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Traditional use of botanicals in reducing post harvest loss at crop stacking stage in Ethiopia: A case of Farta district

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Insect pests, rodents, and microorganisms comprise the larger proportion for the causes of post-harvest loss. The use of insecticidal/pesticidal and insect repellent plants is a deep-rooted tradition and cultural heritage in Ethiopia. This study was conducted to gather information on traditional botanical-based pest control practices by farmers of Farta district, northern Ethiopia. The study identified plants traditionally used as pesticides/insecticides during stacking crops at harvest time. The survey showed farmers are using about 31 species of plants for bottom layering during stacking of their crops. These plants are used as pesticides and insecticides although their level of utilization varied. The most commonly used and effective plant species were *Croton macrostachyus* Del., *Eucalyptus globules* Labill., *Calpurnia aurea* (Ait.) Benth., *Vernonia myriantha* Hook. f. and *Laggera tomentosa (*Sch. Bip. ex A.Rich) Oliv. & Hiern, of which *C. macrostachyus* is the most effective. The insecticidal effect of these botanicals was compared to the synthetic insecticide diazinon (0.1 %). Twelve hours after application of powders of *C. macrostachyus, E. globulus, C. aurea* and *L. tomentosa,* the mean mortality rate of termites was equivalent to that caused by diazinon. Further, the insecticidal effect of different parts of *C. macrostachyus* was compared. Leaves were the most effective. This calls for further identification and adoption of cost-effective and environmental-friendly indigenous/traditional botanical based pest control methods. Identification of active principles from these plants is highly desirable.

Keywords: Mortality, Pesticidal plants, Repellent, Pest control

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Globally, a minimum of 10 % of cereals and legumes are lost after harvest[1]. Post harvests loses, specifically during stacking but also at storage[2] are caused by animal and insect pests. People in developing countries depend on locally available plants to protect their crops from pests[3-5]. Botanical pesticides have biologically active ingredients that are used as repellants or pesticides[2,6]. As elsewhere in Africa[6-8], many pesticidal/insecticidal plants are used by different cultures in Ethiopia. *Croton macrostachyus* is the most common plant[9]. *C. macrostachyus* belongs to the Euphorbiaceae and it is the most abundant plant in the tropics[10]. It is native to Eritrea, Ethiopia, Kenya, Nigeria, Tanzania and Uganda[11,12]. In Ethiopia, *C. macrostachyus* occurs in regions between 1300 and 2500 m above sea level with annual rainfall ranging between 750 and 2000 mm[13]. The aim of this study was to document the pesticidal/insecticidal effect of botanicals in general and *C. macrostachyus* in particular by farmers in Farta district, North Ethiopia, during stacking their crops. Such knowledge based investigation was recommended to African small scale farming by other researchers[5,14].

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Materials and methods

Description of the study area

Farta district is located in South Gondar zone of the Amhara National Regional State (ANRS) (Fig. 1). Its specific location lies between 11° 32’ to 12° 03’ latitude and 37° 31’ to 38°43’ longitude[15,16]. The total area of the district is estimated to be 1117.88 km^2 (111,788 hectare)[15]. Agro-ecologically, about 44 % of the district is classified as Dega (moist highland) while the remaining 56 % is considered as Woina Dega (moist midland). The altitudinal range of the study area varies from 1970 to 4135 m above sea level. The mean maximum temperature of Farta district is 21 °C (from February to May) while the mean minimum temperature is 9.5 °C (from June to January)[15].

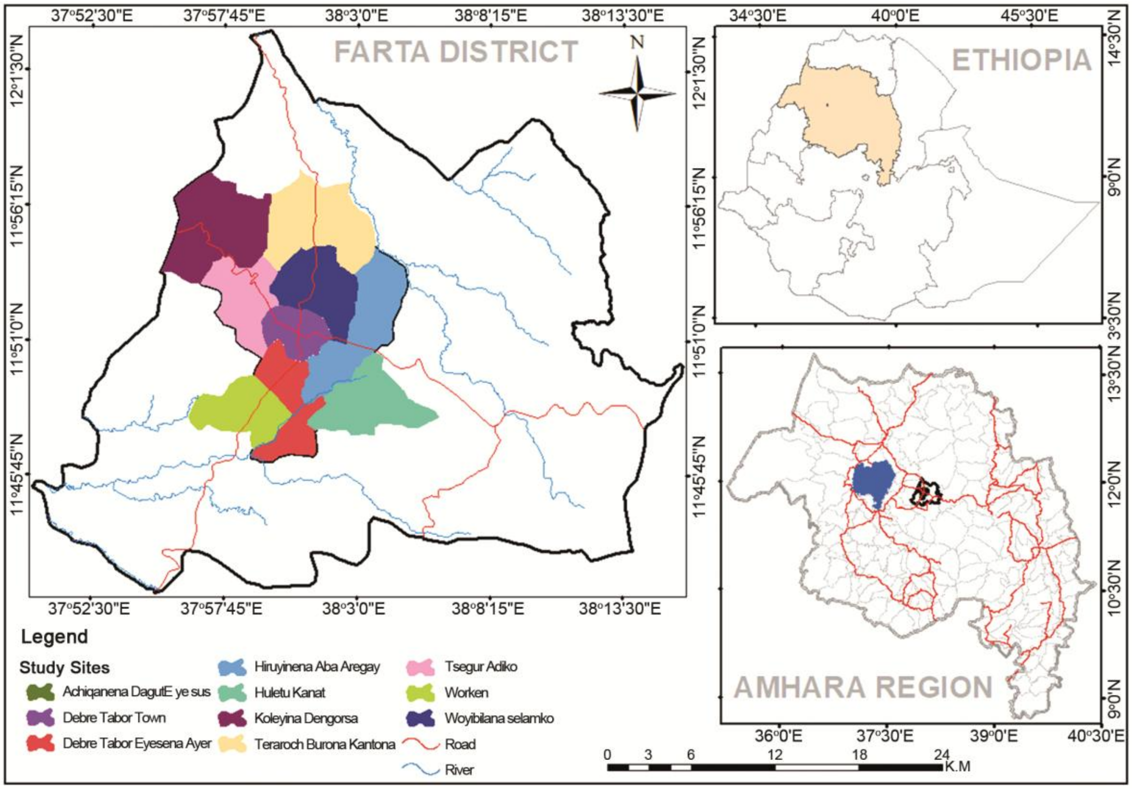

Fig. 1 — Map of the study area (Farta District). Study sites are shown by different colours.

According to the meteorological report of the region[17], the mean annual rainfall is 1570 mm and it is unimodal (May to mid September). In terms of topography, 45 % of the total area is gentle slope, while flat and steep slope lands account for 29 % and 26 %, respectively. The dominant crops grown in the district are barley, wheat, *teff*, sorghum, maize, field beans, peas, chickpeas, millet, lentil, oil crops and tuber crops such as potato. Vegetation of the area (district) is dominated by *Juniperus procera* Hochst.ex Endl., *Eucalyptus globulus* Labill., *Euphorbia abyssinica* J.F.Gmel., *Podocarpus falcatus* (Thumb.) R. Br. ex Mirb., *Croton macrostachyus* Del., *Acacia* spp, *Adhatoda schimperiana* (Hoschst) Hochst. ex Nees, *Cordia Africana* Lam., *Vernonia* spp, *Olea europaea* L. and some exotic tree species[15].

Data collection and analyses

In this study, data was collected by both non-experimental and experimental designs from December 2015 to May 2016. All experimental work was done in June and July 2016.

Non-experimental data collection

The ethnobotanical survey was conducted in eight rural kebeles (small administrative units of the district) of Farta district (around the town Debre Tabor) namely Weybila-Selamko, Buro-kantona, Hiruy-Abaregay, Kanat, Werkien, Debre Tabor Eyesus, Tsegur and Dengors (Fig. 1). Sample informant populations were selected from the total household population of each Kebele using systematic random sampling method. The sample size was determined by employing 4.82 % true value and 95 % confidence interval using the following formula[18]:

$$n = \frac{z^2 * p * q * N}{e^2(N-1) + z^2 * p * q}$$

Where n is sample size; *z* is the value of the standard variate at 95 % confidence interval; p *is* proportion of farmers using pesticidal/insecticidal plants (assumed to be 50 %). *q* is 1 – p. *N* is the size of population of the district while e is acceptable error (0.0482).

Data on knowledge, application, preference and management of insecticidal/pesticidal plants used by the local people to protect their stacked crops was collected. The questionnaire and interview were prepared first in English and were translated to local language (Amharic) for local informants. During this survey, some selected informants were interviewed about why farmers use plants as bottom layer during crop stacking and, what type of insects/ pests attack stacked crops before threshing.

Among the respondents, 73 % were males. The ages of the respondents ranged from 20-80 yrs. Almost all the respondents in the study area were farmers, and among them 44 % could not read and write while the rest respondents are literate. Majority (74 %) was married and the number of children per household ranged from 1-12 yrs. The mean number of land plots for farming owned by the farmers was 4 hectares. The mean annual crop production (No. of quintals per year) was 5.

Experimental data collection

Plant collection and preparation of plant powders

Those plants that were believed to have insecticidal/pesticidal activity by the respondents were selected. Then, the required parts of the plant species were collected from their natural habitats, brought to Fert secondary high school Biology laboratory at Debre Tabor town and stored until extraction. The fruits, leaves, stem, bark, and root parts of *C. macrostachyus* and leaves of *C. aurea*, *C. macrostachyus E. globules*, *L. tomentosa* and *V. myriantha* were collected and thoroughly washed with tap water to remove dirt and impurities. The leaves were dried under shade at room temperature for about 15 days. The completely dried leaves were powdered using local coffee grinder. The fine powder was sieved through kitchen strainer to obtain uniform dust particles and stored in glass container at room temperature in dark place prior to use.

Termites were collected from the affected areas (infested woods) using hard paint brush and placed inside plastic vials. Mouths of the plastic vials were wrapped with perforated mesh close to allow air in and prevent moisture increment. The vials were kept in room at 27±1 °C and normal fluorescent light (40 W) during the day. Movement and mortality of termites were recorded starting 3 h after treatment. For each treatment, 20 termites of undetermined age and sex were placed on each plastic dish containing powder and three replicates of all the treatments were maintained. The control sets were plastic boxes with soil (negative control) and diazinon treated filter paper (positive control). The positive control, 0.1 % diazinon 60 EC (Emulsifiable Concentrate) was diluted in water according to the manufacturer's recommendation (1:1000)[19].

Bioassay procedures for toxicity and repellency tests

Thirty gram of the different plant parts (leaf, bark, stem and root) were powdered and placed on filter paper embedded petri dishes. The filter papers were moistened by distilled water. Pieces of termite-infected woods were placed in the petri dishes to feed the termites. Twenty termites were placed in each petri dish containing powders. The petri dishes were covered with perforated mesh cloth to allow air and then placed in dark area. For each toxicity test, three replicates were made. In addition to the application of each powder, the same gram of soil was used for each experiment as negative control. Then mortality was observed in 3 h intervals after inoculation of the pests for one day. The live and dead termites were counted and the per cent mortality was calculated as number of dead termites divided by the total number of termites multiplied by 100.

Repellency of the powders to the termites was conducted using a direct inoculation of insects onto the powders. The method used was based on the area preference test described by McDonald *et al*., 1970[20]. The test area was 11 cm Whatman number one filter paper deepen in to distilled water and drained before being placed into the experimental plastic dishes. The powders were placed on half area of each plastic dish. The plastic dishes were covered with a perforated cotton cloth and held tightly in place with rubber bands. Each treatment was replicated three times and arranged on the worktable in the laboratory using complete randomized design[21]. The number of termites repelled and moved to the non-powder treated half of each plastic box and the number of termites that did not move was counted one hour after treatment. The percentage repellency was computed using the following equation:

$$\text{\% moved away} = \frac{\text{No.of repelled}}{\text{No.of released}} \times 100$$

Data management and analysis

To analyze the collected data, SPSS Version 20.0 statistical program was used. The data collected from observation, questionnaire and interview were tabulated and organized. Differences were considered as significant at p-value less than 0.05.The chi-square analysis for survey data and ANOVA with post hoc (Fisher's Protected Least Significant Difference, PLSD) mean comparison for experimental data were performed. The level of significance was determined at 95 % confidence level.

Results and discussion

A. Non-experimental results

1 Farmers' knowledge on pesticidal plants and crop stacking processes

About 85 % of the local inhabitants were aware that crops cannot be threshed immediately after harvest because the seeds could not easily be shelled out or shattered and they need time for preparing threshing grounds. Threshing would take a lot of time and energy, and the seeds would be deformed by cattle hooves during threshing (if not dried). It is important to note that though the survey has been conducted by involving 400 eligible respondents, only 92 % of them had awareness on insect repellent plants. Out of 368 knowledgeable residents, 88 % of them were using plants as insect repellents during crop stacking and storage. In addition, 75 % of the respondents use *C. macrostachyus* as protectant by layering it at the bottom of stacked crops and storage pits. In addition to untimely rain, different pests are the causes for post harvest loss, although the degree of loss they incur varies (Table 1). Termites followed by rodents are the major pests. Although productivity could be reduced by numerous biotic and abiotic factors, pests (including rodents and termites) are very distractive in African farmlands[22].

2 Farmers' knowledge on crop stacking techniques

Out of the selected farmers in the study area, 79.5 % of them knew how to stack crops after harvest. This knowledge was transferred mostly along family line. The farmers (73 %) stacked their crops lifting above the ground using large stones and insect (termite) resistant plant logs. For 67 % of respondents, the reasons why they stack their crops lifting above the ground were to prevent from rodent and termites attacks, to allow air to circulate through and to protect their stack from flooding. It also allows hunter animals to move through to catch rodents and allow flood to pass through during unseasonal rainfall (Fig. 2a). Farmers believe that if crops were stacked directly in contact with the ground, heat and moisture would occur which makes it suitable for the growth of mould and termites. When farmers stack their corps, the bundles are arranged in circle putting the grain towards the center and the straw outside (Fig. 2b). These structures help to protect the crops from domestic animals and to drain rainwater to the ground.

3 Pesticidal plants species used to protect stacked crops in Farta district

The informants reported 31 plant species as insecticidal/pesticidal used during stacking their crops (Appendix). The plants belong to 21 families with Asteraceae (five species), Fabaceae (four species), Rosaceae (three species) and Cupressaceae (two species) being the most represented plant families. The remaining families represent only one species each.

Habitat and plant parts used

Most of the pesticidal plants (79 %) were obtained from the wild. The plant parts used during stacking are leaves (45.5 %), leaves and stem (30.3%) and whole plant (24.1%). The greater majority of the study participants drive away insects by layering the fresh leaves during stacking crops until threshing. The use of plant leaves as insect repellent could be one of more sustainable options than any other parts

Fig. 2 — (a) Stacked crops lifted above the ground, (b) Crops stacked in circle and dome shape

Table 1 — The main pests that attack crops during stacking as reported by farmers

Major pests reported	Observed frequency	Expected frequency	Residual	X^2	Df	p-value
Termites	36	67	-31	750	5	< 0.0001
Rodents	28	67	-39			
Mould	25	67	-42			
Bird	23	67	-44			
Weevil	17	67	-50			
All type except weevil	271	67	204			
Total	400					

like roots. This mode of application might not disrupt the natural plant growth and the supply of leaves would continue throughout the year. From the plant species listed, a large number 19 (58 %) species are used in fresh forms (not dried). The growth form analysis of these pesticidal plants revealed that shrubs constitute the largest category with 15 species (46 %) followed by trees with 14 species (42 %). Herbs and climbers accounted for 2 species (6 %) each.

Farmers' preference to traditional pesticidal plants

About 64 % of the respondents in the study area prefer traditional pesticidal plants than modern pesticides. This is true to most small holder farming in Africa[8]. However, 26 % of the respondents used both traditional and modern pesticides to repel/kill pests from their crops. The reasons of preference for cultural methods were associated to the low cost (affordability) and safe applicability. The respondents preference of traditional pesticidal plant was significantly higher than modern pesticides (X^2 = 178.2, df = 2, $p < 0.05$).

Experimental results

1. Toxicity of different botanicals to termites

Percentage mortalities of termites across different time intervals (3, 6, 9 and 12 h) were checked. The insecticidal effect of all plants was significantly higher when compared with negative control (soil) but less effective as compared to the positive control (0.1 % dazinon) when treatment time is less than 12 h. The mean percentage mortality of termites directly exposed to the powders of different plants is presented in Table 2. At 3 h after application, the synthetic insecticide (0.1diazinon) induced the highest mortality (100 %) of termites and it was significantly higher from the mortality by the plant powders ($p < 0.05$).

At 3 h after application, the mortality of termites caused by plant powders ranged from 15 % to 30 %. At 6 h after application, the mortality induced by all plant powders ranged between 40 % and 60 %. They were significantly different from synthetic insecticide (0.1diazinon) which induced 100 % mortality and with each other at $p < 0.05$. As indicated in Table 2, after 9 h of exposure, maximum mortality was registered from diazinon and *Croton macrostachyus.* However, at 12 h after exposure other botanicals such as *Eucalyptus globulus, Calpurnia aurea* and *Laggera tomentosa* induced about 95% mortality. On the contrary, mortality was not observed in all time intervals from the soil.

2. Toxicity result of different parts of *croton macrostachyus* to termites

The mean mortality rate of termites that were exposed to powders of different parts of *Croton macrostachyus* (leaf, fruit, stem, bark and root) is presented in Table 3. At all time intervals, the application of positive control (0.1 % diazinon) induced the highest mortality (100 %). However, the mean mortality induced by different parts of *Croton macrostachyus* 3h after application ranged between 10 % and 20 %. At 9 h after application, the highest mortality next to diazinon was observed from *Croton macrostachyus* leaves (80 %) followed by the bark. The mortality rate of termites 12 h after application of leaves was not different from that of diazinon.

Table 2 — Mortality effect of different botanicals at different time intervals

Treatments of selected plant leaves	Weight of powders (g)	Mean mortality (%) Time interval after application: 3h Mean No. of dead termites N	3h Percentages (%)	6h Mean No. of dead termites N	6h Percentages (%)	9h Mean No. of dead termites	9h Percentages (%)	12h Mean No. of dead termites N	12h Percentages (%)
Croton macrostachyus	30	6[b]	30	12[b]	60	19[a]	95	20[a]	100
Eucalyptus globulus	30	5[bc]	25	10[bcd]	50	16[b]	80	19[a]	95
Calpurnia aurea	30	4[c]	20	9[cd]	45	14[c]	70	19[a]	95
Vernonia myriantha	30	3[cd]	15	9[d]	40	12[d]	60	15[b]	75
Laggra tomentosa	30	5[bc]	25	11[bc]	55	16[b]	80	19[a]	95
Diazinon	0.1	20[a]	100	20[a]	100	20[a]	100	20[a]	100

Mean with in a column followed by different letter are significantly different each other at $p < 0.05$.

Table 3 — Killing effect of different parts of *Croton macrostachyus* when compared to dazinon at different time intervals

Treatments of different parts of *Croton macrostachyus*	Weight of powder (gram)	3h: Mean No. of dead termites N	3h: Percentages (%)	6h: Mean No. of dead termites N	6h: Percentages (%)	9h: Mean No. of dead termites N	9h: Percentages (%)	12h: Mean No. of dead termites N	12h: Percentages (%)
Fruit	30	2^b	10	4^{cd}	20	7^d	35	9^d	45
Leaf	30	4^b	20	12^b	60	16^b	80	20^a	100
Bark	30	3.3^b	15	11^b	55	13^c	65	15^b	75
Stem	30	2^b	10	3^d	15	4^f	20	8^d	40
Root	30	3.3^b	15	6^e	30	9^d	45	12^c	60
Diazinon	0.1	20^a	100	20^a	100	20^a	100	20^a	100

(Interval of time after application of the powders: 3h, 6h, 9h, 12h)

Table 4 — Repellency effect of different botanicals 1 h after application of the treatment

Treatments of selected plants	Weight of powder (g)	Mean Repellency (%) Time interval after 1h application: Mean No of termites repelled	Percentage (%)
Croton macrostachyus	30	17^b	85
Eucalyptus globulus	30	16^b	80
Calpurnia aurea	30	16^b	80
Vernonia myriantha	30	8^c	40
Laggra tomentosa	30	15^b	75
Diazinon	0.1	20^a	100

3. Repellency test of different botanical powders on termites

The repellency effect of the plant powder on termites is presented in Table 4. One hour after the application of treatments, the highest repellency was induced by the synthetic insecticide (0.1% diazinon) followed by the powder of *Croton macrostachyus* (85 %), *Laggera tomentosa* (75 %), *Eucalyptus globulus* (80 %) and *Calpurnia aurea* (80 %). The mean number of repellency caused by the plant powders were not significantly different from each other, but they were significantly different from diazinon ($p < 0.05$). On the contrary, no repellency was caused by the negative control treatment (soil) and very less repellency was observed from *Vernonia myriantha* (40 %). Most plant defensive chemicals discourage insect herbivory by deterring feeding while others could impaire oviposition or larval growth[23].

B. Significance of the study to the farmers

Use of botanicals as pesticides/insecticides in Farta district decreased with age (24.1%, 34.5% and 41.4% for ages of farmers 20 – 40, 41 – 60 and 61 – 80 yrs, respectively). This was similar to the age versus knowledge profile of the Raya-Azebo people of Tigray region (Ethiopia) on insecticidal/pesticidal plants[24]. Also, the knowledge transfer system in the farming community in Ethiopia, according to the respondents, is across family lines (65.1%). These results suggest that there is a steady decline or erosion of knowledge and use of pesticidal/repellent plants across generations. Despite of the benefits, the traditional based pest-controlling methods and application seems to be mostly ignored by young generation. Thus, more awareness creation on the importance and usage of botanicals for pest management and documenting the traditional knowledge before it disappear is a requirement. Moreover, conservation of such beneficial plants is necessary. This can be achieved by encouraging people to grow pesticidal/pest repellent plants in home gardens, farmlands and live fences, and promoting the establishment of local botanical gardens (herbaria). This study is believed to achieve these goals.

Conclusion and recommendation

Farmers in Farta district use different plants as pesticides to protect their stacked crops. The use of botanicals by farmers is cost effective and safe to use. Besides, use of plant-based pesticides is environmentally friendly. Although many plants are used as pesticides by the farmers of Farta district, *Croton macrostachyus*, especially the leaves, is most effective compared to other botanicals. This calls for the isolation and identification of the bioactive ingredients contained in the leaves of *Croton macrostachyus* Del.. Further, awareness creation on the sustainable use of pesticidal/insect repellant plants to farmers is necessary.

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Appendix. List of plants used as pesticidal/insecticidal by local farmers in Farta district, Ethiopia.

No	Scientific name	Family	Local name	Habitat
1	*Acacia negrii* Pic. Serm.	Fabaceae	*Girar*	Open land/wild/
2	*Acacia Senegal* (L.) Willd.	Fabaceae	*Kontir*	Forest/wild/
3	*Acanthus sennii* Chiov.	Acanthaceae	*Kusheshile*	Open land/wild/
4	*Bersama abyssinica* Fresen.	Melianthaceae	*Azamir*	Forest/wild/
5	*Brucea antidysenterica* Mill.	Simarobaceae	*Wanos*	Forest/wild/
6	*Buddleja polystachya* Fresen.	Buddlejeceae	*Anifar*	Forest/wild/
7	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	*Zigita*	Forest/wild/
8	*Capparis tomentosa* Lam.	Capparidaceae	*Gimero*	Forest/wild/
9	*Carduus schimperi* Sch. Bip.	Asteraceae	*Dander*	Edge of farm land /Wild/
10	*Carissa spinarum* L.	Apocynaceae	*Agam*	Forest/wild/
11	*Cordia africana* Lam.	Boraginaceae	*Wanza*	Forest, open land, edge of farmland/semi wild/
12	*Croton macrostachyus* Del.	Euphorbiaceae	*Bisana*	Forest, open land, edge of farmland/semi wild/
13	*Cupressus lusitanica* Mill.	Cupressaceae	*Yeferegj Tsid*	Edge of farmland /Cultivated/
14	*Dodonaea angustifolia* L.f.	Sapindaceae	*Kitkita*	Forest/wild/
15	*Dombiya torrida* (J.F.Gmel.) Bamps	Sterculiaceae	*Wulkifa*	Forest/wild/
16	*Eucalyptus globulus* Labill.	Myrtaceae	*Nech Bahirzaf*	Farm land /Cultivated/
17	*Guizotia schimperi* Sch. Bip.ex Walp.	Asteraceae	*Mech*	Edge of farm land /Wild/
18	*Hagenia abyssinica* (Bruce) J.F.Gmel.	Rosaceae	*koso*	Forest/wild/
19	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	*Yabesha Tsid*	Forest/wild/
20	*Justicia schimperiana* (Hochst.ex Nees) T.Anders	Acanthaceae	*Sensel*	Forest/wild/
21	*Laggera pterodonata* (DC.) Sch. Bip. ex Oliv.	Asteraceae	*Kamo/Keskesa*	Forest/wild/
22	*Laggera tomentosa (*Sch. Bip. ex A.Rich) ex Oliv. & Hiern.	Asteraceae	*Keskeso*	Forest/wild/
23	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	*Atat*	Forest/wild/
24	*Millettia ferruginea* (Hochst.) Bak.	Fabaceae	*Birbira*	Forest/wild/
25	*Olea europaea* L. subsp.cuspidata	Oleaceae	*Weyra*	Forest /semi wild/
26	*Phytolacca dodecandra* L' Her.	Phytolaccaceae	*Endod*	Forest, open land, edge of farmland/ wild/
27	*Prunus africana* (Hook. f.) Kalkman	Rosaceae	*Homa*	Forest/wild/
28	*Pterolobium stellatum* (Forssk) Brenan	Fabaceae	*kentafa*	Forest/wild/
29	*Rhus glutinosa* A. Rich.	Anacardiaceae	*Embis*	Forest/wild/
30	*Rosa abyssinica* R.Br. ex Lind.	Rosaceae	*Kega*	Forest/wild/
31	*Vernonia myriantha* Hook. f.	Asteraceae	*Kotkoto*	Forest/wild/