop pollination. To test the possibility of migratory beekeeping for successive honey production, Holota bee research center has conducted a study in East and West Shewa zones. This was done by using 10 bee colonies (*Apis mellifera*) in standard Zander hive by keeping half of the colonies as stationary beekeeping and migrating the rest half colonies. The procedure of applying the technique and the advantages obtained are summarized below.

1.2 Inputs required to use the technique

- Bee colonies with improved bee hives
- Protective clothes (Overall, veil, gloves)
- Brush
- Chisel
- Queen excluder
- Smoker
- Casting mold
- Bees wax
- Equines or track for colonies transportation during migration
- Temporary beekeeping site in migratory beekeeping

1.3 Steps and procedures to use the technique

Scheduling migratory beekeeping: This practice of involves:

- Tracking of the availability of bee flora resources different from stationary beekeeping area to migrate in the year
- Assessing important characteristics such as the distance between stationary and migratory sites, the flora coverage, time flowering and flowering duration of major bee flora
- Defining the exact time of colonies migration depending on the characteristics of flora phenology
- Making formal agreement with landowners, site preparation to place colonies, and colonies migration
- Following standard seasonal colonies management practices (timely supering and super reducing) has to be followed.
- Honey harvesting and processing
- Recording of all variable costs and revenue for colonies migration

1.4 Scope of using the technique

Migratory beekeeping practices can be facilitated with knowledge of the floral resources and appropriate migration schedules for different beekeeping locations. It can be implemented within geographic honeybee races and can be applied both in modern and transition beekeeping system. Migratory beekeeping should be developed through coordination and communication among beekeepers and land owners in the area.

1.5 Important data to be recorded

- Type and time of flowering plants at different localities
- Indicative colony conditions to decide colony migration
- Honey yield
- Cost and benefit of migratory beekeeping

1.6 Expected benefits of using the technique

Honey yield under colony migration is twofold (51-56 kg/colony/year) compared to honey yield of stationary colonies (25.6 kg honey/colony/year). This implies that migratory beekeeping worth 2500 to 3000 Birr net profit per colony compared to stationary beekeeping system. Moreover, migratory beekeeping also important to strength colonies by minimizing the duration of dearth period and saves the supplementary feeding cost during dearth periods (the cost of 4 kg of sugar/dearth season/colony). Due to current increasing demand for crop pollination and declining of other wild pollinators, migratory beekeeping will have double advantage that that the beekeepers will be renting their colonies for crop pollination and at the same time harvesting honey.

1.7 Precautions needed

Colony migration outside the geographic races of honeybees may causes genetic dilution. Moreover, the placement of colonies should follow the formal agreement of land owners in the areas migrated to.

1.8 Reference

Admasu Adi, Tura Barake, Kibebew Wakjira and Tolera Kumsa (2016). Investigating the effect of migratory beekeeping on honey production in East and west Shewa Zones of Oromia. Oromia Livestock Research Proceedings.

2. Honeybee pollination service to enhance fruit yield of apple

2.1 Background information

Apple plant belongs to the family *Rosaceae* and its flower is bisexual with 5 stigmas and 20-25 stamens. Different apple varieties are reported as the largest economically significant fruit crop worldwide. Due to the self-incompatibility of most cultivars, the plant relies on insect pollination to bear fruits. East African countries apple tree can grow from 2000-3200 meter above sea level. Different varieties of apple trees were introduced by missionaries into the tropical mountains including southwestern Ethiopia before 60 years. Nowadays, apple is widely cultivated in most highland regions of Ethiopia for fruit production. The government promotes fruit trees at the level of smallholder farming. However, the required fruit yield and fruit quality have not been attained. Moreover, many investors are involving in apple farming for fruit production in Ethiopia.

Currently, there is an increasing interest of using honeybees as pollinators, however, lack of awareness on pollination management of apple is the factor as apple flower is highly dependent up on insect pollination. A pollination study was undertaken at Holeta Agricultural Research Center to investigate the effect of honeybee pollination on fruit yield and quality of apple. Three scenarios (Caging the apple plants with the honeybee colonies for intensive pollination, caging the plants with exclusion of honeybees and leaving the plants open to be pollinated under natural condition) were compared. Description as to how to apply the recommended technology is presented below.

2.2 Inputs required to apply the technology

- Apple farm during the flowering stage
- Site for honeybee colonies placement
- Honeybee colonies
- Supplementary feed for honeybees during pollination
- Protective cloth (overall, veil glove)
- Beekeeping equipment (smoker, chisel)

2.3 Steps and procedures to apply the technology

- Similar age of apple variety of ‘Anna’ were used on the plot size of 36m x 12m
- Three pollination management groups such as (1) plants caged with a honey bee colony (2) plants left open for free access to all insect pollinators and (3) plants caged without any insect pollinators were used
- Placing of 4-5 honeybee colonies per hectare in apple farm at 50% flowering stage of the plant

- Manipulation of honeybee colonies at minimum brood combs (two brood combs with 8-9 frames with little pollen and nectar). This is important to enhance the pollen collection tendency of honeybees on target crop.
- Feeding of colonies with one-litter sugar syrup (50%, w/v) to stimulate bees to increase their constancy on apple pollen collection and to increase pollination.
- Harvesting ripen fruit and sort-out according to marketable and non-marketable qualities

2.4 Scope of using the technology

All races of honeybees can pollinate apple flower with similar pollination management practices. Modern hives and chefeke hives can be used for pollination of apple.

2.5 Important data to be recorded

- Ripen fruit yield per tree
- Marketable and non-marketable fruit
- Fruit price

2.6 Expected benefits of using this technology

- Fruit yield of apple increased by 45.5% using honeybees as pollinators compared to open pollination.
- The marketable apple fruit yield per individual tree is 3.2 kg, if caged with honeybees compared to open to all insect pollinators (2.2 kg for trees).
- Insufficient pollination results in higher unmarketable apple fruit yields of apple trees (220 kg per hectare) compared with those exposed to honeybees as pollinators (110 kg per hectare).
- If an apple farmer would have 100 trees supplied with honeybees for pollination during the flowering season, a total marketable apple fruit yield of 320 kg is expected.
- If a kilogram of apple would be valued 40 Ethiopian Birr (ETB), the total financial loss by not using honeybees as pollinators, is 4,000 ETB per 100 apple trees.

2.7 Precautions needed

Insecticide and herbicide application in and around apple farm during the flowering stage must not be undertaken as these have negative effect on honeybee colonies and other pollinators. Placing honeybee colonies for pollination before flowering of apple will negatively affect the visitation of apple flower as other flowers such as weeds growing near and in apple farms are more attractive.

2.8 Reference

Tura Bareke, Admassu Addi and Kibebew Wakjira (2018) Role and economic benefits of honey bees' pollination on fruit yield of Wild Apple (*Malus sylvestris* (L.) Mill.) in central highlands of Ethiopia, Bee World, 95:4, 113-116.

3. Honeybee pollination service to enhances noug (*Guizotia abyssinica*) seed yield

3.1 Background information

The expansion of pollinator-dependent crops cultivation in Ethiopia, together with reports on pollinators decline, raises concern of possible yield gaps. Farmers are directly reliant on pollination services for their food security where the knowledge of pollination service is poor. Noug (*Guizotia abyssinica*) is an indigenous to Ethiopia and economically important edible oilseed crop of tropical and subtropical ecosystems. The annual total production of noug seed is about 159,819.7 metric tons, which is about 26% of the total production of oil crops in the country. It is of economic significance not only for domestic consumption, but also as an export commodity to North America and Europe. Currently, the average national yield per hectare is very low and the farmers mostly grow the crop under conditions that would not enable to exploit its full potential. Noug crop is less responsive to agronomic management practices such as fertilizers application. Fertilizer application promotes vegetative growth rather than increasing seed yield.

So far nothing has been reported about the effects of insect pollination on the yield of this crop. Noug flowering phenology is self-incompatible and is highly responsive to cross-pollination. Noug pollination research was carried out at central highland of Ethiopia to evaluate the effect of honeybee pollination on yield parameters of noug. The plots of equal size (2.5 m by 2.5 m) were arranged in to three treatments (plots with honeybee colonies caged with mesh for intensive pollination, plots caged with mesh to exclude honeybees and other flying insects, plots left open to be pollinated under natural conditions). Brief summary of the recommended treatment and its advantages are given below.

3.2 Inputs required to apply the technology

- Land with recommended tillage
- Noug seed of appropriate variety
- Recommended agronomic practices of noug
- Sites where to place honeybee colonies
- Honeybee colonies
- Sugar syrup for simulative feeding
- Protective cloth (overall, veil glove)
- Beekeeping equipment (smoker, chisel)

3.3 Steps and procedures to apply the technology

- Preparing the land based on recommended tillage practices.

- Sowing noug seed on the plots of 2.5m by 2.5 m with the recommended sowing date and seed rate.
- Agronomic management practices such as weeding have to undertaken
- Placing of 6 to 7 honeybee colonies per hectare when 10% to 15% of noug flowers
- Manipulate honeybee colonies at minimum brood combs (two brood combs with 7-8frameswith less nectar and pollen) to enhance the pollen collection tendency of honeybees from target crop.
- Feeding colonies with one-litter sugar syrup (50 % w/v) to stimulate bees to enhance noug pollen collection.
- Measuring the seed set of noug flower
- Harvesting and measuring the seed yield of noug

3.4 Scope of using the technology

All honeybee races can pollinate noug flower with similar pollination management conditions. Honeybee colonies can be placed in noug farm using modern and chefeke hives.

3.5 Important data to be recorded

- Time of seed set of noug flower
- Seed yield
- Costs incurred and income obtained

3.6 Expected benefits of using the technology

The yield obtained from honeybee pollination plot was highest (4.1 q/ha) compared to open pollinated plot (3.6 q/ha). The percentage of oil content of noug seed was highest for all types of insect pollination (40%) compared to the plots excluded from any pollinators (35%). Seed set per head of noug flower was higher than the open pollinated flower head (33.3 seeds per head) compared to bagged head noug flowers (5.3 seeds per head). Generally, pollination agents increased the seed yield of noug by 43.0%.

3.7 Precautions needed

Insecticide and herbicide application during the flowering stage must not be undertaken as they have negative effects on honeybee colonies and other pollinators. Care should be taken for colonies not to be devastated by ants and other predators during pollination.

3.8 Reference

Admasu Addi and Nuru Adgaba (1999). Effect of honey bee pollination on seed yield and oil content of noug (*Guizotia abyssinica*). First National Conference of the Ethiopian Beekeepers Association. Addis Ababa, Ethiopia.

4. Sugar syrup preparation technique for dearth period feeding of honeybees

4.1 Background information

Availability of natural nectar and pollen becomes scarce for honeybees during dearth (dry and rainy) seasons in Ethiopia. In some areas of the country, even if nectar and pollen are available, honeybees cannot utilize them due to the unfavorable climatic situations. Honeybees supplementary feeding before flowering is vital to stimulate brood rearing so that the adult bees reared will be ready to forage in the field when the flowering period starts. Feeding sugar syrup is among the earliest developed technique

Honeybee colonies may be fed either concentrated or dilute sugar syrup depending up on the purpose of feeding. Thick sugar syrup (67%) and thin sugar syrup (50%) is fed to honeybee colonies depending on the aim of beekeepers. In commercial beekeeping system there is a lack of information on determining the amount of sugar and water needed to prepare the required amount of sugar syrup. The guidelines below show the technique as to how to prepare sugar syrup depending upon the purpose of beekeepers and the amount of sugar syrup needed to feed colonies

4.2 Inputs required to use the technique

- Granulated sugar
- Clean water
- Big plastic container or vessel to mix the sugar and water
- Stick mixer

4.3 Steps and procedures to use the technique

Guide to prepare different amount of thin and thick sugar syrup solution is given in Table 1 and

2. The steps of preparation is summarized as follows:

- Identifying the dearth periods when colonies needed supplementary feeding particularly sugar syrup
- Preparing of sugar syrup by mixing the required amount of sugar and fresh water in vessel/ big container
- Sugar syrup can either be mixed as thick or as thin depending on feeding objective of beekeepers
- To prepare thin sugar syrup solution (50% sucrose solution), use one kilogram of dry sugar mixed in one litter of water.
- To prepare thick sugar syrup solution (67% sucrose solution) use two kilogram of dry sugar mixed in one litter of water.

Table 1. Guide to prepare different amount of thin sugar syrup solution

Water needed (litters)	Sugar needed (kg)	Amount of sugar syrup produced (litters)
1	1	1.575
10	10	15.75
100	100	157.5
2	2	3.15
20	20	31.5
200	200	315

By similar approach, to prepare 200 litters of sugar syrup 127 litters of water and 127 kilograms of sugar are needed.

Table 2. Guide to prepare different amount of thick sugar syrup solution

Water (litters)	Sugar (kg)	Amount of sugar syrup produced (litters)
1	2	2.26
10	20	22.6
100	200	226
2	4	4.25
20	40	45.2
200	400	452

By similar approach, to prepare 1000 litters of sugar syrup of thick solution of (67 %), it needs 884 litters of water and 442 kg of sugar. The sugar syrup must be fed to colonies internally

4.4 Scope of using the technique

Both thick and thin sugar syrup solution can be prepared and used in all agro-ecology and for all honeybee sub-species depending up on the aim of beekeepers.

4.5 Important data to be recorded

- Number of colonies to be fed
- Amount of sugar and water needed
- Cost of sugar

4.6 Expected benefit of using the technique

Preparing the appropriate amount of sugar syrup of a required concentration depending on the number of colonies will help in minimizing the un-necessary loss of sugar syrup.

4.7 Precautions needed

Sugar syrup may cause fermentation due to its high water content if stays for long time. It should be given to the colonies as soon as it is prepared.

4.8 Reference

Somerville D (2005). Fat Bees Skinny Bees-a manual on honey bee nutrition for beekeepers. A report for the rural industries, Australia: Publication No. 05/054

5. Seed propagation techniques for *Schefflera abyssinica*

5.1 Background information

Schefflera abyssinica (Hochst. ex A. Rich.) is an indigenous tree belonging to the family of Araliaceae, branched, small/medium to 30 m tall trees. It often starts life as an epiphyte in the branch of another tree and can then eventually send down roots that grow into the ground, providing extra nutriment and allowing it to grow more vigorously and out-compete the host tree. It grows as an epiphyte mainly on *Acacia abyssinica* and *Olea europea* tree species and finally overwhelms them to become an independent tree in highland areas. *S. abyssinica* is one of the most important honey source plants in south and southwestern Ethiopia. It has abundant nectar and pollen. Honeybees produce large quantities of light and pure white honey which has high demand in the market and could generate good income. However, currently the population of this plant species is highly fragmented and becoming scarce because of the continued forest depletion. It has poor regeneration potential in the forest and also the nature of this plant is not easy to propagate using seeds. Hence, to alleviate this problem, an aqueous smoke solution was used to stimulate the germination of seeds.

The aqueous smoke solution is derived from a wide variety of biotic sources, including wood, straw, mixtures of dry and fresh plant material and charred wood. It is water soluble and consists of the main germination active compound that acts at low concentrations. Smoke-water may be acting on the seed coat in a way similar to scarification, whereby the passage of water and oxygen into the dormant embryo is made easier and can potentially break seed dormancy, stimulate germination and influence seedling establishment. Consequently, an aqueous smoke solution with low concentration level (0.001 ml) had a significant effect in increasing the germination capacity and performance of *S. abyssinica* seedling at the nursery site. Due to this, it is recommended for further use. This technique was tested at Holeta Bee Research Center, in laboratory and greenhouse and was found to be effective. Hereunder is given a description as to how to apply the technique

5.2 Inputs required to use the technique

- 200 gm of small branches and leaves of various plants (*Croton macrostachys*, *Juniperus procera* or *Milletia ferruginea*)
- 100 mm diameter and 200 mm depth beekeeper's smoker
- 250 ml Erlenmeyer flask
- Distilled water
- Forest soil/compost, local and sandy soil
- Polythene tube
- Water can

- Seeds
- Soil sieve

5.3 Steps and procedures to apply the technique

1. Seed collection and processing

Seeds of *S. abyssinica* are available from May to June. To ensure maximum genetic variation within the population, trees which are at least 100 m apart from each other are selected to collect seeds from. Mature seeds or fruits should be collected from 5 to 10 dominant or co-dominant trees with clear bole, well-developed crown and with abundant seeds on each site. Immediately after collection, the mixture of fruits and seeds are packed in perforated sacks or plastic bags and placed on a bench at room temperature for about a week. Seeds from dehiscing fruits are extracted manually/by hand and washed by water and allowed to dry further for 2 days on the same bench.

2. Aqueous smoke extraction and preparation

- Extract smoke by burning 200 gm of small branches and leaves of various plants (*C. macrostachys*, *J. procera* or *M. ferruginea*) in a 100 mm diameter and 200 mm depth beekeeper's smoker for 30 minutes (Fig. 1)
- The generated smoke is forced through plastic hose fitted to the mouth of the smoker by applying pressure on bellow into a 250 ml Erlenmeyer flask (E-flask) containing 200 ml of distilled water.
- The mouth of the E-flask is plugged with a smoke tight rubber material whose center hollowed to allow the entry of plastic hose to the E-flask.
- The smoke is forced into the flask for 30 minutes.
- Then, the resulting smoke water is maintained as a stock solution in a refrigerator at 4°C, and later used to prepare cold aqueous smoke extracts of different dilution levels.



Fig. 1. Setup of the beekeeper's smoker for the preparation of plant-derived aqueous smoke extracts.

3. Nursery establishment

- Level the site of the beds and firm the soil
- Mark out the shape and sizes of the beds

- Use three different soil mixtures (local soil, forest soil, and sand in ratios of 2:1:1) to fill the pot.
- The soils should be sieved before mixing together in the stated ratios
- The soil should be moist enough to run freely into the tube and easily firmed to form the bottom of the tube.
- After seeds are soaked in the smoke solution for 6 hours, seeds sank to the bottom of each test solution will be used for the seedling multiplication.
- Use 15 cm diameter and 20 cm length polythene tube
- Sow seeds directly into the pot at the rate of 5-10 seeds per pot
- It germinates within two weeks

4. Nursery management

- Watering once a day at the evening until hardening off is reached
- **Pot filling:** This is the filling of polythene tubes with the soil prepared as given above. This should be done under a shade near the heap of the soil at the site of the transplant bed.
- Transplant when seedlings raised three leaves
- Shade and watering after pricking out
- **Weeding:** This is the operation of removing weeds in order to reduce competition for water and nutrients. As seedlings are highly affected by aphids (fig. 2 right), weeds should be controlled manually without using any chemicals
- **Hardening off:** This is the process of creating hard conditions to the seedlings towards the planting season. This is done by reducing the amount of water for a week before seedlings are planted out.



Fig.2. Growth status of *S. abyssinica* in 15 cm pot size before transplanted (left), after transplanted (middle) and *S. abyssinica* highly affected by aphids (right)



Fig. 3. Growth status after transplanting to 30 cm pot size (left) and in field condition (right)

5.4 Scope of using the technique

S. abyssinica grows in Afromontane forest, secondary forests and woodlands within the altitudinal range of 1450–2800 m above sea level; often occurs in association with *Hagenia abyssinica*. It is usually found left as scattered tree in farmlands. This technique can boost the germination capacity and nursery survival of *S. abyssinica*.

5.5 Important data to be recorded

- Number of seeds sown
- Number of germinated seeds with consecutive counts
- Germination time
- Time taken since germination experiment started
- Seedling survival rate (SR) is calculated as follows:

$$\text{SR (\%)} = \frac{\text{alive at the end of no. of seedling the test} \times 100}{\text{Number of seedling transplanted}}$$

5.6 Precautions needed

- Avoid high smoke concentration as it decreases the germination capacity of *S. abyssinica*.

5.7 Expected benefits of using the technique

This technique will alleviate the seedling multiplication problem of *S. abyssinica*. Low concentration (0.001ml) of aqueous smoke solution is recommended to easily multiplying the seedlings of *S. abyssinica*. It boosts the survival of seedling after transplanted and planted on the field. Germination capacity of seeds reached up to 83% and survival rate of the planted seedlings reached up to 90%.

5.8 Reference

Tura B. K; Admassu A. M; Kibebew W.H. (2014). Evaluation of Propagation Methods of *Schefflera abyssinica*. *American Journal of Agriculture and Forestry*, 2(6): 278-283.

6. Propagation technique for *Vernonia amygdalina*

6.1 Background information

Vernonia amygdalina is small tree or shrub, growing up to 10 m tall. It is locally known as Ebicha (Afan Oromo) and Girawa (Amharic). *V. amygdalina* is growing in Podocarpus or Pouteria forest, usually in open spots near streams, secondary forests, evergreen woodland and bushland, roadsides, wasteland and also grown in backyard gardens in of Ethiopia.

V. amygdalina is widely used as a hedge-forming shrub/tree and a boundary marker. The wood of *V. amygdalina* is used for fuel and is also termite resistant. The leaves are used to scour pots used for making *tela*, the local beer, and *tej*, honey wine. The leaves and bark are bitter and in local medicine they are used against menstruation pain, as a purgative and vermifuge, in wound dressing and against urinary inflammations. Together with roots they are used against malaria. Leaves can also be browsed and the stems used as tooth brushes. *V. amygdalina* is a very valuable honey source in the country. Especially in warmer areas its nectar secretion is abundant and bees produce a significant surplus of a dark aromatic honey. Honeybees generally collect the nectar and whitish pollen throughout the day. During flowering time honeybees develop very rapidly with a tendency to swarm easily. In some areas honey is generally harvested after flowering season of Ebicha. The main flowering time of this plant is from January to February depending on the rainfall. In these months herbaceous bee forage plants dry up and there are only few bee forage plant species in flower around the area. Due to this, it is considered as dearth period bee forage plant. It has long flowering length (Blooming to shedding) of almost around two months. Thus, instead of giving supplementary feeding during dearth period, planting such bee forage plant near apiary site is very important, especially where there is no diversity of bee forage plants.

V. amygdalina is currently under threat due to population pressure and farm land expansion and increased demand for leaves and fuel wood. Therefore, to alleviate this problem, evaluation of seedling multiplication and growth performance of *V. amygdalina* was done at Holeta Bee Research Center and the result revealed that seed propagation is more effective method without the need for pretreatments. Description of such technique is given bellow.

6.2 Inputs required to use the technique

- Seeds
- Forest soil/compost, local and sandy soil
- Polythene tube
- Water can
- Lands/plots on which to grow the plants
- Soil sieve

6.3 Steps and procedures to use the technique

1. Seed collection

- Seeds of *V. amygdalina* are available from March to April
- Matured seeds of *Vernonia amygdalina* are collected from elite trees
- Immediately after collection, seeds must be packed and allowed to dry for three days at room temperature.

2. Nursery establishment

- Level the site of the beds and firm the soil
- Mark out the shape and sizes of the beds
- Use three different soil mixtures (local soil, forest soil, and sand in ratios of 2:1:1) to fill the pot (Fig. 12).
- The soils should be sieved before mixing together in the stated ratios
- The soil should be moist enough to run freely into the tube and easily firmed to form the bottom of the tube.



Fig. 12. Soil preparation to mix different soil types (left), filling soils into polythene tube (Middle) and *Vernonia amygdalina* with flowers (right)

- Sow directly on the pot (10 cm diameter and 20 cm length polythene tube)
- Watering once a day at the evening until hardening off is reached
- Shade and watering after pricking out
- **Weeding:** This is the operation of removing weeds in order to reduce competition for water and nutrients.
- **Hardening off:** This is the process of creating hard conditions to the seedlings towards the planting season. For this reduce the amount of water for a week before seedlings are planted

3. Field planting

- Prepare planting site one month before planting
- Planting space is 1.5 m apart between plants

6.4 Scope of using the technique

The plant grows on the highlands, mid highlands and lowland areas with the altitudes ranges from 500-2800 meter above sea level in all floristic regions of Ethiopia. Its rainfall range is from 750 to 2000 mm per year. *V. amygdalina* grows on a wide variety of soils: clay, silt, sand and loam. It is also found on light shallow soils, often left in pasture land.

6.5 Important data to be recorded

- Number of planted seedlings
- Survival rate of seedlings
- Planting date
- Time taken to set flower
- Flowering length (blooming to shedding)

6.6 Expected benefits of using the technique

V. amygdalina is used to maintain honeybee colonies during dearth period as it gives flower when other bee forage plants are not flowered, particularly when herbaceous bee forage plants dry. It is easily propagated by seeds without using pretreatments. *V. amygdalina* is fast growing and set flower after the 2 to 2.5 years of planting and highly visited by honeybees. It stays in flower for two months from blooming to shedding.

6.7 References

- Tura B., Admassu A., and Kibebew W. (2017). Screening of Potential Shrubs for Bee Forage Development. *Journal of Plant Sciences*, 5(5): 160-164.
- Azene B. Birnie A., Tengnas B. (1993). Useful trees and shrubs for Ethiopia: Identification, propagation and management for agricultural and pastoral communities. *Regional Soil Conservation Unit, Swedish International Development Authority, Nairobi*. 474 p.
- Fichtl R. and Admasu A. (1994). Honey bee flora of Ethiopia .The National Herbarium, Addis Ababa University and Deutscher Entwicklungsdienst, Mergaf Verlag, Germany.

7. Propagation techniques for *Callistemon citrinus*

7.1 Background information

Callistemon citrinus is a medium-sized shrub or a small tree with numerous drooping branches. Flower-bearing part of the branches is up to 12 cm long with many long-lasting flowers. It is known as bottle brush. *C. citrinus* starts blooming from the branches close to the stems and goes to the end of the branches. When the first bloomed flower gives seeds, the flowers at the end of the branches have flowered and vice versa. *C. citrinus* is cultivated as an ornamental tree in parks and town gardens at altitudes between 1250 and 2500 m above sea level. It can tolerate frost and drought.

C. citrinus is flowered almost all year round and widely cultivated for honeybee forage. It provides a sufficient quantity of nectar and pollen for honey production, initiating brood rearing and strengthening honeybee colonies. With proper management of this plant and other dearth period bee forage plants, it is possible to maintain an apiary of strong and healthy bee colonies. However, poor management of bee forages during dearth, results in weak colonies which are susceptible to various pests and diseases. Such colonies generally abscond and the beekeepers suffer the loss of their bees. This has an adverse effect on honey production. To maintain their bee colonies during dearth period, there is a high demand for this plant from different stakeholders. Thus, to fulfill the demand of the stakeholders, evaluation on seed propagation techniques and growth performance of *C. citrinus* was done at Holeta Bee Research Center and the result revealed that seed propagation is more effective method without the need for seed pretreatments. Description as to how to apply this technique and benefits are summarized below.

7.2 Inputs required to apply the technique

- Seeds of *C. citrinus*
- Forest soil/compost, local and sandy soil
- Polythene tubes
- Water can
- Land on which to grow the plants
- Soil sieve

7.3 Steps and procedures to apply the technique

1. Seed collection

- Collect mature fruits of bottle brush from the elite trees
- Store them in a paper bag in a warm and dry place
- The fruit will open and release the seeds

2. Nursery establishment

- Level the site of the beds and firm the soil
- Mark out the shape and sizes of the beds
- Use three different soil mixtures (local soil, forest soil, and sand in ratios of 2:1:1) to fill the pot.
- The soils should be sieved before mixing together in the stated ratios
- The soil should be moist enough to run freely into the tube and easily firmed to form the bottom of the tube.
- Sow directly on the pot (10 cm diameter and 20 cm length polythene tube)
- Watering once a day at the evening until hardening off is reached. Hardening off is the process of creating hard conditions to the seedlings towards the planting season.
- Shade and water after pricking out
- **Weeding:** This is the operation of removing weeds in order to reduce competition for water and nutrients.
- **Hardening off:** For this reduce the amount of water for a week before seedlings are planted



Figure 5: Seedlings of *Callistemon citrinus*

3. Field planting

- Planting site must be prepared one month before planting
- Planting space 1.5 m apart between plants

7.4 Scope of using the technique

The plant can be grown on the highlands, mid highlands and lowland areas with altitude ranges from 1250-2500 meter above sea level. It is frost and drought tolerant.

7.5 Important data to be recorded

- Number of planted seedlings

- Survival rate of seedlings
- Planting date
- Time taken to set flower
- Flowering length (blooming to shedding)

7.6 Expected benefits of using the technique

C. citrinus gives flower almost all year round and one tree of *C. citrinus* stay in flower for around 6 months from blooming to shedding. It provides a sufficient quantity of nectar and pollen for honeybees throughout the year for the strengthening of honeybee colonies. Thus, it is used to maintain honeybee colonies both during dearth and active period. It is easily propagated by seeds without pretreatments. *C. citrinus* is fast growing and set flower after 2.5 to 3 years of planting and is highly foraged by honeybees.

7.7 References

- Tura B., Admassu A., and Kibebew W. (2017). Screening of Potential Shrubs for Bee Forage Development. *Journal of Plant Sciences*, 5(5): 160-164.
- Admassu A., Kibebew W., Amssalu B., and Ensermu K. (2014). Honeybee forages of Ethiopia. Addis Ababa: United Printers.

8. Buckwheat (*Fagopyrum esculentum* L.) production for dearth period feeding

8.1 Background information

Buckwheat (*Fagopyrum esculentum*) belongs to the family Polygonaceae. It is a warm-season, broad leaved annual plant with superficial surface roots, a weak tap root and erect, reddish stems. The plant produces multiple branches along the stems, heart-shaped leaves, and clusters of small white flowers at the end of the branches. Buckwheat is an excellent bee forage plant. The plant produces numerous, shallow white flowers and abundant nectar and pollen, and has the shortest flowering period of 5-6 weeks and completely matures within 10-11 weeks. The cultivation of buckwheat along with beekeeping may produce 50 to 100 kg of honey per hectare (Rajbhandari, 2010). Buckwheat honey is rather dark, packed with antioxidants and is known for being an excellent honey for coughs and colds, and for use in homemade syrups. Buckwheat is well performed under both rain and irrigation condition. If grown using irrigation water, buckwheat is used as supplementary feeding during the dearth period thus maintaining honeybee colonies. This will help the beekeepers to harvest better amount of honey during honey flow season. A study on buckwheat feeding of honeybee colonies was conducted at Holeta Bee Research Center and the plant was recommended as dearth period bee forage to maintain honeybee colonies particularly, where irrigation water is found. The procedure of establishing the plant and its use are described below.

8.2 Inputs required to establish the plant

- Seeds of buckwheat (*Fagopyrum esculentum*)
- Lands/plots on which to grow the plants
- Ploughing materials

8.3 Steps and procedures followed to establish the plant

- **Land preparation:** prepare seed beds by digging the ground and smoothing the field
- Seeds are sown in row at a rate of 10 kg/ha
- To keep proper spacing and avoiding nutrient competition, spacing used between the plants and rows are 20 and 30 cm, respectively
- Seeds sown are covered with a thin layer of the same soil to protect seeds from birds and facilitate appropriate condition for germination
- Fertilizer is not used to keep its natural growing state
- **Planting time:** end of July and it germinates within 3-4 days
- Planting can be done both under rain fed and irrigation conditions



Fig. 6: Status of *Fagopyrum esculentum* after a month

8.4 Scope of using the forage plant

Fagopyrum esculentum is adapted to highland (around Holeta) and midland (around Fadis, Haro Sabu and Adami-Tullu Jido Kombolcha districts of Oromia region) areas under both rain fed and irrigation. It grows best in soils with light to medium texture and good drainage and will tolerate moderately acidic soils (to a pH of 5). Buckwheat is better adapted to low-fertile soils than most other crops and often the residual nutrients from preceding crops are enough for adequate growth.

8.5 Important data to be recorded

- Sowing date
- Growth performance
- Flowering date
- Flowering length
- Foraging intensity
- Seed yield

8.6 Precautions needed

- Buckwheat will not grow well in compacted, saturated, or coarse soils and is not tolerant to frost, flooding, soil crusting or extreme drought.

8.7 Expected benefits of producing buckwheat

Fagopyrum esculentum is one of the major herbaceous bee forage plants that need the shortest period to set flowers (about 40 days). It stayed in flower for a month from blooming to shedding. *F. esculentum* performed well under both rain and irrigation condition. One hectare of buckwheat provides 120 kg of pollen grains under rain fed and 177 kg under irrigation condition.

In addition to this, about one hectare of buckwheat can produce about 150 kg of seeds without using fertilizer and price of the seeds is expensive. Therefore, it is used as supplementary feeding for honeybee colony maintenance during dearth period using irrigation water. In addition to this, seeds of *Fagopyrum esculentum* are used as poultry feeding.

8.8 References

- Tura B. and Admassu A. (2018). Performance evaluation of herbaceous bee forages for semi-arid parts of the rift valley of central, Ethiopia. *Advances in Plants and Agricultural Research*, 8(5):389-392.
- Tura B. K., Admassu A. M., and Kibebew W. Hora. (2014). Screening of potential herbaceous honey plants for beekeeping development. *Agriculture, Forestry and Fisheries*, 3(5):386-391.
- Ofijan T.(2016). Adaptation of Improved Bee Forages at Haro Sabu District of Kelem Wollega Zone, Ethiopia. In: *Regional Workshop on Review of Completed Research activities of Oromia Agricultural Research Institute*, 192-196 (Tefaye A. A., Dawit A., Amsalu B., Alemu L., and Berhanu S. (eds.). *Proceedings of workshop on completed Research Activities of Livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tullu, Ethiopia 17-21 November 2015*.
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- Rajbhandari B.P. (2010). Buckwheat in the land of Everest. Himalayan College of Agricultural Sciences and Technology, Kathmandu, Nepal.

9. *Echium plantagineum* production for dearth period feeding

9.1 Background information

Echium (*Echium plantagineum* L., Boraginaceae) is an annual herb growing to a height of 1 meter. It is a prolific seed producer and can form seed bank that can last up to five years. *Echium* seeds contain about 27% oil that is enriched with high levels of stearidonic acid and gamma-linolenic acid. These fatty acids are rare in other plants and highly valued in the health and personal care industries. Stearidonic acid, in particular, is an essential ingredient in anti-wrinkle cosmetics, and both stearidonic acid and gamma-linolenic acid provide health benefits analogous to fish oils. The plant is also used for improving soil fertility through its high dry matter content.

Echium is highly attractive to pollinating insects, especially honeybees. It is a common melliferous (honey producing) plant and widely used for honey production. The plant flowers from November to March and the flower is frequently visited for abundant nectar and numerous dark blue pollen loads. *Echium* has a long flowering period and the high number of flower heads per plant that are used for bee colony maintenance or honey production during the active period. The plant performs well under both rain-fed and irrigation conditions. Hence, using irrigation water *Echium* is used to maintain honeybees' colonies as supplementary feeding for the survival of the dearth period. This will help us to harvest a better amount of honey in the next season by keeping the strength of honeybee colonies. A study was conducted at Holeta Bee Research Center and Alage Technical and Vocational Education Training College to evaluate its adaptability to these areas. The plant was found to adapt very well at both sites and hence recommended as dearth period bee forage to maintain honeybee colonies particularly, where irrigation water is found. The procedure of establishing the plant and its use are described below.

9.2 Inputs required to establish the plant

- Seeds of *Echium plantagineum*
- Lands/plots on which to grow the plants
- Ploughing materials

9.3 Steps and procedures to be followed to establish the plant

- **Land preparation:** seedbed is prepared by digging the ground and smoothing the field
- Seeds are sown in a row at a rate of 6 -10 kg/ha depending on the germination capacity of the seeds
- To keep proper spacing and avoid nutrient competition, spacing between the plants and rows must be 20 and 30 cm respectively

- Seeds sown are covered with a thin layer of the same soil to protect seeds from birds and facilitate appropriate condition for germination
- Fertilizer is not used to keep its natural growing state
- **Planting time:** Mid of May under rainfall condition
- Germination takes 15-20 days



Fig. 7: Growth performance of *Echium plantagineum*

9.4 Scope of using the forage plant

Echium plantagineum is adapted to highland (around Holeta) and midland (Adami-Tullu Jido Kombolcha District) areas under both rain fed and irrigation. It grows among the rocks, degraded soils, wasteland, besides shallow water, in overgrazed grassland and along roads at altitudes between 1800 and 2400 meter above sea level in Ethiopia.

9.5 Important data to be recorded

- Sowing date
- Flowering date
- Flowering length
- Foraging intensity
- Seed yield

9.6 Expected benefits of producing *Echium plantagineum*

Echium plantagineum is one of the major herbaceous bee forage plants that have a long flowering period and high number of flower heads per plants. One hectare of buckwheat provides 1900 kg of pollen grains under irrigation and 1300 kg under rain-fed conditions. In addition to this, about one hectare of *Echium* can produce about 310 kg of seeds without using fertilizer and the price of these seeds is very expensive. Sowing of *Echium plantagineum* for dearth period colony maintenance is recommended to ensure year-round availability of bee forages in the area.

9.7 References

- Tura B., and Admassu A. (2018). Performance evaluation of herbaceous bee forages for semi-arid parts of the rift valley of central, Ethiopia. *Advances in Plants and Agricultural Research*, 8(5):389-392.
- Tura B. K., Admassu A. M., and Kibebew W. H. (2014). Screening of potential herbaceous honey plants for beekeeping development. *Agriculture, Forestry and Fisheries*, 3(5):386-391.

10. Pollen grain collection and references preparation technique

10.1 Background information

Ethiopia is endowed with natural and cultivated flora and diverse agro-ecological and climatic conditions which are well-suited for beekeeping. In order to boost the honey production from this huge resource, identification and documentation of bee forage plants with their pollen grains morphology or structure is critical for beekeeping development. Pollen grains have endless morphological variations among the plant species in terms of structure, size, presence, and absence of spine, pores, shape and form. These infinite morphological variations among the pollen grains of different plant species would enable us to trace the botanical origin of pollen grains that can be used for Melissopalynological analysis of honey or to trace back the floral origin of honey. This method was developed by Wodehouse (1935) based on a non-chemical treatment (glycerin-jelly method). Pollen grains of each plant species have its own genetic code of inheritance and special structural patterns that used to determine the botanical and geographical origin of honey. Such information can improve product quality and enhance the market price of honey. The procedure of collecting the pollen grain and its preparation techniques are described below.

10.2 Inputs required to use the technique

- Pollen grain collected directly from a plant
- Paper bag or envelope
- Glycerin jelly
- Ether
- Light microscope
- Water
- Microscopic slide
- Cover slip
- Slide box

10.3 Steps and procedures to use the technique

Sample collection

- Collect ripe pollen grains from matured flower buds directly from the field (fig . 8)



Fig. 8 Pollen grains collection

- Such plants must be those previously confirmed to be foraged by honeybees for nectar and/or pollen
- Flower bud samples are collected from the field and it should be kept in individual envelopes to avoid contamination with other species of pollen grains
- Samples collected from the vicinity of the laboratory should be kept in water indoors to allow full blooming (fig 9) without being contaminated.



Fig. 9: Flower in water to allow full blooming

- During the pollen grains sample collection, local names of plants, altitude, Geographical coordinates should be recorded.

Slides preparations and mounting

- For light microscopic preparations, ripe pollen grains must be shaken directly onto microscope slides (fig 10) and to enhance the transparency of the pollen grains the fat content is washed out using ether to enhance the clearness of pollen grains so that any large, visible, foreign particles would be removed before adding glycerin.
- The slides are then covered with cover slips using warm glycerin jelly (Fig. 10) and kept for ten minutes on warming-plate at 40°C.

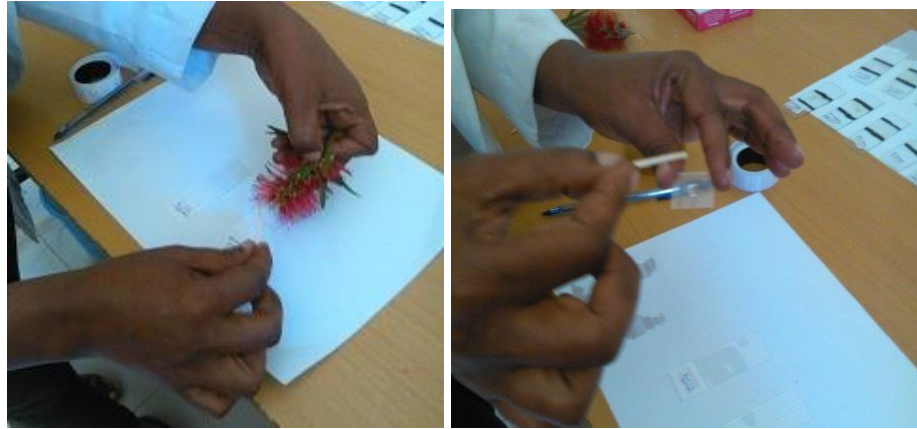


Fig. 10. pollen grains are shaken directly onto microscope (left) and glycerin jelly being added to cover slip for mounting (right)

- The cover slips are gently pressed together to get a uniform, thin layer of glycerin jelly
- Finally, the cover slips are sealed with clear nail varnish.
- Both light and scanning electron microscope can be used to study morphological features of the pollen grains of different plant species.
- Permanent slides for pollen references should be deposited in a slide box

Measurements

- Determine the average size of the pollen grains by measuring 20 pollen grains each for polar axis and equatorial diameter using a calibrated ocular micrometer and the mean and range values are taken.
- For Circular pollen grains without distinctive polar and equatorial views, only diameter dimensions are taken.
- Take length and width measurements for prolate/elongated ones.
- In the case of prolate pollen grains, it is not always possible to get as many pollen grains in polar view as required, so fewer measurements are taken.
- For aperture diameter, spine length, sexine, and nexine thickness an average of 10 measurements should be considered.
- Polar axis (P), equatorial diameter (E), P/E ratio, exine thickness, shape in polar view, shape in equatorial view, spine length should be measured

Photomicrography

- Photographs of different views of the pollen grains are taken using Zeiss light microscope magnification power of 40X linked with computer software (Fig.11).



Fig. 11 Photo of pollen grain received by Zeiss light microscope

Description of pollen grain

The important morphological features of the pollen grains are described based mainly on light microscopy (LM). The following main pollen grain's morphological features will be described:

- Polarity
- Symmetry,
- Form, shape, size, aperture type,
- Number and diameter,
- Exine surface pattern, sexine, and nexine thickness, spine length and type.
- The shapes of the pollen grains will be expressed as the ratio of the length of the polar axis to the equatorial diameter of the pollen grains

10.4 Scope of using the technique

This technique is used to prepare the reference slides by collecting pollen grains directly from honeybee plants everywhere. The prepared slide references from pollen grains are used for Melissopalynological analysis of honey.

10.5 Important data to be recorded

- Plant species
- Sample collection number
- Local names of plants
- Altitude
- Geographical coordinates

10.6 Precautions needed:

- Care should be taken to overcome contamination of pollen grains and inclusion of air bubble

10.7 Expected benefits of using the technique

This work will be useful to assist many of the apicultural activities like in quantifying the accurate bee forage representation of an area, to determine the pollen spectrum of honeys, from which to categorize the major and minor bee plants of an area. Moreover, in marketing of honey, pollen analysis is very important to determine the source of honey which helps honey collectors, processors, and exporters to trace the botanical origin of their raw materials and also to label their products by their origin as special uni-floral or multi-floral honeys. Therefore, preparation of the permanent slides will help to identify the botanical and geographical origin of honey.

10.8 References

- Wodehouse R. P. (1935). Pollen Grains. Their Structure, Identification and Significance in Science and Medicine. McGraw-Hill, New York, N.Y., 574 pp.
- Erdtman G. (1969). *Handbook of palynology*. Muntisguard, Copenhagen. PP 486.
- Nuru A., and Randall H.B. (2002). Pollen grains of some poisonous bee plants of Ethiopia. Rhodes University, Grahams town, South Africa.
- Tura B., and Admassu A. (2018). Honeybee Flora Resources of Guji Zone, Ethiopia. Journal of Biology, Agriculture and Healthcare, 8(21): 1-9.

11. Bamboo hive technology

1.1 Background information

Traditional beekeeping is the major and oldest type of beekeeping practiced in Ethiopia for thousands of years. About 90% of beekeeping in the country is practiced in traditional way with average productivity of 5 to 7 kg crude honey per hive. To boost the productivity of beekeeping movable frame hive, made of timber, was introduced to the country before 50 years. This technology (Movable frame hive) increased honey yield to 25 to 30 kg/hive per harvest and enhanced the quality of honey. However the cost of this hive is increasing from time to time and reached at present to about 3000 Birr. Furthermore trees used for timber are very scarce and it takes many years to replace them through planting seedlings. Thus cutting of these trees for the purpose depletes the existing natural trees like *Cordia Africana*. Despite the good return from timber hive, many beekeepers are unable to afford the initial investment cost to buy an economically reasonable number of hives (a minimum of 3 hives) and it also causes the depletion of important indigenous trees. The escalating cost of timber hives limited the adoption of the movable frame hive to 7%. And hence the production and productivity of honey remained low. Therefore, it is important to look for other cheap, durable and locally available materials that can replace timber for making movable frame hives to reduce the cost and the pressures on scarce naturally growing trees. Movable frame hives made from Bamboo (*Arundinaria alpine*) and Shimel (*Oxytenathera abyssinica*) were evaluated at Holeta Bee Research Center. The suitability, honey yield and cost of these hives were compared to that of timber hives. The results indicated no significant differences in honey yields among hives made from Bamboo, shimel and timber. More over the costs of hives made from bamboo and shimel were two times cheaper than the cost of movable frame made from timber. As the availability of shimel is limited to extreme low lands and bamboos are available at mid and highlands agro ecologies accounting for about 3-6% of the forest lands, bamboo hive technology is taken up more faster and it is on demonstration at different parts of the country. Therefore, hereunder is described the use of bamboo hive technology and its benefits.

11.2 Inputs required for making bamboo hive

Bamboos, Saw (for cutting), or multipurpose (sawing and planing) machine, different size nails (for fixing), hammer, timber for frame making and strengthening the hive body and glue (for fixing)

11.3 Steps and procedures to make the hive

The design of bamboo hive, shown in Fig. 12 and 13, is similar to the one introduced to the country and on use, (the zander hives made of timber). The essential parts of beehives are brood

chamber (with entrance gate and 10 frames), two super chambers (with 10 frames each) and roof (top/lid)

Requirements and dimensions

Brood chamber

Brood chamber is a four-sided bamboo box of rectangular cross-section without a top but with a bottom, in which the brood frames are placed. The brood chamber shall be made of straight bamboo with a thickness of 20 mm. The dimension of the brood chambers is given in Table 3. The chamber box must have 10 mm wide and 20 mm deep fixed bar on the front and back walls of the brood chamber, so that frames can rest on the bar. The four sides of the chamber must be supported by wooden strip and joined by nails

Entrance gate

Entrance gate is an open slit on the brood chamber with dimensions of 100 to 150 mm wide and 15 mm depth. The entrance gate must be provided with bee landing board rigidly fixed. The dimensions of the landing board should be 200 mm long and 30 mm wide.

Super chamber

Super chamber is a four-sided bamboo box of rectangular cross-section without a top or a bottom in which the super frame is placed. It is similar to the brood chamber but placed above it when in use. The dimension of the super chamber is also indicated in Table 3. The thickness of bamboo used for making chamber, the position of bars that holds frames in super are the same with that of brood chamber. There should be outside support strips 495 mm long at the front and rear side and 545 mm at left and right side and 40 mm wide on all the four sides of the outer faces of the side walls for lifting or to protect slipping off the hive parts from any mechanical shake. The strips should be made from timber. The four sides of the chamber should be supported by strips and joined by nails.

Roof or Top cover/lid

This is a cover with four sides and a top to be placed on the super chamber. The outside cover/roof is wider than the rest of the hive providing a bit of an overhang so that water drips beside the hive rather than running down the side of the hive or possibly into the hive. The dimension of the top cover is also indicated in Table 3. It should be made of bamboo splits 20 mm thick and be fixed to the wooden strips with nails. The roof must be suitably covered with a sheet of metal to protect against rain. The sheet shall be made flat and extend 30 mm down below the top edge of the roof board.

Frames

A frame is made up of a top bar, a bottom bar and two side bars in which the bees develop comb to rear brood and store nectar/honey and pollen. The frames are placed in a vertical position in the brood chamber or the super chamber so as to leave space (bee space) in between them for bees to move through. The dimension of the frame is given in Table 3 and 4. The frame has four sides: one top bar, two side bars and one bottom bar. Each side bars are described below and depicted in Fig. 14-16.

Top bar

The top bar should be made of well-seasoned wood. The top bar should be 30 mm wide 20 mm thick and 480 mm in length and preferably the ends of the sides should be joined to the top bar by tongue joints. Four holes for wire reinforcement must be made from the top bar to bottom bar. The hole must be made at the center of top and bottom bars. The hole at both sides shall be 50 mm away from side bars (left and right) while the remaining holes shall be at a distance of 100 mm from each other. The top bar must extend equally on both sides of the frame.

Side bars

The side bars may preferably be of shoulder type. It shall be 20 mm thick 30 mm wide at the bottom and 39 mm wide at the top to provide 10 mm bee space.

Bottom bars

The bottom bar shall be 20 mm wide, 20 mm thick and 440 mm in length. It shall be made of well-seasoned wood

Table 3. Hive and frame dimensions

Hive parts	Length in mm	Width in mm	Height in mm
Brood chamber			
external	500	450	245
internal	460	420	-
Super chamber			
External	500	450	245
Internal	460	420	
Frames			
External	480		230
Internal	400	-	190
Roof (top)	700	650	35
External			

Table 4. Dimension of frame hives

Frame	Length of top bar	Length of bottom bar	Length of depth of frame
External	480mm	440mm	230
Internal	400mm	400mm	190



Fig. 12. Bamboo hive (left) and Bamboo required for hive making (right)



Fig. 13 Bamboo hives with suppers and frames (left) and with brood chamber and two supers (right)

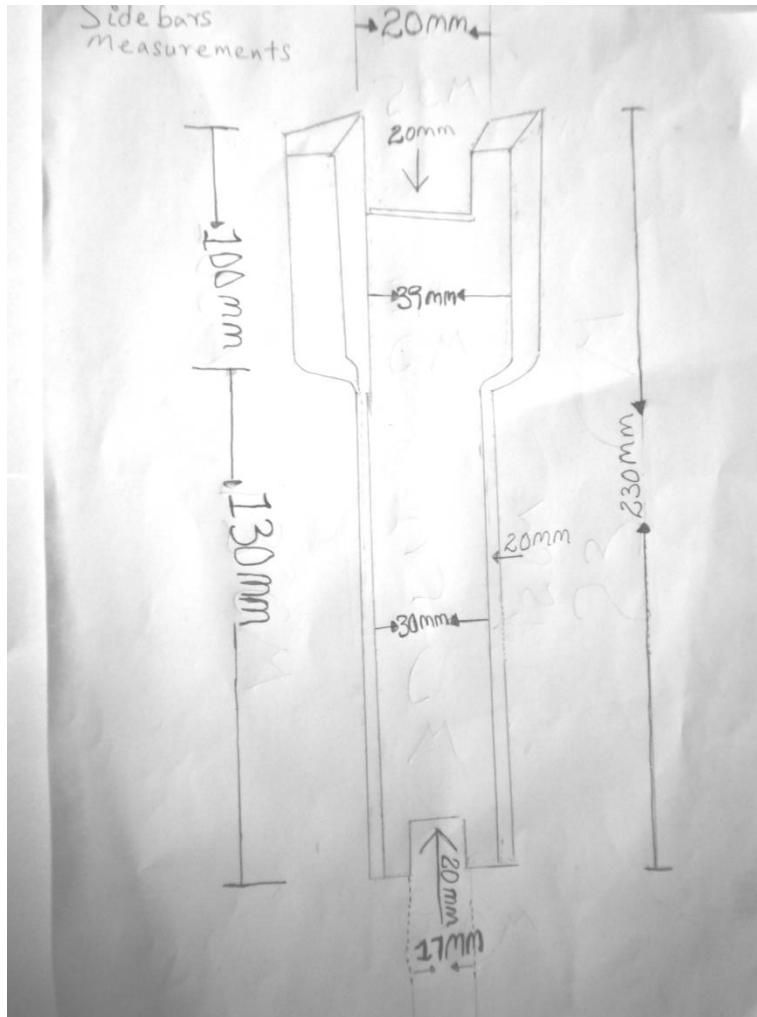


Fig. 14 . Dimension of side bars

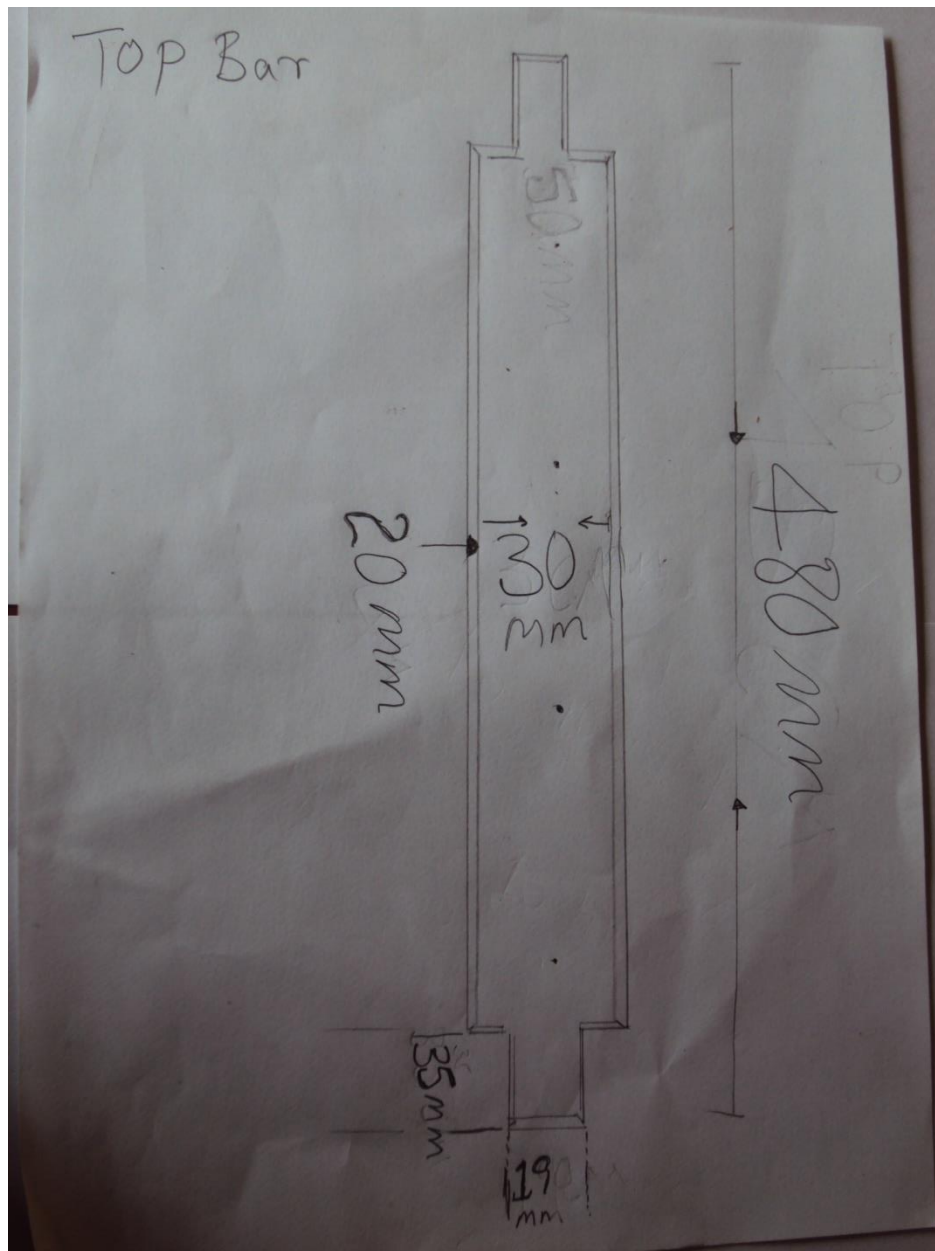


Fig. 15. Dimension of top bar

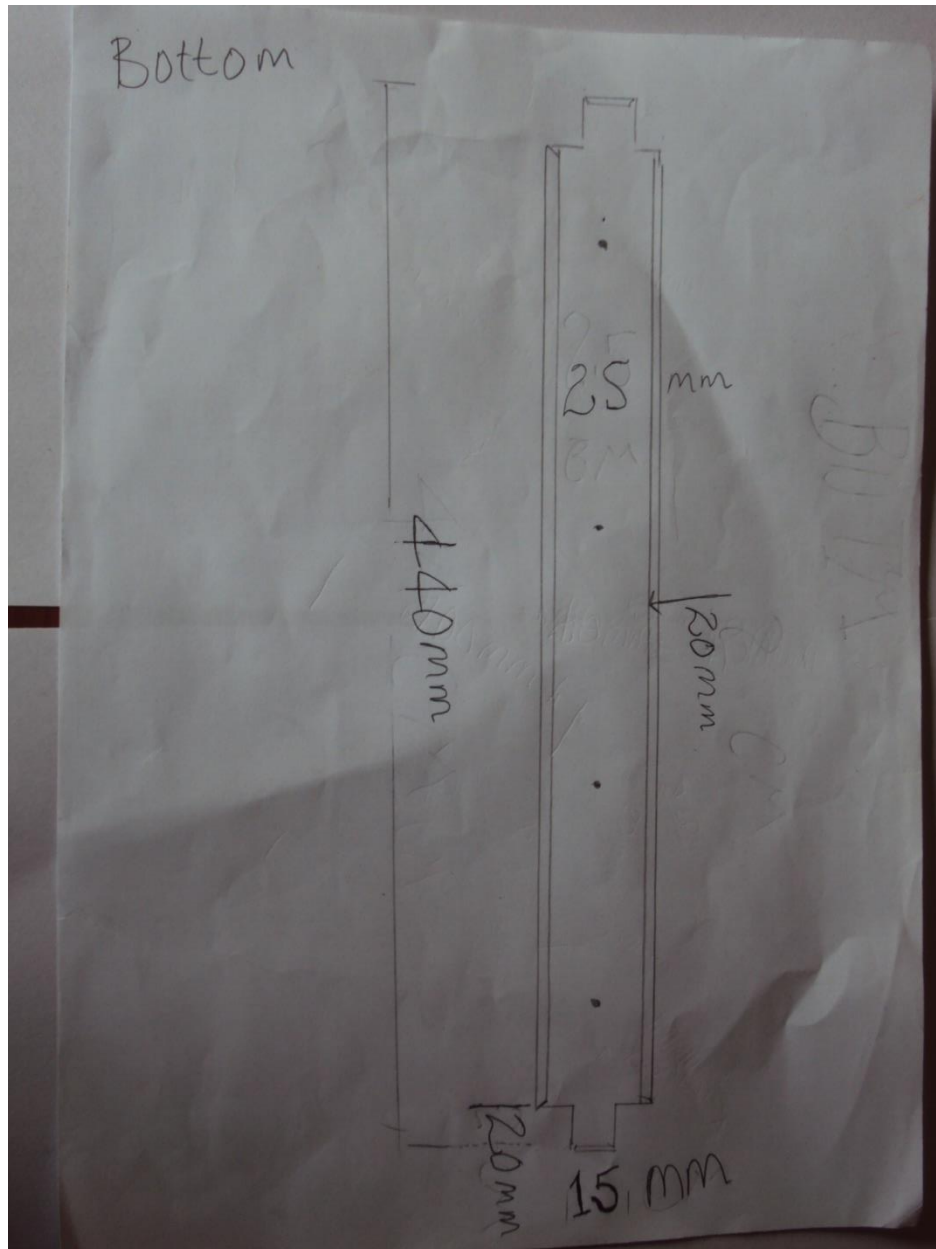


Fig. 16. Dimension of bottom bar

All dimensions stated as internal in this specification shall be regarded as finished dimensions and shall be measured after the completion of finishing operations, such as, planing and sand papering.

11.4 Scope of using the technology

The technology can be used for keeping honeybee colonies in all parts of the country and it is suitable to all honeybee races of Ethiopia. Especially the cost of the hives can be much more cheaper where bamboo is available (mid and highland agro-ecologies).

11.5 Important data to be collected

- Cost of bamboo hive.
- Honey yield per year
- Swarming rate
- Absconding rate
- Amount of Propolis if any
- The presence of damp combs and occurrence Fungus
- Any unusual happenings

11.6 Precautions needed

The different parts of the beehives must have a smooth finish with the edges trimmed square and smooth. Parts of the beehive exposed directly to weather shall be painted with a suitable protective paint. The paint shall be nontoxic and shall not have any odor disagreeable to the bees. The colour of the paint shall either be white or yellow.

All joints must be sound and withstand normal use. For all types of bee hives walls of chambers and roofs must be joined by corner joints properly nailed. There must be one nail at each end and the distance between two consecutive nails should be not more than 75mm.

Only well-seasoned timber (for strip) and dry and straightened bamboo should be used for making the hive. Using non-dry, un matured and un straighten bamboo lead to disrupted design of hives and normal activities of honeybees, which in turn results in low honey yield and quality and absconding of honeybee colonies. The thickness of the wood and bamboo used must be 20 mm, and be free from checks, decay, insect-holes, dead knots, shakes and splits.

11.7 Expected benefits of using the technology

Bamboo hive replaces movable frame hive made of timber which is costly and unaffordable to poor farmers. With the cost of one timber hive (1800 Birr), one can buy at least 2-3 bamboo hives and thus have more honeybee colonies and more economical returns. Furthermore, the technology saves scarce trees from being cut. Yield and quality of honey obtained from bamboo hives are comparable to the one obtained from movable frame hives made of timber.

11.8 Reference

Meseret Gemed and Mebrat Hailu (2015) Development of improved and affordable bee hives, *In regional workshop on review of completed research activities of Oromia Agricultural Research Institute*, pp 114-116, (Amssalu B., Alemu L., Birhanu Sh., Dawit A.A, and Tesfaye A. (eds.)). Proceedings of review workshop on livestock research directorate, held at Adami Tulu Agricultural Research Centre, Adami Tulu, Ethiopia, 17-21 November, 2015. *Oromia Agricultural Research Institute* (IQQO), Finfine, Ethiopia. 242 pp.

12. Royall jell harvesting technique

12.1 Background information

Beekeeping generates different bee products, such as honey, beeswax, pollen, propolis, bee venom and royal jelly. However in our country honey and beeswax are considered most well-known and most important. The knowledge on harvesting of products other than honey and bee wax is scanty and poor. Royal jelly is creamy, milky, white, strongly acid and highly nitrogenous substances produced by young worker honeybee to feed the young larvae and the adult queen bee. Royal jelly performs numerous functions like Stimulating metabolisms, healing wound and chronic tuberculosis and improving of asthenia, nervous break-down and emotional problems. Hence royal jelly has an important commercial appeal and nowadays it is used in many industries like health, foods, pharmaceuticals and cosmetics in many countries around the world. To diversify the incomes of beekeepers, introducing harvesting techniques of high value honeybee product, such as royal jelly is of paramount importance. Beekeepers can harvest royal jell which is highly nutritional, either for market (not yet developed) or for their consumption by spreading on bread and/or mixing with honey.

The commercial production of royal jelly generally relies on queen rearing operations. Therefore the efficiencies of splitting and grafting techniques of queen rearing were evaluated for the production of royal jelly under local conditions at Holeta Bee Research center. Both queen rearing techniques produced comparable yield of royal jelly without affecting honey yield. However, as grafting method is expensive (require different tools) and the technique is somehow complex compared to, splitting method. the technique of royal jelly harvesting using splitting method is recommendable and hence described below.

12.2 Inputs required to use the technique

The basic required inputs are: Strong mother colony to be split, Base hives with its top cover to hive the split, Sugar syrup/pollen for feeding mother colony, Queen excluders to separate or split a mother colony into queen right and queen less colonies and share resources between the two, Nucleus hive to transport frames with royal jelly to extraction room, Sharp blade to cut cells containing royal jelly to the level of royal jelly, Spoon or suction device to remove royal jelly from cells, Dark/amber glass vials to contain royal jelly and Refrigerator for storing royal jelly.

12.3 Steps and procedures to use the techniques

Harvesting royal jelly involves two major activities, splitting and extracting royal jelly from the cells.

1. Splitting colonies and arrangements

Splitting honeybee colony is the technique of splitting a strong colony into two or more. The best time of the year for rearing queens and producing royal jelly is active period, when nectar and pollen are abundant and colonies are populous. The steps and procedures for splitting colony are indicated below.

Select populous colony and feeding

- Select honeybee colony with two stories and having sufficient young bees at age suitable for producing royal jelly and constructing queen cells (between 5 and 20 days old bees), sufficient food (nectar and pollen) and one-day-old larva about the same size as an egg
- If colonies have no enough young bees (about 30000-40000 bees) take sealed worker brood from another hive a few days before their hatching day and add to the selected colonies or shake young bees off comb from another colony to selected mother colony. Younger bees that cannot fly remain while old bees that can fly return to their hives
- supply colonies with honey-sugar supplemented with 5 % of pollen

Splitting honeybee colony into two divisions

- Inspect honeybee colony and place frames containing eggs, sealed broods, nectar or honey and pollen on top supper or chamber
- After having done the arrangement, make the top chamber free of bees by forcing bees to the bottom chamber with smoke
- Then place queen excluder on top of bottom chamber correctly and place the top chamber (free of bees) on top of queen excluder and cover the lid tightly (bottom chamber is queen right while the top chamber is queen less)
- The next day smoke heavily through the entrance to drive most of young bees to the top and split the colony into two: top chamber (above queen excluder), which is most populous with young bees and huge resources, and bottom chamber (below queen excluder and queen right)
- Transfer bees in top chamber with their resources to base hive you already made ready, close with top cover and leave it to its original place
- Move colonies in bottom chamber which is queen right after putting back the top cover to other place at least 500 m away from its original place

Inducing royal jelly production

One of the following two methods can be used for this purpose. These are:

Method 1 checking queen cell construction

- Two days after splitting, inspect queen less split and check whether bees start to construct queen cells (sign for queen rearing)

- 72 hours after splitting or a day after checking queen cell construction, identify combs containing queen cells filled with royal jelly (fig.17)



Fig.17. started queen cells after splitting

Method 2 Cutting Off the Comb

It is also possible to induce bees to make many new queen cells, in which they make royal jelly

- To do this, cut a ragged edge on the underside of a comb that contains eggs in the queenless division on the same day of splitting a colony
- The bees will then make emergency queen cells on the cut edge where the eggs are located.

2. Royal jelly extraction from both royal jelly induction methods

- Three days after splitting or cutting edge of combs, when queen cells accumulate the maximum amount of royal jelly, take out the frames containing queen cells filled with royal jelly and sweep off bees
- Place frames in nucleus boxes and transport to clean place (rooms) where extraction will take place
- Remove larva from each queen cell with a spatula or tweezers, after shortening or cutting the cell to the level of royal jelly with the help of a sharp blade
- Then remove royal jelly either manually using spoon (fig.18) or using a vacuum pump using pumper (fig.19) and deposit in black or amber bottle. The duration of filling a bottle must not surpass 1 h.
- Close the bottle tightly and place in refrigerator at temperature between 2 and 5 °C. until use
- If extraction place is far away from storage room, place the bottle in ice box and transport it to the place of storage



Fig. 18. Queen cells filled with royal jelly(left) and trimmed queen cells and scooping royal jelly using spoon (right)



Fig. 19 Royal jelly pumper

12.4 Scopes of using techniques

The techniques can be used in all agro-ecologies and for all five Ethiopian honeybee races. Since queen rearing can be applied both in box and transitional/chefeka hives, royal jelly can be harvested from both types of hives. The yield of royal jelly varies depending on the strength of the colony, the number of young bees, the season and the surrounding vegetation.

12.5 Important data to be recorded

- Season of the year when royal jelly is harvested
- Types of method used to induce queen cells construction (method 1 or 2)
- Number of queen cells constructed and filled with royal jelly
- Amount of royal jelly harvested per cell and per colony
- Income generated from the sale or from price estimate of royal jelly produced
- Any benefit obtained or problem encountered while using it at home
- How and for what purpose royal jelly is used at home

12.6 Expected benefits of using the techniques

Using the splitting technique on average 15.48 gm/colony of royal jelly is produced without affecting honey yield. The obtained royal jell can either diversify the income or improve the nutritional status of beekeepers when marketed or used for household consumption respectively. Development of this techniques may also encourage production and the development of royal jelly market in the country and consequently attract world market, which contributes to foreign currency earnings.

12.7 Precautions needed

Refrigeration of royal jelly must be at 2–5 °C. That mean the quality and safety of royal jell deteriorate, if stored above this range of temperature. Since royal jelly is an emulsified product and not cellular tissue, freezing ($\leq -18^{\circ}\text{C}$) presents no particular problem and common household freezers can be used. But as there are no criteria for establishing ‘safety’ limits for royal jelly, storage and shelf-life should be kept as brief as possible. For products sold in Europe, the maximum tolerated storage time after production is 18 months if stored at -18°C .

12.8 References

Meseret Gameda, Gemechis Legesse, Teferi Damto and Dheressa Kebaba ()Harvesting royal jelly using splitting and grafting queen rearing methods, In: *Regional Workshop on Review of Completed Research Activities of Oromia Agricultural Research Institute* Tesfaye Alemu Aredo, Kebebew Wakjira, Dawit Abate, Alemu Lema, Mekonnen Diribsa, Tesfaye Alemu Tucho, Felekech Lemecha. (eds.). 2018. Proceedings of Review Workshop on Completed Research Activities of livestock Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 17-21 November 2017. Oromia Agricultural Research Institute (IQOO), Finfinne, Ethiopia. 232 pp. not published

13. Adulterated honey detection techniques

13.1 Background information

Honey is the natural sweet substance produced by honeybees and it is a valuable food having high demand due to its potential health benefits and nutritional values. However due to its high price and low supply compared to demand, honey is exposed to deliberate adulteration. Honey is adulterated with different adulterant materials such as sugar (in boiled or powder form), banana, molasses, candy, maize flour. Adulteration of honey is becoming a serious and cross cutting problem in Africa in general and in our country in particular. This illegal practice is greatly affecting the quality and marketing of bee products and also the health of consumers.

Different methods to detect adulterated honey were developed and available but almost all are requiring laboratory test, modern facilities and chemicals. Furthermore these methods are not available in developing countries and cannot help consumers not to spend their money on false honey and safe guard the consumers from using such honey. Therefore it is very important to seek simple technique which differentiates adulterated honey from true honey that could be used by consumers and other stakeholders who are using or marketing honey. The study to identify false or adulterated honey at field condition using its physical properties was conducted at different research centers located at different parts of our country (Amhara, Tigray and Oromia). Accordingly different simple techniques such as viscosity, color, texture, dissolving ability of suspected honey in water and/or coca cola and vinegar and flaming were identified. The guideline to use these techniques is given below.

13.2 Inputs required to use the techniques

Though, each technique requires its respective inputs, the inputs listed below are the ones needed in general. These include honey suspected of being adulterated, Water, vinegar, matches, coca cola,

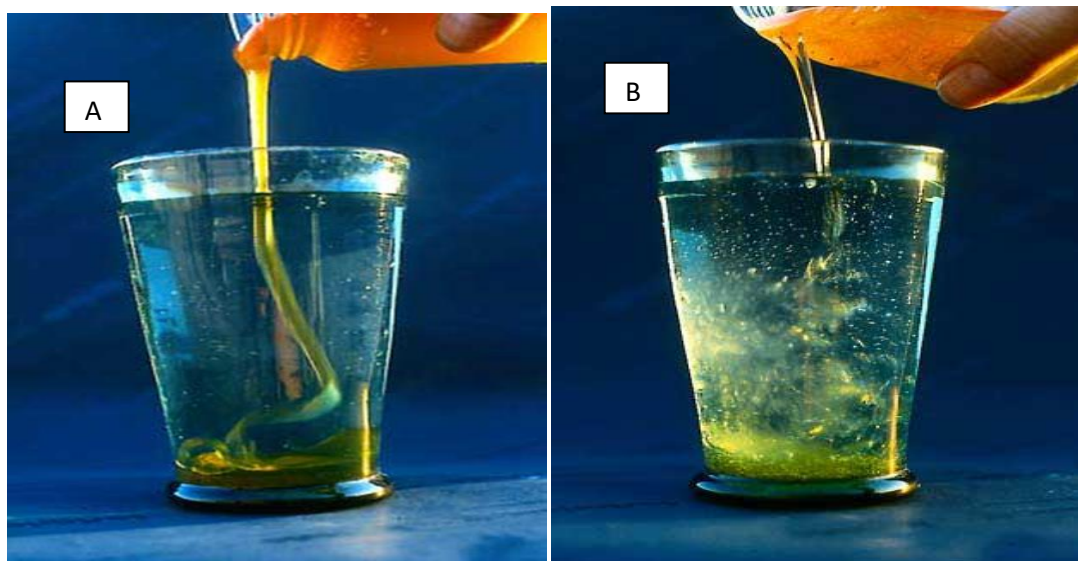
13.3 Steps and procedures to use the techniques

Ten techniques to identify pure honey from adulterated ones are given in Table 3 blow. Techniques listed from 1 to 5 are used to identify pure honey from honey adulterated with indicated adulterant materials such as Airds, sugar in different forms and molasses. The identification is mainly based on color change and formation of layers. The techniques listed from 6 to 10 are used to identify pure honey from honey adulterated with any kind of adulterant materials. A simple field test for adulteration of honey is shown in [fig. 20](#)

Table 3. Different techniques used to identify pure honey from adulterated ones

	Suspected	honey	Identification	Expected Out comes
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	types	techniques	
1	Honey mixed with Aird (a yellow spice used for making sauce('Wat'))	Checking: color and smell	Yellow in color and spicy smell
2	Honey and sugar heated together	Checking: color, layer formation and taste	light white in color; sweet like sugar, form layer (liquid at top and solid at bottom as sugar settle at bottom)
3	honey mixed with equal amount of melted sugar(1:1)	Checking: color and layer	Dark red in color, form layer (liquid at top and solid at bottom)
4	White honey mixed with sugar powder	Checking: color, texture by rubbing	Extra white color and fermented, but look pure honey by naked eye, particles never disappear like pure honey upon rubbing granulated honey between thumb and forefingers
5	Honey mixed with molasses and heated	Checking: color	black in color looks likes coffee honey
6	Adulterated honey	Checking: dissolving tendency in water	Pure honey sinks to the bottom of water, while adulterated honey disperses in water and forms aqueous solution (see fig --below)
7	Adulterated honey	Flaming test	Match-stick deepen in pure/natural honey lights easily, while the one deepen in adulterated honey does not light easily
8	Adulterated honey	Viscosity	Pure honey run slowly thickly and continuously, while, adulterated honey run faster, light and dummy
9	Adulterated honey	Coca cola test	When portion of adulterated honey is added to Coca cola, it over flows, while it doesn't over flow when it is pure honey
10	Adulterated honey	Vinegar test	Pure honey never dissolve in vinegar even upon string (1:1 proportion), while the foreign parts of adulterated honey dissolve in vinegar



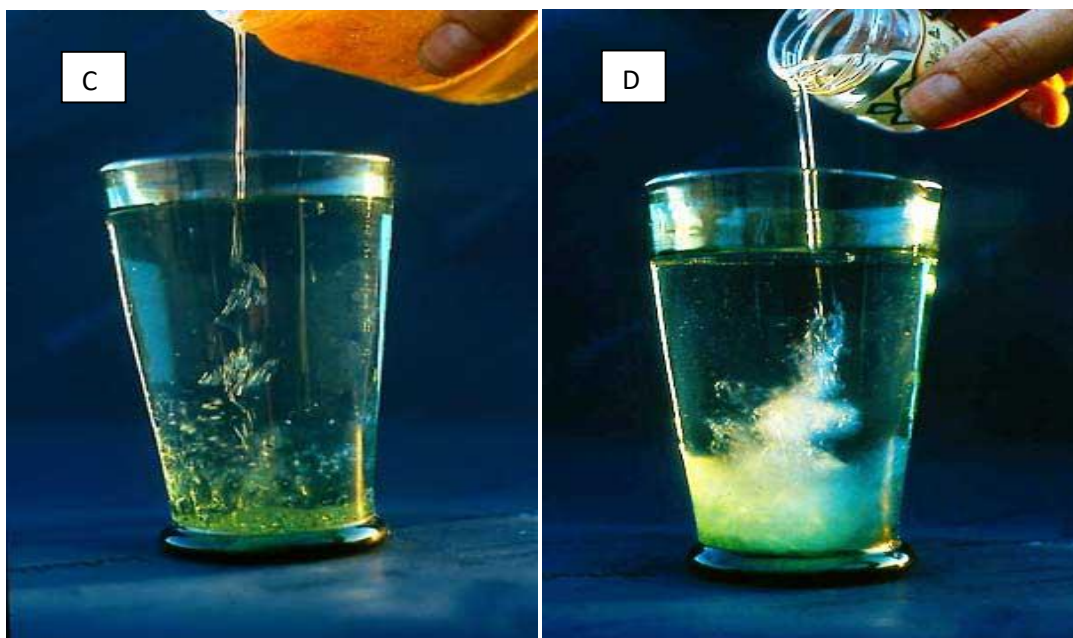


Fig.20 A simple field test for adulteration of honey: A) Pure honey pours and settles without readily dissolving. B) and C) honey mixed homogeneously with equal amounts of a 70% sugar syrup (sucrose) does not pour as straight and creates turbulence and turbidity almost instantly, but particularly after pouring a greater quantity or slightly disturbing the water. The honey syrup settles irregularly at the bottom. D) 70% sugar syrup (sucrose) only; turbidity is even stronger and no distinct settlement at the bottom occurs.

13.4 Scopes of using the techniques

These techniques can be used in all parts of the country. But experience would matter to effectively use the techniques to differentiate pure/natural honey from adulterated ones. These techniques are quicker than that of laboratory test and can be used by consumers market get.

13.5 Important data to be recorded

It is advisable if the user of these techniques record, how much he/she is success full in identifying the natural honey using the techniques, which one of the techniques is more effective, and also Suspected adulterants

13.6 Precautions needed

The techniques indicated to Identify pure honey from the adulterated ones are not as perfect as that of laboratory results, therefore the indicated techniques serve as only quick test but not considered as perfect test or techniques. If one has suspicion, he/she should take the sample or the whole material to laboratory for confirmation.

13.7 Expected benefits of using the techniques

Adulteration of honey which is conducted by some money oriented non-ethical actors, is becoming a serious issue that causes loss of market trust or consumer confidence and poses serious risk to health. Therefore if the consumers are aware of these techniques, the illegal actors may refrain from their illegal activity. Thus market can be supplied with genuine honey and, health risk due to adulterated honey will be minimized.

13.8 Reference

- Meseret Gemedo and Deressa Kebebe (2015) Assessing the effect of adulteration on honey and beeswax quality and designing way of identification, **In** *regional workshop on review of completed research activities of Oromia Agricultural Research Institute*, pp 101-107, (Amssalu B., Alemu L., Birhanu Sh., Dawit A.A, and Tesfaye A. (eds.)). Proceedings of review workshop on livestock research directorate, held at Adami Tulu Agricultural Research Centre, Adami Tulu, Ethiopia, 17-21 November, 2015. *Oromia Agricultural Research Institute (IQQO)*, Finfine, Ethiopia. 242 pp.
- Alemu Tsegaye, Abebe Jenberie, Meressa Lemma, Addisu Bihonegn, Ayalew Girmay and Yesuf Ebrahim: Assessing the Quality of Hive Products, Levels of Adulteration and Major Adulterants along Each of the Value Chain Stages in Eastern Amhara Region, in press

14. Stingless bees domestication techniques

14.1 Background information

Several hundred species of stingless bees are assumed to exist in the world, where about six genera comprising twenty species are found in Africa. The existence of 5 stingless bee species is recently confirmed in Ethiopia of which, *Meliponula beccarii* is the most frequent species.

Meliponula beccarii colony ("Dammuu kanniisa" in Oromiffa and "Tazima neb" in Amharic) lives underground. *M. beccarii* species are very docile, non-stinging and have wide adaptation. These behaviors and the high medicinal value of their honey encouraged people to tame these stingless bee colonies and keep them around their home garden.

In Ethiopia, honey produced by stingless bees is considered important in the treatment of wound, respiratory ailments, surface infection, diarrhea and various other diseases. As a result of these, stingless bees honey has high market demand, fetching higher prices than the honey produced by honeybees. Despite their ecological values through pollination and highly demanded honey, less attention has been given to these valuable stingless bee species in Africa in general, and in Ethiopia in particular. Honey harvesting method from feral colonies, is absolutely traditional and destructive. As the result of these, the stingless bee colonies are under threat and honey harvested in such a way is less quality. Few attempts have been initiated to keep stingless bee colonies as new opportunity for source of income generation in African countries like Ghana, Kenya, Botswana and South Africa.

To optimize the use of stingless bee colonies and protect them from brutal action exercised while harvesting their honey, Holeta Bee Research Center did a study to domesticate stingless bee colonies in pot hive. Accordingly the domestication and management of stingless bees were found successful. The techniques to keep or domesticate stingless bee colonies in pot hives are given below.

14.2 Inputs required for the techniques

Pot hives for nesting stingless bee colonies; shelter for shading the colonies; hoe for excavating the nest cavity of stingless bee colonies; disposable syringe for harvesting honey, falcon tube for feeding colony and sugar for preparing sugar syrup to feed colonies are very important inputs. Apiary site, where stingless bee colonies kept should also be selected and made ready.

14.3 Steps and procedures to use the techniques

Site selection

A good site, selected for the placement of stingless bee colonies should protect the colonies from rain, hot and cold temperature and enemies and covered with multi honeybee floras. Thus the beekeepers should consider the following factors for selecting good apiary:

- Availability of abundant forage resources (flowering plants).
- Availability of water source
- Accessibility – area must be reached easily by the beekeepers
- Adequately shaded with good air circulation
- Well drained land, avoiding damp and water-logged areas

To successfully domesticate stingless bee colonies, it is important to first locate the nest of stingless colony. Then the nest cavity (involucrum) must be taken out and transferred to pot hive carefully. The steps and procedures of locating the stingless bee nests, taking out the nest cavity from underground and transferring to pot hives are given below.

Locate or Search for stingless bee nest

Securing stingless bee colony is the first step and is the difficult part of the exercise. There are different methods used to track stingless bees nest. These are looking for the stingless bees foraging on flower, water or attracting stingless bees using waxes or honey. Then catch the bees and tie long, red thread (helps to easily track bees from distance) on their leg and follow or track the bees while they are flying back to their nest.

Transferring colony to pot hive

It is very important to re-establish a stingless bee colony into a well constructed bee hive. A well designed and constructed beehive will enable the colony to develop properly and store good volumes of honey and pollen. In this case pot hives made of clay soil (fig. 21) is found suitable for local stingless bee (*Meliponula beccarii*). This hive enables to manage the stingless bee colonies more easily than in their natural nest and helps to harvest hive products without damaging the nest of the bees.

Colonies should be transferred when food and other resources are abundant in the environment (beginning of flowering season is preferable) to help colonies establish and grow quickly.

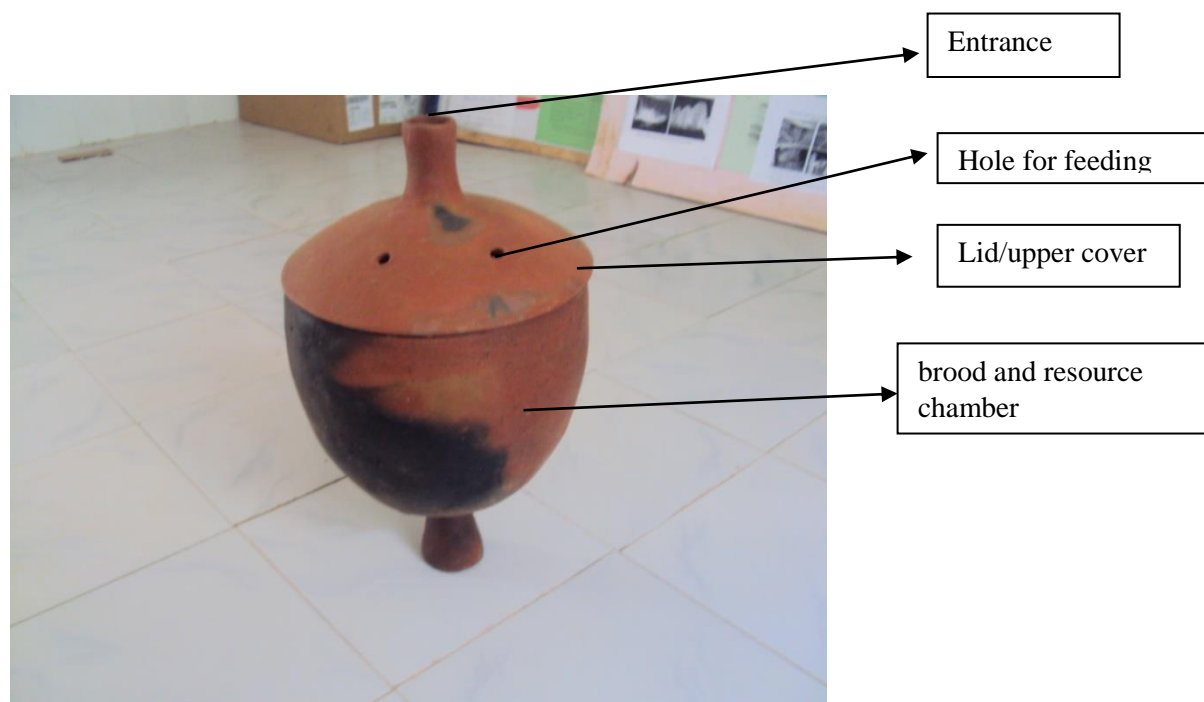


Fig. 21 Pot hive for hiving stinglessbee colony

In transferring a stingless colony from its natural nest into a constructed beehive (pot hive), the following steps must be followed:

- Clean the pot hive and set it up near the natural nest
- By means of appropriate tools such as a hoe, excavate the ground 30 to 50cm away from the entrance of the nest and get nest cavity with care. As much as possible try to leave the nest contents intact and avoid crushing or killing the bees
- Remove the whole nest cavity and place inside the pot hive
- Close the pot hive and secure it well. Use appropriate material such as cello tape to seal all openings except the entrance
- Put the pot hive in the excavated old nest (hole) for at least an hour to allow returnee foragers to join their colony and then after, move it to the set apiary
- Place pot hive inside the hole prepared in new apiary and replace the soil back, leaving the entrance above the ground (fig. 22 left)
- Feed the colony with sugar syrup (sugar:water = 1:1) using a flask tube through holes of pot hive prepared for this purpose (see fig. 22 right) below
- Monitor the re-establishment of the colony in the new hive and check for ants and other pests



Fig. 22 Stingless bee colonies in Pot hives placed under ground(left) and feeding stingless bee colonies with sugar syrup using flacon tubes (right)

Management of the stingless bees

It is vital to put in place sound and effective management practices in order to derive maximum benefits from stingless bees. Stingless bee colonies are prone to many challenges including, extreme weather conditions, pests, diseases, weeds, chemical pesticides, lack of forage and water. Therefore:

- colonies need to be placed under shelter to protect them from the direct impact of the weather such as rainfall and sunshine
- colonies need to be placed under ground and apiary site should be clean and tidy to prevent colonies from pests like ants, lizards, spiders and other intruders having access to nests
- regular monitoring is needed to reduce any stress on colonies from external factors and
- during dearth period, the colonies must be fed with 50% sugar syrup or honey through feeding holes using flacon tubes

Harvesting of Hive Products

Honey, propolis, pollen, Beebread and wax can be harvested from stingless bee colonies. However except for honey, market for the other products is not well established in our country. As a result of this fact, only honey harvest is considered in this manual. The following steps and procedures should be followed to harvest the honey. See the illustrations given in fig. 23.

- Clean honey containers and make other necessary tools like disposable syringe ready
- Open the cover of pot hive (this exposes honey pots)
- Insert the disposable needle into honey pot and suck the honey and discharge the contents in to the honey container

- Repeat the honey collection step until whole honey is exhausted
- Strain honey using cloth (Debela shash)

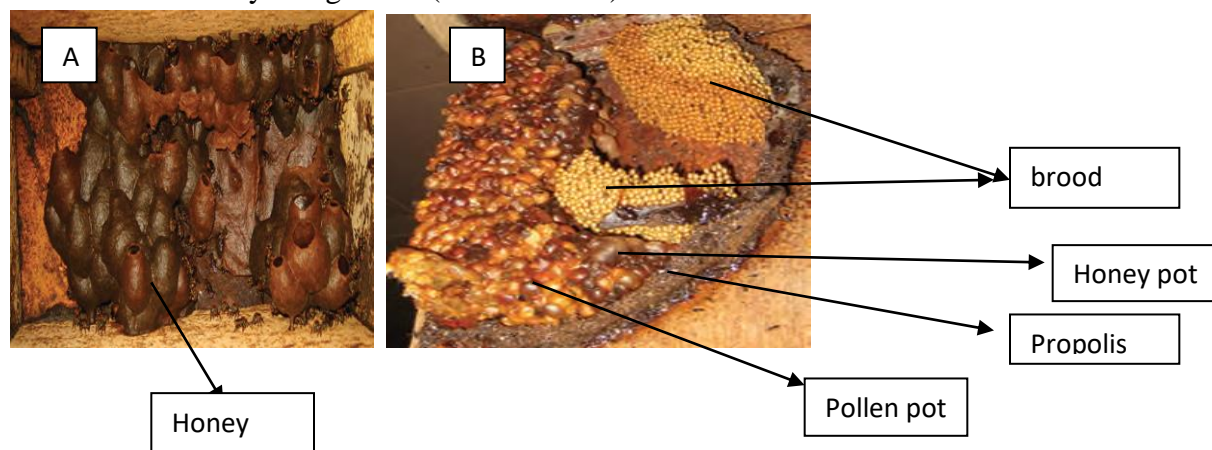


Fig. 23 Inside stingless bee hives showing pots of honey, pollen (Beebread) and propolis (A. honey pots, B. entire nest with pollen, honey pots and brood)

14.4 Scopes of using techniques

Stingless bee colony domestication could be implemented in all areas where ground nesting stingless bee colonies exist- Mostly in midlands and highland agro-ecologies.

14.5 Important data to be recorded

- All cost expenditures to domesticate stingless bee colonies (cost of pot hive, cost of stingless bee colonies if bought, sugar/honey for feeding, shelter making, labor if any, and others)
- Revenue generated (total honey harvested/colony/year and income generated from selling honey)
- Number of stingless bee colonies transferred to pot hives
- Number of stingless bee colonies absconded
- Number of stingless bee colonies adapted

14.6 Expected benefits of using the techniques

Unlike in the traditional method, honey is harvested from stingless bee colonies domesticated using this technique carefully without damaging the nest and bees. Thus the colonies are conserved for the next uses. Domestication and management practices of stingless bees are very important for the production of improved honey quality, income generation, health status and conservation of stingless bee colonies. In other words, as stingless honey has medicinal values to treat different diseases, the time and expenses spent in health stations could be reduced through

taking stingless bee honey and consequently the health status and income of small scale farmers could be improved. The average honey yield per colony varied from 250 ml to 2.3 liter, and the price of stingless bee honey per kg is more than twice that of honey from honeybees.

14.7 Precautions needed

Stingless bees are very good at securing their nest against outside intruders. Some intruders such as flies and beetles take advantage of an unsecured nest and invade colonies which may result in deaths. Constructed hives should therefore be prepared in such a way that all openings and gaps are closed or plugged with appropriate materials. This will enable colonies to re-establish quickly and grow. The beekeepers should carry out the transferring operation as quickly as practicable in order not to offer the opportunity for pests to invade the nest. This means that all necessary equipment and materials should be put in place prior to the opening of the natural nest.

14.8 References

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II. Information

1. Prolific age of honeybee queen (*Apis mellifera*) for optimum honey production

1.1 Background information

Honeybee colony management needs skill to fully utilize the productive capacity of the colony. The performance of honeybee queens plays a major role in colony organization and social reproductive decisions. She influences the brood production and overall productivity of the colonies. As the queen honeybee became aged she started to lay fewer eggs and produce less pheromones that affects both queen attractiveness to workers and her power to control over the colony. Colonies, which have a one-year-old queen have been reported to have a greater colony population and produce 27-30% more honey yield than colonies which have old queens. The old queens lay insufficient eggs to produce enough young workers to maintain the colonies during dearth seasons. The colonies led by old-age queen colonies die off in late dearth period or early honey-flow time.

Replacing older queens with young ones is one of the essential methods to increase the productivity of honeybee colonies. In Ethiopia, beekeepers manage colonies of unknown queens-age in improved beekeeping system. This might be a factor for low productivity of colonies, but not evaluated as important factors. Holeta bee research center studied the effects of queen age on important colony characteristics (brood pattern, brood population, swarming behavior and honey yield survival) and valuable information is generated from the study are summarized as follow.

1.2 Inputs used to generate the information

- Central high land honey bee colonies
- Box hive (Langstroth)
- Nucli box used for queens rearing
- Protective clothes (overall, veil, gloves)
- Beekeeping materials and tools for queen rearing
- Sugar syrup for simulative feeding

1.3 Steps and procedures followed to generate the information

- Colonies of high honey yielder, health and vigor from the same ecotype were selected
- Colonies were strengthened through sugar syrup feeding(50 % W/V) of internal feeding
- Queens have to be reared using splitting method in the best time of the year
- The old queens were replaced by new queens
- Colonies were inspected at 21-day intervals to determine the indicative conditions (swarm check, supering, honey harvesting and super reducing).

- Honey was harvested and evaluated among colonies headed by different queen age

1.4 Important data to be recorded

- Number of queen developed and replaced
- Brood rearing condition of the colony
- Swarming tendency of the colony
- Honey yield of the colony

1.5 Outputs obtained from the information generated

Colonies headed by young queens (less than two years) developed more brood areas, better brood pattern, less swarming tendency and better honey yield (27%) compared to colonies headed by 3-years-old queens. This indicates that old queens should be replaced, after the second year in central-highland conditions.

1.6 Precautions taken while generating the information

Ants can devastate entire colonies overnight. Therefore, careful and regular follow up, feeding sugar syrup and protecting them from pests and predators were undertaken.

1.7 Reference

Zewdu Ararso, Tadele Alemu and Gemechis Legese(2016). Assessing the optimum prolific age of queen honeybee (*Apis melliferabandasii*).Oromia Agricultural Research Institute, Livestock Research Proceedings.