THE EFFECT OF DIFFERENT SOILS ON THE GROWTH AND YIELD OF SOME TEF CULTIVARS

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ABSTRACT

Observation of yields of tef tested in national yield trials (NYT) at different sites and at different times have given variable results. It was assumed that differences in the tef yields were probably due to environmental factors.

Therefore, eleven cultivars (of 1980-81 in the NYT) were seeded on six different soils, collected from different places, in plastic pots with a capacity of 2 kilograms in a randomized complete design in two blocks and grown in a green house where environmental conditions such as humidity, sunshine hours, temperature, were identical for all the treatments. The pots containing the plants were watered as required with distilled water until the plants achieved physiological maturity.

During the growth period, various parameters such as height, tiller number, days to heading were recorded and quantified. After harvest dry weight and seed weight of cultivars were measured. The data obtained were subjected to various statistical analyses.

The results indicated that the tested tef cultivars adapted better in soils dominated by silt along with adequate quantities of available nitrogen and potassium.

1. INTRODUCTION

The farmers of Ethiopia have cultivated tef as far back as recorded history and through the centuries they recognized the various types of tef and have traditionally tried to grow the better types as they existed naturally (Melakehail, 1964).

Tef is believed to be a crop adapted to a great diversity of climatic conditions and soil types and it is generally believed that it does well on well drained fairly previous red or black soils performing best at altitudes of 1700 to 2400 meters (Tadesse, 1969). It was also indicated by Endashaw (1978) that the seedling of tef could establish under nutrient deficient soils by using the nutrients already present in the seed.

The facts enumerated above are indicative of the ecological adaptations of tef, though often, in spite of being economically attractive, it is not a quantitatively rewarding crop in its yield when compared with other cereal crops.

Tef, being the staple food of most Ethiopians, has a high market demand. Because of a high market demand, there are those that produce tef exclusively as a cash crop, foregoing the luxury of home consumption (Mulugeta, 1978). The preference to tef over other cereals is clearly demonstrable by the ever growing demand and this assures the cultivation of tef for a long time to come. The Institute of Agricultural Research's (IAR) report on cereal crops (1981) reported that tef occupied 29.5% of the cultivated land. It also said that area under tef increased from 1,217,000 hectares in 1974 to 1,392,000 hectares in the 1978/79 cropping season - an increase of 14%. However, it is said that the average yield for farmers is only seven quintals per hectare (IAR report, 1981). All these facts call for action to improve the crop through research because the yield is low and alarming when compared with the amount of land and labour used to produce it.

The Debre Zeit Agricultural Experiment Station, which is the coordinating centre for tef research in Ethiopia, has been conducting trials on a number of parameters on tef since 1957 and had released a number of varieties to date.

Selection was believed to be the best tool at hand for yield improvement in tef (Mulugeta, 1973). This belief arose from the earlier assumption that tef would only self-fertilize and breed true (Staten, 1954). But this was found not to be true. Tarke Berhe (1969) was able to cross fertilize tef and he thus has discovered an additional technique for improving tef varieties, though this has not yet been applied in a wide scale.

The Debre Zeit Experiment Station has, therefore, been engaged in improving tef varieties by selection and hybiridization that would give better yield than local varieties traditionally used by farmers and the research trials have enabled farmers of Ethiopia to receive varieties (Cultivars) with better yields. The Debre Zeit Experiment Station research reports (1977 - 1979) confirm the above fact. However, the effect of the different environmental factors, particularly the effect of the soil environment that result in a dramatic increase of yield have not been clearly determined.

Therefore it was the aim of this project to examine the effect the soil environment has on the yield of tef varieties.

2. LITERATURE REVIEW

Very few research reports are to be found in early literature and some of these are either locked up in some Italian archives or, if available, their usefulness have been limited because of language barriers (Mulugeta, 1978). Here below some of the literatures that is available on tef will be considered.

In 1951, Vavilov, recognized that the species was among a number of cultivated plants found only in Ethiopia. Collection and identification of cultivars were done by Melakehail (1964) and Tadesse (1975). Studies of the development of embryo sac and embryo of tef was done by Melakehail (1966). Tadesse (1969) dealt with the uses of tef in the Ethiopian society. Although Clayton et.al. (1974) had described the morphology of tef, a more detailed botanical characterization and morphological description of tef was done by Tadesse (1975). Tareke (1974) dealt with the breeding techniques, and Mulugeta (1978) also dealt with some biological aspects of the species. Endashaw (1978) studies the biochemical and morphological relationships of Eragrostis tef and some other Eragrostis species. Tareke et. al. (1976) studied the sensitivity of tef to removal of floral parts. Studies of Ethephon as a possible selective gametocide on tef was done by Tareke et. al. (1978). A preliminary study of aflatoxin content of selected Ethiopian diets, one of which was tef, was dealt by Abraham (1981).

The general ecology and geography of tef was described by Clayton et. al. (1974). However, the relationship between different varieties of tef and different types of soil and other environmental conditions has not been clearly established in the literature reviewed.

Murphy (1968), studied different soil in the accessible parts of Ethiopia and, in some instance, their relationships with cereals. As far as the effect of environmental factors on the growth of tef was concerned, only broad generalizations were made which said that the crop is adapted to a great diversity of climatic conditions and soil types Tadesse 1969). Recently, however, Mulugeta (1978) studies temperature effect on growth and development of certain tef cultivars. Apart from those mentioned above, the effect of different environmental factors, (i.e. temperature, rainfall, soil type) and the effect of soil nutrients on the growth and development of tef cultivars have not been studied.

3. ORIGIN OF THF PROJECT

Tef National Yield Trials have been conducted in different sites in EThiopia run by Debre Zeit Experiment Station of the Addis Ababa University under the supervision of the Institute of Agricultural Research (IAR). The sites are given in Table 1. The data for the location of the sites were obtained from a report of the Awash Valley Authority (1976).

The experiments conducted so far indicated that Debre Zeit Agricultural Experiment Station has been able to obtain yields of tef that are greater than those obtained by farmers. However, the effect of the different environmental factors responsible for increases of yield have not been clearly determined.

In order to determine the effect of the environmental factors, it was necessary to look into the existing data on yield and compare the yield output of the different cultivars.

Data on yield in quintals per hectare of tef from NYT of the sites (in Table 1) for 1977, 1978 and 1979 were collected. The source of the data was the Debre Zeit Agricultural Experiment Station, NYT tef reports for the above indicated years (Table 2).

Cultivars that were grown in as many different sites were identified to make comparison of yield out-put. These cultivars had the following codes (see Table 2).

1. DZ - 01 - 354
2. DZ - 01 - 787
3. (418 x T - 140) (186 x A-40) TB'75 - 31 - 8LS - 0BS
4. (T - 140 x 566) (T - 140 x 186) TB' 75 - 33 - 3LS - 0BS
5. (186 x 566) 354 TB 75 - 82 - 14LS - 0BS.

The data of yield of cultivars were of 1977, 1978 and 1979. Cultivar with code DZ-01-354 had the highest yield at Kulumsa in 1977, 1978 and 1979. The cultivar had the lowest yield at Jimma in 1977, at Quiha in 1978 and at Ginichi in 1979. (See underlined figures in Table 2).

Cultivar with code DZ-01-787 had highest yield at Kulumsa in 1977, 1978 and 1979. This cultivar had the lowest yield at Jimma in 1977, at Quiha in 1978 and at Tefki in 1979.

Cultivar with code (418 x T - 140) (186 x A - 40) TB'75-31-8LS-0BS had highest yield at Kulumsa in 1977, 1978 and 1979. The cultivar had the lowest yield at Soddo in 1977, at Quiha in 1978 and at Chefe Donsa in 1979.

Cultivar with code (T-140 x 566) (T-140 x 186) TB'75-33-3LS-0BS had highest yield at Kulumsa in 1977, at Debre

Zeit in 1978 and in 1979. The cultivar had the lowest yield at Jimma in 1977, at Quiha in 1978 and at Chefe Donsa in 1979.

Cultivar with code (186 x 566) 354 TB'75-82-14LS-0BS.had highest yield at Kulumsa in 1977, at Debre Zeit in 1978 and at Kulums in 1979. The cultivar had lowest yield at Soddo in 1977, at Quiha in 1978 and at Chefe Donsa in 1979.

Observation of the yield of the above cultivars indicated that all had highest yield either at Kulumsa or Debre Zeit while most of the cultivars had the lowest yield either at Jimma or at Quiha. Lowest yield of cultivars were also recorded at other sites, however, they were not as frequent as at Jimma and at Quiha.

The yield differnce of a cultivar, i.e. between the highest and the lowest, was very big. For example, the yield difference of cultivar DZ-01-354 between the highest at Kulumsa and the lowest at Jimma was 25.30 quintals per hectare in 1977. The percentage difference being 281. The biggest yield difference, in percentage, was about 400 for cultivar (418 x T-140) (186 x A-40) TB'-75-31-8LS-0BS and the lowest was 72 for cultivar (T-140 x 566) (T-140 x 186) TB'75-33-3LS-0BS.

These differences of yields of cultivars over the different sites were presumed to have been brought about by environmental factors rather than by differences of cultivars.

It was the aim of the project to examine the effect of the edaphic factors of the environment on the unaccountable yield differences of tef cultivars observed.

Therefore, an experiment was conducted on different tef cultivars that were grown in different soils under a green house condition where temperature and amount of water added were identical for all the treatments.

Table 1: Location of sites where Tef National Yield Trials are conducted.

SITES	LOCATION
Illala (Jimma)	08°23'N, 37°36'E
Endibir	08°07'N, 37°37'E
Sodo (Wadu)	06°52'N,37°45'E
Jimma (Melko)	07°39'N, 36°49'E
Alemaya	09°22'N, 42°03'E
Maimekdem	13°33'N, 39°36'E
Quiha	13°28'N, 39°36'E
Awassa	07°02'N, 38°29'E
Arsi Negelle	07°24'N, 38°44'E
Bele (Sidamo)	07°00'N, 37°39'E
Ambo	09°00'N, 37°52'E
Kobo	12°09'N, 29°40'E
Holleta	09°5'N, 38°30'E
Ginchi	09°01'N, 38°12'E
Kulumsa	08°04'N, 39°14'E
Akaki Beseka	08°52'N, 38°47'E
Chefe-Donsa	08°58'N, 39°06'E
Bolo Giorgis	08°49'N, 39°21'E
Ejere	08°45'N, 38°58'E
Tefki	08°39'N, 38°30'E
Tulu-Bolo	08°39'N, 38°12'E
Debre Zeit	08°55'N, 38°58'E

Table 2: Yield of Cultivars from NYT in Quintals per Hectar.

Cultivar Code	DZ-01-354			DZ-01-787		
NYT CODE	01	01	01	08	05	02
SITE / YEAR	1977	1978	1979	1977	1978	1979
AMBO	-	35.55	-	-	32.87	-
AWASSA	-	21.29	24.92	-	20.58	19.28
BOLO GIORGIS	-	23.37	-	-	27.70	-
CHEFFE DONSA	-	13.81	15.02	-	13.27	15.73
DEBRE ZEIT(HS)	22.06	30.10	22.20	20.08	27.70	20.95
DEBRE ZEIT (LS)	14.82	21.91	23.02	13.98	23.03	19.25
GINCHI	11.39	15.53	14.63	15.05	17.90	19.33
HOLLETA	12.42	19.43	22.68	15.80	16.15	24.75
JIMMA	9.00	11.92	-	5.40	11.68	-
KOLUMSA	34.30	33.83	32.97	25.80	30.33	30.25
QUIHA	-	11.54	-	-	8.22	-
SODDO	7.17	20.53	-	8.00	16.25	-
TEFKI	-	-	18.30	-	-	15.56

Table 2: (Cont'd)

CULTIVAR CODE	(418xT-140)(186xA-40)TB'75-31-8LS-OBS			(T-140x566)(T-140x186)TB'75-35-3LS-OBS		
NYT CODE	09	06	03	10	07	04
SITE / YEAR	1977	1978	1979	1977	1978	1979
AMBO	-	31.88	-	-	32.41	-
ANASSA	-	28.46	17.38	-	25.08	15.63
BOLO GIORGIS	-	23.30	-	-	24.38	-
CHEFE DONSA	-	16.03	14.63	-	14.96	15.30
DEBRE ZEIT (HS)	18.52	34.42	26.64	19.83	35.22	22.83
DEBRE ZEIT (LS)	18.76	28.81	27.77	17.65	30.01	26.43
GINCHI	10.36	16.92	18.58	9.91	17.63	17.27
HOLLETA	16.54	21.73	22.55	18.38	20.27	19.68
JIMMA	8.25	16.24	-	6.51	17.03	-
KULUMSA	32.70	37.70	30.33	30.70	29.65	-
QUIHA	-	13.04	-	-	10.84	-
SODDO	6.51	15.64	-	7.51	19.42	-
TEFKI	-	-	15.96	-	-	15.85

4. MATERIALS AND METHODS

Data were collected through soil analysis and pot experiments in the greenhouse. The materials and methods used were the following:

4.1 Seed Collections: Tef seeds were collected from the Debre Zeit Experiment Station. There were eleven (11) cultivars (varieties) of tef that had passed to the National Yield Trial in 1980. The cultivars of tef had codes that started from 01 and went up to 11 (Table 3). These were the codes given to cultivars of NYT in 1980-81.

Table 3 - NYT Codes and Cultivar Codes of Tef used in the Experiment

No.	NYT Code	Cultivar Code
1	01	DZ-01-354
2	02	DZ-01-787
3	03	DZ-01-238
4	04	(418xT-140) (186xA-40) TB'75-318-LS-OBS
5	05	(418x7-140) (186xA-40) TB'75-31-9LS-OBS
6	06	(566x186) 354-TB'76-44-3LS-OBS
7	07	(186xT-4 508-TB'76-44-3LS-OBS
8	08	(T-140x566) (T-140x186) TB'76-26-7LS-OBS
9	01	(48x566) 196-TB'76-79-7LS-OBS
10	10	(566x186) (418x186) Gond. Sel 196-2ILS-OLS
11	11	(418x566) 508 (086x566) 354

4.2 Soil Collection: Soils were collected on different occasions between October and December 1980, from six different sites: Akaki, Chefe Donsa, Debre Zeit, Holleta, Jimma Gerima Guda and Jimma Melko. These sites were each in the vicinity of a Tef National Yield Trial. The particular sites from where soils were collected were fields which have had no fertilizer applied. The only site which did not have tef yield trial was that of Jimma Gerima Guda. About 100 kg. of soil was taken from the plough horizon (top 10-15 cm) from each of the sites. The soils were removed from different corners and from the centre of the field and thoroughly mixed.

4.3 Procedure Used in Soil Analyses

a) All mechanical and chemical soil analyses were made in duplicate on an air dried fraction of the sample passing through a standard 2 mm seive and the average values recorded.

b) Soil colour was determined by comparison with Munsell soil color chart, model 1959, using both air dry and moist soils.

c) Soil pH was determined by Devis et.al.'s (1970) method. pH was determined in a 1:1 soil to distilled water mixture with a Pye Unicam pH-meter model 78.

d) Electrical conductivity was determined using a Harris conductivity meter on the same soil to distilled water mixture as used for pH determination.

e) Day's (1965) particle fractionation and paraicle size analysis was followed to determine the texture of the different soils. Soil textural analysis was made by the hydrometer method (Bouyoucos method) after pretreatment with 9% hydrogen peroxide and 5% sodium hexametaphosphate.

f) Chapman's (1965) Cation Exchange Capacity (CEC) determination by ammonium saturation method was followed. This method was also used to determine Na, K, Ca, Mg and Mn.

From each soil sample, 5 gm soil was weighed with a Mettler balance and put on a filter paper. Five ml of 1N ammonium acetate was added to each soil sample and all were left overnight. The soil solutions were each washed five times with 30 ml of 1N ammonium acetate (with pH-7) each time and the leachate was collected into a 250 ml volumetric flask. Finally, the flask was topped upto the mark with deionized (distilled) water. This leachate was used to determine the exchangeable cations

(Ca^{+2}, Mg^{+2}, Na^{+}, K^{+} and Mn^{+2}) using Atomic absorption spectrophotometer series 2, unicam SP 90A.

Reading were taken at 589 nm for sodium; 766.5 nm for potassium; 422.7 nm for calcium; 285.2 nm for magnesium and 279.5 nm for manganese.

The remaining soil on each filter paper was washed with repeated portions of 30 ml of absolute alcohol (ethanol) until the excess ammonium from the ammonium (acetate) was totally removed. Complete removal of excess ammonium ion was tested by Nessler's reagent which turns yellow in the presence of ammonium ion and remains colourless when absent. When all excess ammonium ions were removed, the soil was taken for distillation. The soil was distilled with 30 ml of 40% NaOH. The distillate was received into 25 ml of 2% Boric acid with mixed indicator. After the distillation was over, the distillate was titrated against 0.01N H_2SO_4 to determine the amount of ammonium ion concentration that was in each soil.

g) Total nitrogen was determined using the modified Kjeldahl digestion method (Bremner, 1965) with copper sulfate - selenium mixture as a catalyst. The sample was digested with concentrated sulfuric acid to convert all forms of nitrogen to ammonium nitrogen. The solution was made alkaline by the addition of excess sodium hydroxide and distilled in a Kjeldahl apparatus (flask) into 2% boric acid. The ammonium ion was then titrated with 0.01N sulfuric acid.

h) Olsen et. al's (1965) method was followed to determine the available phosphorus. Two grams of soil from each sample was weighed using a Melter balance and was put in a 250 ml extracting bottles. A tea spoonful of phosphrus-free activated charcoal was added to each bottle to absorb colour due to organic matter. Forty ml of 0.5M sodium bicarbonate ($NaHCo_3$) of pH 8.5 were added. The bottles were then shaken on an orbital shaken for exactly 30 minutes. The solutions thus made were filtered leaving the first two drops (which were not clear). With a pipette, 10 ml of the aliquot from each filterate was put into a 50 ml volumetric flask. Then 2.5 ml of 2N sulfuric acid was added separately to the flasks to remove Co_2 from excess sodium bicarbonate (to avoid interference in the colorimetric readings). When all the Co_2 gas was removed, 5 ml of 1% ammonium molybdate solution was added to each flask and was mixed well. Each volumetric flask was diluted with distilled water upto the neck. Two ml of the reducing agent, stannous chloride, was then added and the volume of each flask topped upto the mark with distilled water. The flasks were left for 10 minutes for the blue color to develop fully. Finally, the absorbance was read with spectrophotometer at 660 nm.

i) Mclean's (1965) Colorimetric method was followed to determine the exchangeable Aluminium. Ten grams of soil from each sample was leached with 1N potassium chloride (KCl). Leaching was performed for no less than two hours. The leachate was put in a 100 ml volumetric flask and was made upto the mark with 1N KCl. A ten ml. aliquot was taken and put in a 25 ml volumetric flask. To each flask 2 ml thyoglycolic acid was added and were shaken. Ten ml aluminion reagent was then added and the flasks were topped upto the mark with distilled water. Finally, each flask was put in a boiling water bath for exactly 16 minutes and cooled. The absorbance was read with Bosch and Lomb Colorimeter at 530 nm.

j) Olson's (1965) ammonium acetate extraction method was followed to determine the exchangeable irons. Ten gram of soil from each sample was placed in 100 ml beaker. Fifty ml of 1N ammonium acetate was added and shaken well. After 12 hours, the solution was filtered and washed five times with 30 ml of 1N ammonium acetate. The leachate was evaporated to dryness. The residue was treated with 10 ml aqua regia. Again, the solution was evaported to dryness. A small amount of water was then added. The solution was transferred into a fifty ml volumetric flask. Five ml of 5N ammonium acetate, one ml of 10% hydroxylamine hydrochloride and one ml of orthophenanthrolin reagent were added. The solution was diluted with distilled water to the 50 ml mark. The absorbance was read at 510 nm.

k) Fiskel's (1965) Hydrochloric acid extraction method was followed to determined the available copper. Two grams of soil from each sample was placed in 50 ml glass centrifuge tube. Twenty ml of 0.1N HCl was added to each tube and the tubes were shaken on a horizontal mechanical shaken for 1 hour. The solutions were filtered and the filterate was used to determine the concentration of copper using atomic absorption spectrophotometer, Perkin 270 at a wavelength of 324.8 nm.

The same method was followed to determine the amount of available zinc in the soils. The zinc was determined by the same instrument used for copper determination but was read at a wavelength of 213.9nm.

1) Allison's (1965) organic carbon of soil analysis was followed to determine the organic carbon content of each soil sample. One gram of soil from each sample was placed in a 500 ml erlymeyer flask. Ten ml of 1N potassium dichromate ($K_2Cr_2O_7$) was added to each flask. Twenty ml of concentrated sulfuric acid was then added. The contents in the flask was heated at 150°C for one minute and cooled. Two hundred ml of distilled water was added to each flask and filtered. To each filterate four drops of ortho-phenanthroline was added. Finally, each flask containing the filterate was titrated with 0.5N iron sulfate. After having determined the organic carbon, the organic matter of each soil was calculated by multiplying the organic carbon by a factor, 1.724.

4.4 Procedure used in Pot Experiment: Soils that were brought from the six sites were left for air drying from 2-3 months in the ecology laboratory at the science building at Arat Kilo. Two kg. of air dried soil was placed in transparent plastic bags (pots). Soils were then put into twenty two pots from each of the six different soils. The pots were grouped into two identical groups so that there were 11 pots of each of the soil on one side and another 11 on the other side. The pots were thus placed in two blocks (Block I and Block II). The position of the pots in the blocks were determined according to different sets of random numbers for each block.

Complete randomization of tef cultivars were made using random number tables. The assigning of tef cultivars to the pots of the first block was different from that of the second. Hence, the experiment was set up in a complete randomized block design in two replications.

In order to create a more or less similar micro-climate and to eliminate edge effect, extra pots with soil were put on the edges of each block.

Before sowing, the experimental pots were wetted with distilled water and the edge pots with tap water. After four days, when the water had wetted the soil in the bags, more distilled or tap water was added to the respective experimental and edge effect pots until they were saturated. After a day, when the water had drained down the pots, the wetted soils were leveled using glass rods. Separate glass rods were used to avoid nutrient contamination from one soil to another. The pots were then ready for sowing. 70 seeds were placed in each pot of the two blocks. To ensure equal treatment of seeds per pot, seeds were counted using a hand lens. The seeds were broadcast on the soil of the treatment pots as well as the pots for correcting edge effect.

.4.5 Procedure followed from Germination to Harvesting Period:

The pots were regularly watered to ensure that water was not a limiting factor for germination. Because of the fact that the germinating seeds in the different pots were variable in number, the pot with the least number of germinating seeds was selected to standardize the number of seedlings per pot. The pot with the least number of germinating seeds had 15 seedlings. Therefore, the number of seedlings per pot were brought down to 15 by thinning out and, at the same time, equal spacing for the remaining seedlings, as far as visual observation permitted, was ensured by replanting the seedlings. The procedure of thinning out enabled the maintaining of uniform numbers of young plants in all the pots right from the start, before competition set in.

Throughout the experimental period, only distilled water was provided to the treatment pots and weeds were removed by hand whenever the wherever they appeared.

Starting from 2 weeks after the period of germination until the final day of harvest, various growth parameters were recorded. They were:

a) Plant height at 10 day intervals

b) Number of tillers per pot at 10 day intervals

c) Number of days to headling.

The plants were finally harvested at about 90 days after sowing. Practically all the plants had matured by then.

The harvested material from each pot was then chopped up, put in a paper bag, sealed and oven-dried (at 105^{o}C for 2 hours). The paper bags were finally transferred to a desiccator for cooling and weighed to determine the total above ground dry matter production per pot of 15 plants.

After having determined the dry matter, the seed of the plants were separated from the chaff by hand. Weighing of seeds was carried out using a Borch P 115 one pan balance.

4.6 Recorded data and soil analysis: During the experimental period, the following data were recorded to compare performances of cultivars;

a) Plant height: Individual plant heights were recorded at 10 day intervals. The sum of the heights of the 15 tef plants per pot were added and then divided by the number of plants to obtain the mean height per pot.

b) The above ground dry matter of tef in each pot was collected separately, and all the 15 tef plants were weighed.

c) Seeds from the tef plants harvested from each pot were collected separately and weighed.

d) Number of days to heading for the different cultivars were recorded. A cultivar on different soils took different numbers of days to heading. Different cultivars on the same soil also took different days to mature. Therefore the number of days to heading of each of the 15 tef plants of a cultivar in a pot was recorded and the sum of the days were divided by the number of plants to obtain the average number of days to heading for that cultivar.

e) The number of tillers that were produced on each of the treatment pots were counted until the tef plants were harvested. The sum of the number of tillers of each cultivar on the different soils in each block were then recorded at 10 day intervals.

f) Results of color tests, soil mechanical and chemical analysis were recorded for the different soils.

4.7 <u>Growth Rate Analysis:</u> To compare, the growth activities of two systems their relative growth rates must be measured (Street and Opik, 1976). Therefore, to compare the growth activities of the eleven cultivars, their mean relative growth rates were calculated by following the formula in Hunt (1978). It was

$$1 - 2^{R} = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

where R = mean relative growth rate; W_2 = Weight at T_2, i.e. final weight; W_1 = Weight at time T_1, i.e. initial weight. T_2 = final time, T_1 = initial time; e = the base of natural logarithms.

The mean relative growth rate can be computed from plant growth parameters e.g. height, width or weight of plants recorded at any two times separated by a specified interval during the actively growing period of the plant (Evans, 1972). Units that are more commonly used to express mean relative growth rate are: $[gg^{-1}]$ Week^{-1}; $[gg^{-1}]$ day^{-1} and $[mgg^{-1}]$ week (Hunt, 1978).

In addition, it may be mentioned that percent per week, or per day have also been used where easy interpretation is required across a large range of values (Hunt, 1978).

5. RESULTS

5.1 Growth Rate

The mean relative growth rates of plant heights were computed at 10 day intervals, starting from the 20th day after sowing for each cultivar in the six different soils. Expression of mean relative growth rate as percent per day was that had been followed (see Table 4).

The mean relative growth rate (RGR) indicated that between the 20th and 30th day after sowing, cultivar 01, 02, 04, 05, 06, and 07 had the highest mean RGR on Akaki soil. Within the above mentioned range of time, cultivar 03 on Jimma Melko Soil, cultivar 08 and 09 on Debre Zeit soil had the highest mean RGR. Cultivar 06 which had the highest on Akaki had also the same result on Debre Zeit soil between the 20th and 30th days after sowing.

There were cultivars that had highest RGR between the 40th and 50th day after sowing. Cultivar 10 on Holleta soil and cultivar 11 on Akaki soil had highest RGR in the above mentioned range of time.

TABLE 4 - MEAN RELATIVE GROWTH RATE OF PLANT HEIGHT AS PERCENT PER DAY

CULTIVAR	01						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.0	4.0	4.6	4.8	2.6	3.2	0.5
CHEFE DONSA	4.0	3.1	3.2	1.6	3.9	1.9	0.1
DEBRE ZEIT	4.4	2.8	2.7	3.2	1.1	1.5	0.2
HOLLETA	3.5	3.6	2.9	4.0	2.2	0.1	0.0
JIMMA GERIMA GUDA	1.8	4.3	4.2	3.6	3.0	1.1	0.2
JIMMA MELKO	4.9	2.2	2.9	3.4	3.6	4.6	0.9

Table 4 (Cont'd)

CULTIVAR	02						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.8	4.2	4.9	4.3	2.5	2.4	2.3
CHEFE DONSA	4.2	2.9	3.6	3.6	2.7	1.8	0.2
DEBRE ZEIT	4.8	4.5	3.2	2.7	1.4	0.5	0.1
HOLLETA	4.5	3.1	3.0	3.5	1.8	2.1	0.0
JIMMA GERIMA GUDA	4.9	4.7	4.7	0.5	5.7	1.0	0.0
JIMMA MELKO	4.0	2.3	3.3	3.9	2.4	1.7	2.4

Table 4 (Cont'd)

CULTIVAR	03						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	6.0	5.0	4.6	4.5	2.6	3.3	1.0
CHEFE DONSA	4.9	3.6	2.9	3.5	3.7	1.2	0.1
DEBRE ZEIT	4.9	3.9	3.7	3.3	1.4	0.3	0.4
HOLLETA	4.2	4.0	2.4	3.4	3.8	0.6	0.0
JIMMA GERIMA GUDA	3.9	5.9	5.1	3.8	3.2	1.0	0.0
JIMMA MELKO	7.0	0.9	3.1	3.8	1.7	4.5	2.5

Table 4 (Cont'd)

CULTIVAR	04						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.1	4.7	4.3	3.5	2.7	2.1	0.1
CHEFE DONSA	3.7	3.6	2.8	2.9	3.5	0.8	0.0
DEBRE ZEIT	4.2	4.2	2.6	3.5	0.9	0.1	0.0
HOLLETA	4.5	4.1	2.5	3.1	2.5	0.9	0.1
JIMMA GERIMA GUDA	3.9	4.4	4.0	6.1	1.1	0.1	0.0
JIMMA MELKO	4.3	2.2	3.2	4.7	2.5	3.1	0.6

Table 4 (Cont'd)

CULTIVAR	05						
Soil \ Days after sowing	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	4.9	4.0	4.4	4.9	2.7	2.5	1.1
CHEFE DONSA	3.5	3.6	3.1	3.2	3.4	0.1	0.0
DEBRE ZEIT	4.4	3.2	3.9	2.9	1.0	0.1	0.0
HOLLETA	4.2	1.9	2.4	3.7	2.3	0.4	0.0
JIMMA GERIMA GUDA	4.8	4.4	3.8	3.1	2.7	0.3	0.1
JIMMA MELKO	4.5	2.8	3.6	3.8	2.3	2.7	1.0

Table 4 (Cont'd)

CULTIVAR	06						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	6.0	4.5	4.2	5.2	2.8	4.3	3.1
CHEFE DONSA	4.2	3.8	3.3	3.2	3.3	1.2	0.1
DEBRE ZEIT	6.0	4.1	2.8	2.9	1.4	0.1	0.0
HOLLETA	3.8	3.1	3.6	3.4	2.9	0.1	0.0
JIMMA GERIMA GUDA	4.5	5.9	3.6	4.3	2.2	0.6	0.1
JIMMA MELKO	4.8	3.2	2.8	3.4	3.5	5.1	0.6

Table 4 (Cont'd)

CULTIVAR	07						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	6.7	4.2	5.2	1.8	2.6	3.7	0.6
CHEFE DONSA	5.0	2.7	2.6	3.7	3.8	1.1	0.1
DEBRE ZEIT	5.0	4.6	2.7	2.9	1.2	0.0	0.0
HOLLETA	3.7	2.8	2.8	4.1	2.3	0.1	0.1
JIMMA GERIMA GUDA	4.7	4.5	4.9	4.1	1.8	0.6	0.1
JIMMA MELKO	4.1	3.9	3.0	3.2	2.0	4.0	1.4

Table 4 (Cont'd)

CULTIVAR	08						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.4	4.6	5.4	4.4	2.3	2.2	1.0
CHEFE DONSA	4.7	3.4	2.9	3.2	2.7	1.6	0.0
DEBRE ZEIT	6.8	3.8	2.7	1.6	2.2	0.0	0.0
HOLLETA	4.7	3.3	2.5	3.1	3.1	0.3	0.0
JIMMA GERIMA GUDA	5.4	4.4	4.8	3.7	1.5	0.6	0.0
JIMMA MELKO	4.6	3.2	3.4	3.7	2.6	3.1	2.1

Table 4 (Cont'd)

CULTIVAR	09						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.1	4.2	4.8	4.8	2.3	3.7	0.7
CHEFE DONSA	4.9	3.5	3.4	3.7	3.3	1.8	0.2
DEBRE ZEIT	5.9	4.4	3.9	3.0	1.5	0.8	0.0
HOLLETA	3.8	3.4	1.5	5.1	2.8	0.7	0.0
JIMMA GERIMA GUDA	4.1	4.9	4.9	4.2	2.4	0.8	0.0
JIMMA MELKO	5.0	3.5	4.0	3.8	2.5	3.9	0.7

Table 4 (Cont'd)

CULTIVAR	10						
Soil \ Days after sowing	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.6	5.1	4.4	3.8	2.8	3.4	1.3
CHEFE DONSA	4.0	3.2	2.9	4.2	2.3	3.3	0.4
DEBRE ZEIT	5.8	4.1	2.9	3.1	2.3	0.5	0.0
HOLLETA	4.2	0.3	5.9	2.0	5.0	1.5	0.0
JIMMA GERIMA GUDA	5.4	4.1	4.1	4.0	2.3	1.7	0.2
JIMMA MELKO	4.1	4.6	3.5	3.6	2.9	3.7	2.5

Table 4 (Cont'd)

CULTIVAR	11						
Days after sowing / Soil	20-30	30-40	40-50	50-60	60-70	70-80	80-90
AKAKI	5.9	6.1	7.1	1.9	2.4	1.9	0.1
CHEFE DONSA	4.6	2.7	4.0	4.0	3.5	0.8	0.1
DEBRE ZEIT	5.6	4.0	3.7	3.6	1.8	0.2	0.0
HOLLETA	5.3	4.7	4.1	3.0	2.9	1.5	0.0
JIMMA GERIMA GUDA	5.4	4.5	4.3	4.7	2.3	2.7	0.1
JIMMA MELKO	4.1	2.7	3.4	4.1	2.7	3.1	3.9

The mean RGR, starting from the 30th to the 70th day of the growth period showed much irregularities which implied that the amount of biomass that was assimilated by the different cultivars, within the above specified range of time, were variable,

From the 70th day onwards, the mean RGR progressively decreased indicating the cultivars rate of assimilation were slower and some of the cultivars had no growth at all. Cultivar 01 & 02 on Holleta; 03 on Holleta and Jimma Gerima Guda; 04 on Chefe Donsa, Debre Zeit and Jimma Gerima Guda; 05 on Chefe Donsa, Debre Zeit and Holleta; 06 on Debre Zeit and Holleta; 07 on Debre Zeit; 08 on Chefe Donsa and Holleta; 09 on Debre Zeit, Holleta and Jimma Gerima Guda; 10 on Debre Zeit and Holleta; and 11 on Debre Zeit and Holleta had no growth at all between the 80th and 90th days of the growth period. Within the 80th to 90th days of growth all cultivars had the lowest mean RGR on all the soils or no net growth al all.

Rank of overall seed weight, total dry weight, total final average height of cultivars on all the soils and their average rank of ranks was also computed (Table 5).

Table 5

RANK OF OVERALL SEED WEIGHT, TOTAL DRY WEIGHT, TOTAL FINAL AVERAGE HEIGHT OF CULTIVARS ON ALL THE SOILS AND THEIR AVERAGE RANK OF RANKS:

CULTIVAR \ RANK	TOTAL SEED HEIGHT	TOTAL DRY HEIGHT	FINAL AVERAGE HEIGHT	AVERAGE OF RANKS
01	11	10	7	10
02	5	1	4	2
03	8	11	6	9
04	4	3	10	6
05	10	9	11	11
06	1	4	2	1
07	3	5	8	5
08	2	8	9	7
09	6	6	3	4
10	9	2	1	3
11	7	7	5	7

5.2 Statistical Treatment of Data

a) Variance analyses following Sokal and Rohlf (1969); was conducted on six growth characters. The procedure with replications was strictly followed and levels of significance at various percentages determined. The results showing the sum of squares (ss), the mean squares (Ms) and the variance ratio ($F = \frac{Ms}{Ms\ error}$) are given in Table 6.

b) In order to determine the cultivars that performed significantly higher or lower on each soil and the soils that produced dry matter significantly higher or lower for each cultivar type, Duncan's Multiple-Range Test for mean separation (Little and Hills, 1978) was applied only to the dry weight data. These results are given on Table 7 and 8.

c) Standard method correlations of dry weights and seed weights of each cultivar separately, as dependent variable and each edaphic factor, as independent variable, were computed and levels of significance at various levels were determined. These results are given on Table 9 and 10.

d) Standard method (simple) correlations of dry weight of tef as dependent variable and edaphic factors as independent variable were made (Table 11).

e) Multiple correlations between some soil analytical results as independent variable and dry weight as dependent variable were computed with the help of a computer model NCR-8455. The results are given on Table 12.

TABLE 6 - ANALYSES OF VARIANCE

HARACTER	AVERAGE PLANT HEIGHT (cm) 20 DAYS AFTER SOWING				AVERAGE PLANT HEIGHT (cm) 50 DAYS AFTER SOWING				AVERAGE CHANGE IN HIGHT PER DAY (cm) BETWEEN THE 40TH AND 60TH DAY AFTER SOWING			
URCE OF RIATION	df	SS	MS	FS	df	SS	MS	FS	df	SS	MS	FS
IVARS	10	86.58	8.66	NS 1.68	10	229.96	22.99	NS 0.93	10	0.3426	0.03	NC 0.8903
S	5	2673.28	534.66	***** 104.00	5	34755.38	6951.08	***** 282.35	5	38.64	7.73	***** 202.56
RACTION . X SOIL	50	63.02	1.26	NS 0.25	50	741.76	14.84	NS 0.60	50	1.92	0.04	NS 1.01
R. (WITH ROUP ATION)	66	339.28	5.14		66	1624.83	24.62		66	2.52	0.04	
L	131	3162.16			131	37351.87			131	43.4221		

NOT SIGNIFICANT

DEGREES OF FREEDOM

SS - SUM OF SQUARES

MS - MEAN SQUARES

FS - VARIANCE RATIO

***** = SIGNIFICANT AT 0.5% LEVEL

CHARACTER	AVERAGE FINAL HEIGHT (cm) BEFORE HARVEST				TOTAL ABOVE GROUND DRY (WEIGHT (Gm) / 15 PLANTS				TOTAL SEED WEIGHT (Gm)/15 PLANTS			
SOURCE OF VARIATION	df	SS	MS	FS	df	SS	MS	FS	df	SS	MS	FS
CULTIVARS	10	2717.15	271.72	63.88 *****	10	20.52	2.05	0.99 NS	10	7.23	0.72	1.39 NS
SOILS	5	51786.88	10357.38	2434.85 ******	5	3102.42	602.42	229.09	5	449.26	89.85	173.29 ******
INTERACTION CULT X SOIL	50	1657.79	33.16	**** 7.79	50	105.38	2.11	NS 1.03	50	13.87	0.20	NS 0.54
ERROR (WITH IN GROUP VARIATION	66	208.75	4.25		66	436.93	2.07		66	34.22	0.52	
TOTAL	131	56442.58			131	3365.24			131	504.57		

NS= NOT SIGNIFICANT SS= SUM OF SQUARES FS= VARIANLE RATIO

df= DEGREES OF FREEDOM MS= MEAN SQUARES ******* = SIGNIFICANT AT).5% LEVEL

TABLE - 7 CULTIVARS' RANK BASED ON DRY MATTER PRODUCTION ON EACH SOIL

RANK	AKAKI SOIL	CHEFE DONSA SOIL	DEBRE ZEIT SOIL	HOLLETA SOIL	JIMMA GERIMA GUDA SOIL	JIMMA MILKO SOIL
1	CULTIVAR (CV) 10 a	CV.05 a	CV.06 a	CV.09 a	CV.04 a	CV.02 a
2	CV.02 a	CV.02 a	CV.07 ab	CV.02 a	CV.02 a	CV.02 a
3	CV.04 a	CV.11 a	CV.08 ab	CV.05 a	CV.10 ab	CV.06 a
4	CV.03 a	CV.09 a	CV.04 ab	CV.07 a	CV.09,01 ab	CV.09 a
5	CV.06 a	CV.03,10 a	CV.02 ab	CV.06 a	CV.06 ab	CV.03 a
6	CV.08,05 a	CV.04 a	CV.10 ab	CV.11 a	CV.08,11 ab	CV.04 a
7	CV.01 a	CV.01 a	CV.11 ab	CV.01 a	CV.07 ab	CV.05,01 a
8	CV.07 a	CV.06 a	CV.09 ab	CV.08 a	CV.03 ab	CV.08 a
9	CV.11 a	CV.07 a	CV.05 ab	CV.10 a	CV.15 a	CV.07,11 a
10	CV.09 a	CV.08 a	CV.01 b	CV.03 a		
11			CV.03 b	CV.04 a		

(i) Cultivars assigned different letter or letters are significantly different in tef dry matter production from each other at 5% probability level.

(ii) Cultivars assigned the same letter or letters below them are not significantly different at 5% probability level.

(iii) CV stands for cultivar.

TABLE 8 - RANK OF SOILS BASED ON THEIR DRY MATTER PRODUCTION FOR EACH OF THE CULTIVARS

RANK	CULTIVAR 01 (CV.01)	CV.02	CV.03	CV.04	CV.05	CV.06	CV.07	CV.08	CV.09	CV.10	CV.11
1	DEBRE ZEIT (DZ) a	DZ a	DZ a	DZ a	DZ a	DZ a	DZ a	DZ a	DZ a	DZ a	DZ a
2	JIMMA GERIMA GUDA (JGG) a	JGG a	JGG a	JGG a	JGG b	JGG b	JGG b	JGG b	JGG b	JGG a	JGG a
3	AKAKI (AK) b	AK b	AK b	AK b	CD c	HOL. c	HOL. c	AK c	HOL. c	AK b	CD b
4	HOLLETA (HOL) b	HOL. b	CD b	CD b	HOL. c	AK c	AK c	HOL. c	CD c	CD b	HOL. b
5	CHEFE DONSA (CD) b	CD b	HOL. b	HOL. b	AK c	CD.JM c	CD c	CD.JM c	JM c	JM b	JM b
6	JIMMA MELKO (JM) b	JM b	JM b	JM b	JM c		JM c		AK c	HOL. b	JM b

(i) Soils assigned different letter or letters are significantly different in tef dry matter production from each other 5% probability level.

(ii) Soils assigned the same letter or letters are not significantly different in tef dry matter production at 5% probability level.

TABLE 9 - CORRELATION COEFFICIENTS OF THE SEED WEIGHTS OF EACH CULTIVAR WITH VARIOUS EDAPHIC FACTORS

EDAPHIC FACTOR / CULTIVAR	SAND	SILT	CLAY	P_2O_5	N	K	Na	Ca	Mg	Mn	Zn	Fe	Al	CEC	ORGANIC CARBON
01	0.11	0.88**	-0.91***	-0.08	0.43	0.97***	0.59	-0.10	-0.16	0.25	0.56	-0.16	0.43	-0.26	0.69
02	0.04	0.88**	-0.86**	-0.03	0.39	0.97***	0.65	-0.50	-0.08	0.18	0.53	-0.09	-0.50	-0.25	0.66
03	0.006	0.88**	-0.84**	-0.008	0.39	0.97***	0.67	-0.08	-0.04	0.13	0.52	-0.11	-0.55	-0.18	0.65
04	0.08	0.82**	-0.82**	-0.06	0.27	0.94***	0.70	-0.08	-0.04	0.13	0.41	0.00	-0.49	-0.25	0.58
05	0.10	0.76**	-0.79*	-0.03	0.19	0.91*	0.75	-0.10	0.01	0.09	0.34	0.05	-0.49	-0.26	0.51
06	0.08	0.83**	-0.84**	-0.06	0.31	0.95***	0.68	-0.11	-0.06	0.16	0.45	-0.02	-0.48	-0.26	0.61
07	0.04	0.84**	-0.82**	-0.06	0.32	0.95***	0.69	-0.11	-0.06	0.14	0.46	-0.004	-0.51	-0.26	0.62
08	0.01	0.88**	-0.85**	-0.06	0.39	0.97***	0.65	-0.07	-0.08	0.16	0.52	-0.08	-0.53	-0.21	0.67
09	0.04	0.89**	-0.87**	-0.05	0.41	0.98***	0.63	-0.10	-0.10	0.90	0.64	-0.11	-0.50	-0.23	0.68
10	0.08	0.81**	-0.82**	-0.06	0.27	0.93***	0.70	-0.14	-0.04	0.14	0.41	0.02	-0.48	-0.29	0.57
11	0.05	0.86**	0.85**	0.007	0.37	0.96***	0.68	-0.15	-0.04	0.15	0.52	-0.10	-0.51	-0.23	0.63

1. Those with one (*) asterick are significant at 10% level.
2. Those with two (**) asterick are significant at 5% level.
3. Those with three (***) astericks are significant at 1% level.
4. Those without astericks mean they are not significant.

TABLE 10 CORRELATION COEFICIENTS OF THE DRY WEIGHTS OF EACH CULTIVAR WITH VARIOUS EDAPHIC FACTORS

EDAPHIC FACTOR / CULTIVAR	SAND	SILT	CLAY	P_2O_5	N	K	Na	Ca	Mg	Mn	Zn	Fe	Al	CEC	ORGANIC CARBON
01	-0.004	0.90**	-0.85**	-0.08	0.42	0.98***	0.63	-0.06	-0.11	0.17	0.55	-0.08	-0.53	-0.21	0.70
02	0.02	0.86**	-0.83**	-0.04	0.36	0.96***	0.68	-0.08	-0.05	0.13	0.49	-0.05	-0.54	-0.21	0.64
03	-0.03	0.87**	-0.81**	0.03	0.37	0.97***	0.68	-0.04	-0.04	0.10	0.15	-0.05	-0.58	-0.17	0.66
04	-0.02	0.88**	-0.82**	-0.07	0.39	0.97***	0.66	-0.04	-0.07	0.13	0.51	-0.05	-0.56	-0.19	0.67
05	0.08	0.77*	-0.78*	0.04	0.20	0.91**	0.78*	-0.12	0.07	0.04	0.36	0.003	-0.53	-0.21	0.50
06	0.08	0.77*	-0.79*	-0.08	0.21	0.92***	0.73*	-0.08	-0.02	0.11	0.35	0.07	-0.49	-0.27	0.54
07	0.11	0.79*	-0.82**	-0.06	0.23	0.92***	0.71	-0.08	-0.03	0.13	0.38	0.02	-0.48	-0.26	0.55
08	0.05	0.80*	-0.80*	-0.08	0.26	0.93***	0.71	-0.04	-0.03	0.11	0.39	0.03	-0.52	-0.23	0.58
09	0.07	0.85**	-0.86**	-0.07	0.37	0.96***	0.63	-0.84	-0.12	0.23	0.51	-0.03	-0.44	-0.34	0.65
10	0.03	0.84**	-0.78*	-0.07	0.32	0.95***	0.17	-0.01	-0.03	0.08	0.44	0.01	-0.58	-0.18	0.63
11	0.02	0.84**	-0.82**	0.008	0.32	0.95***	0.72	-0.14	-0.009	0.11	0.37	-0.04	-0.54	-0.23	0.60

1. Those with one (*) asterick are significant at 10% level.
2. " " two (**) astericks are significant at 5% level.
3. " " three (***) astericks are significant at 1% level.
4. " without astericks mean they are not significant.

Table 11 - SIMPLE CORRELATION COEFFICIENTS (r) BETWEEN DRY WEIGHT OF TEF AND EDAPHIC FACTORS TAKEN SINGLY.

No	Edaphic factor in Percentage	Mean	r
1	Nitrogen	0.22	0.32 NS
2	Cation Exchange Capacity	28.17	-0.28 NS
3	Organic Carbon	2.52	0.64*
4	Sand	27.50	0.01 NS
5	Silt	32.92	0.84**
6	Clay	39.58	-0.81**
7	Phosphorus	0.06	-0.08
8	Sodium	0.003	0.69*
9	Magnesium	0.16	-0.08 NS
10	Potassium	0.19	0.27 NS
11	Calcium	0.02	-0.35 NS
12	Manganse	0.001	0.15 NS

1. One asterick (*) indicates that the coefficient is significant at 10% level.
2. Two astericks (**) indicate that the value is significant at 5% level.
3. NS means not significant.

Table 12 - MULTIPLE CORRELATIONS (R) BETWEEN TOTAL WEIGHT OF TEF ON EACH SOIL AS DEPENDENT VARIABLE AND VARIOUS COMBINATIONS OF EDAPHIC FACTORS AS INDEPENDENT VARIABLES TAKEN IN TWO'S

No	Edaphic factors in Percentage	R
1	Sand and nitrogen	0.35 NS
2	" " cation exchange capacity	0.30 NS
3	" " organic carbon	0.66 "
4	" " silt	0.87 "
5	" " clay	0.86 "
6	" " phosphorus	0.08 "
7	" " sodium	0.69 "
8	" " magnesium	0.08 "
9	" " potassium	0.28 "
10	" " calcium	0.37 "
11	" " manganese	0.17 "
12	Silt and nitrogen	0.99***
13	" " manganese	0.82 NS
14	" " cation exchange capacity	0.85 "
15	" " organic carbon	0.91*
16	" " phosphorus	0.84 NS
17	" " sodium	0.94"
18	" " magnesium	0.86 NS
19	" " potassium	0.99***
20	" " calcium	0.85 NS
21	" " clay	0.86 NS
22	Clay and organic carbon	0.81 NS
23	" " cation exchange capacity	0.81 NS
24	" " nitrogen	0.82 NS
25	" " calcium	0.81 NS
26	" " manganese	0.88*
27	" " sodium	0.95**

1. One asterick (*) indicates significance at 10% level.
2. Two astericks (**) indicate " " 2.5% level.
3. Three astericks (***) indicate significance at 0.5% level.
4. NS means not significant.

5.3 <u>The Growth of Plants in the Greenhouse:</u>

The daily range of temperature (between maximum and minium) varied from 6°C to 49°C. The average daily range of variation was 28.19°C. The average daily temperature over the growing period was 24.91°C. The average daily minimum temperature was 10.82°C and the average daily maximum temperature 39.o1°C. The relative humidity as recorded by a hair hygrometer, varied, on average, from 59% to 100%.

An exact treatment of the problem of plant ecophysiology is inconceivable without a methodology which permits the use of high-sensitive measuring and recording instruments, and the carrying out of experiments under conditions which correspond very nearly to the natural behaviour of the plant to be studied as well as to the natural climate of their normal habitat (Eckardt, 1965). The greenhouse, where the tef cultivars were grown did not permit the fulfilment of these conditions though one cannot confidently say conditions similar to the greenhouse do not exist in nature.

It is known that under controlled environmental conditions, for every species there is an optimum temperature for maximum growth and development and that usually this effect varies for seedling growth, flowering and fruit development (Downs, 1975).

Mulugeta (1978) while studying the effect of temperature on growth and development of tef under controlled and programmed Biotron conditions indicated that the temperature regime between 15 to 20°C was optimum for tef growth.

The experiment conducted in the greenhouse was not under a fixed range of temperature regimes that allowed optimum growth of the cultivars which would have made the comparison of the growth parameters of the cultivars even more sound. The aim of the experiment was however, to see how each cultivar responded to the different soils when other environmental conditions were identical for all the cultivars.

After sowing, emergence records were collected. The time needed for the seeds to emerge was from 4 to 8 days. In the different soils, the number of seeds that failed to emerge were different in number. The soil that had the least number of emergence was that of Jimma Melko and the soil that had the highest number of emergence was that of Debre Zeit. It has success of a species and its natural distribution. Variation of germination in the different soils was not unexpected. The number of emerged seedlings in the different soils decreased inthe following order: Debre Zeit, Jimma Gerima Guda, Holleta, Chefe Donsa, Akaki and Jimma Melko.

The weed populations in the different soils were also different. The most weedy soil was Jimma Gerima Guda and the least was Akaki. The weed population in the different soils decreased in the following sequence: Jimma Gerima Guda, Jimma Melko, Holleta, Debre Zeit, Chefe Donsa, and Akaki. However, weeds were constantly removed whenever and wherever they appeared right after germination was completed and when the distinction between tef and non-tef seedlings was clear.

5.4 The Performance of Cultivars In the Greenhouse:

Cultivar 01

This cultivar attained its maximum height on Debre Zeit and minimum height on Jimma Melko soils. The average final height of this cultivar in the different soils decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and Jimma Melko. The final average height achieved by this cultivar on Debre Zeit soil was by more than two times greater than that on Jimma Melko soil.

The highest above ground dry weight of the cultivar was obtained from Debre Zeit and the lowest from Jimma Melko soil. The dry weight obtained on Debre Zeit was more than five and a half times greater than that obtained on Jimma Melko soil, which was the lowest of all. The second highest dry weight value was found on Jimma Gerima Guda which was very slightly smaller than on Debre Zeit soil. The quantity of the above ground dry weight of this cultivar on the different soils, starting from the highest, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Akaki, Holleta, Chefe Donsa and Jimma Melko.

The highest seed weight for the cultivar was obtained from Debre Zeit soil. The higest seed weight obtained was more than 12.5 times greater than the lowest. The second highest, from Jimma Gerima Guda, was slightly smaller than the highest but exceeded the third highest by more than 3 times. The fourth highest was from Akaki and was follwed by that from Chefe Donsa. The least quantity of seed yield was obtained from Jimma Melko soil.

This cultivar had the least sum total seed weight of all other cultivars when the seed weight of the cultivar in the different soil was summed up together and compared with the sum total seed weight of other cultivars. However, it stood 7th by rank when the overall average final height of the cultivar was compared with those of others on all the soils. The average rank of ranks of overall seed weight, dry weight and average final height placed the cultivar in the 10th position.

The mean number of days to heading ranged from 58.37 days on Holleta soil to 71.06 days on Jimma Melko soil.

When the sum of the tiller numbers that were counted over the growing period was average for the blocks, the cul cultivar had the 8th position on Debre Zeit soil and the 2nd position by rank on Jimma Gerima Guda. The rest of the soils did not have tillers.

Cultivar 02

It had maximum height on Debre Zeit soil. The height of this cultivar on Jimma Gerima Guda was very slightly exceeded by its height on Debre Zeit soil. The minimum final mean height of the cultivar occurred on Jimma Melko soil.

This was two and a half times smaller than that found on the Debre Zeit soil. The final mean height of the cultivar in the different soils decreased in the following sequence: Debre Zeit, Jimma Gerima Guda, Holleta, Chefe Donsa, Akaki and Jimma Melko.

The lowest dry weight was obtained from Jimma Melko soil and the highest value from Debre Zeit soil. The lowest was five and a half times smaller than the highest. The second highest dry weight was found on Jimma Gerima Guda soil and was followed by Akaki, then Holleta which was in turn followed by Chefe Donsa and finally by Jimma Melko soil.

Quantitatively speaking, the highest seed yield for this cultivar was obtained from Debre Zeit soil and was 38.5 times greater than the lowest seed yields from Jimma Melko soil. The second highest seed weight, recorded from Jimma Gerima Guda soil, was only 8.9% smaller than the highest. Despite the fact that the first and the second highest seed yields were comparable, the second and third highest had very wide difference. The second highest was 5.32 times greater than the third highest.

The cultivar stood fifth by rank in overall seed weight when compared with the others. However, it stood first by rank in overall dry waight, and fourth in overall average final height. The average rank of ranks of the three parameter, i.e, average final height, dry weight and seed weight, was second.

The mean days to heading of the cultivar in the different soils range from 56.9 days, on Debre Zeit soil, to 84.8 days, on Jimma Melko soil.

In the number of tillers counted over the growing period on Debre Zeit soil, this cultivar stood second and sixth on Jimma Gerima Guda soil. It produced no tillers in the other soils.

Cultivar 03

Unlike cultivar 01 and 02, this cultivar achieved its maximum average final height on Jimma Gerima Guda soil. The height on Jimma Gerima Guda exceeded only slightly the height on Debre Zeit soil. The average final heights on both Jimma Gerima Guda and Debre Zeit soil were almost two and a half times greater than the smallest height, which was on Jimma Melko soil. This cultivar had the lowest height of all other cultivars on Jimma Melko soil. Its heights in the different soils, starting with the tallest, decreased in the following order: Jimma Gerima Guda, Debre Zeit, Akaki, Holleta, Chefe Donsa and Jimma Melko.

The highest dry weight was obtained on Debre Zeit soil and the lowest on Jimma Melko soil as was the case with cultivars 01 and 02. The highest dry weight was five times greater than the lowest. The above ground dry weight values, starting from the highest, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Akaki, Holleta, Chefe Donsa, and Jimma Melko.

Seed yield weight of the cultivar on the six different soils, starting from the highest, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Chefe Donsa, Akaki, Holleta and Jimma Melko. Seed yield weight difference between the highest on Debre Zeit, and the second highest on Jimma Gerima Guda, was very small. But the difference was very wide between the second and the third, obtained on Chefe Donsa soil. The lowest yielder of seed, Jimma Melko soil, was more than 17.3 times smaller than the highest.

In overall seed weight, the cultivar ranked 9th but had the lowest overall dry weight. On the other hand, the average final height was 5th by rank. The average rank of ranks of the overall seed weight, dry weight and average final height indicated that it stood 9th among the 11 cultivars.

The mean number of days to heading for the cultivar ranged from 57.27 days, on Debre Zeit soil, to 77.17 days, on Jimma Melko soil.

This cultivar ranked 9th in the number of tillers counted over the growing period on Debre Zeit soil, and 8th on Jimma Gerima Guda soil. It produced no tillers on the other soils.

Cultivar 04

The minimum height measurement of the cultivar was obtained on Jimma Melko soil. The height on Jimma Melko soil was smaller by half than that on Debre Zeit soil. The cultivar had its maximum height on Debre Zeit soil. The next highest height was on Jimma Gerima Guda soil, then on Akaki soil, followed by Holleta, Chefe Donsa and finally, Jimma Melko.

As far as above ground dry matter was concerned, this cultivar, like the other three cultivars considered, had the highest above ground dry weight on Debre Zeit soil and the lowest on Jimma Melko soil. The lowest value was more than 8.5 times smaller than the highest value. Values of dry weight on Debre Zeit soil or Jimma Gerima Guda soil exceeded by more than 3 times the value obtained on any of Akaki, Chefe Donsa, Holleta, or Jimma Melko soils.

The highest seed weight was on Debre Zeit soil and the lowest on Jimma Melko soil. The highest seed weight was 13.8 times the lowest. The second best yield of seed weight, that of Jimma Gerima Guda, was 22.4% smaller than the highest. The seed yield on Holleta soil, which was the third highest, was much smaller than the second. Starting from the highest, the seed yield weights on the different soils decreased in the following sequence: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and finally Jimma Melko.

Out of the eleven cultivars considered, the total of the seed weights of this cultivar stood fourth by rank. When the overall above ground dry weight was considered, it ranked third but the average final height ranked 10^{th}. The average rank of ranks of all of the above parameter, i.e., average final height, dry matter weight, and seed weight, placed the cultivar in the sixth position.

The mean number of days to heading for the cultivar ranged from 55.7 days, on Debre Zeit soil, to 71.1 days on Jimma Melko soil.

In the number of tillers this cultivar ranked 4th on Debre Zeit soil and 1st on Jimma Gerima Guda soil. It produced no tillers on the other soils.

Cultivar 05

This cultivar had its minimum height on Jimma Melko soil and its maximum on Debre Zeit soil. The height on Jimma Melko soil was half of that on Debre Zeit soil. The second highest height was on Jimma Gerima Guda soil, followed by that on Akaki, Holleta, Chefe Donsa and Jimma Melko soils in that order.

As far as the highest and the lowest above ground dry weight values were concerned, this cultivar, like the other four cultivars described above, had its highest value on Debre Zeit soil. This was a little more than six times greater than the lowest value which occured on Jimma Melko soil. The second highest above ground dry weight was on Jimma Gerima Guda soil and it was 27% less than the highest. Starting from the highest dry weight yield, the weight of this cultivar on the different soils, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Chefe Donsa, Holleta, Akaki, Jimma Melko.

Like the cultivars already described, the highest seed yield weight was obtained from Debre Zeit and the lowest from Jimma Melko soils. The seed yield weight of this cultivar on the different soils, starting from the highest decreased in the order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and Jimma Melko. The least seed yield, from Jimma Melko, was smaller by 12.94 times than the highest. The second highest seed yield was 31.78% smaller than the highest. The difference between the first and second highest seed yields was smaller than between the second and the third. Differences among the third, the fourth, fifth and the last were negligible.

Unlike the previous cultivars, cultivars 05 showed less variation in rank when the ranks of the total final mean height, total seed weight and the total above ground dry weight as well as the average rank of ranks were compared. Its rank was 10th in overall final height. The average rank of ranks indicated that the cultivar had an 11th position.

The mean number of days to heading for the cultivar ranged from 56.7 days on Debre Zeit soil to 73.4 days on Akaki soil.

Cultivar 05 had the 5th highest number of tillers on Debre Zeit soil and the 8th highest on Jimma Gerima Guda soil as compared with the number of tillers of other cultivars on these soils. No tiller was formed on the other four soils.

Cultivar 06

Like the cultivars already considered, the highest height measurement was found on Debre Zeit soil and the lowest on Jimma Melko soil. The height of the cultivar on different soils, starting from the highest and going to the lowest produced the following order: Debre Zeit, Jimma Gerima Guda, Akaki, Holleta, Chefe Donsa and Jimma Melko. The Jimma Melko soil value was smaller than those obtained on Debre Zeit soil by half.

The lowest dry weight obtained was on both Jimma Melko and Chefe Donsa soils and this was 8 times less than the highest recorded, which was on Debre Zeitsoil. The second highest dry weight obtained, from Jimma Gerima Guda soil, was 28% less than the highest. The dry weight yield, starting from the highest, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki and Chefe Donsa and Jimma Melko.

The highest seed yield weight of this cultivar, from Debre Zeit soil, was the highest of all the cultivars. The second highest seed yield for this cultivar was from Jimma Gerima Guda soil, and the lowest yielder from Jimma Melko soil. The seed yield weight of this cultivar in the six different soils decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and Jimma Melko. The difference in seed yield between Jimma Gerima Guda and Holleta was very large as compared with the difference between the two highest yields. Differences among the third, fourth, fifth, and sixth highest yields were comparatively small. The least seed weight, on Jimma Melko was smaller than the best seed yield, on Debre Zeit soil, by more than 19.1 times. The second best seed yield was only 18.9% smaller than the best one.

The yield of this cultivar in overall seed weight was the best of all. The cultivar stood second in overall average final height and fourth in overall above ground dry matter. Like cultivar 05, it also showed less variability in its ranks of the total seed weight and final mean height. The average rank of ranks of this cultivar indicated that its overall performance exceeded that of any other cultivar.

The mean days to heading ranged from 55.1 days on Debre Zeit soil, to 78.1 days on Akaki soil.

This cultivar had the 5th highest number of tillers on Debre Zeit soil and the 7th highest on Jimma Gerima Guda soil compared with the number of tillers of the other cultivars. Cultivar 06 did not produce tillers on Chefe Donsa, Akaki, Holleta and Jimma Melko soils.

Cultivar 07

Like most of the cultivars described above, the highest height measurement value was obtained on Debre Zeit soil and the lowest value on Jimma Melko soil. Height on Jimma Gerima Guda soil was slightly smaller than that on Debre Zeit soil. The height on Jimma Melko soil was slightly below half that on Debre Zeit soil. The height of the cultivar in the six different soils examined, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Chefe Donsa, Akaki and Jimma Melko.

As far as the dry weight of the cultivar was concerned, the lowest dry weight yield was obtained on Chefe Donsa soil, unlike all of the other cultivar described before. The next lowest was that on Akaki. Jimma Melko, which had produced the lowest weights of the cultivars already considered, produced the third lowest dry weight of this cultivar. The highest dry weight yield, obtained from Debre Zeit, was more than 8.5 times greater than the lowest. The second highest yield, obtained from Jimma Gerima Guda soil, was 28.2% smaller than the highest. The third highest dry weight yield, recorded on Holleta, was 4 times less than the yield obtained on Debre Zeit.

The highest seed weight yield was from Debre Zeit soil and the lowest from Jimma Melko. The highest seed weight was greater than the lowest by more than 15 times. The second best seed yield, from Jimma Gerima Guda, was 19% smaller than the highest. There was a big difference between the second and third highest seed yield weights. The differences among the third, fourth, fifth and sixth were not as big as between the second and the third. Starting from the highest, the seed weight of the cultivar on different soils decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and Jimma Melko.

The average rank of ranks placed the cultivar in the fifth position. It stood third in overall seed weight, fifth in total above ground dry weight and eighth in the total average final height.

The mean number of days to heading ranged from 55.8 days on Debre Zeit soil to 74.8 days on Jimma Melko soil.

Cultivar 07, unlike any other cultivar, tillered on three soils, viz: Debre Zeit, Jimma Gerima Guda and Jimma Melko soils.

The number of tillers counted on Debre Zeit soil was the highest of all the cultivars while tillers counted on Jimma Gerima Guda were the 5^{th} highest in number.

Cultivar 08

The maximum height measurement was obtained from Debre Zeit soil and, the second highest from Jimma Gerima Guda soil. This was the case with most of the cultivars already described. Then came Akaki which gave the third highest height measurement followed by Holleta which in turn was followed by Chefe Donsa. The least height measurement occured on Jimma Melko soil as was the case with all other cultivars so far described. The highest height measurement value was almost twice as large as the lowest.

This cultivar had its lowest dry weight both at Jimma Melko and Chefe Donsa soils. This was 7.5 times smaller than the highest dry weight yield, which was obtained from Debre Zeit soil. The next lowest dry weight yield was from Holleta soil. Jimma Gerima Guda soil gave the second best dry weight yield and this was 23.3% less than that of Debre Zeit soil. The third highest dry weight yield was that from Akaki soil and it was four and a half times smaller than that from Debre Zeit soil.

The cultivar had the highest seed yield weight on Debre Zeit soil and the lowest on Jimma Melko soil. The second highest seed yield was from Jimma Gerima Guda soil. There was only 7% difference between the first and the second highest yields. However, the difference between the second yield and the third highest yields was comparatively large. Differences among the third, fourth, fifth and sixth yields were less than that between the 2^{nd} and 3^{rd}. Starting from the highest, the seed yield weight of the cultivar in the six different soils decreased in the following order: Debre Zeit, Jimma Gerima Guda, Akaki, Holleta, Chefe Donsa, and Jimma Melko. The highest yield, from Debre Zeit soil, was 16.5 times greater than the lowest, from Jimma Melko and Chefe Donsa soils.

In total seed weight, the cultivar ranked second. On the other hand, the overall above ground dry weight and final mean height ranked 8^{th} and 9^{th} respectively. The fact that the above two parameters, dry weight and final mean height, had lower ranks than those of most cultivars and the fact that the total seed yield weight was the second highest of all the cultivars suggest that the seed yield of the cultivar per unit dry weight is greater than those of most other cultivars examined. The average rank of ranks of all the parameters considered places the cultivar in the 7^{th} position.

The mean days to heading for the cultivar ranged from 55.9 days on Debre Zeit soil to 75.3 days on Jimma Melko soil.

Cultivar 08 had tillers on 2 soils - Debre Zeit and Jimma Gerima Guda. The number of tillers counted over the growing period was the third highest in both Debre Zeit and Jimma Gerima Guda soils. The other soils did not produce tillers.

Cultivar 09

This cultivar had the third highest height measurement of all the cultivars, being exceeded only by cultivars 11 and 10. The maximum height was achieved on Debre Zeit soil. The lowest height measurement for the cultivar was obtained on Jimma Melko soil, which had a value that was slightly smaller than half of that found on Debre Zeit soil. The height of the cultivar in the six different soils, starting from the highest, decreased in the following sequence: Debre Zeit, Jimma Gerima Guda, Holleta, Chefe Donsa, Akaki, Jimma Melko.

Unlike most of the cultivars already described, the lowest above ground dry weight was obtained from Akaki soil. The highest was obtained from Debre Zeit soil and it was 8.5 times greater than that obtained from Akaki soil. The second highest dry weight yield, obtained from Jimma Gerima Guda soil, was 3 times smaller than the highest. Jimma Melko dry weight yield was the second to the lowest and was exceeded by Chefe Donsa.

The seed weight of this cultivar on the six different soils starting with the highest, decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Akaki, Chefe Donsa and Jimma Melko. Therefore, the highest seed yield weight was obtained on Debre Zeit soil and the lowest on Jimma Melko soil. The lowest seed yield weight was 14 times smaller than the highest. The second best yield, from Jimma Gerima Guda soil, was 4.6% smaller than the highest. The difference between the second and the third best yields of seed weight was comparatively greater than that between the first and the second, but the third, fourth, fifth and sixth seed yields had negligible differences among them.

The ranks of overall seed weight and overall above ground dry weight of this cultivar match perfectly, standing 6th among those of the eleven cultivars. The overall average final height of this cultivar had the third highest position by rank. This was indicative of the fact that the tef plants of this particular cultivar were among the tallest. The average ranks of this cultivar showed that it was fourth by rank for the three parameters quantified, i.e, average final height, dry weight and seed weight.

The mean number of days to heading for the cultivar ranged from 57.3 days, on Jimma Gerima Guda soil, to 70.9, on Jimma Melko soil.

Cultivar 09, like most of the other cultivars, tillered on Debre Zeit and Jimma Gerima Guda soils. The number counted over the growing period was the 7^{th} highest on Debre Zeit soil and the 4^{th} highest on Jimma Gerima Guda soil. The cultivar did not produce tillers on Akaki, Chefe Donsa, Holleta and Jimma Melko soils.

Cultivar 10

This cultivar had the highest height measurement of all the cultivars. Like most of the cultivars described above, the highest height measurement occurred on Debre Zeit soil and the lowest on Jimma Melko soil. The lowest height measurement was half of that obtained from Debre Zeit soil. The heightof this cultivar in the different soils, starting from the highest, decreased in the following sequence: Debre Zeit, Jimma Gerima Guda, Akaki, Holleta, Chefe Donsa and Jimma Melko.

The highest dry weight yield was recorded from Debre Zeit soil and the lowest from Holleta soil. The above ground dry weight yield obtained from the six different soils, starting from the highest, had the following order: Debre Zeit, Jimma Gerima Guda, Akaki, Chefe Donsa, Jimma Melko and

Holleta. The lowest dry weight yield was more than 5 times smaller than the highest. The second highest yield, from Jimma Gerima Guda soil, was only 15.0% smaller than the highest. However, the third highest from Akaki soils was more than three times smaller than the highest.

Debre Zeit soil produced the best seed yield for this cultivar. The lowest seed weight was from Jimma Melkosoil. The weight of the lowest seed yield was 11.5 times smaller than the highest. The second highest from Jimma Gerima Guda, was 24.9% smaller than the highest. The difference between the second highest and the third highest was larger than the difference between the highest and the second highest. The rest of the seed weights, obtained from Holleta, Chefe Donsa, Akaki and Jimma Melko, had small differences among them. Starting from the highest, the seed weights decreased in the following order: Debre Zeit, Jimma Gerima Guda, Holleta, Chefe Donsa, Akaki and finally, Jimma Melko.

This cultivar had the highest overall final height and the second highest overall above ground dry weight of all the cultivars. However, in total seed yield it ranked 9^{th}. This cultivar thus produced far less seeds per unit body weight than most of the other cultivars.

The average ranks indicated that it had the third position when all the parameter quantified, i.e., average final height, dry weight and seed weight, were considered.

The mean number of days to heading for the cultivar ranged from 83 days on Debre Zeit soil to 77.8 days on Jimma Melko soil.

This cultivar had the 8th highest number of tillers on Debre Zeit soil and the 9th highest on Jimma Gerima Guda soil. Tillers were not produced on Akaki, Chefe Donsa, Holleta and Jimma Melko soils.

Cultivar 11

It had the second highest mean height of all the cultivars, its highest, on Debre Zeit soil, being exceeded only by that of cyltivar 10. Its lowest mean height on Jimma Melko soil was two and a half times smaller than that on Debre Zeit soil. The sequence of mean height measurements of the cultivar on the six differentsoils, starting from the highest, decreased in the following manner: Debre Zeit, Jimma Gerima Guda, Holleta Chefe Donsa, Akaki and Jimma Melko.

Like all the other 10 cultivars, the highest seed weight yield was obtained from Debre Zeit soil and the lowest from

Jimma Melko. The highest seed yield weight was about 30 times greater than the lowest. The second highest, from Jimma Gerima Guda, was 11.3% smaller than the highest. The difference between the second and the third highest seed weights were large; but small among the third, fourth, fifth and sixth highest. Starting from the highest, the seed weight of the cultivar on the different soils decreased in the following sequence: Debre Zeit, Jimma Gerima Guda, Chefe Donsa, Akaki, Jimma Melko.

In average rank of ranks, this cultivar had the same position as cultivar 08. The overall seed weight was 7^{th} by rank, the overall above ground dry weight was 7^{th}, and the total final mean height was fifth by rank.

The mean number of days to heading for this cultivar ranged from 59.1 days, on Debre Zeit soil, to 80.6 days, on Jimma Melko soil.

This cultivar had tillers on Debre Zeit and Jimma Gerima Guda soils. It had the least number of tillers on Debre Zeit soil and the 5^{th} highest on Jimma Gerima Guda soil. On the other soils: Akaki, Chefe Donsa, Holleta and Jimma Melko tillers were not produced.

5.5 THE RESULTS OF SOIL ANALYSIS:

From the description of the performances of cultivars, it was apparent that they performed best either on Debre Zeit or Jimma Gerima Guda soils. On the other hand, most cultivars had their poorest (worst) performances on Jimma Melko soil. The performances in the other soils, i.e., in Holleta, Chefe Donsa and Akaki soils, were intermediate except for 2 cultivars.

Therefore, before trying to account for the differential performances of the cultivars, it is worthwhile to discuss the different soils on which they were grown in the greenhouse.

As indicated in section 4.3 the soils on which the cultivars were grown have been analyzed as to their mechanical composition and chemical content. Results are shown in Appendix 6.

The colour of the soils were variable, through 3 (50%) of them had dark reddish brown colour when moist. In half the soils, the clay content exceeded 55%.

The pH ranged from 5.43, which was acidic, to 7.8, which was weakly alkaline. The exchangeable cations, Ca, Mg, and K showed wide variations, but variation in sodium content was not as wide.

Phosphorus and Percent nitrogen also had much variation among the soils analyzed. The lowest value of exchangeable phosphorus (for Jimma Melko soil) was by 130 times smaller than the highest value (for Chefe Donsa Soil). The lowest value of nitrogen (for Akaki soil) was five times smaller than the highest value (for Jimma Gerima Soil).

AKAKI SOIL

The percent clay of Akaki soil exceeded that of Holleta, Debre Zeit, and Jimma Gerima Guda, The percent silt of this soil was the second smallest and the percent sand ranked third. The percentages of clay, silt and sand were 56.25, 18.75 and 25.00 respectively. The textural class of this soil was thus clayey. It had a poor internal drainage and upon watering the soil, swelling always occurred.

The pH was slightly alkaline with a value of 7.8. It was the only soil that had a pH value above neutral. The rest of the soils had values below 7 which made them fall into acidic soils.

Akaki soil had the highest electrical conductivity of all the soils. The bulk density was only exceeded by Jimma Melko soil.

Determination of cation exchange capacity (CEC) revealed the fact that the soil had the highest CEC, and the percent base saturation was fifth by rank.

It was the second best in the amount of phosphorus present and was exceeded only by Chefe Donsa soil. Unlike phosphorus, the percent nitrogen was the second smallest.

Akaki soil ranked third in the amount of aluminium present. The amount of copper (Cu^{++}) was equal in amount to that present in Debre Zeit soil. Both soils had the second smallest amount of the ion.

The amount of zinc and manganese were the smallest for this soil. It ranked first in the amount of calcium present, fourth in potassium, third in magnesium and third in sodium.

CHEFE DONSA SOIL

Chefe Donsa soil had the second highest percent clay next to Jimma Melko soil. It ranked third in the percent silt present. The sand content in the soil was the smallest of all. The proportion of clay, silt and sand were 60% 23.7% and 16.2% respectively. The soil was thus clayey.

Like Debre Zeit soil, Chefe Donsa soil was slightly acid to neutral with a pH value of 6.92. The electrical conductivity of this soil ranked third and was exceeded only by Akaki and Debre Zeit soils. It ranked third in bulk density. The percent pore space of this soil was the highest of all. This might well be due to the clayey nature of the soil. Clayey soils are more fine textured soils than sandy soils and as such have higher percentage of pore space (Buckman and Brady, 1969)

The percent organic carbon as well as the percent organic matter of this soil were the smallest of all of the soils amounting to 1.4% and 2.4% respectively.

It was the second best in cation exchange capacity and was exceeded only by Akaki soil. Chefe Donsa soil had the highest amount of exchangeable phosphorus. Like Jimma Melko soil, the percent nitrogen was the second highest and was exceeded by that of Jimma Gerima Guda only,

The amount of aluminium present in Chefe Donsa soil was equal to that of Jimma Gerima Guda and both raked second to last, exceeding only by Holleta soil. Like Holleta soil, it ranked fourth in the amount of exchangeable iron (Fe^{+3}) and fifth in the amount of manganese ion.

Chefe Donsa soil was second in the amount of clacium, potassium as well as sodium and first in magnesium. The percent base saturation was fourth.

DEBRE ZEIT SOIL

The percent clay of this soil was the second smallest, exceeding that of Jimma Garima Guda soil only. The percent silt was also the second smallest and the % sand is the second highest. The percent clay, silt and sand of this soil were 22.5%, 45.0% and 32.5% respectively. The class of the soil was thus loamy.

The pH of the soil was slightly acid to neutral and had a value of 6.98. This value is exceeded by the pH value of Akaki soil only.

Electrical conductivity of the soil was the second best and, again was exceeded only by that of Akaki soil.

The bulk density was the smallest, being exceeded by the other soils. The percent pore space was third and was exceeded by those Chefe Donsa and Holleta soil only.

The percent Organic carbon as well as the percent organic matter were third in rank.

The CEC (cation exchange capacity) was fourth in rank The amount of phosphorus was third, being exceeded by Chefe Donsa and Akaki soils. On the other hand, the percent nitrogen present was the smallest of all.

Aluminium ion concentration was the smallest of all the soils. It had copper ion (Cu^{++}) concentration that was equal to that of Akaki soil, ranking fourth. Debre Zeit soil had the second smallest amount of zinc concentration and the third smallest amount of manganese ion concentration of the six soils examined.

As far as the exchangeable bases (cations) were concerned, it had calcium which was the third smallest in amount. It ranked first in the amount of potassium and sodium; and percentage of base saturation.

HOLLETA SOIL

The percent clay of this soil exceeded that of Debre Zeit and Jimma Gerima Guda. Therefore, it ranked fourth in percent clay content. The percent silt was the smallest of all the soils while the percent sand was the highest of all. The amounts of clay, silt and sand in percentages were 31.25, 17.50 and 51.25 respectively. The texture of Holleta soil was thus sandy clay loam.

It had a pH of 5.5., which indicated that it was an acidic soil. The electrical conductivity ranked fourth, exceeding that of Jimma Melko and Jimma Gerima Guda. The bulk density was the second smallest. The total percent pore space was the second highest of all and was exceeded by that of Chefe Donsa soil only.

The percent organic carbon (as well as the organic matter) ranked fourth. It had greater organic matter than Akaki and Chefe Donsa soils.

The cation exchange capacity of the soil ranked fifth, exceeding that of Jimma Melko soil only.

The concentration of phosphorus was equal to that of Jimma Gerima Guda, both soils ranking second from last. It ranked third in percent nitrogen, being greater than Akaki and Debre Zeit soils.

Of all the soils that were examined the highest amount of aluminium was recorded for Holleta soil. The same was true for the amount of copper present. Exchangeable iron (ferric ion) was second to last and was equal to that in Chefe Donsa soil. It ranked third in zinc, being exceeded by that of Chefe Donsa and Jimma Gerima Guda soils. It had the highest concentration of manganese of all the soils.

Holleta soil ranked last in calcium, third in potassium, fourth in magnesium and fifth in sodium. Its rank based on the percent base saturation, as determined from the CEC and exchangeable bases, was second and was exceeded only by that of Debre Zeit soil.

JIMMA GERIMA GUDA SOIL

The percent clay was the smallest, the percentage silt was the highest and percent sand the fourth highest, exceeding those of Jimma Melko and Chefe Donsa soils. The percentage values of the clay, silt and sand were 6.25, 72.50 and 21.25 respectively. The soil was therefore silty loam.

Like Debre Zeit soil, it had one of the least bulk densities and it ranked fifth in total percent pore space.

The percent organic carbon as well as the percent organic matter of this particular soil was the highest of all. It had also the highest percent nitrogen. The amount of phosphorus, however, put it in the fourth position. It had phosphorus that was equal in amount to Holleta soil.

Aluminium content of the soil was the second smallest, the least was that of Debre Zeit. Copper (Cu^{++}) and iron ions were the smallest of all the soils. It has the highest zinc content and ranked second in the amount of manganese.

Among the exchangeable bases (cations); potassium and magnesium were the lowest of all, while calcium was third and sodium fourth by rank, The percent base saturation of this soil was the lowest of all.

JIMMA MELKO SOIL

It had the highest percentage of clay of all the soil, it was fourth in percent silt and it had the second smallest percent sand, exceeding only that of Chefe Donsa soil. The percent clay , silt and sand of this soil were 61.2, 20.0 and 18.7 respectively. The soil was thus clayey.

pH for this soil was the smallest of all, having a value of 5.4 . It was, therefore, a strongly acidic soil like that of Holleta. The electrical conductivity of this soil was the second lowest, exceeding only that of Jimma Gerima Guda. It had the highest bulk density, and it had the lowest percent pore space.

The percent organic carbon and organic matter were the second highest and were exceeded only those of Jimma Gerima Guda soil.

Jimma Melko soil had the lowest cation exchange capacity (CEC).

It had the smallest phosphorus content. The percent nitrogen was the second highest next to Jimma Gerima Guda soil. It was second in the amount of aluminium present in it and was exceeded by Holleta soil. It ranked third in the amount of copper and was first in the amount of iron persent. Zinc in Jimma Melko soils occupied a fourth position exceeding that of Debre Zeit and Akaki soils. The amount of manganese was third, being next to Holleta and Jimma Gerima Guda soils.

Calcium was second from the last, so were potassium and manganese. Sodium was last. The percent base saturation was the third highest.

6. GENERAL DISCUSSION:

Computation of the mean relative growth rate (RGR) of plant height indicated (Table 4) that the figures obtained were high for all the cultivars during the early stage of development (between the 20^{th} and 30^{th} days after sowing) of the plants and progressively decreased as the cultivars approached physiological maturity (from the 70^{th} days after sowing).

During the initial growth stage, the amount of soil nutrients in the different soils would be greater than in the final stages of development of plants and this would enable faster growth of plants, hence higher mean RGR was obtained.

The availability of nutrients would progressively decrease as the age of plants increased. This would slow down the rate of growth of the cultivars. In the final stage of development (maturity stage) the cultivars had accumulated enough biomass and had become senescent that the net gain of biomass was comparatively very small and the mean RGR was small as well.

Leaf and tiller sensecence would partially explain for the irregular rate of mean relative growth that was observed from the 30th to the 70th days. Rate of apparent photosynthesis would decrease as leaves, tillers or stem senesce and this would sharply decrease the amount of biomass added to the plant body. However, other environmental factors might have equally affected the mean RGR as did senscence during the above mentioned range of days of cultivar growth.

Studies of growth of a whole plant or a whole life cycle of a plant indicate that the different growth phases result in a sigmoid curve or simply a growth curve. Any growth curve has three phases: Phase of cell formation, when growth rate increased slowly; phase of cell elongation, when growth rate increased rapidly; and phase of cell maturation, when again, the rate slows down. Computation of the mean RGR of a plant height should reflect the phases of the growth curve, i.e. it had to be slow in the initial stage followed by being fast in the grand period of growth and, again, slow during the maturity stage. This, however, was not fully realized in this experiment when mean RGR were computed from plant heights of the cultivars. This was particularly true of the mean RGR of the cultivars from the 30th to the 70th days of growth of the cultivars.

The fact that the experiment was done in a greenhouse where controlled environmental conditions were absent would be a possible explanation for the deviation of results of the mean RGR between the 30th and the 70th days of growth. Temperature could be another environmental factor that might have affected the growth rates. For example, the daily range of temperature of the green house varied from 6^{o}c to 49^{o}c. At temperatures above 45^{o}c enzymes are denatured or inactivated. Therefore temperature as high as 49^{o}c could retard growth of cultivars and could introduce unexpected results to the mean RGR. In addition to this, growth was not measured during the first 20 days after sowing.

Therefore, it would be necessary to study the rate of change of the mean relative growth under a controlled environmental conditions in order to get a better understanding of the growth activities of the different cultivars.

The performance of cultivars as well as the results of the analysis of the soils showed wide variations. The variations of cultivars performance and that of soil analytical results dictated the application of statistical methods to analyze the sources of variations of cultivars' performance; to examine if differences of performances of cultivars, depending on some of the parameters quantified, were significantly different from each other ; and to determine how the different soil analytical results affect the performance of cultivars in particular and of tef in general.

To analyze the source of variations, analysis of variance were computed on six growth characters (Table 6). They were:

Average plant height (cm) 20 days after sowing;
Average plant height (cm) 50 days after sowing;
Average final height (cm) before harvest.
Average change in height per day between the 40th and 60th day after sowing.
Total seed weight (gm) per 15 plants.
Total dry weight (gm) per 15 plants

The results indicated that the variance due to cultivar type was not significant (even at 10% level) for the characters with the exception of the average final height before harvest. Neither was the variance due to the interactions of soils and cultivars significant. However, the variance due to soils was significant at 0.5% level or less.

To identify the cultivars that had significantly higher tef dry matter on a given soil and the soils that produced significantly higher tef dry matter for a given cultivar , analyses were made with Duncan's multiple-range tests (Table 7 and 8). The results indicated that all cultivars had comparable yielding abilities of tef dry matter on Akaki, Chefe Donsa, Holleta or Jimma Melko Soil. In the other two soils, i.e., Debre Zeit or Jimma Gerima Guda some cultivars had significant dry matter weight differences. On Debre Zeit, cultivar 06 had significantly higher (at 5% level) dry matter than cultivar 01 or cultivar 03; and on Jimma Gerima Guda soils cultivar 04 or 02 had significantly higher (at 5% level) dry matter than cultivar 05. The rest of the cultivars, i.e., cultivar 07, 08, 04, 02, 10, 11, 09 or 05 on Debre Zeit soil, and cultivar 10, 09, 01, 06, 08, 11, 07 or 03 on Jimma Gerima Guda soil, had comparable dry matter production with differences that were not significantly higher or lower among them.

The soils that produced significantly higher dry matter for each cultivar were analyzed. Jimma Gerima Guda produced dry matter of cultivar 01, 02, 03, 04, 10 or 11 that was comparable with that produced on Debre Zeit soil. The differences in dry matter yield of each cultivar mentioned above in the two soils were not significantly different. However, the dry matter production of the two soils for the cultivars - 01, 02, 03, 04, 10 or 11 - were signficantly higher (at 5% level) than that produced by Akaki, Chefe Donsa, Holleta or Jimma Melko separately. The other cultivars, i.e. cultivar 05, 06, 07, 08 or 09 each had dry matter on Debre Zeit soil that was significantly higher (at 5% level) than that produced on Jimma Gerima Guda soil and yet, that produced on Jimma Gerima Guda for each cultivar mentioned above was significantly higher (at 5% level) than that obtained on Akaki, Chefe Donsa, Holleta, or Jimma Melko separately. However, dry matter production of Akaki, Chefe Donsa, Holleta or Jimma Melko for each cultivar mentioned above (05, 06, 07, 08 and 09) were comparable.

Analyses of variance as well as Duncan's multiple-range test indicated that the soils were mostly responsible for the difference of performance of cultivars.

To examine if variations of performance of cultivars corresponded to similar variations in soil analytical results and to determine how the different soil analytical results affect the performance of cultivars in particular and of tef in general, simple correlation coefficients were computed between:

A) Seed weights of each cultivar and each edaphic factor of soil analytical results (Table 9).

B) Dry weights of each cultivar and each edaphic factor (Table 10) and

C) Total dry weights of tef on each soil and each edaphic factor (Table 11).

Correlations of seed weight of each cultivar with each factor of soils indicated that all the cultivars had significant and positive correlation coefficients (r) with potassium at 5% level or less. Each cultivar had also significant and positive coefficient with the silt content of the soil at 10% level. Clay was significantly correlated with the seed weights of each cultivar at 10% level but the correlation cof ficients were all negative. The other edaphic factors - sand, nitrogen, sodium, calcium, magnesium, manganese, zinc, iron, aluminium, cation exchange capacity and organic carbon - were not significantly correlated with seed weights of the cultivars.

The dry weight of each cultivar on the different soils was also correlated with edaphic factors. Again, each cultivar had significant and positive coefficients with potassium at 1% level and with silt at 10% level. The clay contents of the soil had also significant and nega ve correlation coefficients with the dry weights of each cultivar at 10% level. The other edaphic factors were not significantly correlated with the dry weights of the cultivars.

Since the soils were implicated for the differences of performances of cultivars (Table 6) and since each cultivar showed significant correlation coefficients with particular edaphic factors, i.e., potassium, silt and clay, correlations were also made between total dry weights of tef on each soil, which was achieved by adding the dry weights of the cultivars on a soil, and each edaphic factor to examine if similar relationships were maintained by the dry weights of tef in general. The results indicated that dry weights of tef had significant and positive coefficients with silt of the soil at 10% level; and significant but negative coefficients with clay contents of the soil at 10% level. The other edaphic factors were not significantly correlated with the dry weights of tef at 10% level of significance.

In simple correlations, edaphic factors were taken singly to be correlated with the dry weights or seed weights of tef cultivars and with the dry weights of tef. In all the correlations, each cultivar had positive and significant coefficient with potassium or silt. Potassium is a macronutrient needed in relatively large amounts by all plants and is important in metabolism in the formation of carbohydrates and proteins; it also aids in the uptake of other nutrients and in their movement within the plant (Thompson <u>et.al</u>.. 1978). Soil containing too much clay may have high water - holding capacity but inadequate aeration and the decreased aeration resulting from soil compaction caused a decrease in the uptake of potassium (Thompson <u>et. al</u>., 1978). The fact that the dry weights and seed weights of each cultivar in particular and dry weights of tef in general had high and positive correlation with potassium and silt were closely linked with the adequate aeration that silt-dominated soils would have which would facilitate rapid absorption of potassium for optimal plant growth. On the other hand, the fact that the dry weight and seed weight of cultivars had significant but negative performance of the cultivars. Moreover, plant growth depends not on single factors (as in single correlations explained above) but on a multitude of factors that usually interact strongly (Kelley , 1948). As such the absence of significant correlations between several edaphic factors and dry weights of cultivars was not unexpected.

The combined effects of edaphic factors on yield of tef were examined using multiple correlation analysis (R)(Table 12). The dependent variable was the total dry weights of tef on each soil and the independent variables, taken in two's were the edaphic factors determined by soil analysis. Two dependent variables were taken at a time to be correlated with the dry weights because the number of soil samples were only six and as such did not leave enough degrees of freedom for more independent variables to be used at a time.

The results of the multiple correlation analyses indicated that

(a) Percent clay and percent sodium together were significant at 2.5% level;

(b) Percent silt and percent organic carbon together were signficant at 10% level;

(c) Percent silt and percent nitrogen together were significant at 0.5% level or less;

(d) Percent silt and percent sodium together were significant at 10% level;

(e) Percent silt and percent potassium together were significant at 0.5% level or less;

(f) Percent clay and percent manganese together were significant at 10% level.

The highest multiple correlation coefficients were thus obtained when dry weightwas correlated with silt and potassium. Variations in total dry weights of tef were accompanied by similar variations of silt and nitrogen or silt and potassium of the soils. It seems, therefore, that the silt content, the nitrogen and potassium of the soils have been the edaphic factors that were partly responsible for the differences in dry weight of tef on the different soils.

The good vegetative growth of cultivars on Jimma Gerima Guda soil could be best explained on the basis of the results of the multiple correlation. Jimma Gerima Guda soil, though it had only the second rank by dry weights of the tef produced on it, had plants (in many instances) that were comparable in height to those on Debre Zeit soil. Over the growing period of the cultivars, Jimma Gerima Guda soil had dark green thin films on top of its soil. Microscopic examination of the thin green films revealed that they were blue green algae. These blue green algae had heterocysts. It is a known fact that nitrogen fixing in the blue green algae is by species which form the thick-walled, colorless heterocyst cells (smith, 1955; Fogg, 1973; Etherington, 1974). In addition, the soil was silty loam and was characterized by the highest percentage of silt (72.5%) of the soils examined.

Debre Zeit soil was the best soil for it had loamy texture. Loamy textured soils are best for most agricultural purposes (Brade-Bricks, 1962). Loam and silty loam soils are highly desirable for most uses because they have enough clay to store adequate amount of water and plant nutrients for optimum plant growth but not so much clay as to cause poor aeration or to make working with them difficult (Thompson et.al 1978). Both Jimma Gerima Guda and Debre Zeit soils were silty loam and loam in texture respectively.

The relatively poorer performance of cultivars on the other soils could be explained from the point of textural composition of the soils. Akaki, Chefe Donsa and Jimma

Melko soils were clayey. In simple correlations, the clay contents of the soil were negatively and significantly correlated with the dry weights of tef, i.e., an increase in the clay content of soils is accompanied by a decrease in dry weight yields of tef and vice versa. The fact that the textural composition of Akaki, Chefe Donsa and Jimma Melko soils were dominated by the clay fraction might have resulted in the poorer performance of cultivars on these soils. Holleta soils was sandy clay loam in texture though acidic. On Holleta soils, the performance of cultivars were not comparable to those of Debre Zeit and Jimma Gerima Guda. In many instances, the dry weights of tef on Holleta soil were greater than those on Akaki, Chefe Donsa and Jimma Melko. The acidic nature of the soil is belived to have interfered with the proper performance of cultivars on Holleta soil.

The total dry weight of tef produced on a given soil in the greenhouse experiments was divided by the total number of cultivars (11) that produced it. The resulting average values of production in the different soils were used to place the different soils according to their relative levels of fertility on the horizontal axis of a graph. The dry weights produced by a specific cultivar on the different soils were placed along the vertical axis. The position of each soil was marked on the graph based on these two axes. The cultivar whose production of dry weight on a given soil was exactly the average for all the cultivars would place the positions of the soils on the diagonal line drawn at 45^{o} from the origin. The reason why this diagonal line should show the average production of a cultivar on the different soils is that since the horizontal axis shows average production of cultivars on the different soils, any cultivar producing the same dry matter as the average for a soil joins with this line at a point equidistant from both axes. The diagonal line passes through this point. If the cultivar has produced more than average on a given soil, its value on the vertical axis will be greater than that on the horizontal axis; the point then lies to the left of the diagonal line. If, on the other hand, it produces less than average, the horizontal value will be greater, shifting the point to the right or (below) the diagonal line. The further away from the diagonal the point lies, the more it deviates from the average for that level of soil fertility. The graphs made in this way are shown in figures (figure 1 to 11).

IN THE FOLLOWING FIGURES (FIGURE 1 - 11)

(1)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON AKAKI SOIL
(2)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON CHEFE DONSA SOIL
(3)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON DEBRE ZEIT SOIL
(4)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON HOLLETA SOIL
(5)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON JIMMA GERIMA GUDA SOIL
(6)	=	DRY WEIGHT OF THE CULTIVAR GROWN ON JIMMA MELKO SOIL

AK	=	AKAKI SOIL
CD	=	CHEFE DONSA SOIL
DZ	=	DEBRE ZEIT SOIL
HOL	=	HOLLETA SOIL
JGG	=	JIMMA GERIMA GUDA SOIL
JM	=	JIMMA MELKO SOIL

Fig. 1 AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 01

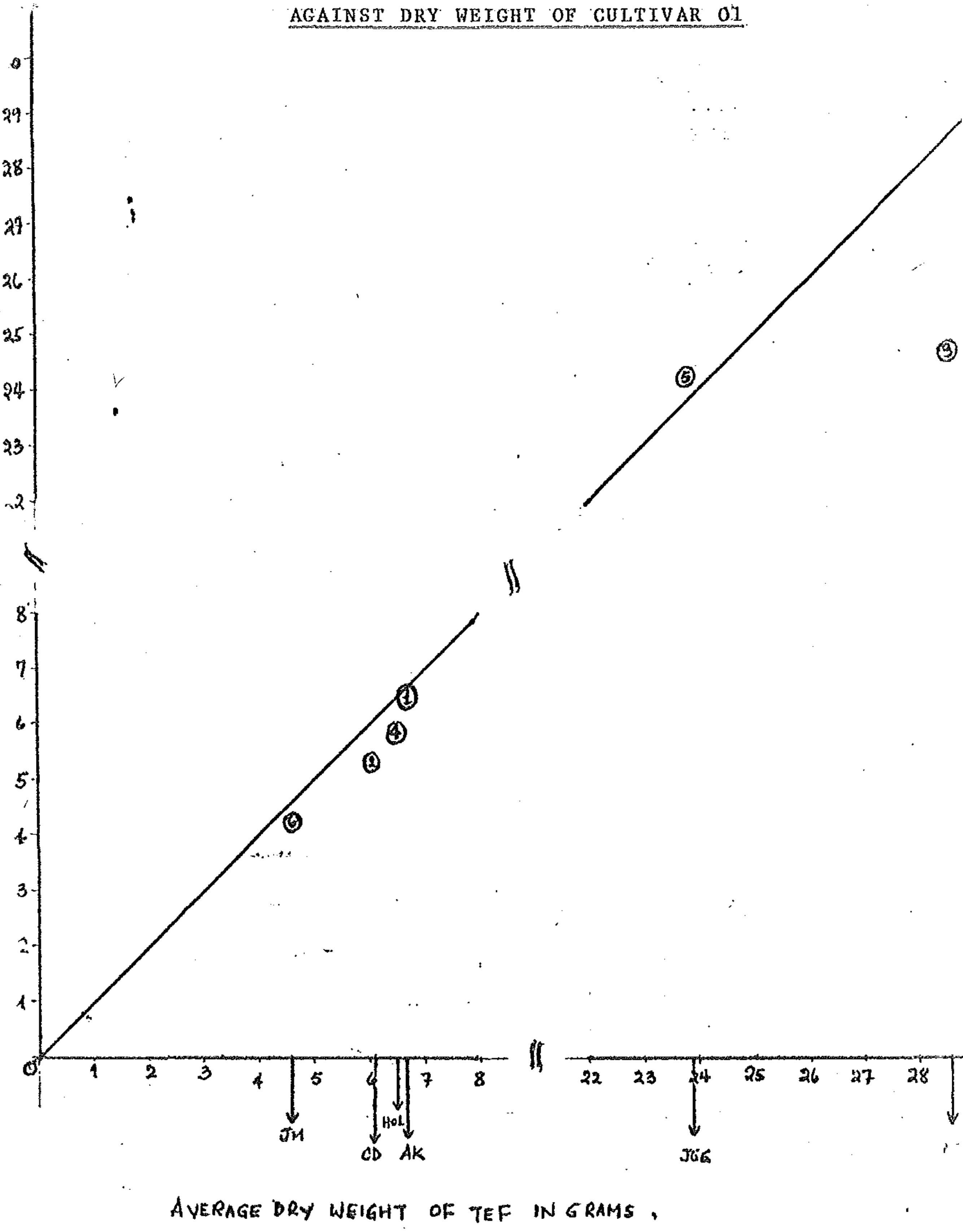


Fig. 2: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 02

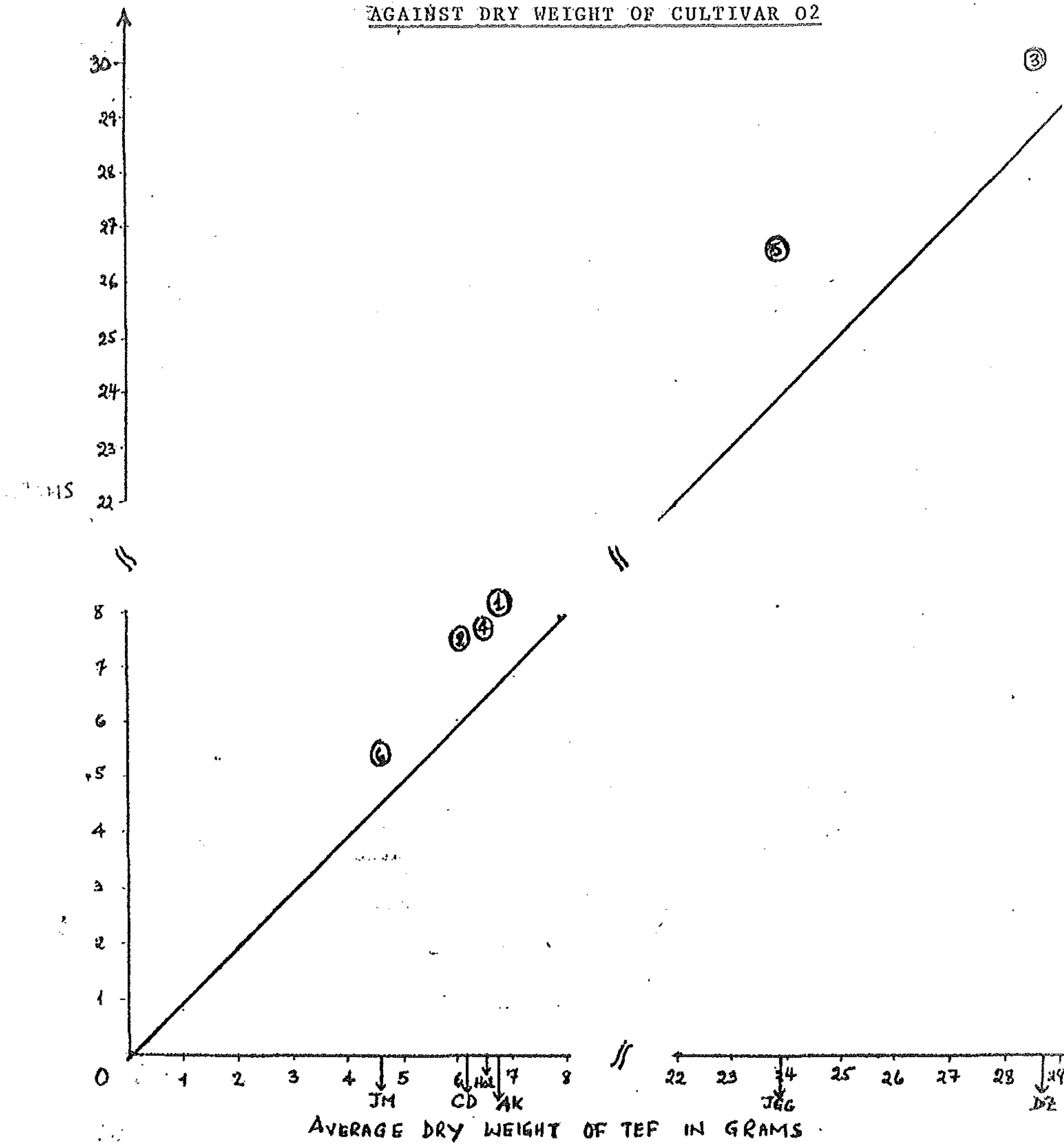


Fig. 3: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 03

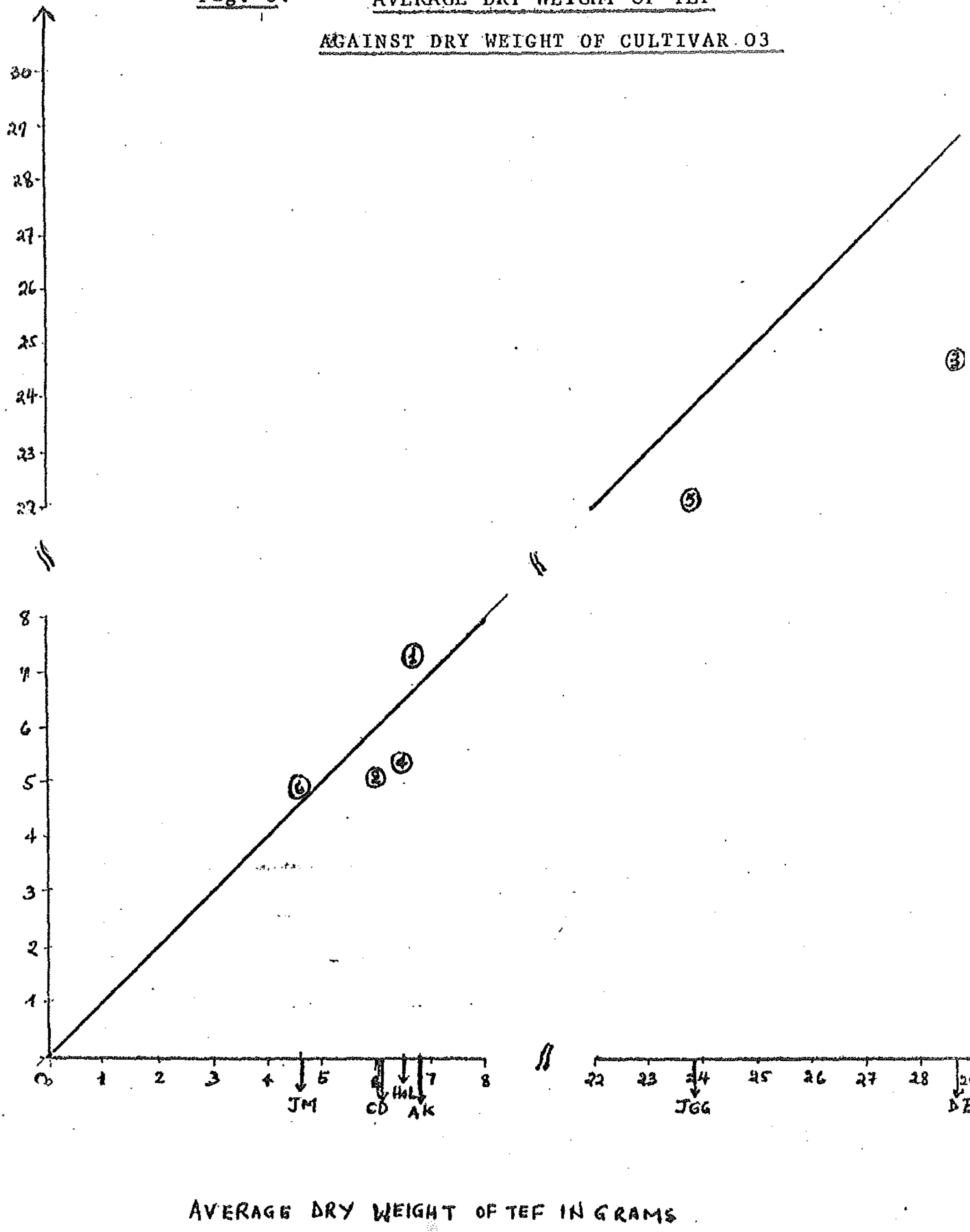
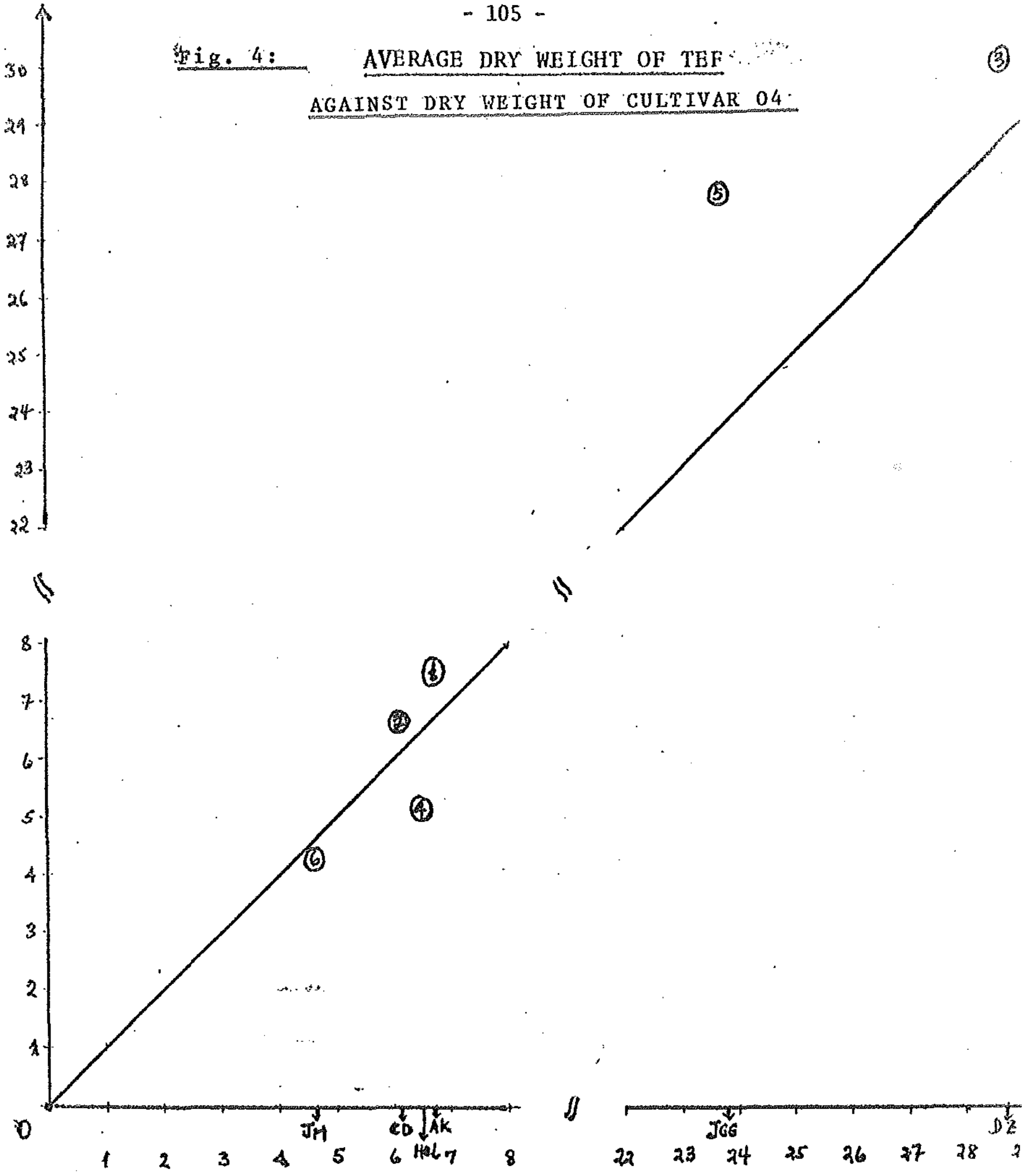


Fig. 4: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 04



AVERAGE DRY WEIGHT OF TEF IN GRAMS.

Fig. 5: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 05

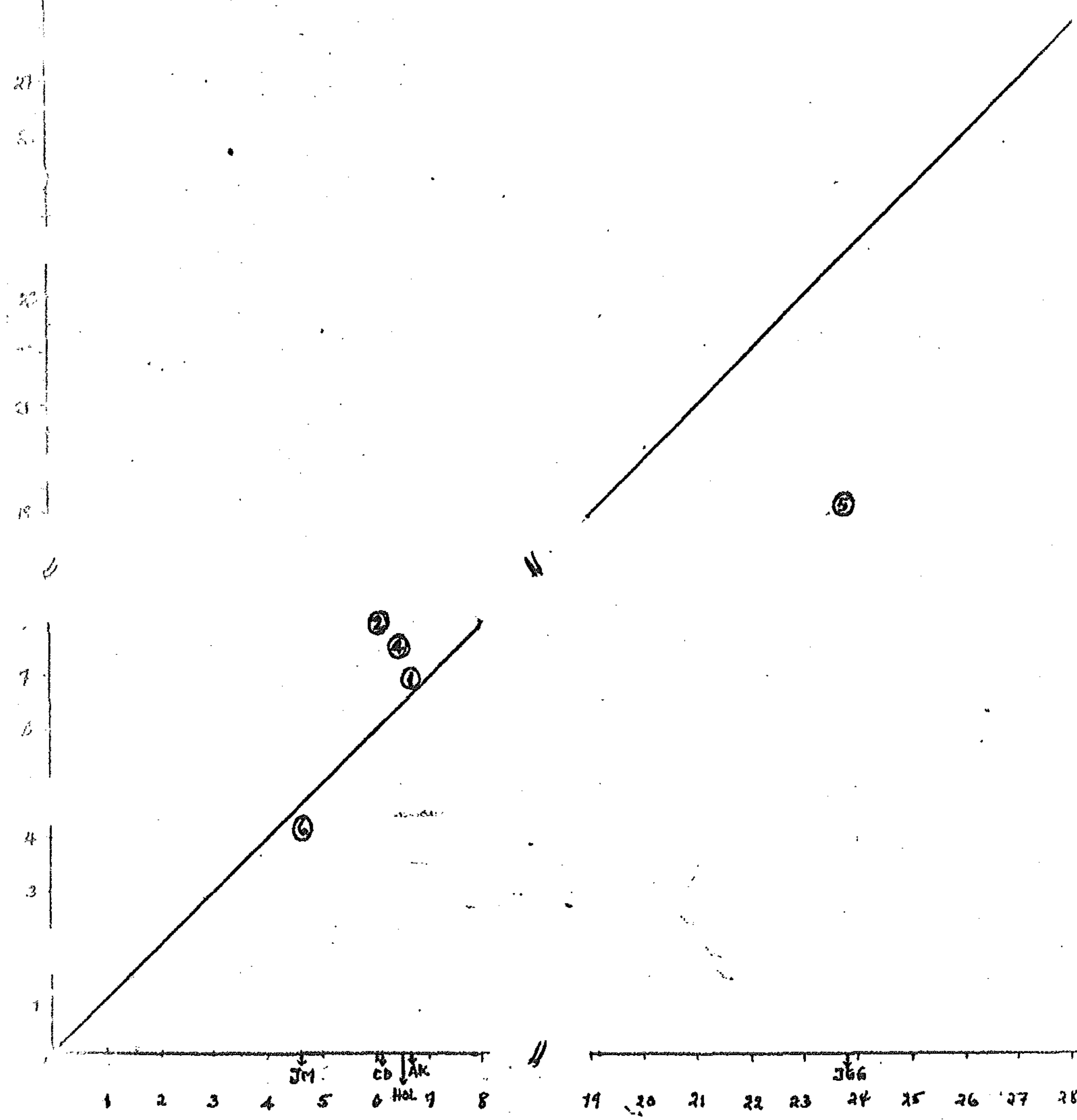


Fig. 6: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 06

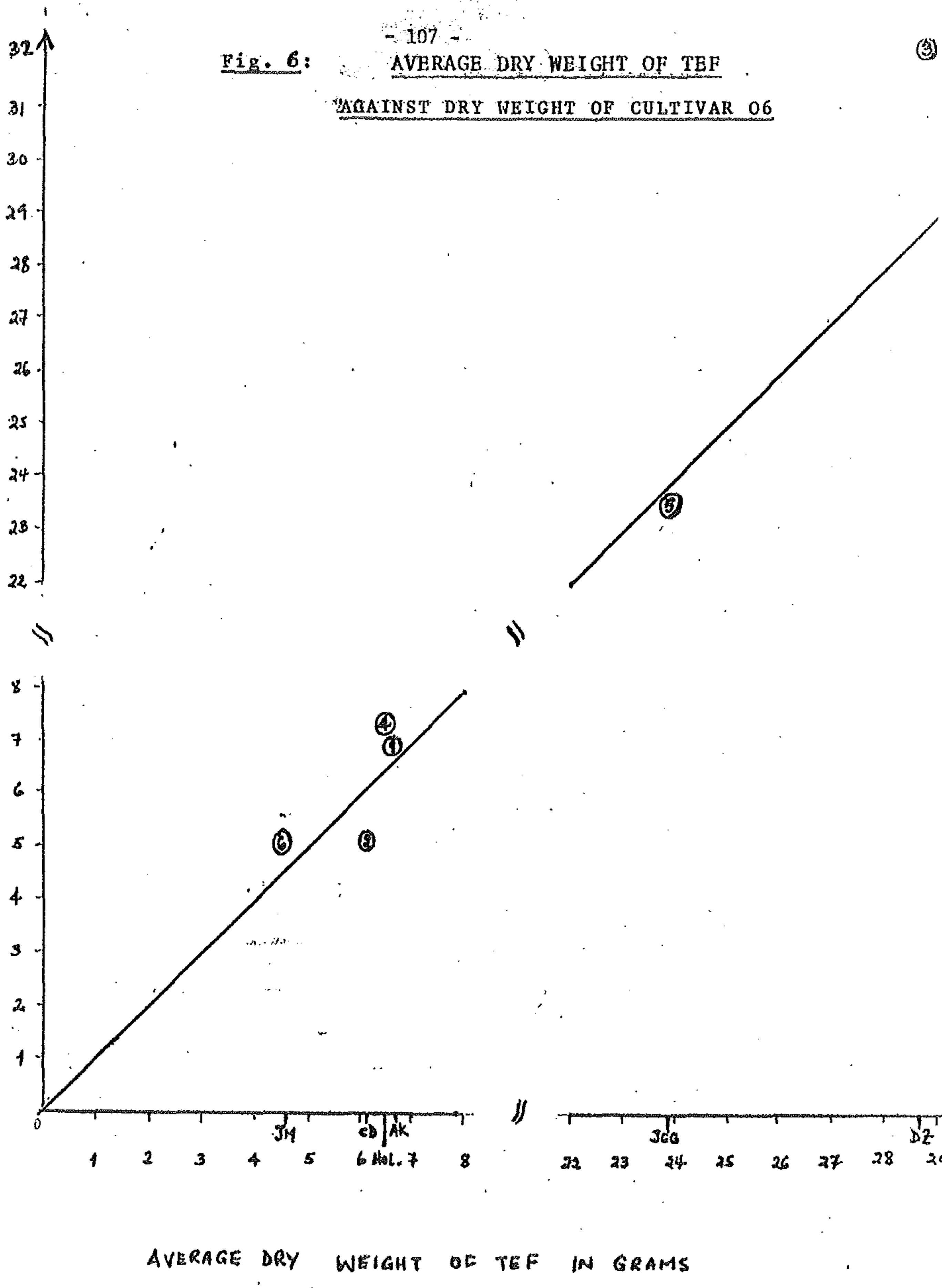


Fig. 7: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 07

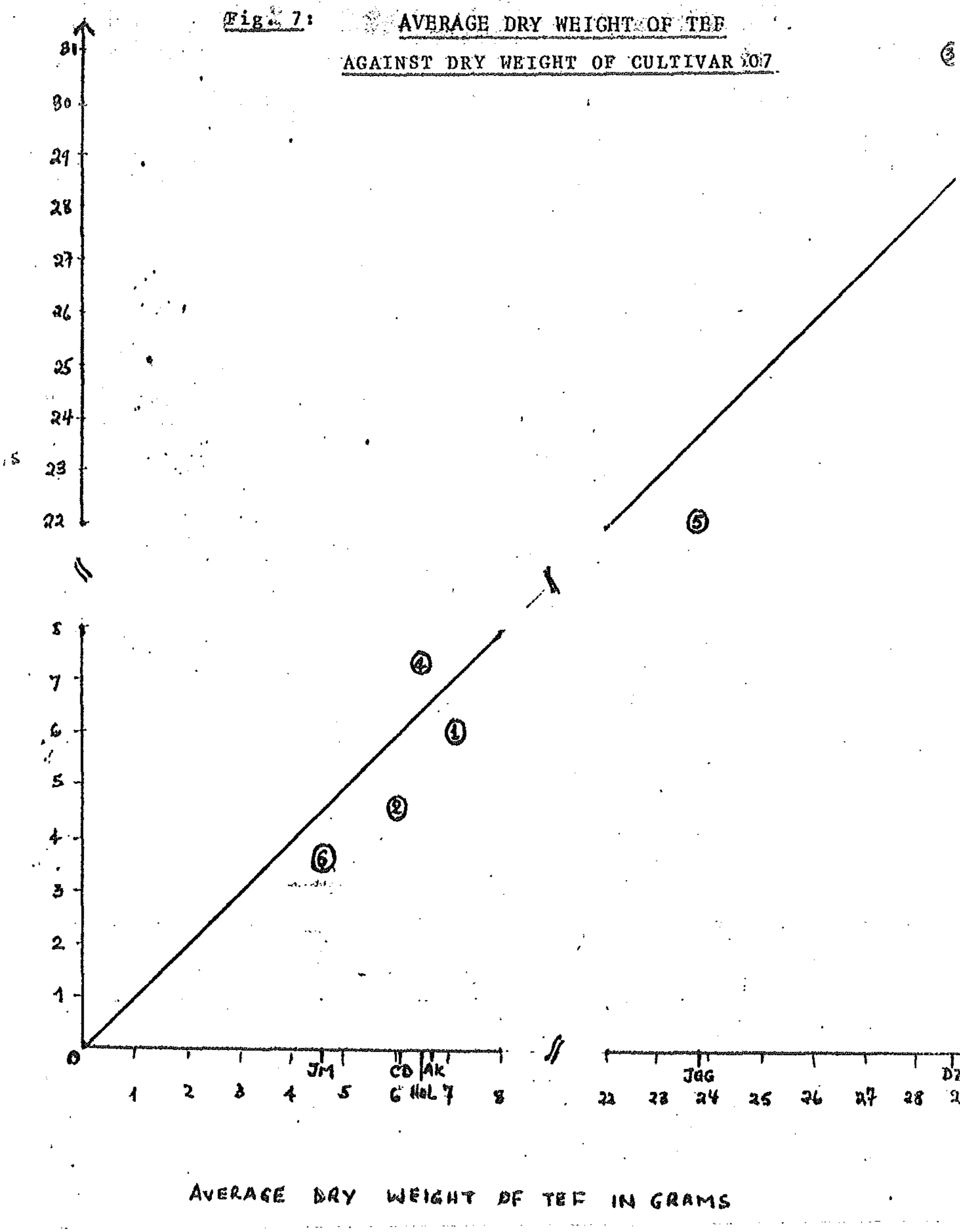


Fig. 8: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 08

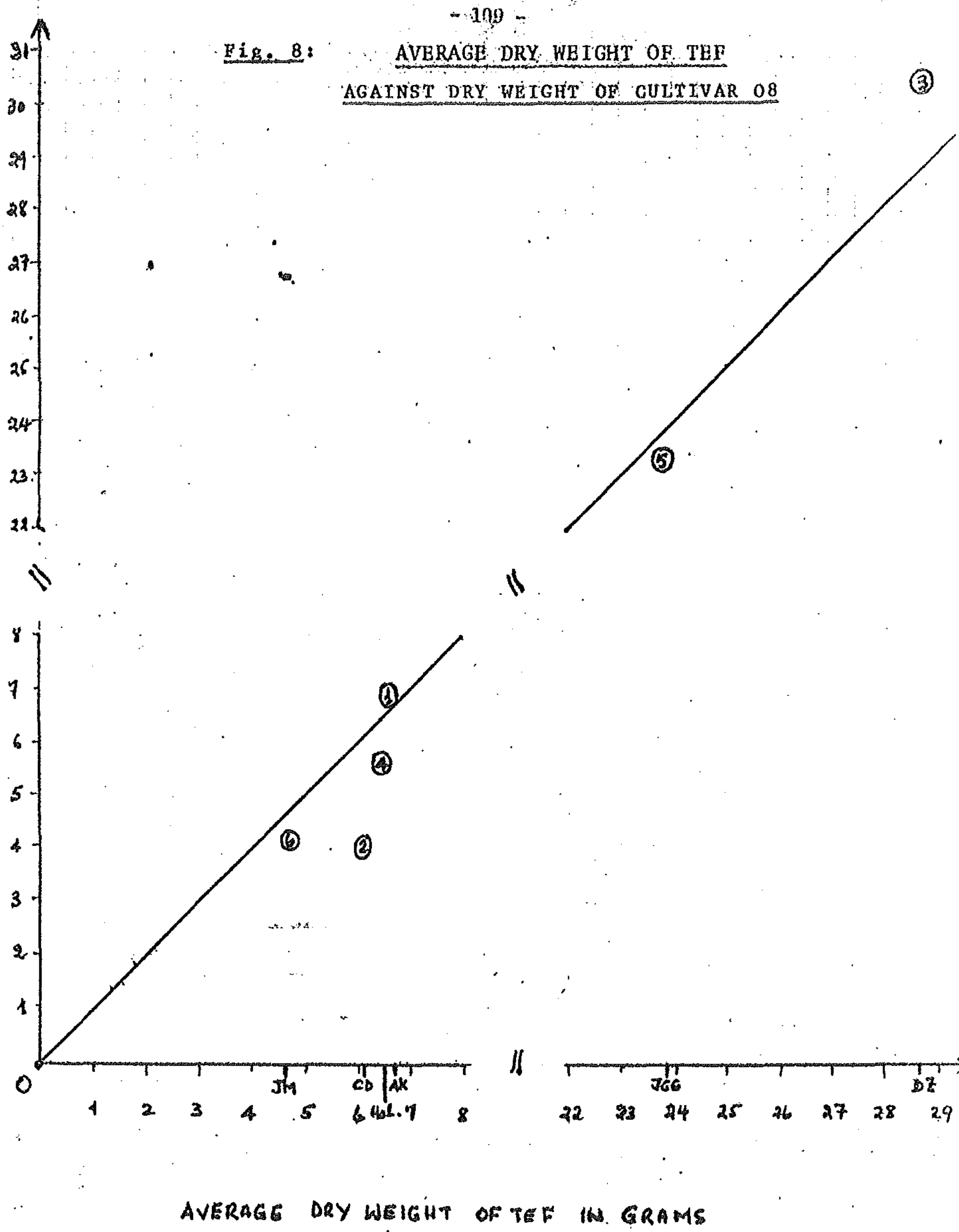


Fig. 9: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 09

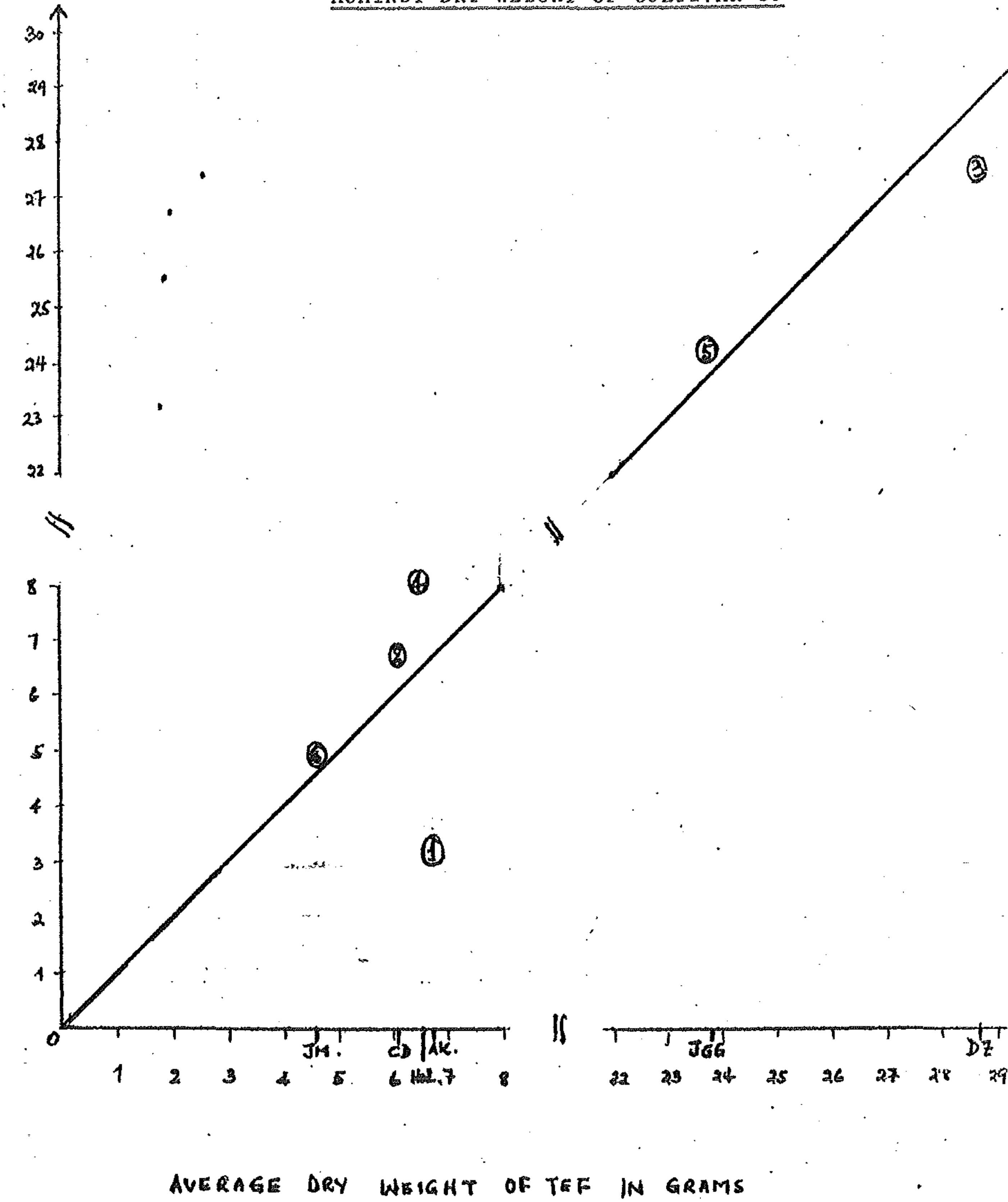


Fig. 10: **AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 10**

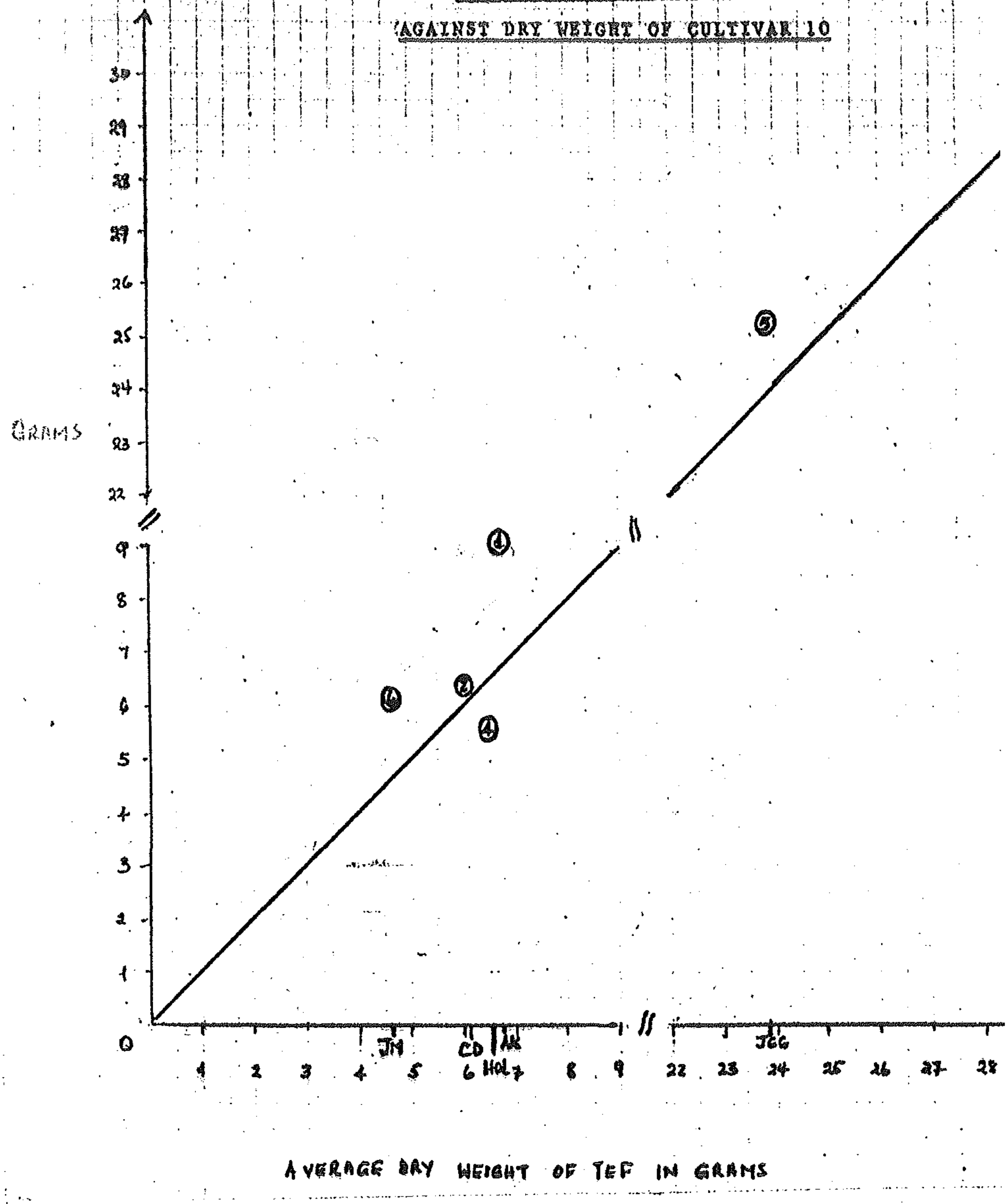
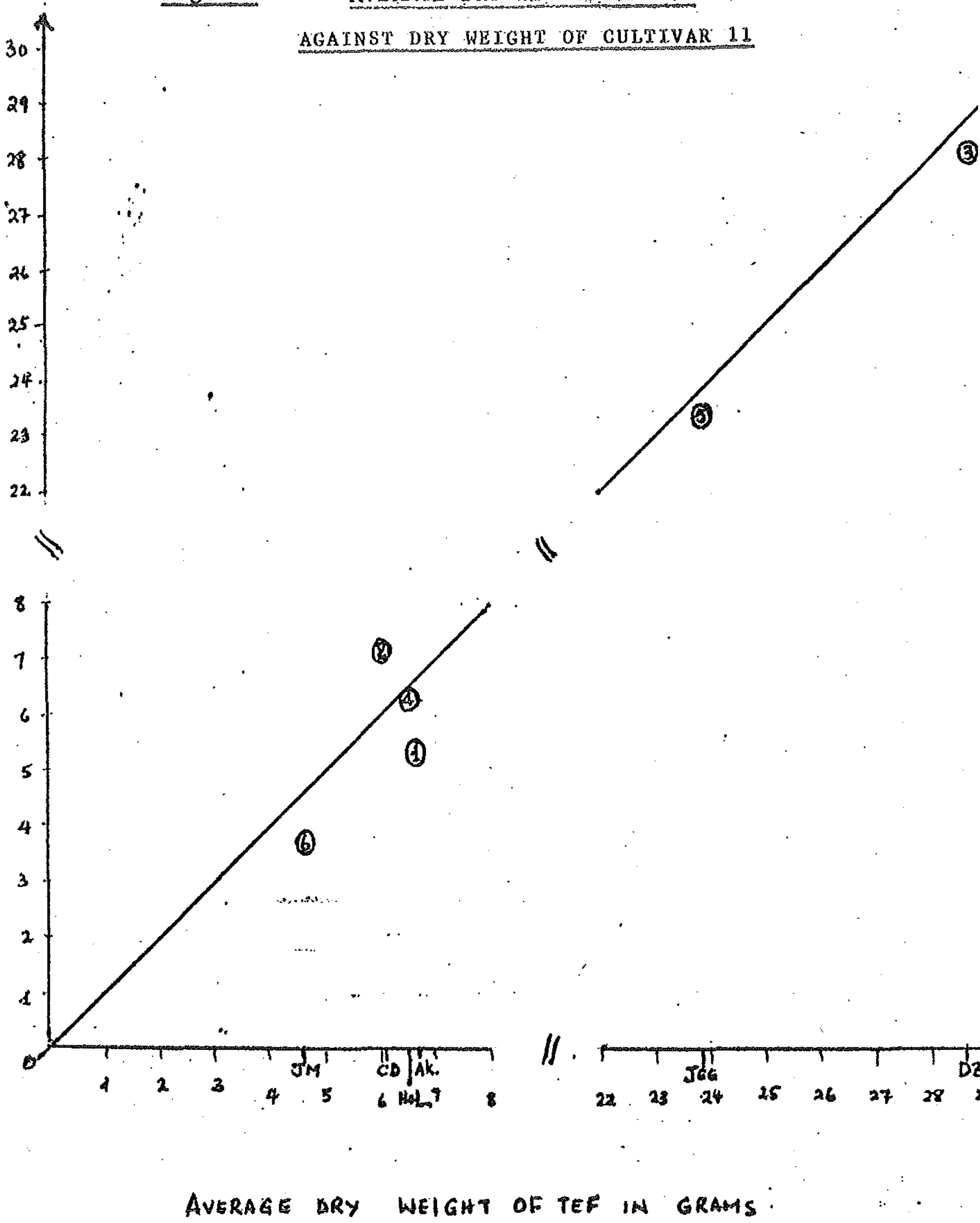


Fig. 11: AVERAGE DRY WEIGHT OF TEF AGAINST DRY WEIGHT OF CULTIVAR 11



From these graphs it became possible to see those cultivars that performed higher or lower than average for the given level of soil fertility.

The performance of cultivar 01 on Akaki, chefe Donsa, Debre Zeit, Holleta and Jimma Melko soils was below average. On Jimma Gerima Guda soil the cultivar performed slightly above average.

The soils on which it performed below average had higher clay content than the soil on which it performed above average. Also, Jimma Gerima Guda soil had the highest percent silt of all the soil. In percent sand, Jimma Gerima Guda had values similar to the rest of the soils. Therefore, it seems likely that cultivar 01 has better performance on soils that have low clay content and high silt content.

Cultivar 02 performed above average on all the soils According to soil chemical and mechanical analyses results, it was clear that the six different soils had different contents of sand, silt and clay. Moreover, the nutrient availability of the soils were also variable. The fact that the cultivar had performed above average on all the soils could only mean that it had great adaptation to a wide range of soils.

Cultivar 03 performed slightly above average on Akaki and Jimma Melko soils. On Chefe Donsa, Debre Zeit , Holleta and Jimma Gerima Guda soils, it performed below average. Both Akaki and Jimma Melko soils had clayey type of soils. The one other soil which had clayey soil and on which the cultivar's performance was below average was that of Chefe Donsa. The rest of the soils, i.e. Debre Zeit, Holleta and Jimma Gerima Guda had textures that were loamy; sandy clay loam and silty loam respectively. Therefore, as far as this cultivar was considered, it seemed to have better growth response on clayey soils than on the other soils.

Cultivar 04 performed above average on Akaki, Chefe Donsa, Debre Zeit and Jimma Gerima Guds soils. The cultivar performed below average on Holleta and Jimma Melko Soils. The below average performance of the cultivar could be better explained by considering the nutrients and pH than with the textural content of the soils. Both soils, Jimma Melko and Holleta, on which the cultivar had below average performance, had the lowest and the second lowest pH values- 5.4 and 5.6 respectively. On the other hand, these two soils had the highest aluminium content of all other soils. At pH values below 5.0 to 5.5., aluminium, iron , and manganese are often soluble in sufficient quantities to be toxic to the growth of some plants (Buckman and Brady, 1969). In acid soils, alûminium may also be involved in the immobilization of phosphorus by production of very insoluble phosphates (Etherington, 1964).

Cereals suffering from phosphate starvation are retarted at every stage of their life-history, from the emergence of the second leaf to the time of ripening (Russel, 1973). Therefore, this cultivar might have been affected by the strongly acidic conditions of the soils and might have become sensitive to the concentration of aluminium in the soils which could retard its growth.

Cultivar 05 performed above average on Akaki, Chefe Donsa and Holleta soils. Its performance was below average on Debre Zeit, Jimma Gerima Guda, and Jimma Melko soils. Akaki, Chefe Donsa and Holleta had lower percent organic carbon as well as percent organic matter than the other three soils. Thus, the cultivar seemed to favour the soils that had relatively low organic matter for better performance.

Cultivar 06 performed above average on Akaki, Debre Zeit Holleta and Jimma Melko Soils. Its performace was below average on Chefe Donsa and Jimma Gerima Guda soils. Both soils had relatively lowers and content than most of the soils considered. It was likely that this cultivar did not favour soils that had low sand content.

Cultivar 07 performed above average on Debre Zeit and Holleta soils. Its performace on Akaki, Chefe Donsa, Jimma Gerima Guda and Jimma Melko soils was below average. Of the six soils, Debre Zeit and Holleta soils were among those that had low clay-22.5% and 31.3% respectively. Debre Zeit and Holleta soils had the highest and the second highest percent sand of all, i.e., 51% and 32.5% respectively. The facts enumerated above strongly suggest that the cultivar performed better on soils that had high sand content and low clay content. The cultivar was one of those that had poor performance because it succeeded in performing above average in two of the six soils.

Cultivar 08 performed above average on Akaki and Debre Zeit soils. It performed below average on Chefe Donsa, H Holleta, Jimma Gerima- uda and Jimma Melko soils. Akaki and Debre Zeit soils had pH values that were greater than those of other soils and approached neutral. Akaki with pH value of

7.8 was weakly alkaline while Debre Zeit was neutral, with a pH of 6.98. But both had the lowest and the second lowest nitrogen contents. Therefore, the cultivar seemed to favour those soils with near neutral pH (which are neither acidic nor alkaline) and relatively lower nitrogen contents. It was one of the cultivars that had poor performance and adaptive capacity because it performed above average in only two of the soils out of the six.

Cultivar 09 performed above average on Chefe Donsa Holleta, Jimma Melko, and Jimma Gerima Guda soils. It performed below average on Akaki and Debre Zeit soils.

This was in contrast with cultivar 08 which had above average performance on Akaki and Debre Zeit soils. The concentration of the edaphic factors that were needed for the proper development of cultivar 08 seemed to have an antagonizing effect on the proper development of cultivar 09. This cultivar, therefore , grew properly on those soils where cultivar 08 could not properly grow and seemed to favour soils with low sand content, low phosphorus content and high nitrogen content.

Cultivar 10, unlike most of the cultivar considered before, performed above average on all soils except on Holleta. Among the soils considered, Holleta was the only one that had sandy clay loam texture. Other features that characterized this soil were that it had highest cuprous ion content, the highest aluminium ion content, the lowest percent silt, The highest percent sand, the lowest calcium ion content, and a low pH.

From the point of view of texture, the cultivar seemed to like those soils that had high percent silt with low percent sand. The relatively high amount of aluminium together with low pH could very well retard and interfere with the proper development of this cultivar on the particular soil.

Although its performance was below average on Holleta soil, it was one of the cultivars that had one of the highest adaptive capacity since it was able to perform above average in the 5 out of the 6 soils.

Cultivar 11 performed below average on all the soils except on Chefe Donsa. Chefe Donsa soil had the lowest percent sand and was clayey in texture. It had the lowest organic carbon content, highest phosphorus and magnesium contents of all other soils. since the cultivar had performed above average only on Chefe Donsa soil, it seemed more likely than not, that proper development for the cultivar could probably be attained on soils that had high phosphorus content along with high magnesium content on clayey soils.

From the graph it was evident that cultivar 11 and 01 performed above average on only one of the six soils (Fig.1 and 11). It was therefore, highly probable that these two cultivars had the poorest adaptive capacity of all the soils they were grown on.

The cultivar that performed best was identified for each of the soils. The cultivars were the following: Cultivar 06 on Debre Zeit soil; cultivar 04 on Jimma Gerima Guda soil; cultivar 05 on Chefe Donsa soil; Cultivar 10 on Akaki soil; cultivar 09 on Holleta soil; and cultivar 10 on Jimma Melko soil.

Also, the soil on which a cultivar performed its best was identified. Here all of the eleven cultivars performed best on only one soil - Debre Zeit. This is not unexpected Debre Zeit soil was loamy soil. Loam is neither heavy nor light.

Here, it was possible to identify the only case where the soil on which the cultivar performed best of all was also the soil on which the performance was the best for the cultivar. Cultivar 06 performed the best of all other cultivars on Debre Zeit soil and, again, it was on Debre Zeit soil that cultivar 06 performed its best.

The cultivar that performed the poorest for each soil was also identified. The cultivar that performed least for each soil were the following : Cultivar 03 on Debre Zeit soil; cultivar 05 on Jimma Gerima Guda soil; Cultivar 08 on Chefe Donsa soil and cultivar 07 as well as 11 on Jimma Melko soil.

The soil on which a cultivar performed its poorest was also identified. Cultivars 01, 02, 03, 04, 05, 06, 07, 08 and 11 had the poorest performance on only one soil, Jimma Melko. However, there were cases where a cultivar had its poorest performance on two soils simultaneously. This was true of cultivar 08 and 06 that had poorest performances on Chefe Donsa , Jimma Melko soils. The other soil on which cultivar 09, had its poorest performance was that of Akaki.

Therefore, the soils on which all the cultivars had their poorest performance were: Akaki, Chefe Donsa and Jimma Melko. These soils had one common characteristic that identified them from the other soils studied. They were all clayey in texture.

Again it was possible to identify the few cases where the soil or soils on which thecultivar performed least of all was also the soil or soils on which the performance was the poorest for the cultivar. This was true of cultivar 09 on Akaki soil, cultivar 08 on Chefe Donsa soil and cultivar 07 as well as cultivar 11 on Jimma Melko soil.

7. CONCLUSION

Among the soils studied, the soil texture seemed to have the greatest influence on the growth and yield of tef cultivars. Clayey textured soils of Akaki, Chefe Donsa and Jimma Melko were responsible for the poorest performance of the cultivars.

The sandy clay loam of Holleta soil shares a similar fate with the clayey textured soils considered above, except that it was not a soil where a cultivar performed its worst. Murphy(1968) while describing the soils of Addis Ababa - Dukem - Debre Zeit - Modjo said that the young tef on this wet clayey textured soil often had a yellow cast indicating lack of aeration and available nitrogen. He went on to say that the physical properties of the entire profile of the blackland clay soils limited the best usage of these soils to the growing of shallow rooted crops such as tef or wheat.

The other soils, the loam textured Debre Zeit soil and the silty loam textured Jimma Gerima Guda soils were the best for the optimum growth of cultivars from among the soils considered under greenhouse conditions.

The fact that soil texture seemed to have the greatest influence on the growth and perfomance of tef cultivars is to be expected. Alexander (1969) pointed out that textural designation serves far greater purpose than simple nomenclatural subdivisions because the ease with which a soil is worked, its aeration, and moisture relation - hence its biological activity - are governed to a great extent by texture.

The cultivars did not show much variation among themselves when the seed weights or dry weights on a given soil were compared (Table 7). Thus they had, in most cases, comparable performances.

The factors that were responsible for yield differences were differences in soils.

There are thousands of different kinds of soils. The physical and chemical properties, the various uses and the response to management of the different soils vary. There are soils that are suitable for particular crops. There are also soils that do not give satisfactory yield output for particular crops. For example, the clayey soils of Akaki, Chefe Donsa and Jimma Melko soils were responsible for the poorest performance of the tef cultivars under a greenhouse condition. The performance of cultivars under field conditions would be as similar as under greenhouse condition since condition similar to the greenhouse would exist in nature.

Though the soil samples examined were few it was possible to conclude that tef cultivars from NYT were better adapted to soil types that were not clayey and perform better on soil dominated by silt along adequate quantities of nitrogen and potassium.

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APPENDICES

Appendix 1: Average Plant Height In Centimeters

CULTIVAR	O1															
Days after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	5.6	4.4	9.9	6.6	13.5	11.2	19.6	19.3	29.7	33.1	41.4	40.2	57.4	55.3	59.1	59.3
CHEFE DONSA	10.5	8.6	16.6	12.0	21.8	17.2	28.5	25.1	31.6	31.5	48.0	45.1	55.1	57.4	56.1	57.6
DEBRE ZEIT	24.9	14.5	40.5	20.4	53.7	26.9	71.0	34.6	98.6	47.5	104.4	58.3	104.8	84.3	105.0	88.7
HOLLETA	12.4	13.5	17.41	19.3	25.8	27.0	32.9	37.7	53.8	50.6	61.5	68.6	62.5	69.4	62.5	69.4
JIMMA GERIMA GUDA	17.7	12.0	17.1	18.4	27.7	26.8	43.8	39.8	63.9	55.0	84.1	76.4	91.2	88.39	92.0	92.0
JIMMA MELKO	5.2	5.4	8.6	8.7	10.9	10.7	14.7	14.1	21.5	19.0	30.4	27.7	46.4	45.7	50.2	50.1

....%

Appendix 1: (Cont'd)

CULTIVAR	03															
Days after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	5.2	3.9	10.0	6.7	16.5	10.9	25.7	17.7	38.3	30.2	48.4	40.1	66.0	56.6	67.4	68.5
CHEFE DONSA	7.4	8.1	11.5	13.9	17.1	19.6	21.5	27.3	31.8	37.3	44.2	55.6	52.2	60.6	52.4	61.6
DEBRE ZEIT	16.2	18.0	28.7	26.4	39.3	42.8	53.8	64.7	76.8	87.1	87.2	101.6	92.5	102.4	100.3	102.5
HOLLETA	8.8	9.6	14.2	13.4	21.8	19.1	26.9	25.0	37.2	35.7	50.9	56.5	52.8	60.7	52.8	61.3
JIMMA GERIMA GUDA	11.6	9.1	16.6	14.1	30.7	24.7	53.7	38.0	78.9	56.3	100.5	84.6	102.9	101.2	103.2	101.2
JIMMA MELKO	3.5	4.5	6.2	9.9	8.8	8.9	12.5	11.7	18.6	16.5	23.4	18.4	37.4	28.2	46.5	37.9

....%

Appendix 1: (Cont'd)

CULTIVAR	04															
's after sowing	20		30		40		50		60		70		80		90	
Block / oil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKI	7.3	5.0	12.5	8.0	21.4	11.5	30.5	19.9	41.3	30.8	50.2	44.1	54.3	61.6	54.3	63.3
HEFE DONSA	8.4	9.1	12.3	13.1	17.7	18.7	22.7	25.4	31.2	32.9	42.5	49.3	44.2	54.9	44.3	55.0
EBRE ZEIT	23.2	17.7	36.6	26.1	53.1	41.8	58.9	64.7	92.2	83.2	98.3	93.6	98.7	94.3	98.7	94.7
OLLETA	10.8	10.8	10.3	17.5	15.0	28.3	21.0	35.5	27.5	47.8	37.8	52.1	58.2	62.3	58.9	62.5
IMMA GERIMA GUDA	11.2	13.4	17.0	19.4	27.5	29.1	34.4	49.4	68.8	85.7	82.9	90.8	84.2	84.2	91.0	84.3
IMMA MELKO	7.0	5.5	10.9	8.2	12.6	11.3	17.5	15.5	29.0	23.8	38.9	28.8	50.5	41.6	51.0	46.6

....%

Appendix 1: (Cont'd)

CULTIVAR	05															
Days after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	4.5	5.5	7.2	9.1	10.9	13.3	15.8	21.6	26.7	34.3	38.2	42.0	48.4	54.1	57.7	57.5
CHEFE DONSA	10.2	9.5	13.3	14.7	19.9	20.5	26.1	28.4	36.8	38.5	49.7	55.8	50.2	56.5	51.0	56.5
DEBRE ZEIT	20.0	19.3	33.9	27.4	44.9	39.5	61.0	62.8	84.6	82.4	92.0	91.7	92.8	92.8	92.4	93.0
HOLLETA	13.2	12.2	19.6	19.0	23.5	23.1	29.9	29.5	45.4	40.3	53.1	55.0	54.0	58.1	54.1	58.1
JIMMA GERIMA GUDA	12.9	9.6	21.1	15.3	30.4	26.3	48.9	42.7	70.2	63.9	86.0	78.2	87.2	81.2	87.4	81.6
JIMMA MELKO	6.1	5.7	9.8	8.8	12.8	11.5	18.5	16.1	27.0	24.1	35.3	29.2	47.6	37.2	48.0	45.5

......%

Appendix 1: (Cont'd)

CULTIVAR	06														
Days after sowing	20		30		40		50		60		70		80		
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
AKAKI	5.0	3.1	9.8	4.8	14.9	8.1	21.4	13.4	35.4	23.5	40.7	37.0	62.9	56.9	66.
CHEFE DONSA	10.1	7.5	14.6	12.0	21.5	17.6	29.4	25.3	42.4	32.8	51.6	52.0	65.8	61.5	56.
DEBRE ZEIT	22.5	14.4	38.1	28.9	53.6	48.2	69.2	65.0	93.9	84.0	103.2	102.3	103.5	103.0	103
HOLLETA	11.8	12.2	17.6	17.4	25.2	22.4	35.2	33.0	50.8	46.7	63.0	65.9	63.2	65.9	63
JIMMA GERIMA GUDA	12.3	11.4	20.3	16.8	39.7	27.7	49.2	47.0	69.5	78.0	89.6	93.9	95.1	100.5	95
JIMMA MELKO	4.4	5.7	7.2	9.2	9.9	12.5	15.0	15.0	16.6	25.6	24.4	34.9	49.5	49.6	52

....%

Appendix 1: (Cont'd)

CULTIVAR	07															
Days after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	4.6	4.8	7.5	11.0	11.3	16.7	18.5	28.8	28.2	28.2	36.7	35.7	53.0	52.7	56.1	56.9
CHEFE DONSA	10.0	7.8	16.3	13.1	20.2	18.3	26.0	24.1	40.5	31.8	56.5	48.9	61.1	57.7	61.1	58.0
DEBRE ZEIT	21.6	15.1	36.0	24.6	52.7	42.8	69.2	55.9	92.6	75.8	99.0	89.7	99.9	90.0	100.0	90.0
HOLLETA	13.9	11.5	21.1	15.7	27.7	20.9	35.3	29.0	55.6	40.8	61.7	60.0	62.0	61.1	62.6	61.6
JIMMA GERIMA GUDA	12.9	10.4	21.3	16.0	33.0	26.0	52.2	43.4	76.8	67.8	88.0	84.6	96.5	88.0	96.5	88.1
JIMMA MELKO	5.4	4.8	9.4	6.0	14.8	7.9	20.4	10.3	26.3	16.1	29.7	22.0	42.0	34.8	50.1	38.9

....%

Appendix 1: (Cont'd)

CULTIVAR	08															
ays after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	4.7	4.9	8.5	7.9	13.9	12.4	23.1	21.3	34.1	35.0	42.1	45.1	45.5	63.1	56.4	63.3
CHEFE DONSA	6.3	9.5	11.7	13.4	16.9	18.3	22.0	25.0	30.4	34.5	37.5	47.4	47.3	52.4	47.3	53.4
DEBRE ZEIT	23.4	11.0	38.4	29.2	51.1	47.3	64.0	65.1	74.9	76.9	89.3	99.4	90.0	99.8	99.0	100.7
HOLLETA	10.9	10.1	17.3	16.3	23.8	22.8	31.3	28.3	44.5	37.4	57.4	54.2	58.9	56.0	58.9	56.6
JIMMA GERIMA GUDA	12.5	11.0	20.8	19.3	33.0	29.3	53.5	47.8	75.1	70.2	83.2	86.2	91.1	87.2	91.3	87.2
JIMMA MELKO	4.6	5.3	7.9	7.8	10.7	10.9	16.0	14.4	23.6	20.5	29.1	27.9	36.8	40.9	44.7	51.5

....8

Appendix 1: (Cont'd)

CULTIVAR	09															
ays after sowing	20		30		40		50		60		70		80		90	
Block / Soil	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	3.8	5.5	6.4	9.2	10.0	13.6	16.3	22.0	28.6	33.4	38.4	41.2	53.7	57.0	58.9	59.9
CHEFE DONSA	9.6	6.1	16.0	9.8	21.6	14.9	30.8	20.2	45.2	29.2	62.1	40.5	66.4	56.9	66.4	59.0
DEBRE ZEIT	17.6	12.9	30.6	24.6	44.6	40.9	61.2	64.7	83.5	96.3	97.1	101.9	104.7	108.4	104.8	108.4
HOLLETA	12.1	11.3	17.9	16.5	25.1	23.2	23.8	32.3	48.8	44.4	62.1	61.5	63.0	69.0	63.0	69.6
JIMMA GERIMA GUDA	11.5	10.8	19.0	15.7	30.7	25.7	47.7	4419	7177	69.0	90.0	87.9	100.4	92.7	100.8	92.9
JIMMA MELKO	5.2	4.8	8.9	7.7	12.2	11.2	18.4	16.5	27.0	24.0	34.6	31.3	49.8	46.9	52.7	51.3

Appendix 1: (Cont'd)

CULTIVAR	10															
Days after sowing	20		30		40		50		60		70		80		90	
Soil \ Block	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	5.6	4.6	9.6	8.4	15.2	14.6	23.3	22.9	37.1	30.3	48.1	41.8	66.4	59.3	73.9	69.1
CHEFE DONSA	8.0	9.6	12.4	13.7	18.0	18.0	24.4	24.0	39.6	33.8	48.6	43.8	67.9	61.0	69.8	63.5
DEBRE ZEIT	19.4	17.2	35.2	29.8	47.1	50.7	52.6	68.2	86.6	84.4	115.3	109.5	121.3	115.1	121.5	115.6
HOLLETA	11.3	9.5	17.3	14.2	12.4	20.4	30.6	28.1	43.2	28.8	57.1	53.0	72.5	65.0	72.5	65.2
JIMMA GERIMA GUDA	11.7	11.9	21.5	19.2	33.0	28.2	49.9	42.4	72.6	64.6	90.4	83.1	112.3	93.5	113.1	95.8
JIMMA MELKO	6.0	4.7	8.9	7.2	13.1	10.3	20.7	15.3	29.8	21.9	39.3	29.8	55.4	44.8	69.7	58.6

Appendix 1: (Cont'd)

CULTIVAR	11															
Days after sowing	20		30		40		50		60		70		80		90	
Soil \ Block	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AKAKI	3.2	4.6	5.9	8.2	10.0	15.9	17.6	35.2	28.6	35.3	36.3	44.3	44.3	53.7	39.1	57.8
CHEFE DONSA	7.5	8.8	11.7	14.3	16.6	17.5	23.7	26.9	34.5	41.3	47.4	59.9	49.6	66.5	50.7	66.5
DEBRE ZEIT	17.3	14.8	31.6	24.2	45.4	38.0	62.5	59.0	90.5	82.6	105.7	101.7	109.2	103.5	109.2	103.6
HOLLETA	9.1	6.1	14.5	11.2	21.2	19.8	30.3	31.4	43.8	40.3	57.2	54.0	60.0	69.8	60.0	69.3
JIMMA GERIMA GUDA	9.1	9.0	16.8	14.2	27.2	21.4	40.5	34.6	66.2	53.4	92.0	58.3	100.1	97.4	100.3	98.4
JIMMA MELKO	4.3	3.4	6.7	5.0	8.9	6.1	12.4	9.0	19.8	12.5	25.6	16.8	35.6	22.3	49.9	35.3

Appendix 2: DRY WEIGHT IN GM. PER POT OF 15 PLANTS

CULTIVAR	SOIL / BLOCK	AKAKI	CHEFE DONSA	DEBRE ZEIT	HOLLETA	JIMMA GERIMA GUDA	JIMMA MELKO
01	1	3.3	2.3	10.9	2.7	10.1	2.8
	2	3.2	3.0	13.9	3.1	10.1	1.5
02	1	4.6	3.8	16.6	3.5	11.9	3.8
	2	3.5	3.7	13.7	4.2	14.8	1.6
03	1	2.9	4.1	14.6	4.0	9.9	3.0
	2	4.5	2.2	9.7	1.4	12.3	1.7
04	1	3.6	2.8	16.2	2.2	15.4	2.6
	2	3.9	2.6	13.9	2.9	12.5	1.8
05	1	3.7	4.5	16.6	3.8	9.9	2.3
	2	3.0	3.5	9.7	3.7	9.3	2.0
06	1	3.6	2.9	20.2	3.5	14.5	2.3
	2	3.2	2.3	12.5	3.7	9.0	2.9
07	1	3.5	2.4	16.7	2.9	12.1	1.5
	2	2.7	2.3	14.4	4.5	11.1	2.2
08	1	4.1	1.8	16.9	3.0	12.6	1.9
	2	2.6	2.2	13.6	2.6	10.8	2.1
09	1	2.3	2.7	16.1	4.0	13.9	2.9
	2	0.9	4.0	11.4	4.0	10.3	1.9
10	1	6.0	3.0	15.9	1.8	13.5	3.9
	2	3.1	3.3	13.7	3.7	11.7	2.3
11	1	3.0	4.6	14.6	3.8	13.2	2.2
	2	2.4	2.6	13.6	2.6	10.2	1.5

Appendix 3: SEED WEIGHT IN GM. PER POT OF 15 PLANTS

CULTIVAR	SOIL / BLOCK	AKAKI	CHEFE DONSA	DEBRE ZEIT	HOLLETA	JIMMA GERIMA GUDA	JIMMA MELKO
01	1	0.35	0.68	4.85	0.93	2.95	0.30
	2	1.02	0.45	1.95	1.25	3.85	0.23
02	1	0.54	0.62	4.81	0.90	4.62	0.11
	2	0.35	0.94	5.25	0.81	4.54	0.15
03	1	1.05	0.65	2.91	0.75	5.05	0.28
	2	0.61	1.04	5.63	0.74	2.82	0.21
04	1	0.69	0.45	4.45	0.92	4.05	0.35
	2	1.05	0.75	6.25	1.05	4.25	0.43
05	1	0.63	0.60	3.33	0.85	2.75	0.35
	2	0.71	0.62	5.75	0.83	3.45	0.35
06	1	0.91	0.60	4.80	1.0	3.35	0.31
	2	0.60	0.85	7.65	1.30	6.80	0.35
07	1	0.74	0.62	5.04	0.65	4.49	0.53
	2	0.55	0.65	6.55	0.94	4.95	0.23
08	1	0.69	0.54	4.39	0.82	5.09	0.28
	2	1.13	0.91	6.50	0.83	5.03	0.40
09	1	0.65	0.99	3.75	0.94	3.82	0.23
	2	0.90	0.55	5.27	1.02	4.79	0.40
10	1	0.42	0.62	4.25	0.89	3.13	0.45
	2	0.60	0.55	4.89	0.81	3.72	0.34
11	1	0.35	0.59	4.20	0.81	3.85	0.18
	2	0.75	1.31	4.93	1.05	4.25	0.12

Appendix 4: AVERAGE DAYS TO HEADING PER POT OF 15 PLANTS

CULTIVAR	SOIL / BLOCK	AKAKI	CHEFE DONSA	DEBRE ZEIT	HOLLETA	JIMMA GERIMA GUDA	JIMMA MELKO
01	1	68.6	58.3	53.2	56.1	60.1	69.7
	2	71.3	66.2	72.3	60.7	62.3	72.4
02	1	80.7	64.8	54.7	61.5	63.4	84.0
	2	80.1	68.4	63.2	67.3	66.9	85.6
03	1	68.9	63.1	57.9	60.1	55.9	74.7
	2	74.8	63.3	56.7	62.5	63.4	79.7
04	1	63.7	61.9	53.6	58.3	60.9	68.8
	2	72.5	70.4	57.8	60.7	61.6	73.5
05	1	75.2	60.4	54.3	59.1	58.7	67.6
	2	71.5	63.3	59.1	62.3	63.6	77.1
06	1	69.8	58.7	53.3	56.4	57.7	68.3
	2	87.2	65.4	56.8	59.6	60.4	69.6
07	1	73.7	59.7	53.9	55.0	56.7	72.7
	2	71.1	67.0	57.3	61.3	61.4	77.0
08	1	73.9	64.0	54.1	60.5	57.8	75.4
	2	70.5	66.1	57.7	63.2	59.7	75.2
09	1	70.1	61.3	57.1	57.6	52.7	69.8
	2	71.5	68.8	60.5	65.5	61.9	72.1
10	1	74.4	70.7	63.6	65.4	66.9	76.0
	2	76.3	69.2	62.4	66.9	69.9	79.2
11	1	73.5	62.5	57.3	59.9	61.5	75.5
	2	68.0	64.7	60.9	67.8	71.0	85.8

Appendix 5: TILLER NUMBERS COUNTED OVER THE GROWING PERIOD.

CULTIVAR	SOIL / BLOCK	AKAKI	CHEFE DONSA	DEBRE ZEIT	HOLLETA	JIMMA GERIMA GUDA	JIMMA MELKO
01	1	-	-	8	-	27	-
	2	-	-	11	-	23	-
02	1	-	-	15	-	9	-
	2	-	-	19	-	6	-
C3	1	-	-	2	-	8	-
	2	-	-	14	-	3	-
04	1	-	-	12	-	26	-
	2	-	-	16	-	31	-
05	1	-	-	5	-	-	-
	2	-	-	20	-	11	-
06	1	-	-	10	-	1	-
	2	-	-	15	-	11	-
07	1	-	-	16	-	5	6
	2	-	-	20	-	14	-
08	1	-	-	11	-	14	-
	2	-	-	21	-	27	-
09	1	-	-	9	-	-	-
	2	-	-	12	-	21	-
10	1	-	-	8	-	-	-
	2	-	-	16	-	9	-
11	1	-	-	7	-	2	-
	2	-	-	7	-	17	-

Appendix 6 - RESULTS OF SOIL COLOUR TEST, MECHANICAL AND CHEMICAL ANALYSES

SOIL	SOIL COLOUR		BULK DENSITY IN Gm/ml	PERCENT TOTAL PORE-SPACE	p^H	ELECTRICAL CONDUCT-IVITY m mhos/cm	MECHANICAL ANALYSIS			TEXTURAL CLASS
	DRY SOIL	WET SOIL					PERCENT SAND	PERCENT SILT	PERCENT CLAY	
AKAKI	10 Yr 2/1 BLACK	2.5 Yr 3/0 DARK REDDISH GRAY	0.94	56.86	7.8 Weakly alkaline	42.12	25.00	18.75	56.25	CLAY
CHEFE DONSA	10 Yr 3/1 DARK GRAY	10 Yr 3/1 VERY DARK GRAY	0.92	59.18	6.92 Slightly acid	25.74	16.25	23.75	60.00	CLAY
DEBRE ZEIT	10 Yr 5/2 GRAY BROWN	10 Yr 2/2 VERY DARK BROWN	0.82	57.45	6.98 Slightly acid	35.10	32.50	45.00	22.50	LOAM
HOLLETA	7.5 Yr 4/4 DARK BROWN	5 Yr 3/3 DARK REDDISH BROWN	0.88	58.82	5.46 Strongly acid	10.53	51.25	17.50	31.25	SANDY CLAY LOAM
JIMMA GERIMA GUDA	7.5 Yr 35/2 DARK BROWN	5 Yr 2/2 DARK REDDISH BROWN	0.85	52.13	5.76 Moderately acidic	6.20	21.25	72.50	6.25	SILT LOAM
JIMMA MELKO	5.0 Yr 4/4 REDDISH BROWN	5 Yr 3/2 DARK REDDISH BROWN	1.0	50.94	5.43 Strongly acidic	9.83	18.75	20.00	61.25	CLAY

....%

SOIL	CONCENTRATION IN PPM							
	Mn	Zn	Fe	Al	Cu^{++}	CATION EXCHANGE CAPACITY	ORGANIC CARBON	ORGANIC MATTER
AKAKI	0.175	0.22	2.72	2.25	0.02	570	14400	24898
CHEFE DONSA	0.190	1.23	2.50	1.15	0.06	430	14000	24206
DEBRE ZEIT	0.655	0.54	5.00	Trace	0.02	196	24200	41842
HOLLETA	1.828	0.72	2.50	14.5	0.10	130	16000	27664
JIMMA GERIMA GUDA	1.710	3.64	1.50	1.15	Trace	244	57600	99590
JIMMA MELKO	1.325	0.58	6.00	7.25	0.04	120	25000	43225