A COMPARATIVE STUDY ON THE EFFECT OF "GUIE" IN THREE AREAS: SENDAFA, DEBRE BERHAN AND FICHE

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ABSTRACT

Samples were collected from the three sites: Sendafa, Debre Berhan and Fiche to study changes induced by "Guie" practice. The chemical and physical changes as well as the growth of barley in these soils was compared for the three sites.

The laboratory study involved the determinations for particle size distribution, the ignition experiment, the determination for changes in organic carbon, total nitrogen, available phosphorous, pH, electrical conductivity, carbonates, the exchangeable cations, the cation exchange capacity properties of the soils. Plant analysis for percent nitrogen and percent phosphorous was determined for barley grown in the greenhouse experiment.

In the Greenhouse experiment the height of barley plants was recorded as well as the counts on emergence, heading and fresh and dry weights and weed score was done to evaluate the differences between the three sites.

The results from the laboratory and greenhouse studies showed similar variations among the treatments of the three sites. The interior heap layers exposed to high temperatures both the negative and positive effects from "Guie" practice. The main positive effects were found to be the increase in available phosphorous and the change from find to sand sized particles. In contrast the main negative effects were found to be the losses in organic carbon and total nitrogen.

The growth study in the greenhouse experiment also showed variations only among the treatments. The best growth was found to be in the mixed treatment where optimum condition was attained by mixing all the different Guie affected and unaffected soils.

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INTRODUCTION AND LITERATURE REVIEW

In most tropical and sub-tropical regions shifting cultivation is a common practice and it often involves land clearing for cultivation by burning the vegetation. This practice has a number of local names among which Tana Baker in China; Rab and Jhuming in India; Chitemene in Zimbabwe and Milpa in Central America are terms used. Under increased pressure the system leads to the disappearance of forest or woodland in favour of savanna grassland (Nye and Greenland, 1960).

In the central highlands of Ethiopia, a traditional soil management practice similar to shifting cultivation is employed to improve ferrility related soil problems. The practice is locally referred to as "Guie" and it involves burning of soil along with some organic substances. The predominont crop on most "Guie" soils is barley which is grcwn invariably following soil burning (hereafter referred to as "Guie") and depending on local conditions the same crop of barley or horse bean or wheat may be grown in the second year. The burnt soil results in high yields of barley the first year up to 30 quintals per hectare but yields are drastically reduced the second year and on the majority of the "Guie" soils the land is not cropped the third year (Tesfaye and Dagnatchew, 1973). The high yield following "Guie" could result from a number of modifications in soil chemical and physical properties as well as other indirect advantages. Some of the positive influences of "Guie" are considered to be:

i. The mineralization of nutrients available for plant growth as phosphorous, ammonium nitrogin, potassium, calcium, magnesium etc.

ii. The improvement of soil physical properties as texture, drainage, aeration and water percolation.

iii. The sterilizing effect due to high temperatures which is beneficial in weed control.

The soils under "Guie" are naturally fertile (Murphy, 1959). These soils occur approximately between 2,000 and 3,500 meters, (Legesse and Whermann, 1975 receiving between 1,100 and 1,500 mm annual rainfall with a yearly average temperature of 14.5°C (Gouin, 1959 - 1967). These soils are characterized by their hydromorphic horizons due to their high clay content of the 2:1 type and the short rainy season (June to August) during which 70 - 80% of the rainfall occurs consequently unless subjected to "Guie", these soils are of low productivity since they have poor drainage, poor aeration, poor infiltration capacity which hamper good plant growth. The productivity of these soils is increased by "Guie" influence mainly due to the temperature effect. According to Legesse and Whermann (1975) a maximum temperature of 650°C is recorded for the interior of the "Guie" heap.

Land that has formed good sod through several years of fallow (10 to 15 years) is required for the practice since the sod ensures proper ignition. The fallow land is repeatedly ploughed (three to four times) in criss - cross direction to dislodge the turf and thereby facilitate the piling of loose soil into heaps of about 180 cms diameter and 60 cms height on the average (Whermann and Legesse, 1965).

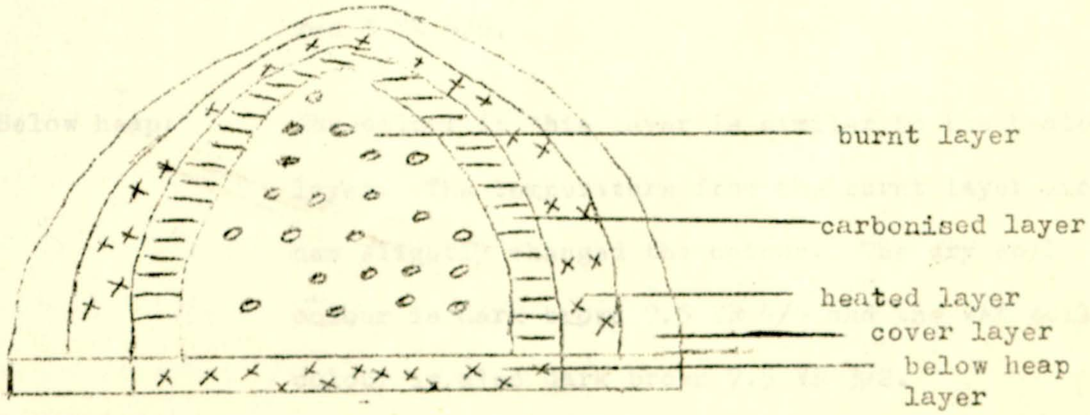
During the construction of the heaps the sod is placed towards the center and loose soil is piled on the outside to enhance thorough combustion of the organic substance by producing a more air tight condition in the interior of the heap. The heap is set afire by introducing burning cow-dung into the center of the heap and the soil is left to burn up to fourteen days (Whermann and Legesse, 1965)

A cross section of burnt heap displays distinct layers formed due to increasing temperature gradient towards the center of the heap. Whermann and Legesse (1965) have described four above ground and one below heap layers. A similar observation was made by the present author. The different layers include:

i. Cover layer
ii. Heated layer
iii. Carbonised layer
iv. Burnt layer
v. Below heap layer

The following sketch and descriptions illustrate the different layers produced by increasing temperature gradient towards the center of the heap.

Cross - section of a heap after burning



i. Cover layer: There is no change in the colour of the soil which indicates the absence of detectable heat effect on this property. Dry soil colour is dark brown 7.5YR 4/4 and the wet soil colour is also dark brown 7.5 YR 3/2*.

ii. Heated layer: A slight change in soil colour is observed due to the effect of the heat that is conducted from the burnt layer. The dry soil colour is reddish brown 5 YR 4/3, and the wet soil colour is dark reddish brown 5 YR 3/2.

iii. Carbonised layer: A very distinct change in the soil colour is observed in this layer. The burning of organic substance in the adjoining inner layer has resulted in the fumigation of this layer. The dry soil colour is black 5 YR 2/2, and the wet soil colour is also black 5 YR 2/2.

iv. Burnt layer: In the burnt layer the organic substance is totally ashed by the high temperature effect. (650°C recorded) A characterstic brick like colour is observed. The dry soil colour is reddish yellow 5 YR 6/8 and the wet soil colour is yellowish red 5 YR 4/6.

v. Below heap: The colour in this layer is similar to the heated layer. The temperature from the burnt layer above has slightly changed the colour. The dry soil colour is dark brown 7.5 YR 4/4 and the wet soil colour is also dark brown 7.5 YR 3/2.

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* Determined by Munsell Soil Colour Charts, 1954 edition.

The effect of temperature due to soil heating and/or soil burning on the chemical, physical and other soil properties as well as the response of plant growth on temperature affected soils have been studied by a number of investigators. (Bouyoucus, 1923; Sreenivasan and Aurangbadkar, 1940; Mukerjee, 1954; Nishita and Haug, 1971; Tesfaye and Dagnatchew, 1973; Sahlemedhin and Sanchez, 1978).

Various workers have demonstrated that changes in soil physical properties such as texture, water-holding capacity, aggregate stability etc. generally occur from igniting soils to high temperatures. The changes in heat of wetting, non-free water and plasticity were studied in soils ignited at 110; 230°, 485° and 800°C (Bouyoucus, 1923). The results obtained from this experiment show that these properties began to be affected at about the same initial temperature of 230°C, were greatly affected at 485°C and completely changed at 800°C.

An apparent change in the particle size distribution was observed from an experiment on the effect of oven and fire heating of black cotton soils (Sreenivasan and Aurangabadkar, 1940). In general, a marked decrease in the clay content and a corresponding increase in the contents of silt and fine sand was observed after soil heating. The results show that a change from a finer to coarser fraction is positively correlated with increasing temperature.

The increase in permeability of heated soil is considered to be due to the increase in the non-capilary pore volume brought about by the aggregation of soil particles (Rar and Wadhawan, 1953). A similar result was obtained from a study of the changes in porosity, pore size distribution and pF water relation in soils heated at various temperature levels (60°, 150°, 225°, 360°, 600°, 800° and 1000°C). From this work permeability was found to bear a linear relationship to non-capillary porosity (Rao and Ramacharlu, 1955).

The variations in the rate of water evaporation from the above heat treatments indicated that the evaporation time curve was increased with increase in temperature. The higher rate of evaporation from heated sorts is attributed to the aggregation of sort particles, increase in non-capillary pores and a predominance of coarser particle size (Ramacharlu, 1956).

Dry and wet sieve analyses were carried out for unheated soils and soils heated at the above temperature levels to determine the changes in the water stabilities of soil aggregates from the heat treatments (Rao and Ramacharlu, 1957). The curves for heated and unheated soils under dry sieving were similar while those for the wet sieve analysis showed distinct deferences, the curve for the heated soil being higher than the non-heated soil. This suggests that temperature promotes the stability of aggregates already present in unheated soil. (Rao and Ramacharlu, 1957).

A study on soils heated at various temperatures(100°, 200°, 300°, 400°, 600°, 800° and 1000°C) showed that the particle size distribution remained unchanged until the heating temperature was in 300° to 400°C range (Nishita and Haug, 1971). The sand fraction increased while the silt and clay fractions decreased above this temperature range.

A similar result was obtained by Sahlemedhin and Sanchez (1978) for soils heated at different temperatures (100°, 200°, 400° and 600°C). The particle size distribution was not affected up to 200°C where as at 400° and 600°C the sand content increased and the clay content decreased sharply. These changes were found out to be more

Pronounced in soils with higher initial clay content. The Vertisol with 55% clay changed to sand; the Amorphous soil with 49% clay changed to a loamy sand and the Ultisol with 32% clay changed to sandy loam when heated to 600°C.

On the basis of X-ray diffraction analysis, differential thermal analysis and infra red absorption spectrometric analysis the above investigators found an irreversible conversion of mineral structure at higher temperatures (400° to 600°C). Heating soil at 200°C does not have a significant effect on clay mineralogy except for removal of absorbed free water, but heating at 400° and 600°C results in removal of structural hydroxyls which is followed by collapse and disintegration of crystalline minerals.

There was a rise in pH values as the temperature rose to above 200°C on soil heating. At lower temperatures there were no change in pH values as demonstrated by a study on the prolonged heating of some soils at 50° and 100°C for six months (Rotini, Lotti and Baldacci, 1963). From the work of Nishita and Haug, 1971; the pH for all soils studied dropped to a minimum at 200°C but progressively increased above this temperature. The drop in pH at 200°C has been explained by the authers to be mainly due to the formation of oxides (Fe & Mg oxides Progressive increase in pH above 200°C is said to be from dehydration effect and mineralization of nutrients from organic and inorganic sources by increasing the solubilities of mainly cations as calcium, magnesium and potassium etc. (Steenkamp, 1978).

According to the works of many investigators a decrease in cation exchange capacity is a consistent trend in heated soils. The work of Rotini et al (1963) showed that the soils heated at 50°C and 100°C had a remarkable decrease in the cation exchange capacity. This change was rapid for high clay soils but gradual for low clay soils (Nishita and Haug, 1972). The main cause for decrease in the cation exchange capacity seems to be the decomposition of humus and transformation of clays as the loss in organic matter and the fusion of clays to sand sized particles to reduce surface area positively correlates with the decline of the cation exchange capacity in heated soils.

One of the most important benefit of soil heating is reported to be an increase in the availability of some nutrients such as phosphorous, calcium, magnesium, ammonium etc. A study on the effect of light and hot burning on nitrogen and phosphorous contents in soils indicate a difference in the degree of change at lower and higher temperatures (Vlamis, J. and K.O. Gowans, 1961). An initial high increase in phosphorous (10 fold) was obtained from the "light" burning where as nitrogen showed less increase (4 fold) from the same treatment. From the hot burning the nitrogen increased by 8 fold while the phosphorous showed no change and remained 10 fold as in "light" burning. This finding is explained by the greater release of phosphorous at elevated temperatures due to the decomposition of the less heat resistant organic phosphorous compounds which is unlike nitrogen, Thus the high mineralization of phosphorous from organic sources is demonstrated from their findings.

The improvement of soil fertility by the application of heat was investigated by other workers. Among these Mukerjee (1954) using pot experiments compared the effect of pre-heating soil and latter addition of organic matter with that of pre-heating of soil into which dung has been incorporated. The results obtained show that the soil heated in which dung is incorporated had higher phosphate content. As the only difference between the treatments was the addition of the dung, the higher phosphate content was attributed to the mineralization of phosphate due to heating the dung.

From an experiment on "Guie" Whermann and Legesse (1965) found that the available phosphorous in the top soil (unaffected) was too low (0.5 ppm.) to result in high yield. After Guie the center of the heap (the burnt layer) had a relatively very high content (75 ppm) which is the mineralization product of about 50% of the organic phosphorous of the heap.

Sahlemedhin and Sanchez (1978) compcred available phosphorous content of three soils (a Vertisol, an Amorphous soil and an Ultisol) at different temperature levels (100°, 200°, 400° and 600°C). In all three soils, the increase was significant at and greater than 200°C. The amorphous soil with the lowest initial available phosphorous and high organic matter showed the highest increase of all the three at 400°C. The Ultisol at 400°C. The peak in the phosphorous content of the amorphous soil with high organic matter is explained to be due to the transformation of organic phosphorous into inorganic form at temperatures equal to or greater than 400°C as explained by Mehta (1965).

From the study on the changes in phosphorous availability by phosphorous fractionation analysis, aluminium phosphate, iron phosphate, calcium phosphate and occluded iron phosphate were reduced whereas occluded aluminium phosphate was not affected by temperature effects (Legesse and Whermann, 1975). The reduction in the above forms might be due to the increase in solubility mainly by the adjustment in pH to more favourable higher values.

Loss in organic matter and total nitrogen from soil burning is reported by many investigators. There is a close correlation between the loss in organic carbon and total nitrogen since most of the nitrogen in the soil is in organic form. Table I illustrates the values of organic carbon and total nitrogen as affected by soil burning. The loss of total nitrogen due to burning ranged from a low value of about 50% (exceptional) to a high value of 93% while that of organic carbon was close to 90%. Thus in both cases, one can say that close to 90% of both total nitrogen and organic carbon are destroyed. The calculated C/N ratio shows a slight increase which is indicative of the greater loss of nitrogen than of carbon.

Table 1. Relation in loss of total nitrogen and organic carbon from soil burning

	Unburnt %	C/N*	Burnt %	C/N*	Source
Total nitrogen	0.10	14.21	0.02	15.0	Wherman and
Organic carbon	2.70		0.30		Legesse, 1965
Total nitrogen	-		-	-	
Organic carbon	2.85		0.31		Donahue, 1972
Total nitrogen	0.2667	11.21	.0186	13.28	Schimidt,
Organic carbon	2.9885		0.2471		1975
Total nitrogen	0.74	2.54	0.37	0.46	Sahlemedhin and
Organic carbon	1.88		0.17		Sanchy, 1978.

* Calculated by the present author.

According to Nishita and Haug (1972), the decomposition of organic matter starts at 100°C, the lowest temperature where effect of heating is observed. The nitrate level decreases above 100°C and it becomes undetectable in the 200 - 250°C range which is claimed to be the temperature level for the complete decomposition of organic matter. Unlike the above results, Sahlemedhin and Sanchez (1978) found that organic matter was almost eliminated at the elevated temperature of 400°C.

Ammonium nitrogen however, tends to accumulate after exposure to high temperatures which probably is due to the slow down of the conversion of ammonium to nitrate after the destruction of nitrifying organisms (Mukirjee, 1954). In the case of "Guie" where the decomposition of organic matter occurs at the interior of soil heaps, the ammonia gas so released would be adsorbed at the exchange sites of the less heat affected outer layers as plant available exchangeable ammonium ions. In the burnt layer of the heap the organic matter should be destroyed 650°C and thus the lowest ammonium nitrogen (30 p.p.m) is reported (Whermann and Legesse, 1965). The high ammonium in the heated second layer (540 p.p.m) implies the adsorption effect as explained above. From an incubation experiment which showed high ammonium requirements the same investigators reasoned that the high need for ammonium could not be satisfied by the mineralization of nitrogen alone and thus the adsorbed ammonium nitrogen must have been used.

The nutrients held on structural edges and surfaces in exchangeable form are released as a result of soil heating. The availability of these nutrients might even be increased and the decrease in the exchangeable cations does not reflect loss by itself. From a study on the effect of heating black cotton soils a decrease in calcium and magnesium and an increase in sodium and potassium was reported

(Sreenivasan and Aurangabadkar, 1940).

The effect of temperature and moisture on exchangeable potassium was investigated by Burns and Barber (1965). Their results showed that an increase in temperature caused a higher level of exchangeable potassium. Mukerjee (1954), however reported a reduction in total potassium and an increase in available potassium from soil heating.

Much of research on "Guie" has focused on the laboratory study of the chemical and physical changes arising from the practice. Donahue (1972) compared burnt and unburnt fallow near Sagure (Arssi). Soil burning increased the pH from 5.85 to 7.10; available phosphorous from 38.1 to 184.5parts per million; total carbonate from 0 to 20% and it decreased organic carbon from 2.85 to 0.31%.

Schmidt (1975) studied the surface 5 cms soil under "Guie" heap and unburnt soil and reported that the pH increased from 6.0 to 6.5; the organic matter was reduced from 5.2 to 0.43%; the total nitrogen decreased from 0.2667 to 0.0186; where as the available phosphorous increased from 35 to 347 p.p.m. and available potassium rose from high to very high.

The works by Sahlemedhin and Sanchez refered above previously studied chemical, physical and mineralogical changes by heating different soils at various oven temperatures to simulate the "Guie" condition.

Soil fertility studies and the search for proper cultural practice to replace "Guie" are limited. The major work in this aspect which includes both the fertility and drainage problems, is being tackled by the Department of Soil Science of the institute of Agricultural Research.

(The trials have started at Sheno in 1968). Their study at Sheno substation includes yield trials with various level of fetilizers and different methods of land preparation like cambered beds, mold board and disc plough to observe effects in facilitating drainage. Results so far indicate that positive response in grain yield from the application of 60 - 60 kg/ha ($N-P_2O_5$). Such high yield were made possible with the provision of adequate drainage through deeper ploughing or planting on cambered beds (Mesfin Abebe, 1979).

Tesfaye and Dagnatchew (1973) conducted pot experiment and field trials on "Guie" soil of Debre Berhan area. A preliminary study indicated that poor internal drainage and deficiency of mainly nitrogen and phosphorous were the major problems of these soils. Lime application showed no significant response. From the field fertilizer trials the highest yield was produced by the 60 - 60 - ON - P_2O_5 - K_2O kg/Ha treatment followed by 40 - 60 - 0 kg/Ha. When the response of barley to individual fertilizer was considered, the yield from phosphorous application was more than nitrogen (Tesfaye and Dagnatchew, 1973).

A similar field fertilizer trial was conducted to compare yield from soil burning and fertilizer applications (Legesse and Whermann, 1975). The results showed that 90 - 80 - 60 kg/Ha of $N-P_2O_5-K_2O$ application increased the yield by about 2.7 fold above that of the "Guie" yield (33.3 quintal/hectar for 90 - 80 - 60 kg/Ha of N - N - P_2O_5 - K_2O and 9.2 quintal /hectar for Guie)

Possible variations among "Guie" soils in their inherent properties as well as the changes that occur due to burning have not so far been considered in works done on "Guie". The release and loss of nutrients, and the improvement of the physical condition of the soils under "Guie" practice in different localities must be understood to provide a wider knowledge of the mechanisms that are taking place as a result of soil burning.

The results from earlier experiments on the influence of "Guie" on soil chemical properties show that there are marked differences between soils of different areas. The changes in pH, organic matter, phosphorous, nitrogen due to "Guie" application from different experiments conducted by independent workers is illustrated in Table 2.

Table 2. Some Chemical Analysis of soils after "Guie"

Place	pH (H_2O)	% organic matter	% Total Nitrogen	Phosphorous ppm	Source
Legebri	6.3	-	0.02	75	Whermann and Legesse, 1965
Sagure	7.1	0.54	-	184.5	Donahue, 1972
Debre Berhan	5.8	-	-	low	Tesfaye and Dagnatchew, 1973
-	6.3	0.43	0.02	347	Schmidt, 1975
Sheno	6.3	0.07	-	570	Sahlemedhin and Sanchz, 1978

Such variations in chemical properties might arise from many possible sources. This study was aimed at finding any possible changes which may be induced by "Guie" in three separate localities. Laboratory and greenhouse experiments were carried out in order to investigate whether there are variations in the effect of "Guie" in these different localities. These are some of the questions which this study attempts to answer.

i. The major "Guie" areas in northern Shoa have almost similar climatic conditions and cultural practices. Are there any variations in the "Guie" changes in these localities?

ii. If there are any variations do they show any influence on crop growth under the same green house conditions?

iii. Do these variations manifest a threat to land deterioration as a result of "Guie"?

Legesse and Whermann (1975) estimated that about 540,000 hectares are under "Guie" practice every 10 years. Figure 1 shows the distribution of "Guie" in Ethiopia and Figure 2 shows the major "Guie" area in Northern Shoa where the three sites for the present experiment were identified.

A comparative study on the effect of "Guie" in the different localities was carried out to evaluate the changes that occur in the physical and chemical properties as well as the nutritional potentials of these soils in greenhouse studies. The study involved chemical and physical analysis of soil samples from the three localities and a green house experiment to assess if local "Guie" variations show differences in growth response as well. The results from the laboratory

Die Verbreitung des „GUIE" in Äthiopien

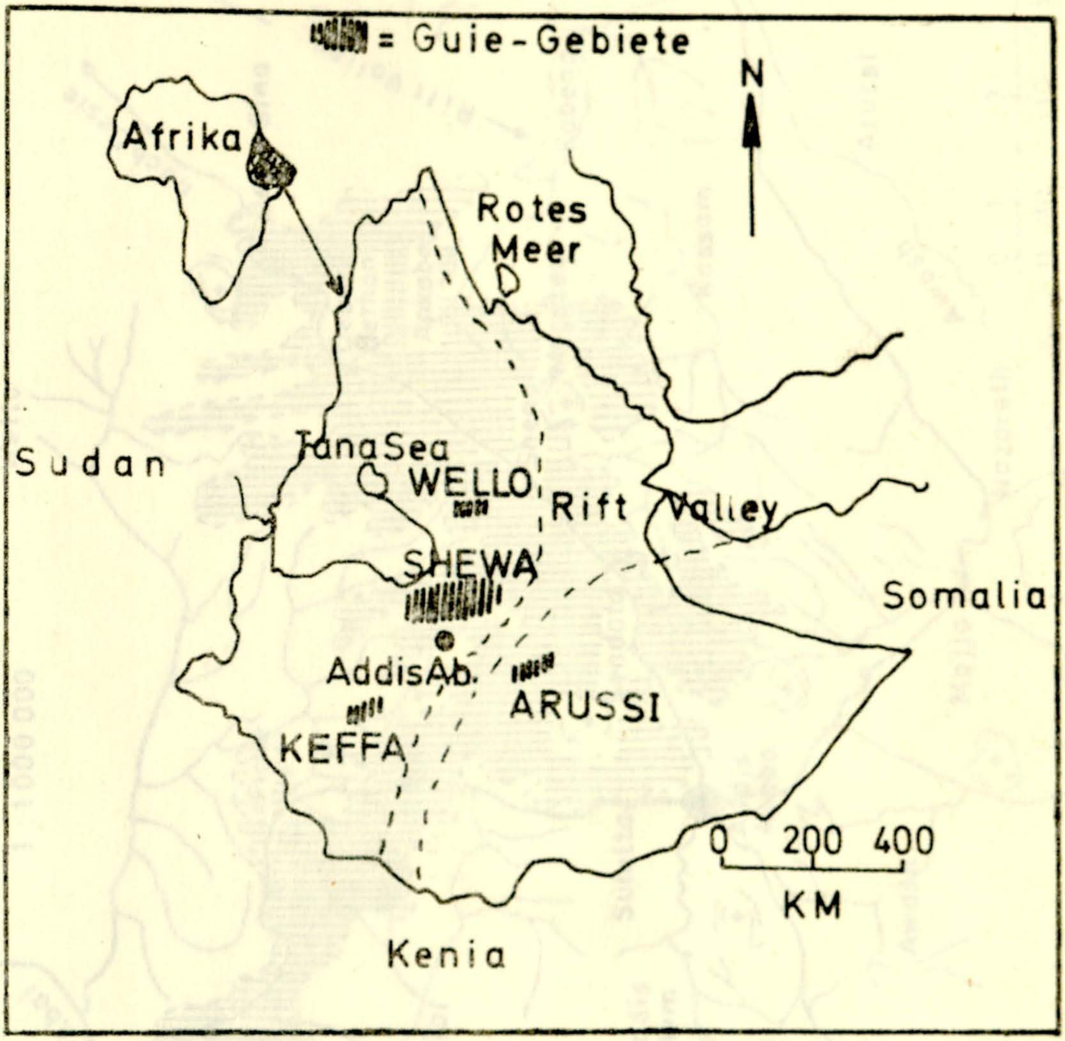
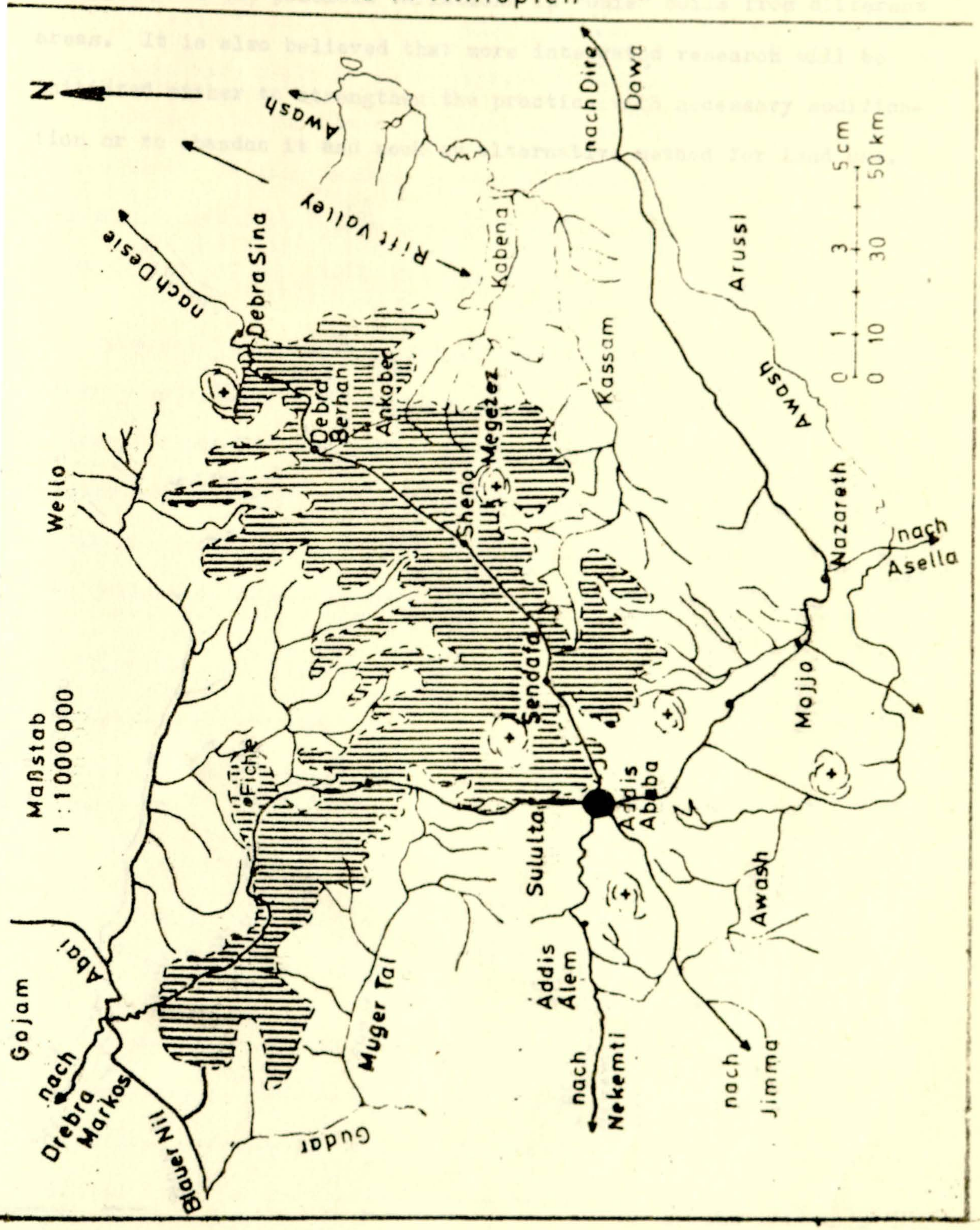


FIGURE 1: Distribution of"Guie" in Ethiopia (from Legesse and Whermann, 1975

Verbreitung der Guie-Standorte im Hochland der Shewa-Provinz in Äthiopien



2: Distribution of 'Guie" in Northern Sheoa (from Legesse and Whermann, 1975) and green house studies are expected either to verify or nullify the hypothesis on the possible variations in "Guie" soils from different areas. It is also believed that more integrated research will be initiated either to strengthen the practice with necessary modification or to abandon it and seek on alternative method for land use.

Material and Methods

A preliminary survey was done along the main highway from Addis Ababa to Debre Sina and from Addis Ababa to Fitche. The relative frequency and abundance of the "Guie" heaps were compared and the three sites were selected to be representative and also resonably for apart for the objective of this study. The three selected localities were: 1) near Sendafa (about 30 kms north east of Addis Ababa), 2) near Debre Berhan (about 123 kms north east of Addis Ababa), and near Fiche (about 134 kms north of Addis Ababa).

From each site soils from different layers of a "Guie" heap and non-heap soils were sampled. All in all seven different samples were collected from six "Guie"fields in the three selected sites. The samples from adjoining fields were mixed which gave one representative sample per area. Thus, a total of twenty one samples seven per site were collected. These included samples from

1. The cover layer
2. The heated layer
3. The carbonised layer
4. The burnt layer
5. The below heap
6. The between heap
7. The ploughed (fallow)

The soil preparation for the physical and chemical analysis was made according to Jackson (1973). It involved air drying at room temperature, grinding by mortar and pestle, and sieving through 2 mm sieve (10 to 20 meshes per inch) by a mechanical shaker. The prepared samples were stored in plastic cans. As needed, sub-samples were finaly ground (35 mesh) for the various determinations.

The analytical study on the chemical and physical properties was done at the Institute of Agricultural Research (IAR) laboratory at Holetta and the greenhouse experiment was conducted at the Institute of Pathobiology of Addis Ababa University.

2.1 Greenhouse Experiment

The pot arrangement for the greenhouse experiment was according to the completely randomized design which is most efficient in situations of little variability among the experimental units associated with position in the experimental area (Little and Hills, 1978). The only source of variation for this experiment was the soil variation due to locations and heating temperatures of the "Guie".

In each pot 700 gm of air dry soil was used to grow the test crop, a Sheno local barley. The seeds were obtained from the barley breeding unit of Institute of Agricultural Research station at Holetta.

The treatments per site were eight and the experiment was done in three replicates. The eight treatments per site include 1) cover soil 2) heated soil 3) carbonised soil 4) burnt soil 5) under heap soil 6) between heap soil 7) ploughed soil and 8) a 1:1 mixture by weight of the above seven.

Fifteen barley seeds were planted on the same date and a number of growth parameters were measured at different intervals during the experiment. These included emergency percent, stem height, tillering, heading (time and number), and weight (fresh and dry).

The emergency count was done at four different dates; four, five, six, and fourteen days after planting beyond which these was no further emergence. The percent emergency was calculated out of the fifteen s seeds originally planted for each date. Likewise the tillering and heading percent was compared for the various treatments by finding the percentage from the total planted per pot.

The stem height measurement was done on three randomly selected plants at nine different intervals up to the ceasation of heigher increase; i.e. 20, 24, 30, 58, 63, 72, 76, 81 and 92 days after planting.

The plants were harvested at three different stages of growth. The first group of randomly selected three plants at tillering stage; the next group of randomly selected three plants at heading stage and the remaining plants at the end of the experiment when they were dry. Their fresh weight was recorded and after oven drying at 105°C for 24 hours the dry weight was measured.

The visual weed score was determined 58 days after planting. This was followed by continuous weeding until the final harvest in order to avoid the side effects of competition which might bias the growth of barley in pots with high weed population.

2.2 Soil and Plant Analysis

Soil analysis: The soil physical and chemical analysis were made in duplicates along with a standard sample per ten analysis to check the quality of the determinations.

The dry and moist soil colour was determined with a Munsell soil colour chart. The appropriate hue, value and chroma were included.

Particle size distribution was determined by the hydrometer method (Bouyoucus, 1927) for silt and clay using calgon as a dispersing agent (FAO Soils Bulletin 10, 1970). 40 gms soil was soaked overnight with 50 ml of 10% calgon solution (mixture of 8 gm of 0.35 N sodium hexametaphosphate and 20 gms of 0.15 N sodium carbonate) to enhance dispersion. About 500 ml distilled water was added to the soaked soil and was stirred at high speed for 5 minutes with a mechanical stirrer. The dispersed solution was transferred to a 100 ml graduated cylinder and the volume made to a liter with distilled water. After a thorough mixing with a plunger the density of the soil suspension was read at 40 seconds (settling time for sand) and at 6½ hours (settling time for silt) derived from Stoke's Law. The correction for the room temperature was added to or subtracted from the particular readings and the percent sand, silt and clay was calculated from weight taken.

The total loss from ignition was determined by treating 20 gm of soil at 100°, 300°, 500°, and 800°C for 48 hours in a muffle furnace. The soils after the treatment were immediately placed in dessicator and were weighed after cooling. From the difference in weight (initial weight - final weight) the percent loss was calculated.

Soil pH was determined on a direct reading pH meter using a glass electrode with a saturated potassium chloride colomel reference electrode (FAO Soils Bulletin 10, 1970). Twenty five gm of soil was shaken in a 1:1 ratio of water and also 25 gm of soil was shaken in a 1:1 ratio of 1N potassium chloride solution. Soil pH in water and potassium chloride was read as described above.

Soil organic carbon was determined by the Walkely Black procedure (Jackson, 1973). To one gm soil 10 ml of the oxidizing agent 1N potassium dichromate and 20 ml of concentrated sulfuric acid were added to supply heat of dilution. The suspension was heated at 150°C for one minute, cooled and then about 20 ml distilled water was added. It was then filtered and ferroin indicator was added in the filterate which was titrated against 0.5 N ferrous ammonium sulphate to determine excess dichromate. The soil organic matter was calculated by multiplying the percent organic carbon with the factor 1.74, i.e. % organic matter = 1.74 x % organic carbon.

Total nitrogen in soil was determined by the Macro Kjeldahl procedure for both digestion and distillation (Jackson, 1973). About a spoonful of the copper sulphate - selenium catalyst mixture was added to 1 gm soil to which 6 ml distilled water and 8 ml concentrated sulfuric acid were added. This was digested for 30 minutes in 20, 1005 Tectator heating unit and distilled by adding 25 ml of 40% sodium hydroxide into 25 ml 2% Boric acid mixed ferroin indicator. The distillate was titrated against 0.01N sulfuric acid to a pink end point. The volume of the blank titration was subtracted from the soil titration volume and the percent total nitrogen was calculated.

Available phospherous was determined by the Olsen procedure, the chlorostanneous reduced molybdo-phospheric blue colour method in a sulfuric acid system (Jackson, 1973). It consisted of adding a spoonful of phosphate-free activated charcoal to 2 gm soil and extracting the available phosphorous with 40 ml of 0.5 M sodium bicarbonate, pH 8.5. After shaking with a mechanical shaker for 30 minutes, the soil suspension was fltered through a phosphorous free filtered paper. From the filtrate an aliquot (usually 10 ml) was pipetted, diluted to

50 ml with water and 2.5 ml of 1N sulfuric acid was added to decrease pH of the solution which reduces interference in color development. To this solution 5 ml of ammonium molybdate and 0.2 ml stanneous chloride (reducing agent) was added and intimately mixed. With 10-20 minutes the absorbance was read against a reagent blank at 720 nm on a sphectrophotometer Series 2, Unicum SP 600. The concentration was read from a standard curve, i.e. a graph of absorbance versus concentration.

Cation exchange capacity was determined by the ammonium saturation procedure (F.A.O. Soils Bulletin, 1970). It consisted of soaking 5 gm soil in 50 ml of 1N ammonium acetate solution, pH7. The soil suspension was filtered and the resedue was wahed 5 times by 30 ml of the same solution to ensure maximum replacement of the exchangeable cations by ammonium. The filtrate was reserved for exchangeable cation determination. The soil was then washed with 30 ml ethanol 4 - 6 times to remove excess ammonium. The soil was soaked over night with 50 ml of 10% potassium chloride, pH 2.5 and then if 4 times with 30 ml of the same solution to displace ammonium from the exchange site by potassium. From the leachate 10 ml aliquot was distilled by adding 5 ml of 40% sodium hydroxide and ammonia was trapped with 2% Boric acid mixed indicator. The distilate was titrated against 0.1N ammonium ferous sulfate solution.

Exchangeable cations were determined by the ammonium acetate extraction procedure (FAO Soils Bulletin 10, 1970). The filterate reserved from the cation exchange capacity determination was aspirated into an atomic absorption spectrophotometer Series 2, Unicam Sp 90, and the intensity of the absorption was measured at 589 nm for sodium, 766.5 nm for potassium, 422.7 nm for calcium and 285.2 nm for magnesium.

Calcium carbonate was determined by the calcimeter method which involved treating 10 gm. of soil with 15 ml dilute hydrochloride acid and measuring the volume of carbon dioxide which is evolved by the reaction between the soil carbonates and the acid (F.A.O. Soil Bulletin, 1970).

Plant analysis for nitrogen and phosphorous generally followed the same procedures as soils. Nitrogen analysis involved the weighing of 0.14 gm of oven dry plant sample and employing the same digesting, distilling and titrating procedures described for the soil nitrogen determination. Phosphorous determination, however, involved wet ashing for one hour in magnesium nitrate to prevent the loss of phosphorous during the ashing at 500°C. Then 0.5 gm of the ashed sample was analysed for phosphorous by the molybdenum blue method.

RESULTS

3.1 Changes in Physical Properties

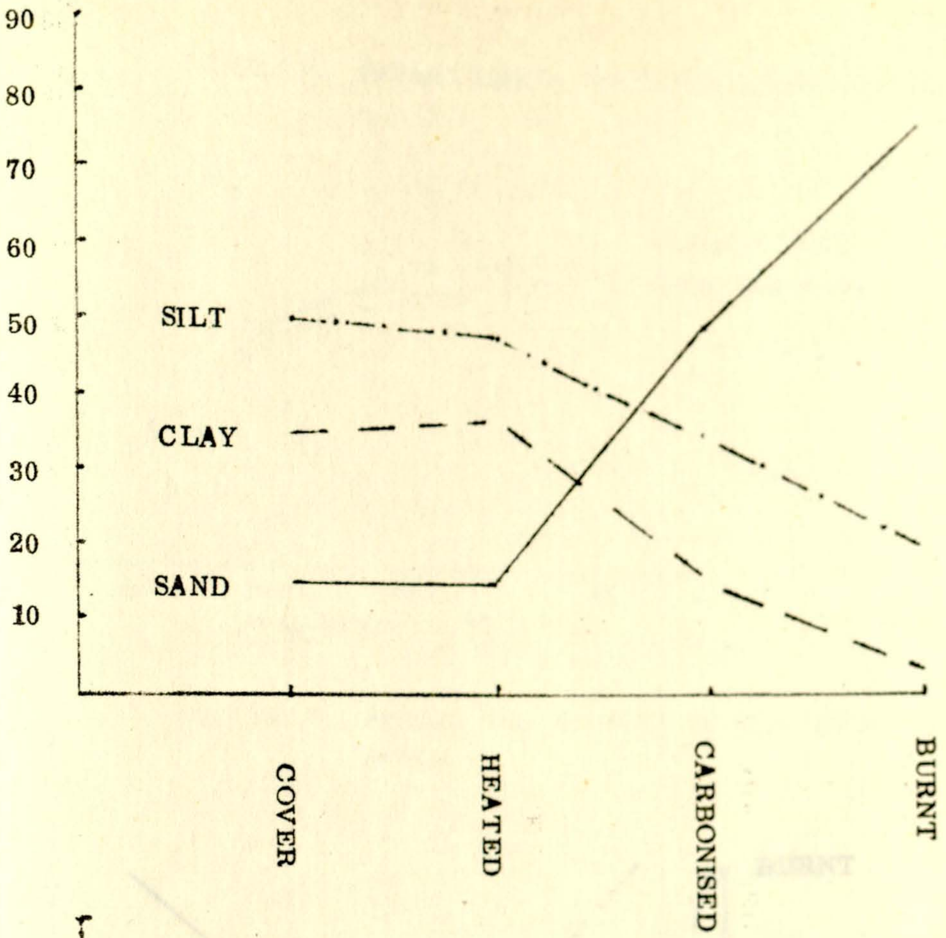
The results of the particles size distribution as a result of different heat treatment on soils from the three sites showed a similar influence in the proportions of sand, silt and clay. For Sendafa the percent sand increased from 15 in the cover to 87 in the burnt layer whereas the silt and clay percents decreased from 50 in the cover to 11 in the burnt and from 35 in the cover to 2 in the burnt respectively. For Debre Berhan the percent sand increased from 20 in the cover to 85 in the burnt while the percent silt and clay decreased from 47 in the cover to 13 in burnt and from 33 in cover to 2 in burnt respectively. For Fiche the percent sand increased from 15 in cover to 77 in burnt whereas the percent silt and clay decreased from 50 in cover to 20 in the burnt and from 35 in cover to 3 in burnt respectively. Thus a similar tendency of increase in sand and decrease in silt and clay from the outer towards the inner heap layers is observed for all three sites.

The increase in the sand sized particles in the interior layers is due to the high temperature effect and the relatively lower sand percent for Fiche as compared to Debre Berhan and Sendafa might be an indication of slight temperature difference.

The results from the ignition experiment on the below heap and ploughed soils indicate higher loss in weight for Fich soils as compared to Debre Berhan and Sendafa. For Fiche at 800°C level the percent loss in weight of the ploughed soil is 24 and the percent loss in weight of the below heap is 20. For Debre Berhan at 800°C level the

Treatment	Sendafa				Debre-Berhan				Fitche			
	Sand % 2-0.05 mm	Silt % 50-2u	Clay % 2u	Textural class	Sand % 2-05 mm	Silt % 50-2u	Clay % 2u	Textural class	Sand % 2-.05 mm	Silt% 50-2u	Clay % 2u	Textural class
A-Cover	15	50	35	Silty clay loam	20	47	33	Silty clay loam	15	50	35	Silty clay loam
B-Heated	15	48	37	Silty clay loam	12	43	45	Silty clay	15	48	37	Silty clay loam
C-Carbonised	58	34	8	Sandy Loam	48	41.0	11	Sandy Loam	50	35	15	Loam
D-burnt	87	11	2	Sand	85	13	2	Loamy sandy	77	20	3	Loamy Sand
E-Below Heap	16	44	40	Silty Clay	18	45	37	Silty Clay loam	25	43	32	Clay Loam
F-Between Heap	18	37	45	Clay	18	47	35	Silty Clay loam	29	37	34	Clay loam
G-Ploghed	14	49	37	Silty Clay loam	15	44	41	Silty Clay	28	40	32	Clay loam

FIGURE: 3: Particle size distribution of Fiche as affected by "Guie"



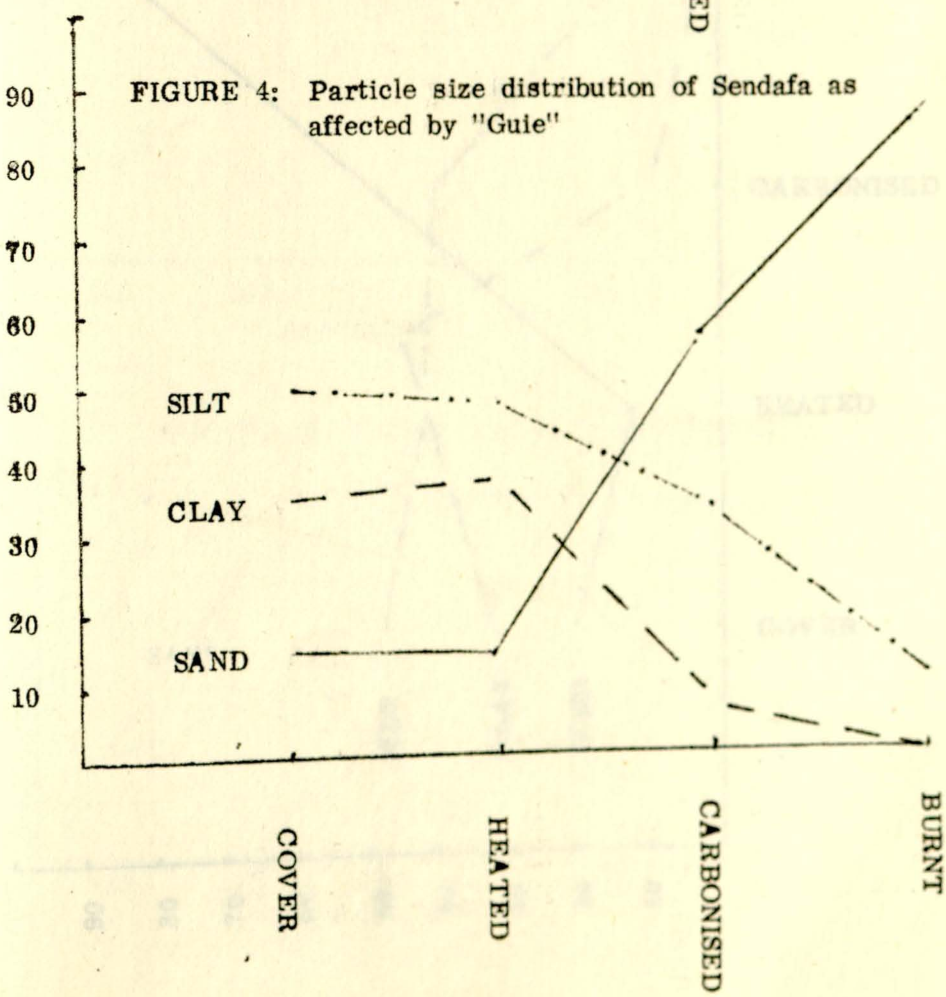


FIGURE 4: Particle size distribution of Sendafa as affected by "Guie"

FIGURE 5: Particle size distribution of Debre Berhan as affected by "Guie"

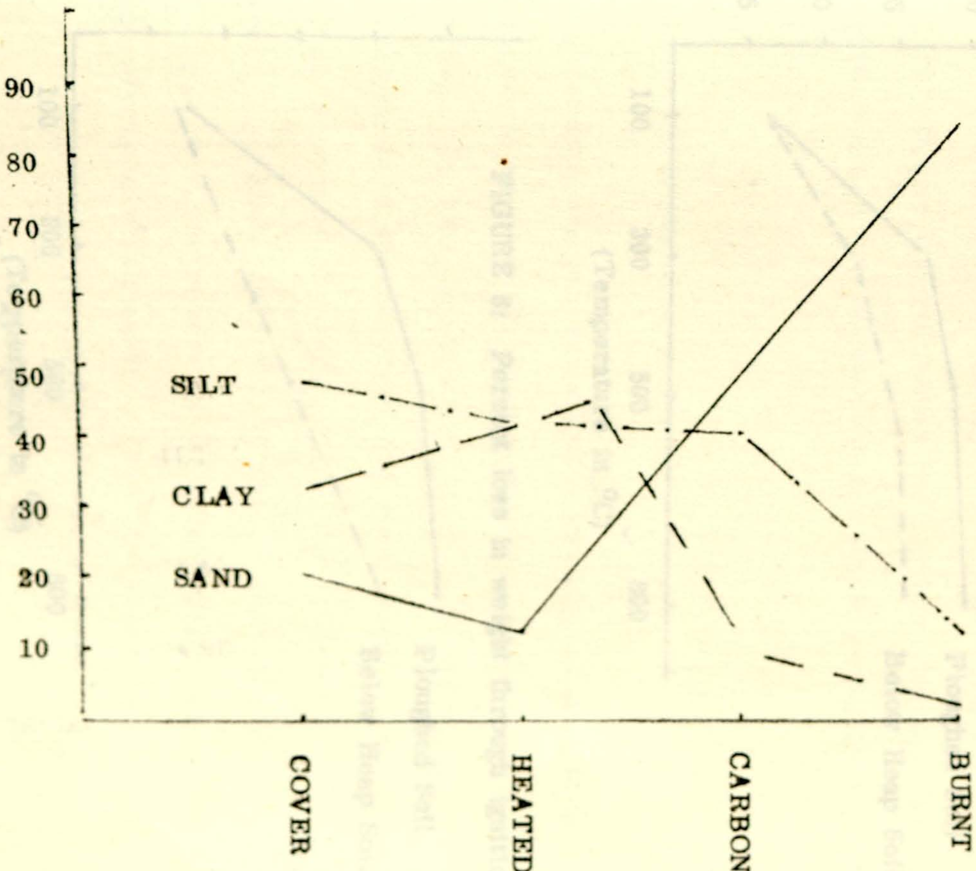


FIGURE 6: Percent loss in weight through ignition for Sendafa

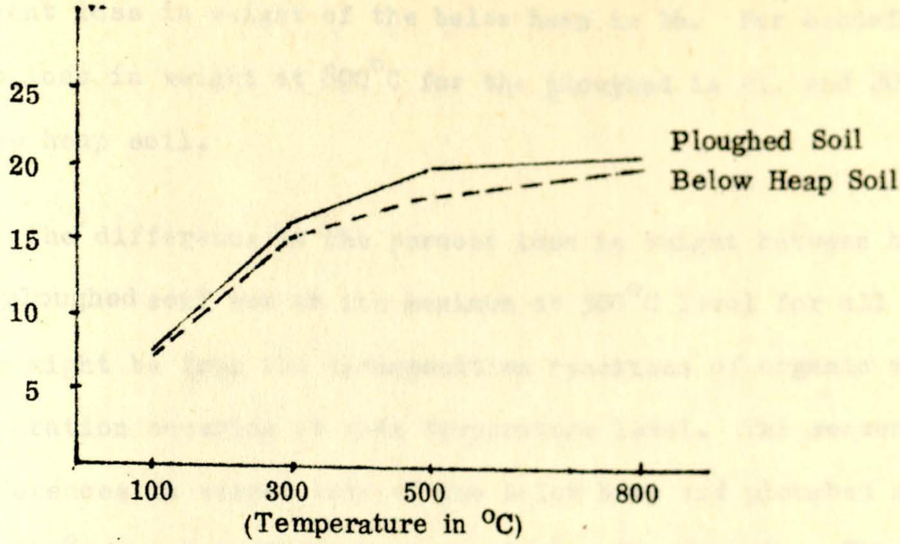


FIGURE 7: Percent loss in weight through ignition for Debre Berhan

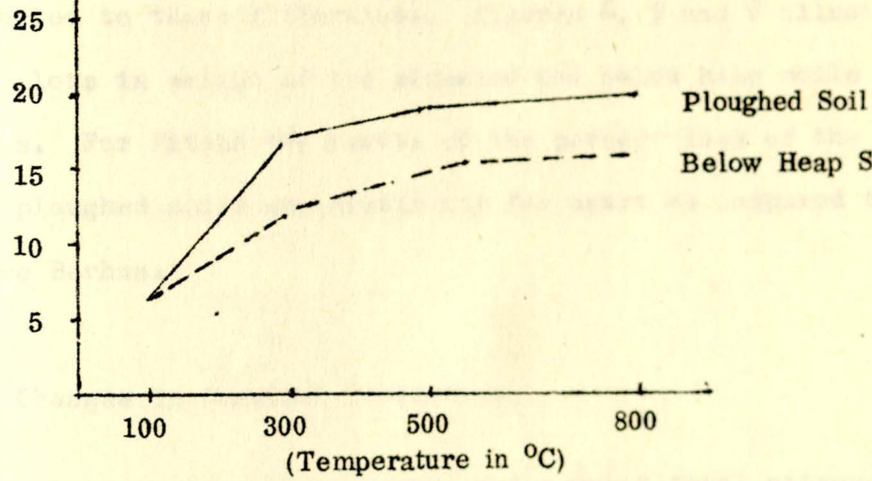
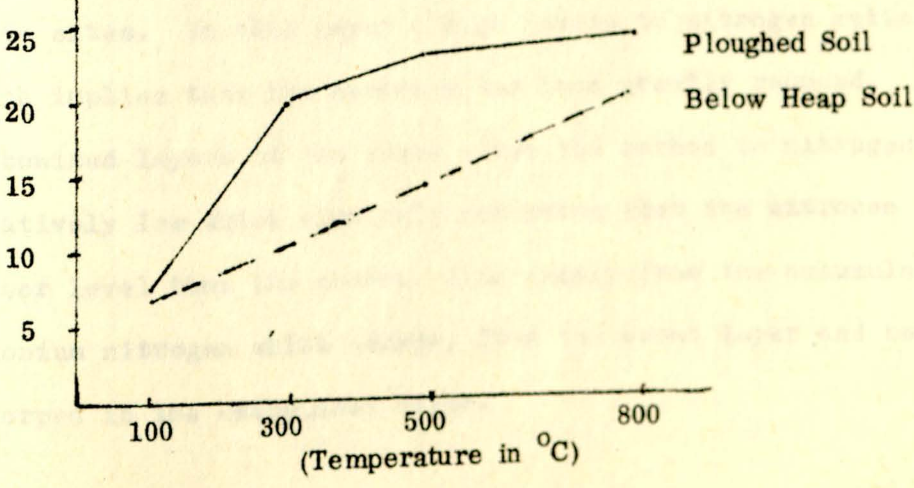


FIGURE 8: Percent loss in weight through ignition for Fiche



percent loss in weight of the below heap is 16. For Sendafa the percent loss in weight at 800°C for the ploughed is 21. and 20 for the below heap soil.

The difference in the percent loss in weight between below and the ploughed soil was at its maximum at 300°C level for all three sites. This might be from the decomposition reactions of organic matter and dehydration occuring at this temperature level. The sequence for the differences in weight loss of the below heap and ploughed soils except the 800°C level is Fiche > Debre Berhan > Sendafa. The duration of the "Guie" and the organic matter content of the soils might have contributed to these differences. Figures 6, 7 and 8 illustrate the percent loss in weight of the ploughed and below heap soils of the three sites. For Fitche the curves of the percent loss of the below heap and ploughed soils are distinctly far apart as compared to Sendafa and Debre Berhan.

3.2 Changes in Chemical Properties

The percent organic carbon and percent total nitrogen also follow the same trend as both are highly reduced in the burnt layers of the three sites. In this layer a high carbon to nitrogen ratio is observed which implies that the nitrogen has been greatly reduced. In the carbonised layers of the three sites the carbon to nitrogen ratio is relatively low which similarly indicates that the nitrogen is at a higher level than the cover. This mainly from the accumulation of ammonium nitrogen which escapes from the burnt layer and becomes adsorped in the carbonised layer.

Table 4. Total Nitrogen, Organic Carbon and Available Phosphorous as affected by "Guie"

	SENDAFA				DEBRE BERHAN				FICHE			
	Organic Carbon %	Total Nitrogen %	C/N	Available Phosphorous (ppm)	Organic Carbon %	Total Nitrogen %	C/N	Available Phosphorous (ppm)	Organic Carbon %	Total Nitrogen %	C/N	Available Phosphorous (ppm)
A Cover	2.95	0.30	9.83	24	3.09	0.30	10.30	25	5.01	0.42	11.93	42
B Heated	3.84	0.38	10.11	34	4.37	0.44	9.93	68	4.03	0.49	8.23	87
C Carbonised	2.62	0.38	10.38	184	2.09	0.32	6.53	69	2.78	0.40	6.95	53
D Burnt	0.69	0.06	11.50	168	0.14	0.01	14.0	82	0.39	0.03	13.0	136
E-Below Heap	3.38	0.35	9.66	25	2.38	0.19	12.53	19	2.82	0.37	7.62	37
F-Between Heap	3.09	0.33	9.36	25	2.02	0.24	8.42	21	4.23	0.40	10.58	78
G-Ploughed	4.08	0.41	9.95	42	2.97	0.29	10.24	37	4.44	0.42	10.57	41

The results for the available phosphorous analysis showed a remarkable increase in the burnt and carbonised layers. Fiche soils with an initial available phosphorous content of 42 changed to 136 ppm (parts per million) as compared to Sendafa soils which increased from 24 to 188 ppm and Debre Berhan soils which increased from 25 to 82 ppm. In the carbonised layer Sendafa has the highest (184ppm) followed by Debre Berhan (69 ppm) and Fiche (53 ppm).

The changes in the exchangeable cations (Na, K, Ca and mg) as a result of "Guie" is not consistent for the three areas. For soils from Sendafa sodium seems to be unaffected whereas potassium, calcium and magnesium have increased through burning. This is evident from the steady increase in the relative percent of the sum of exchangeable cations from the outer towards the center of the heap. The change in the exchangeable cations for soils from Debre Berhan is clearly seen in that Na and K show a marked increase where as Ca and mg show a marked decrease. mg and Ca showd an initial increase in heated layer and then declining in the carbonised and burnt layers. A lower relative percent of 63 for the sum of exchangeable cations in the burnt layer of the same site indicates the decrease in the diavalent (Ca and mg) cations which out weigh the increase of the monovalent cations (Na and K). For Fiche a decrease in Na, Ca and mg is observed while K shows an increase from the "Guie" effect (Table 5). The burnt layer of Fiche soil showed the lowest percentage exchangeable cations.

It is also observed that the below heap layer especially for Fiche (Rel % of cover 86) are low values following the Rel% value for burnt layer in both sites. The implication being that they are affected from the "Guie" on top of them.

Table 5. Exchangeable Cations in meq/100 g soil as affected by "Guie"

	SENDAFA						DEBRE BERHAN						
	Na	k	Ca	Mg	Sum	Rel.%	Na	K	Ca	Mg	Sum	Rel.%	Na
A-Cover	0.06	1.01	13.65	2.34	17.06	100	0.05	0.92	18.60	4.18	23.75	100	0.1
B-Heated	0.04	0.85	18.45	3.08	22.42	131	0.10	0.92	24.00	4.80	29.82	126	0.1
C-Carbonised	0.08	0.93	23.15	3.47	27.67	162	0.11	2.34	18.00	2.15	22.6	95	0.1
D-Burnt	0.05	3.12	20.55	2.95	26.67	156	0.27	3.30	9.60	1.84	15.01	63	0.0
E-Below Heap	-	1.06	16.20	2.91	20.17	118	0.15	0.66	16.20	3.30	20.31	86	0.1
F-Between Heap	0.04	0.95	16.80	3.28	21.07	124	0.05	0.85	18.00	3.85	22.75	96	0.1
G-Ploughed	0.04	0.94	18.60	3.47	23.05	135	0.07	0.95	19.20	4.35	24.57	103	0.1

The cation exchange capacity of the cover is almost equal for all the three sites. An increase in cation exchange capacity over the cover is found in the heated layer which might be due to the slight increase of clay sized particles in this layer. In contrast the lowest C.E.C. values for all three sites was found to be in the burnt layer. A high drop in the cation exchange capacity is observed for Debre Berhan from 37.5 to 13 meq/100 gm soil (milli equivalent per hundred gram) where the drops for Fiche was 36 to 8 meq/100 gm soil and for Sendafa from 38 to 21 meq/100 gm soil. These comparative changes in the cation exchange capacity are more illustrated from the relative percent values.

Table 6. Cation exchanges capacity in meq/100g soil as affected by "Guie"

	Sendafa		Debre Berhan		Fitcho	
	meq/100g	Rel. %	meq/100g	Rel. %	meq/100g	Rel.%
A-Cover	37.5	100.0	37.5	100.0	36.25	100.0
B-heated	46.5	120.4	47.5	127.0	42.5	117.0
C-Carbonised	26.0	70.0	17.5	46.6	22.5	62.0
D-Burnt	21.25	57.0	12.5	30.6	17.5	48.0
E-Below Heap	33.5	89.4	35.0	93.6	38.75	107.0
F-Between Heap	32.5	86.6	37.5	100.0	33.75	93.0
G-Ploughed	37.5	100.0	30.0	80.0	35.0	96.4

The changes in pH, conductivity and carbonates values showed an increase with increasing temperature gradient similarly for all three sites. Considering the change in pH the soils from Fiche with the

Table 7. pH, Electrical conductivity and total carbonates as affected by "Guie"

	SENDAFA				DEBRE BERHAN				FICHE			
	pH H_2O	pH Kcl	Conduct mmhos/cm	Carbonates %	pH H_2O	pH Kcl	Conduct mmhos/cm	Carbonates %	pH H_2O	pH Kcl	Conduct mmhos/cm	Carbonates %
A-Cover	5.58	4.43	0.30	0.04	5.80	4.60	0.30	0.06	4.90	4.00	0.37	0.09
B-Heated	5.93	4.74	0.49	0.06	5.85	4.8	0.62	0.09	5.98	4.77	.42	.06
C-Carbonised	6.25	5.20	0.93	0.13	6.35	5.33	0.76	0.07	5.88	4.60	0.83	0.10
D-Burnt	6.45	5.30	0.76	0.19	6.05	4.95	0.47	0.27	6.08	5.0	0.51	0.13
E-Below Heap	6.08	4.90	0.43	0.06	5.65	4.45	0.59	0.07	6.18	5.05	0.61	0.06
F-Between Heap	5.03	4.55	0.38	0.04	5.90	4.65	0.37	0.48	5.83	4.55	0.35	0.04
G-Ploughed	5.80	4.60	0.57	0.07	6.05	4.95	0.49	0.05	4.98	4.13	0.32	0.04

lowest initial pH have attained about the same values in the burnt layer as the other two sites. The pH in water of the burnt layers of Sendafa is 6.45 as compared to Debre Berhan 6.05 and Fiche 6.08. The electrical conductivity unlike the pH has reached high value in the carbonised layer for all the three sites. The sequence in decreasing order of the electrical conductivity of the carbonised layer is Sendafa (0.93 mmhos/cm) Fiche (0.83 mmhos/cm) Debre Berhan (0.76 mmhos/cm). The total carbonates are low values and show a slight increase with temperature their highest being in the burnt layers. The percent carbonate in the burnt layer are higher for Debre Berhan (0.27.%) as compared to Sendafa (0.19%) and Fiche (0.13%).

3.3 Plant Analysis

Plant analysis for the percent phosphorous content shows that the highest level is for plants grown in the burnt soils for all the three sites. The burnt layer of Debre Berhan had plants with highest phosphorous content (1.1 %) compared to Sendafa (0.97 %) and Fiche (0.77 %). On the other hand plants grown in below heap soil show a relatively low phosphorous content than all the other treatments (Sendafa 0.15 %, Debre Berhan 0.13 %, and Fiche o.15 %). The phosphorous content of the plants in the mixed layer was lower than the phosphorous content of all other soils except the below heap soils. The percent nitrogen content from the results of plant analysis shows a consistent increase from less affected to more affected interior portions of the heap soil. The most heat affected burnt layer however, has the least percent nitrogen of all, while the peak in the percent nitrogen for each site is attained in the carbonised layer. The plant nitrogen contents in the carbonised layer is 2.3 percent; 2.25 percent and 2.0 percent for Debre Berhan, Fiche and Sendafa respectively.

Table 8. Percent phosphorous and percent nitrogen contents for plants grown in greenhouse experiment

	Sendafa		Debre Berhan		Fiche	
	% P	% N	% P	% N	% P	% N
A-Cover	0.38	1.35	0.76	1.10	0.55	1.25
B-Heated	0.44	1.75	0.57	1.90	0.54	1.40
C-Carbonised	0.45	2.00	0.37	2.30	0.55	2.25
D-Burnt	0.97	1.00	1.10	1.10	0.77	1.05
E-Below Heap	0.15	1.45	0.13	2.05	0.15	1.30
F-Between Heap	0.64	1.45	0.09	1.05	0.002	1.65
G-Ploughed	0.27	1.40	0.17	1.50	0.37	1.40
H-Mixed	0.003	1.15	0.37	1.50	0.26	1.20

3.4 Plant Growth Measurements

Plant height measurement data showed no significant variation among the three sites. The mean height at 92 days after planting was 58 cms for Sendafa, 55.7 cms for Fiche and 53.5 cms for Debre Berhan. Variation among the treatments however, is marked and shows the same general trend for all sites. The maximum height for all sites was attained by plants grown in the mixed soils. The plant height of the burnt and carbonised soils follow the plants of the mixed soil and a marked retarded growth is observed in the burnt layer especially at the early growth period.

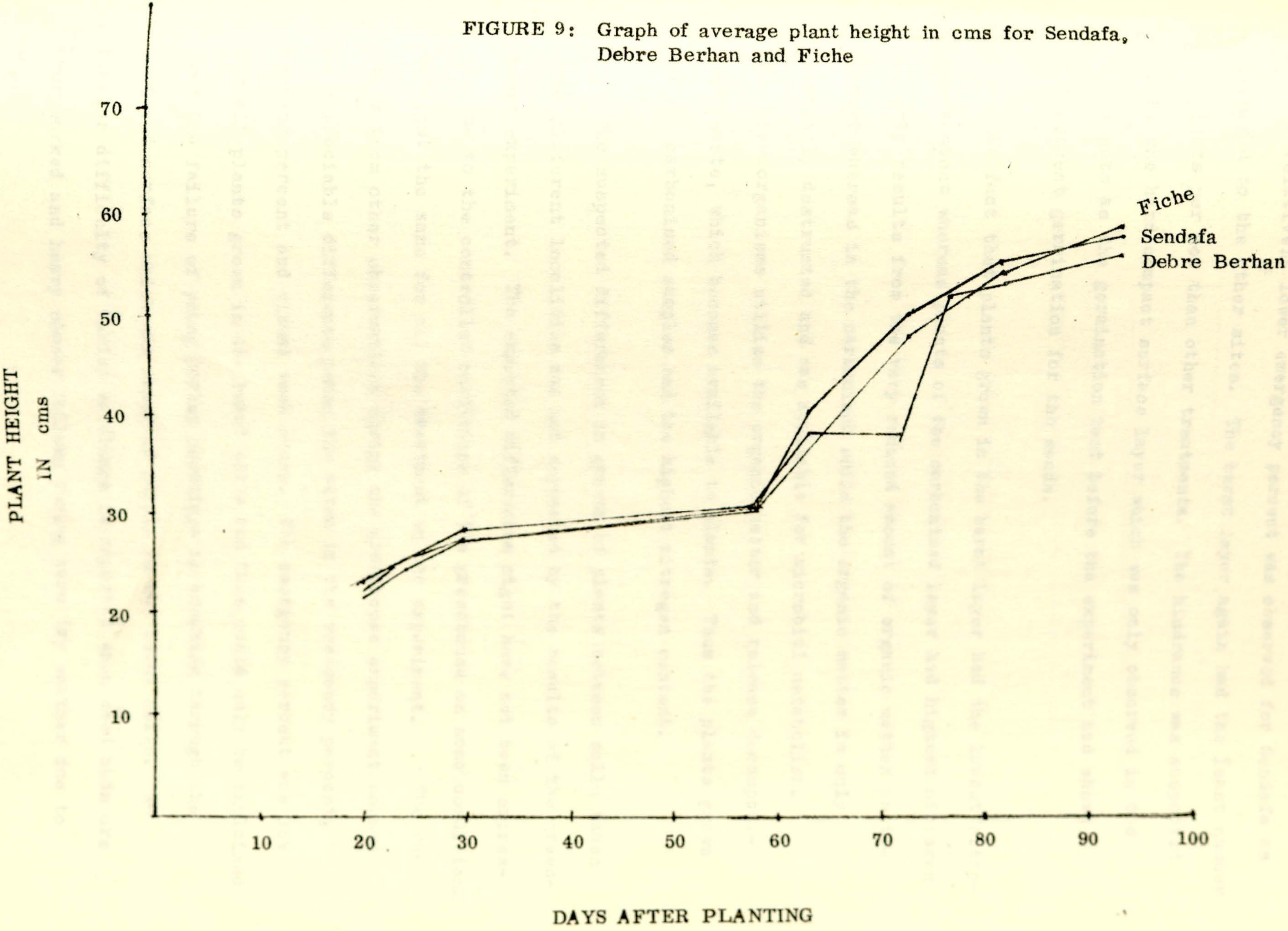
Table: 9 Height measurements of Barley in cms

	SENDAFA								
	DAYS AFTER PLANTING								
	20	24	30	58	63	72	76	81	92
A- Cover	22.8	24.9	28.5	28.8	37.4	[illegible]	56.5	58.4	58.6
B-Heated	24.2	25.5	27.2	27.7	37.5	43.6	51.3	55.1	56.8
C-Carbo-nised	24.2	31.5	33.9	34.1	45.0	56.3	58.9	59.8	59.9
D-Burnt	16.7	22.7	26.1	32.3	36.5	47.6	52.3	54.8	57.2
E-Below Heap	23.2	23.6	28.2	28.8	42.2	47.7	54.7	56.9	57.7
F-Between Heap	22.4	22.5	25.3	28.3	40.5	49.9	53.3	55.5	55.7
G-Ploughed	20.77	20.7	26.0	26.2	39.2	44.9	55.0	57.6	58.0
M-Mixed	26.7	28.9	30.9	34.0	45.0	59.5	62.0	61.8	61.9
Mean	22.6	25.0	28.3	30.0	40.4	49.9	55.5	57.5	58.2

	DEBRE BERHAN								
	DAYS AFTER PLANTING								
	20	24	30	58	63	72	76	81	92
A- Cover	19.0	21.8	25.4	31.2	32.7	32.7	48.0	48.2	48.2
B-Heated	22.2	24.8	28.5	29.1	36.6	36.6	47.2	47.7	51.9
C-Carbo-nised	19.8	23.8	28.2	31.2	40.4	40.4	56.3	57.0	58.3
D-Burnt	9.1	13.7	16.6	23.9	28.2	28.2	53.9	56.2	56.7
E-Below Heap	23.4	24.1	26.2	31.4	39.3	39.3	54.8	55.0	55.9
F-Between Heap	24.6	26.9	29.4	33.5	43.6	43.6	47.7	47.5	47.5
G-Ploughed	24.3	27.4	30.4	34.4	44.1	44.1	45.7	46.1	47.4
M-Mixed	25.6	29.2	31.7	34.0	40.1	40.1	61.8	61.9	61.9
Mean	21.0	24.0	27.0	31.0	38.1	38.1	51.9	52.8	53.5

	DAYS AFTER PLANTING								
	20	24	30	58	63	72	76	81	92
A- Cover	26.0	29.2	30.6	34.8	40.5	54.3	54.8	54.8	54.8
B-Heated	25.3	26.4	28.3	28.6	38.9	50.7	60.4	63.3	63.7
C-Carbo-nised	23.7	26.0	29.8	34.0	40.5	54.5	55.7	55.8	55.7
D-Burnt	6.2	7.5	10.6	18.7	20.9	32.5	40.9	46.9	55.5
E-Below Heap	21.8	22.7	26.5	27.8	38.6	44.5	50.5	55.2	56.7
F-Between Heap	24.8	26.4	28.5	32.2	41.3	47.1	49.6	51.2	51.0
G-Ploughed	26.5	28.3	33.0	34.5	42.8	46.6	46.8	46.8	46.8
M-Mixed	22.9	33.0	28.8	28.8	35.3	52.6	58.9	59.4	61.0
Mean	22.1	24.9	27.0	29.9	37.4	47.9	52.2	54.2	58.7

FIGURE 9: Graph of average plant height in cms for Sendafa, Debre Berhan and Fiche



A relatively lower emergency percent was observed for Sendafa as compared to the other sites. The burnt layer again had the least number of plants per pot than other treatments. The hindrance was suspected to be the hard compact surface layer which was only observed in the burnt pots as the germination test before the experiment had shown 100 percent germination for the seeds.

The fact that plants grown in the burnt layer had the lowest nitrogen content whereas plants of the carbonised layer had highest nitrogen clearly results from the very reduced amount of organic matter in the former whereas in the carbonised soils the organic matter is only partially destructed and was available for microbial metabolism. The microorganisms utilize the organic matter and release decomposition waste, which becomes available to plants. Thus the plants grown in the carbonised samples had the highest nitrogen content.

The suspected differences in growth of plants between soils taken from different localities was not supported by the results of the greenhouse experiment. The expected differences might have not been expressed due to the controlled conditions of the greenhouse as some conditions were not the same for all the treatment in the experiment. The results from other observations during the greenhouse experiment showed no appreciable difference among the sites in the emergency percent, heading percent and visual weed score. The emergency percent was low for all plants grown in the burnt soils and this could only be explained from the failure of young barley seedlings in breaking through the hardened surface which was observed mainly in the burnt soils. A similar difficulty of barley seedlings is reported when seed beds are over worked and heavy shower follows during warm dry weather due to

Table 10. Emergency percent of barley grown in the Greenhouse expt.

	SENDAFA				DEBRE BERHAN				FICHE			
	DAYS AFTER PLANTING											
	4	5	6	14	4	5	6	14	4	5	6	14
A-Cover	15.6	51.1	77.8	93.3	91.1	97.8	100	100	55.6	91.1	80.0	88.9
B-Heated	4.4	51.1	80.1	100	55.6	93.3	93.3	93.3	60.0	82.2	82.2	84.4
C-Carbonised	4.4	26.7	51.1	82.2	6.7	42.2	57.8	75.6	26.7	66.7	91.1	86.7
D-Burnt	2.2	33.3	44.4	73.3	2.2	11.1	28.9	44.4	-	4.4	4.4	17.8
E-Below Heap	2.2	55.6	88.2	93.3	26.7	86.7	93.3	97.8	17.8	75.6	93.3	97.8
F-Between Heap	4.4	53.3	75.6	82.2	31.1	97.8	97.8	100	20.0	93.3	95.5	95.6
G-Ploughed	13.3	88.9	93.3	95.6	40.0	88.9	91.1	93.3	46.7	95.6	86.6	91.1
M-Mixed	11.1	73.3	77.8	91.1	16.7	68.9	91.1	93.3	20.0	64.4	82.2	95.6

hardened crust formed by the loose surface soil (Deloirt and Ahlgrem, (1967).

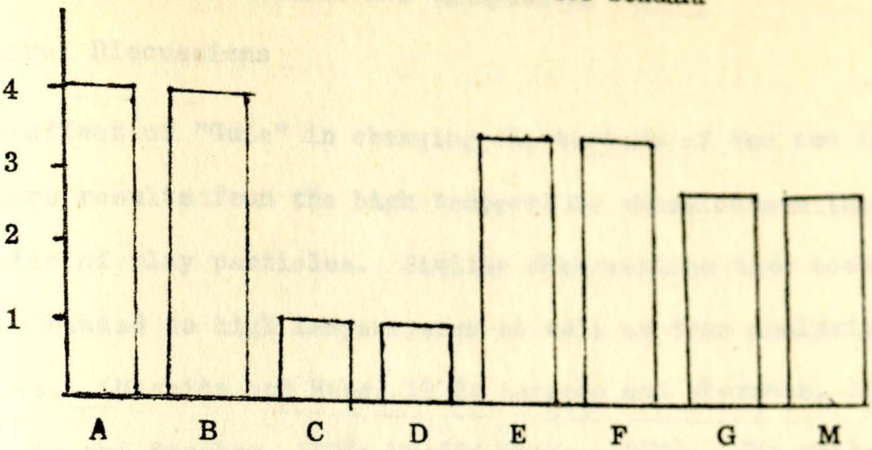
The percent heading in the heated carbonised and burnt is generally low than the other treatments for all three sites. The below heap percent heding value is strikingly lower (26.4). for Fiche than Sendafa (97.6) and Debre Berhan 79.1 on the ninety second day after planting. The percent heading of heated of Debre Berhan is nill probably due to the relatively high plant nitrogen content (2.3 %).

From the observation on weed population the burnt and carbonised treatments were completely free of weeds where as the cover ploughed and between heap treatments were full of weeds. The below heap and heated with about equal weed population had lower weeds than the above three which indicates a slight effect from the temperature.

Table II: Heading percent of barley grown in the greenhouse experiment

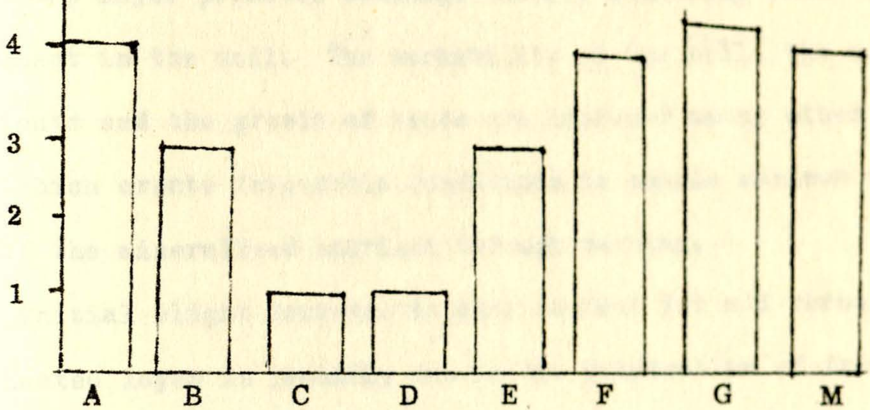
	SENDAFA				DEBRE BERHAN				FITCHE			
	DAYS AFTER PLANTING											
	72	76	81	92	72	76	81	92	72	76	81	92
A-Cover	-	6.7	42.0	61.1	46.5	80.8	97.5	97.5	44.0	77.9	90.6	90.6
B-Heated	-	-	13.8	45.8	-	-	-	-	-	4.17	8.3	21.6
C-Carbonised	17.6	31.2	55.2	55.2	11.1	21.4	47.9	65.7	3.9	35.4	49.1	49.1
D-Burnt	3.0	29.6	51.1	63.7	-	18.1	56.1	66.5	-	-	-	11.1
E-Below Heap	-	11.2	71.3	79.1	12.5	78.6	92.9	97.6	-	-	13.9	26.4
F-Between Heap	23.6	36.1	45.9	45.9	41.9	63.0	90.0	96.7	45.1	74.4	86.5	86.5
G-Ploughed	3.0	12.4	43.9	63.3	80.2	93.0	93.0	93.0	46.7	74.4	91.7	91.7
M-mixed	14.2	61.9	85.7	85.7	4.2	50.0	85.[illegible]	85.0	3.0	12.8	55.4	61.5

FIGURE 10: Visual Weed Score for Sendafa



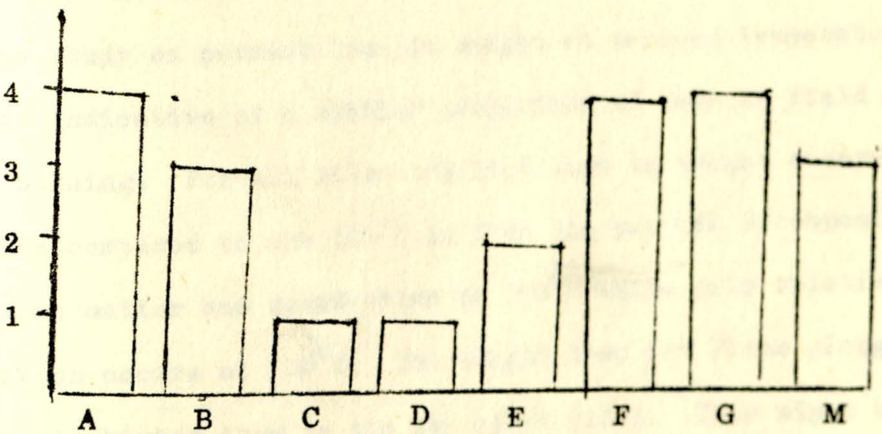
(Treatments)

FIGURE 11: Visual Weed Score for Debre Berhan



(Treatments)

FIGURE 12: Visual Weed Score for Fiche



(Treatments)

A - Cover B - Heated C - Carbonised D - Burnt

Heap F - Between Heap G - Ploughed M - Mixed

Discussions and Conclusions

4.1 General Discussions

The effect of "Guie" in changing the texture of the two innermost layers results from the high temperature which causes the disintegration of clay particles. Similar observations have been made for soils heated to high temperatures as well as from analysis of Guie soils. (Nishita and Haug, 1972; Legesse and Whermann, 1975; Sehlemedhin and Sanchez, 1978; Mesfin Abebe, 1979). The marked change of fine soil particles into sand-sized particles in this largest heap layer promotes drainage thereby enhancing water and air movement in the soil. The workability of the soil, the mobility of nutrients and the growth of roots are improved among other properties which create favourable conditions to enable maximum utilization of the mineralized nutrient through burning.

An initial slight increase in clay content for all three sites in the heated layer is probably due to the dehydration of free water which binds soil particles. Thus the proportion of finer particles increase from heating at lower temperatures and then declines at higher temperatures.

The study on percent loss in weight at various temperature levels might be indicative of a similar proportion of loss in field conditions during burning. For all sites the high loss in weight observed at 300^{o} when compared to the $100^{o}C$ is from the partial decomposition of organic matter and dehydration of $300^{o}C$ while only relatively little dehydration occurs at $100^{o}C$. The weight loss for Fiche ploughed soil is markedly higher than in the two other sites. This might be partly explained by the relatively higher organic matter content in the former site.

The colour change for all sites follows a uniform gradient from the original gray colour in the outer layers to reddish brown in the innermost layer. The reddish brown colour which develops in the

The colour change for all sites follows a uniform gradient from the original gray colour in the outer layers to reddish brown in the innermost layer. The reddish brown colour which develops in the burnt layer is said to be iron oxides mainly which prevail in osicized conditions. It is also possible that manganese oxides with a similar reddish colour might have contributed to the colour of burnt layer.

The pH change due to soil burning is primarly from the oxidation reactions and the release of ions from the organic matter complex and the soil. The pH increase from burning influences the availability of nutrients, mainly of phosphorous, which is low in "Guie" soils.

The decrease in the exchangeable cations from exposure to higher temperature is directly related to the proportion of organic matter and the clay content. The heated layer with higher clay content has an increased cation exchange capacity and the burnt with lowest clay has the least cation exchange capacity. The cations mineralised from the breakdown of clay structures might be converted to available forms. At higher temperatures calcium and magnesium were decreased but potassium which might have been part of the clay structure. Thus the destruction of organic matter and breakdown of clay structure decrease both cation exchange capacity and exchangeable cations.

When we look at the results of total nitrogen and organic carbon both have been greatly reduced. This is evident as the organic matter is what burns during "Guie" leading to the disintegration of clay particles. The calculated loss of total nitrogen and organic carbon previously cited is overwhelming and it is the major disadvantage of the practice. The carbon to nitrogen ratio fluctuation at the different layers reflects the losses mainly of organic matter from varying temperature effects.

The most important benefit from Guie is the increase in the amount of available phosphorous. This increase results from the mineralization of organic and inorganic phosphorous as well as the rise in pH which reduces fixation of inorganic phosphorous, thereby increasing the solubility and also increasing phosphorous availability. The decrease in clay fraction might also reduce phosphorous fixation depending on the type of clay mineral. The phosphorous mineralization is the predominant influence which is responseble for the high yield after "Guie" along with the improvement of the physical conditions.

The nitrogen and phosphorous contents from the plant analysis showed high phosphorous contents in plants grown in the burnt samples and high nitrogen in plants grown in carbonised samples. The phosphorous content for the plants varies concurrently with the phosphorous percentage in the soil analysis.

4.2 Conclusions

The results indicate that, depending on the temperature, "Guie" markedly affected the physical and chemical properties of soil, which was reflected in better growth of the test crop in mixed soil during the greenhouse experiment. The innermost layer, the burnt soil, experienced a drastic change in its properties, and the soil in this layer is the most significantly affected.

The increase in available phosphorous seems to come mainly from organic sources, and sufficient amounts might be attained at lower temperatures than the temperature levels in the burnt layer (650°C). The nitrogen mineralisation again is at its peak in the carbonised layer and burning at lower temperatures will produce high nitrogen probably by increasing microbial activity.

The tremendous loss of organic carbon and total nitrogen is the results of the complete destruction of organic matter through the very high temperature in the core of the Guie. Thus reduction of the temperature of the "Guie" practice should be considered, and field experiments in soil burning should focus at such changes which may help minimizing the losses and still improve the physical and chemical properties conducive for plant growth.

The comparative study of the suspected variations of "Guie" benefits and losses in different areas has shown that "Guie" more or less has the same influence in the areas investigated. The greenhouse study has also supported the soil chemical and physical results, and thus the same temperature level should have caused this marked uniformity in the changes in the soil property due to burning.

The slight differences in the results may be partly explained by

The slight differences in the results may be partly explained by differences between the local soils. The very significant differences between the results of some earlier workers may be due to differences in sampling, preparation, analysis procedures etc. or some other artificial differences but are definitely not caused by differences in the "Guie" practice of the localities.

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Appendix Table 1. Dry weight of barley from the greenhouse experiment

	Sendafa			Debre Berhan			Fitche		
	Days After Planting			Days After Planting			Days After Planting		
	50	85	115	50	85	115	50	85	115
A-Cover	0.67	1.7	0.80	1.2	0.70	0.90	0.77	2.3	1.68
B-Heated	0.58	2.1	0.88	1.5	1.10	1.30	0.84	2.4	1.60
C-Caronised	1.12	1.2	1.20	3.2	1.70	1.90	1.0	4.7	2.1
D-Burnt	0.39	1.7	0.76	1.4	0.70	0.80	-	0.95	0.53
E-Below Heap	0.97	1.6	0.80	1.1	0.80	0.93	0.77	2.2	1.50
F-Between Heap	0.65	1.7	0.74	1.0	0.74	0.90	0.58	1.2	1.10
G-Ploughed	0.63	1.5	0.62	0.96	0.90	1.0	0.46	1.1	1.10
H-Mixed	0.97	1.8	0.83	1.90	1.20	1.50	0.72	2.1	1.4

D E C L A R A T I O N

I, the undersigned declare that this thesis is my work and that all sources of material used for the thesis have been duly acknowledged.

Name Anketse Berhan Kifle

Signature ABK

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