AN ECO-PHYSIOLOGICAL STUDY OF CULTIVATED BARLEYS IN WELMERA

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A B S T R A C T

In eco-physiological studies, problems that originate from field observations are tackled both through field work and laboratory studies. This paper presents a study made on the eco-physiology of barley (Hordeum Sect. Cerealia Ands.) cultivars cultivated in Welmera, Shoa.

Field studies, i.e. observations, discussions with farmers, seed, plant and soil sample collections and laboratory experiments and analyses, i.e. pot experiments in the greenhouse on 9 barley cultivars each cultivar planted in the 9 soils from the areas where the cultivars were collected and mechanical and chemical analyses of the soils were carried out in the years 1979 and 1980. The data gathered were subjected to various statistical treatments.

The results showed that there are wide differences both among the 9 soils and among the 8 cultivars of barley which were successfully grown. One cultivar failed because of poor germination. The differences observed among the soils were both physical and chemical, some being more fertile and hence more suitable for most cultivars while a few were extremely poor and unsuitable for most cultivars except those that appeared to be specially adapted. The barley cultivars studied showed wide differences in their responses to these soils and their distribution within Welmera appeared to be largely a result of the differences in edaphic factors. Soil physical conditions, level of the available forms of cationic nutrients and some important anions, eg. phosphorus, and toxic heavy metals appeared to have

stronger impact on the performances of barley cultivars than other factors. The climatic and the socio-economic factors also seem to have some role, but of a smaller magnitude, in determining cultivar distribution within the area studied. The soils based on their fertility in decreasing order were Foeta, North of Holetta, Suba Road, Berfeta 2, Welmera Choke, Wachacha 2, Wachacha 1, Bedi and Berfeta 1.

Several specific hypotheses were generated and the need for further studies shown: - Baleme requires a soil low in clay and high in calcium carbonate, Kesele requires a soil with low clay and high sand contents, Netch Gebs is sensitive to heavy metal toxicity, Semereta is sensitive to both physical, requiring soils with clay content greater than about 26%, and chemical conditions of soils, i.e. it is an indicater of overall fertility of soils, Enat Netch Gebs requires soils with high proportion of exchangeable magnesium to exchangeable calcium, Keye Gebs requires soils that are rich in nutrients, Mouga requires soils that are well drained and rich in nutrients and Senef-Kollo requires soils with high exchangeable cations particularly exchangeable calcium and magnesium.

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1. I N T R O D U C T I O N

1.1 THE ORIGIN OF THE RESEARCH PROBLEM AND BACKGROUND INFORMATION ON IT:

The problem under investigation originated from Dr. Tewolde Berhan G. Egziabher from field observations and discussions with peasant farmers made during his repeated visits to Welmera as part of the Research and Development Systems in Rural Setting Project (Science and Technology Commission, 1979). From his observations and discussions it became clear that:

(i) within the small woreda of Welmera (420 sq. km.) different barley cultivars are being grown in areas with topographic differences;

(ii) in some parts of this woreda fields without any obvious topographic differences (eg. farms adjacent to one another) are used for the cultivation of different cultivars; only one variety being grown on one particular farm.

The peasants claim that only some cultivars can yield satisfactorily on the heavily leached red soils. Both personal observations and discussions made by the author with the farmers regarding cultivars, soil types and cultural practices employed confirmed this. A hypothesis was then formulated to the effect that the distribution of barley cultivars within the woreda is governed by the nutritional status of the soils.

This paper attempts to elucidate the factors governing such a distribution of barley cultivars, as to whether the practice is purely a matter of the persuit of cultural heritage or whether there is any scientific reason behind it. It was thus felt that an eco-physiological approach might help to show any scientific reason that may cause the choice of cultivars. Eckardt (1965) has stated that eco-physiology deals with all the relationships existing between living beings and their physical and biotic environment. He has further clarified that it embraces the study of the adaptive structural and functional features which link the individual organism to its specific environment.

Various approaches can be used to tackle eco-physiological problems. Studies can be conducted through the determination of physical, chemical and biological changes in the experimental species, through the evaluation of the modifications brought about in the environment because of it, through extrapolation into the environment in which the species lives from experiments carried out under controlled environmental conditions or through the correlation between biological processes and different measurable meteorological or edaphic parameters (Eckardt, 1965; Bannister, 1976).

This particular work deals with the response of barley cultivars to different soil types.

As background information to the problem at hand, it is known that Ethiopian crops in general and cereals in particular, which actually make the major food of developing countries (Evans and Wardlaw, 1976) are receiving more and more attention throughout the world due to their potential as sources of genes for varietal improvement (Qualset, 1975; Purseglove, 1976a; Endashaw, 1979). Among the desirable characters discussed by these authors are:

(a) tolerance to drought stress,
(b) earliness,
(c) resistance to diseases (rust, viruses, smuts, etc.)
(d) adaptability to poor soils,
(e) frost resistance,
(f) food quality.

Ethiopia's long agricultural history (Sauer, 1952; Mesfin, 1972; Purseglove, 1976 a,b) coupled with its diversified topography, altitude and rainfall has favoured the development of diverse crop cultivars with highly desirable characters. Adaptations are usually external expressions of genetic differences. There are clear indications that performance or survival of varieties and hence their distributions are controlled by one or a few factors. Moreover, in cultivated crops this distribution pattern is further modified by cultural and socio-economic factors (Carlson and Horne, 1962; Frankel and Bennett, 1970; Qualset, 1975; Endashaw, 1979). Nevertheless, the modernization of Ethiopia's agriculture has not been capable of full exploitation of these diversified germplasm resources. The existence of diverse forms of barley in Ethiopia had been indicated by many scholars including Chiovenda (1912), Vavilov (1951), Harlan and Zohary (1966), de Candolle (1967), Zohary (1970), Qualset (1975), Melake Haile Mengesha (1975) and Purseglove (1976 a and b). It has been shown that barley needs urgent attention as a crop of high potential because of its wide ecological plasticity and physiological amplitude (Barghouti and Hadjichristodoulou, 1979). What makes such studies even more important is the fact that it is the toiling broad masses that would benefit most from them because it is the food of the poorer elements of society, those who live in isolated rural communities especially in mountainous areas.

1.2 THE SITE OF THE PROJECT

The area covered in this investigation is the Welmera woreda located in Menagesha awraja, Shoa administrative region west of Addis Ababa, from 8° 50' N to 9° 14' N latitude and from 38° 263'' E to 38° 30' E longitude. Even though this is a small woreda, it has a very wide altitudinal range (2,100 - 3,350m) which include high mountains, flat and rolling areas, steep cliffs and moderately sloping hills of volcanic rocks of acidic, basic and intermediate types (Gezahegne, 1979). The common rock types are shown to be basalts and trachybasalts; generally areas of high relief having acidic and intermediate rocks and rolling grounds having basic rocks. —— Mt. Foeta, though a high mountain, has basic rocks.

According to Hailu and Pinto (1977), this woreda receives an anual rainfall of over 1,000mm , the main rains occurring from mid-June to the end of September. They also pointed out that during the rainy period the area experiences heavy cloud cover with short sunshine hours, high humidity and low monthly air temperatures. The growing season for barley corresponds with the main rains. Figure 1 gives the sites from which the cultivars were collected, and Table 1 summarizes the description of each cultivar.

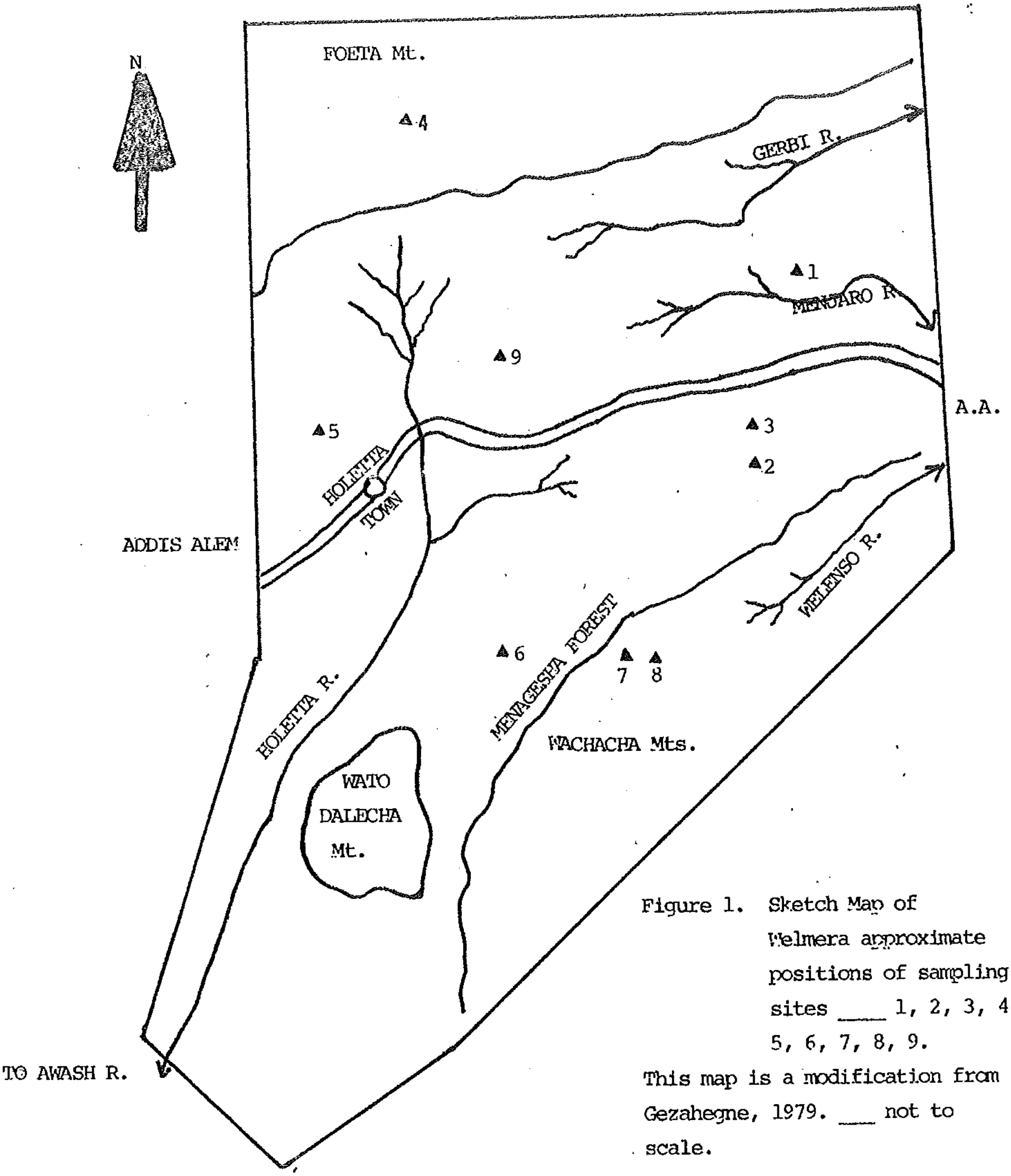

Figure 1. Sketch Map of Welmera approximate positions of sampling sites ____ 1, 2, 3, 4, 5, 6, 7, 8, 9.

This map is a modification from Gezahegne, 1979. ___ not to scale.

TABLE 1. SAMPLING SITE AND CULTIVAR DESCRIPTIONS FOR BARLEY COLLECTED FROM WELMERA WOREDA

SAMPLING SITE	ALTITUDE (METRES)	ROCK-TYPE	CULTIVAR (LOCAL NAME)	DESCRIPTION OF CULTIVAR				
				NUMBER OF ROWS	GRAIN COLOUR	LENGTH OF HEAD (cm)	NUMBER OF GRAINS PER HEAD	DEGREE OF COMPACTNESS OF EAR *
BEDI, NEAR MENJARO RIVER	2,600	TRACHYBASALT	BALEME	2	WHITE	6	16	9
BERFETA 1, SENDELE AREA	2,445	PORPHYRITIC PYROXENE BASALT	SENEF-KOLLO	2	YELLOWISH-WHITE	5	18	10
BERFETA 2, BETWEEN SENDELE AND MENAGESHA TOWN	2,500	PORPHYRITIC OLIVINE BASALT	KEYE GEBS (RED BARLEY)	IRREGULAR	DEEP RED	8.75	66	6
FOETA, DEME AREA	2,900	PORPHYRITIC PYROXENE BASALT	MOUGA	6	GREY	6.25	60	3
NORTH OF HOLETTA, BEKEKA AND KORE	2,600	APHANITIC BASALT	NETCH GEBS (WHITE BARLEY)	6	WHITE	6.5	48	4
SUBA ROAD, ROGIE-GINUE AREA	2,400	UNCERTAIN IDENTITY	SEMERETA	2	WHITISH-PURPLE	7	20	8
WACHACHA 1, ABOUT 15 km FROM THE UPPER END OF MENAGESHA FOREST	2,950	TRACHYTE OF WACHACHA	OSHONKOLLO	2	BRIGHT PURPLE	6	26	7
NEAR WACHACHA 1, 15 km FROM THE UPPER END OF MENAGESHA FOREST	2,950	TRACHYTE OF WACHACHA	KETE (FREE TRESHING)**	6	WHITE	4	42	1

TABLE 1. (Cont'd)

SAMPLING SITE	ALTITUDE (METRES)	ROCK-TYPE	CULTIVAR (LOCAL NAMES)	DESCRIPTION OF CULTIVAR				
				NUMBER OF ROWS	GRAIN COLOUR	LENGTH OF HEAD (cm)	NUMBER OF GRAINS PER HEAD	DEGREE OF * COMPACTNESS OF EAR
WACHACHA 2, ABOUT 15 km FROM THE UPPER END OF MENAGESHA FOREST	2,950	TRACHYTE OF WACHACHA	ENAT NETCH GEBS (WHITE "MOTHER" BARLEY)	6	YELLOWISH	8	72	5
WELMERA CHOKE, NEAR THE MARSHY AREA	2,650	PORPHYRITIC PYROXENE BASALT	KESELE OR TIKUR GEBS (BLACK BARLEY)	6	BLACK	6	60	2

* COMPACTNESS OF EAR WAS GRADED IN THE FOLLOWING MANNER

MOST COMPACT (6 - ROW) ———1

LEAST COMPACT (6 - ROW) ———5

IRREGULAR ———————6

MOST COMPACT (2 - ROW) ———7

LEAST COMPACT §(2 - ROW) ———10

** NO SEEDS WERE OBTAINED AND CONSEQUENTLY NOT INCLUDED IN THE EXPERIMENTATION

2. LITERATURE REVIEW

2.1 GENERAL BOTANICAL CHARACTERISTICS OF CULTIVATED BARLEY

Due to its wide distribution and its importance as a feed and or malting crop, barley has received considerable attention in the countries of the temperate zone. Only a brief review of the salient features of this crop will be presented here.

Barley is an important small grain cereal crop, belonging to the family Gramineae (Poaceae), subfamily Pooideae, tribe Hordeae, genus *Hordeum*, section Cerealia Ands. (Aberg, 1940; Thakur, 1975). The members of the tribe Hordeae have spikes with a zigzaging rachis. In this tribe the evolutionary advancement has been towards the reduction of the spreading type of inflorescence to a single spike; all members having completely sessile spikelets usually more or less sunk in depressions of the spike axis; each spikelet containing a small number of flowers. In some cases one flowered spikelets are the rule (Thakur, 1975).

In the genus *Hordeum* the inflorescence is a spike with three spikelets borne at each rachis node; each spikelet containing a single floret. A spike usually contains 10-30 nodes. Each spikelet is subtended by a pair of glumes. The vegetative portion of the barley plant is similar to that of the related cereal grasses except that the auricles of its leaves are conspicuous.

The genus contains both wild and cultivated species. The common wild members are the diploids *H. spontaneum* C. Koch, *H. agriocrithon* E. Aberg, *H. maritinum* With. having fourteen chromosomes, and the tetraploids *H. jubatum* L., *H. murinum* L., *H. bulbosum* L. with twenty eight chromosomes (Shands and Dickson, 1953; Bowden, 1959; Nilan, 1964). All the cultivated barleys have fourteen chromosomes. There are several views as to how the cultivated taxa should be classified. Nevertheless, it appears that there is now a general agreement that all of them should be classified into three species in the following manner (Aberg, 1940; Shands and Dickson, 1953; Thankur, 1975).

(i) *Hordeum vulgare* L. emend Lam.

This is the common six-row barley. All the three florets at each node of the rachis are fertile ---(isospiculate).

(ii) *Hordeum distichum* L emend Lam.

This is the two-row species. The central florets are fertile while the much reduced lateral florets are either male or vestigial. These lateral florets occasionally produce a few seeds-(heterospiculate).

(iii) *Hordeum irregulare* Åberg and Wiebe

This is the name given to a newly defined species of barley. The median florets are fertile, while the proportion of fertile and infertile lateral florets varies considerably. Since irregular barleys are found here in Ethiopia, it is highly likely that they originated here. It is for this reason that they are referred to as a group of "Abyssinian intermediate" barleys (irregular mixture of isospiculate and heterospiculate spikelets) (Bowden, 1959).

Some members of the cultivated species are awned, some are awnless and others are hooded (Thakur, 1975). The grains of the crop are 8-12mm. long, 3-4mm wide and 2-3mm thick. About 10-15% of the kernel consists of hull in the hulled varieties. The naked varieties come free from the hull when treshed. The seed requires less moisture (50% of dryweight) to germinate than those of oats (55%) and wheat (65%). Also it has the lowest transpiration ratio compared to oats and wheat. Under conditions of natural fertility and favourable growing season, in order to produce one Kg. of dry matter (grain and straw) barley uses up 155-205 kg. of water (Barghouti and Hadjichristodoulou, 1979). In general, the grains of barley take 5-7 days to germinate, some varieties take twice as many days (Nuttonson, 1957). Nuttonson (1957) also pointed out that the optimum temperature for germination is 15-20°C. Thakur (1975) has pointed out that barley is a surface feeding crop with varying lateral spread of roots.

In barley tillering usually occurs after the appearance of the third leaf when nodes also develop, 10-15 days in some and 20-25 days in others after emergence (Nuttonson, 1957).

Barley is essentially a self-fertilized plant. There is also a rare occurrence of cross-pollination. The major advantage of this combined pollination mechanism is that both genetic flexibility and fixation of different lines are facilitated. Man selects the more attractive ones (Zohary, Undated). Flowering and fertilization take place mostly prior to the heading stage, before the emergence of the spike from the boot. From shooting to shortly after heading is the growth developmental period during which cereals are most sensitive to temperature and soil moisture conditions (Thakur, 1975).

2.2 GENERAL ECOLOGY AND GEOGRAPHY

Although barley is essentially a temperate crop (Takaharshi, 1955; Papadakis, 1966; Purseglove, 1976 a), many varieties are adapted to a wide range of ecological and climatic conditions. Any domesticated plant can be regarded as an artefact since it is a product of human manipulation (Helbaek, 1959). This is to say that it is really the effects of human activities aimed at producing food from a wide range of environments that has caused the development of diverse forms, ecological groups and varieties of barley which differ considerably in their physiological responses to the external environment. The adaptability to a wide ecological range of these cultivars can be seen from the fact that they are cultivated from 70°North to the drier tropics (India, Indochina, Nile delta), on mountains even near the equator (Ethiopia) and from lowland areas below sea level (Dead sea more than 300 metres below sea level) to very high mountains (Himalayas - Tibet, Pamir, over 4000 metres above sea level) (Takaharshi, 1955; Nuttonson, 1957; Nilan, 1964). This wide distribution which is largely attributable to human activities is not shared by its wild progenitor, *H. spontaneum* (Nuttonson, 1957; Nilan, 1964).

Barley is one of the most dependable cereals under extreme conditions of frost and drought. Since it is a crop with cultivars that can mature in a short growing season, it can escape frost and drought. This is why it is described as drought escaping rather than drought resistant (Nuttonson, 1957; Nilan, 1964). It is suited to a wide range of rainfall areas, 650 - 2000mm, well distributed during the growing period (I.A.R., 1979). It can stand much dry heat, but not hot humid climates (Thakur, 1975; Hailu and Pinto, 1977).

Thus barley is a very important grain crop in many areas of the world where the growing season may be cut short either by lack of sufficient moisture or by low temperatures in northern areas or higher altitudes. It reaches farther towards the desert than any other grain crop. It is highly demanding in its soil requirements and although barley is adapted to a wide range of edaphic conditions, each variety is known to have a narrow range (Thakur, 1975). Optimal soils for barley cultivation are of light texture, good drainage and high pH. Acid soils result in aluminium or manganese toxicity and phosphorus deficiency. High nitrogen causes lodging (Nuttonson, 1957; CADU, 1969; Barghouti and Hadjichristodoulou, 1979).

2.3 PRODUCTION AND USE

Among the leading barley producers of the world arethe U.S.S.R. (producing one fifth of the world total), the U.S.A. and Canada. The highest yield (40 Q/ha) has been obtained by Denmark. The world average is 18.5 Q/ha (Nuttonson, 1957; Thakur, 1975).

The barley grain contains from 50-60% dry weight of grain starch, 10-20% moisture and 7.5 - 15% protein (feed barley - 15%, food barley 12.8%, malting barley - 12.4%). In high quality malting barley the grain must be sun ripened and must also be high in starch and low in protein and water content (Cook, 1962; Hailu and Pinto, 1977).

In those countries where it is produced in abundance barley has many varied uses. It is best regarded as a feed and malting crop. It is only in the poorer areas of the world that the crop is primarily cultivated for human consumption. The principal obstacle to the uses of barley flour in bread is that it contains very little or no gluten and will not make light porous bread. Nevertheless, barley bread and cakes are known to be made in some parts of the world (Moore, 1960; Thakur, 1975), and "qitta" a flat unleavened bread and "injera", a flat leavened bread, are made from barley in the barley producing areas of Ethiopia.

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2.4 RESEARCH ON BARLEY

Barley, which is now regarded as a "poor man's crop" (Barghouti and Hadjichristodoulou, 1979) has not been fully exploited for its desirable characteristics. Most of the research work done so far focuses attention on feed and malting barley. The research institutions with international responsibility for research in barley are the International Wheat and Maize Improvement Centre (CIMMYT) and the International Centre for Agricultural Research in the Dry Areas (ICARDA). The latter is particularly making research on barley as human food. The results obtained so far are reported to be highly promising. In some respects barley shows advantages over wheat. For a given period of time and a given amount of moisture and heat it is known to produce more than most wheat varieties. Various studies have shown that it does much better than wheat in areas where the annual rainfall or irrigation water is less than 450mm. and greater than 650mm. (Barghouti and Hadjichristodoulou, 1979). Thus, barley is a crop that does well on marginal lands.

It is a pity that man had neglected many of these desirable qualities despite the fact that the crop is just as old as human civilization. One aspect of barley research undertaken currently aims at maximum exploitation and preservation of the desirable qualities that this crop can offer.

2.5 THE ORIGIN AND EVOLUTION OF CULTIVATED BARLEY

The history and evolution of a cultivated plant is usually revealed through an investigation of its wild progenitors, the place where it was first brought into cultivation, the route of its migration and the processes involved in its evolutionary change under cultivation. An integrated assessment of the available information obtained from archeological and anthropological studies and the usual biological researches including comparative morphology, biogeography, ecology, genetics and cytology are extremely important for this study (Takaharshi, 1955; Helbaek, 1959).

What is known of the origin and evolution of barley is the result of many years of observation and research made by Vavilov, de Candolle, Bowden, Shieman, Aberg, Takaharshi, Nuttonson among others. Findings from the earliest centres of human habitation strongly indicate that barley is one of the oldest cultivated crops. Cultural historians and botanists through their joint activities have succeeded in characterizing the kinds of barley utilized by peoples of antiquity and the times and places of their cultivation. Today, different sources in the literature agree that two-row barley with tough-rachis and wheat were domesticated around the begining of 7,000 B.C. in the Iraq-Kurdistan area (Staudt,1961;

Zohary, 1963; Harlan and Zohary, 1966; Zohary, Undated; Nilan, 1964; Purseglove, 1976a,b). In a discussion of the progenitors of wheat and barley Zohary (Undated) pointed out that: (1) Eincorn wheat (Triticum monococcum), (2) Emmer wheat (Triticum dicoccum) and (3) two-row barley (Hordeum distichum) were the primitive crops cultivated at the initiation of agriculture. The same views were again given in a joint paper with Harlan (1966). Takaharshi (1955) reported that broken grains of six-row barley that appeared to be of the predynastic period (5,000 B.C.) were found by Netolitsky from the stomach of an Egyptian mummy. The barley at that time besides being of the six-row type was mostly of the dense eared variety. The six-row and lax-eared (tetrastichum) was found in excavations from the Saqqara Pyramid of Egypt. This was also about 5,000 years old. In short the literature makes it clear that the crop was utilized by the ancient Egyptians, Chinese, the Bronze Age Men of Italy, the stone Age Men of Switzerland and the ancient Romans and Greeks (Moore, 1960).

The more recent and reliable pieces of evidence are infavour of the notion that barley was brought under cultivation independently in two major centres. From this observation Takaharshi (1955) placed all the barleys into two groups, the oriental and the occidental. The occidental barleys are those found within the distribution centre of H. spontaneum; the chief centre of these barleys is the near East. Takaharshi (1955) reported that the chief centre of diversity of cultivated barley is Ethiopia and that the barleys of this centre have well defined relationships with those of the near East. The oriental barleys of Japan, China, Korea and India are distinctly different from the Occidental barley. This observation lead to the conclusion that these must have another centre of diversity. The distinctiveness is largely characterized by being short-statured, six-row, hooded, brittle awned, hull-less and resistant to certain races of mildew (Takaharashi, 1955; Nilan, 1964). It is strongly believed that representatives of these two groups must have hybridized somewhere around Nepal (Takaharashi, 1955; Nilan, 1964).

Eventhough the cultivation of barley is believed to have been started in two major centres, the evidence favours the near East as the original home. Today, an active gene exchange between the two groups has reduced the gaps between them (Takaharshi, 1955).

It is well known that in the tribe Hordeae evolutionary development took place by reduction. The sort of developmental reductions involved were that of the inflorescence type from panicle to ear and that of spikelets from several to a single one. Other changes that characterize evolutionary advancement in this tribe are the changes from disintegrating spikelets to non-disintegrating and from brittle-rachis to tough-rachis. Many authorities including Aberg (1940), Takaharshi (1955), Nuttonson (1957), Helbaek (1959), Staudt (1961), Zohary (1963), Nilan (1964), and Harlan and Zohary (1966) have dealt with the phylogenetic problems of barley. Two major opposing views of evolutionary trend have been alternating in their acceptance.

(1) There was a time when some believed the six-row brittle-rachis type to be the ancestor of both the cultivated six-row and the wild two-row brittle-rachis barleys. This claim was

strongly supported by Aberg (1940), who justified his stand by showing that not only in the genus Hordeum but also in the tribe Hordeae as a whole reduction of the inflorescence is the rule. His discovery of a six-row brittle-rachis barley, *H. agriocrithon*, among samples collected from Southern China was used as an argument in support of this thesis.

(2) The view currently held by most authors is in favour of an earlier theory that the six-row tough-rachis and widely distributed (cultivated) species, *H. vulgare* arose from the two-row cultivated species, which itself, arose from the two-row brittle-rachis species, *H. spontaneum*. Although the discovery of a six-row brittle rachis species, *H. agriocrithon* created some problems that resulted in a revision of the phylogenetic line, more recent biological as well as archeological studies reaffirmed that *H. spontaneum* is a more likely candidate as a progenitor of cultivated barley than anyother presently known species (Zohary, 1963; Nilan, 1964).

The belief that *H. agriocrithon* is the ancestor of cultivated barley had been refuted by the fact that eventhough it has brittle-rachis, it does not seem to be a primitive species considering other criteria. However, it is thought to be a hybrid species between *H. spontaneum* and *H. vulgare*. The possibility of such hybridization or even introgression rested in the fact that *H. spontaneum* and *H. vulgare* have been found growing side by side, especially in Indochina (Takaharshi, 1955; Nilan, 1964).

Several authorities including Takaharshi (1955) believed that the naked barleys have orginated through mutation of a recessive gene responsible for nakedness of grain. Takaharshi (1955) also showed that the naked barleys are more frequent in the orient, decreasing towards the west. He indicated that inspite of Vavilov's belief that the centre of origin for naked barleys is southeastern Asia, Orlov's work showed a diversity of forms in Ethiopia.

3. THE CULTIVATION OF BARLEY IN ETHIOPIA

It was first thought that Ethiopia was a centre of origin for cultivated barley. More recent work, however, has shown that the crop was introduced via Syria-Egypt or Yemen (Qualset, 1975; Purseglove, 1976a). After an exhaustive review of the literature, Simoons (1965) summarized the findings of various workers and concluded that Ethiopia is only a centre of diversity. He attributes this diversity to the mixing of different taxa in the same field and to enhanced mutation because of shock arising from the high variations between day and night temperature and intense ultra violet light. According to Purseglove (1976b) Doggett is of the opinion that Hordeum vulgare had been introduced to Ethiopia some 5,000 years ago.

In Ethiopia barley stands fourth (next to maize, tef and sorghum) in cereal production (Hailu and Pinto, 1977). It is grown mostly in the "dega", to some extent in the "woina dega" and very rarely in the "kolla" areas. All the fourteen administrative regions grow barley, but the lofty highlands of Shoa, Arsi, Bale and Gondar are the most important accounting for 75% of the total (Asrat, 1965). The crop occupies 600,000 hectares or 10.7% of the cropland with the mean yield of 9.3 Q/ha (Hailu and Pinto, 1977) and 10 Q/ha (I.A.R., 1979).

In a report on barley production and research in Ethiopia, Hailu and Pinto (1977) pointed out that as a result of wide differences in topography, soil and climatic conditions there exists a wide variation in sowing period. The growing season in the central highlands is during the summer rains, sowing being from mid - June to mid - July and harvesting from November to December. In areas with bimodal rainfall, sowing is from mid - March to mid - April and harvesting from August to September. These areas also crop on winter rains from October to February or March. The crop is mostly grown at high altitudes, 1800 - 3,000m above sea level where at least 500mm of rainfall is received during the crop's life (3½ - 6 months -- the farmers of Welmera, in fact claim that there are cultivars which require only a 2 month growing season). As pointed out by I.A.R. (1979), the most suitable areas for barley are those with altitudes ranging from 2,200 to 3,000m and the length of the period between sowing and harvesting varies from 4 to 5 months depending on the cultivars used.

3.1 CULTURAL PRACTICES AND PRODUCTION

In the highland areas a fallow system is often used. In the Bedi area barley is grown on land that has been fallowed for 1 or 3 years. In some vertisols of Shoa (eg. Debre Birhan, Fitche) the soil is burnt (guie) and one or two crops of barley are grown after which the land is abandoned for 10 to 15 years (Anketse Birhan, 1980). In the lowland areas of Shoa, eg. Yerer and Kereyu, barley follows tef, sorghum or field peas. In Arsi barley is grown in an alternating fallow - crop pattern in some areas and is succeeded by wheat in other areas. In the red soils of Gojam the crop is grown on fallowed land. The above are just a few of the practices employed by Ethiopian barley farmers (Hailu and Pinto, 1977). The rationale behind the use of various practices as discussed by these authors is the fact that the central highlands of

Ethiopia, which are the major centres of barley production, have had centuries of intensive cultivation resulting in deforestation, erosion, topsoil and organic matter depletion. The soils are, therefore, of very low fertility. This has contributed to the mean yield being as low as 10 Q/ha whereas the world average is 18.5 Q/ha and the world maximum is 40 Q/ha. The low yields, however, should be viewed against the facts (I.A.R., 1979) showing that many varieties of barley can tolerate some acidity and have been grown successfully on reddish brown clay soils of pH 5.5 - 6.0 with fertilizers.

3.2 USES OF BARLEY

Barley is a crop of several uses in this country. Unlike countries that produce it for the purpose of animal feed and brewing, about 40% is produced for human food in Ethiopia. It is prepared as food in various ways including in the form of "injera","Kollo", "besso", "chiko", "kinche","atmit", "genfo", etc. About 3% of the barley produced currently is used in the making of beer. Of the rest by far the greatest proportion is used in the making of the local alcoholic drinks, "tella" and "arequie". Indigenous barley is usually high in protein and this makes it unsuitable for malting purposes. Malting barley is now grown in Arsi and Bale as a result of research which made its introduction into Ethiopia possible. Although three varieties of good malting quality have now been selected for the Chilalo highlands in Arsi, and for Holetta and for Sheno in Shoa (I.A.R., 1974) commercial production of malting barley is undertaken only in Arsi and Bale (Hailu Gebre, personal communication).

3.3 GENETIC CONSERVATION

All the three species of barley are known to occur in Ethiopia (Chiovenda, 1912; Asrat, 1965). Some authorities including Cufodontis (1953) think that there is only one species of cultivated barley, *H. vulgare*, within which there are several distinct varieties. This seems to be a result of conflicting views on the biological species concept as applied to cultivated plants. The current belief is that it is best to treat all the cultivated barleys under three species, each with a number of varieties (Thakur, 1975). All these three species are represented in Ethiopia.

Owing to the fact that Ethiopia is a centre of diversity for this crop (Frankel and Bennett, 1970; Melake Hail Mengesha, 1975; Endashaw, 1979), many land races are known to occur. Barley is the third highest crop in the list of crop genetic diversity in Ethiopia, next to coffee and tef (Melake Hail Mengesha, 1975; Endashaw, 1979). It is believed that these are about 3,300 local cultivars as screened at Holetta and Debre Zeit research stations (Hailu and Pinto, 1977). In the Ethiopian farmers' fields these usually do not occur in the pure state. In the terminology of Hailu and Pinto (1977), a composite populations, which, over a long period of time, has become location specific and relatively yield stable in its places of occurrence. The local cultivars of barley have not been fully studied yet, but, the very limited number investigated have proved to be a valuable source of germplasm in the developed world (Melake Hail Mengesha, 1975; Qualset, 1975; Endashaw, 1979). It was with this understanding and awareness of the danger of genetic erosion that the Plant Genetic Resource Centre for Ethiopia (PGRC/E) listed the conservation of barley germplasm among those that need urgent action (Work plan, 1977; Activity Report, 1976-79).

3.4 GENERAL RESEARCH PROBLEMS

According to Hailu and Pinto (1977) there are many practical problems in barley research in this country of which the major ones are: inaccessibility of the major barley producing areas, diseases and climatic and soil problems.

These authors claim that major attention had been geared towards the adaptation and improvement of malting barley due to the urgency of the need to produce more malt for the brewing factories. Various trials have been conducted in different barley growing areas for this purpose. Places included in the trials have been Holetta, Bedi, Sheno, Fitche, Arsi-Negelle, Sagure, Bekoji, Alemaya, Burie, Amanuel, Gondar, Dabat and Hawzen.

As far as research on food barley is concerned although not sufficient, some work has also been done. The attempts in this respect have been the breeding of cultivars with broad adaptation and good yield stability. Due attention is also being given to the selection of cultivars which are resistant to diseases, tolerant to water logging, can compete with weeds, have fair performance on poor soils, are tolerant to frost and are quick maturing. Moreover there are plans to develop high-lysine food barleys. This is just about to start (Hailu Gebre personal communication).

4. MATERIALS AND METHODS

Data were collected through field observations, soil analyses and pot experiments in the greenhouse.

4.1 FIELD TRIPS, SEED AND SOIL COLLECTIONS

Field trips were made to the area on different occasions between June 13 and November 19, 1979. During the field trips the following activities were carried out.

(a) Before going to each area of interest a farmer, who was known to be a good source of information, was consulted. This farmer could identify at least the major cultivars and also was well versed as to where exactly each occurred and the various cultural practices employed in the woreda.

(b) Seeds of 10 cultivars, encountered in the different areas. were secured from the peasants.

(c) The fields from which the seeds had been harvested were indentified and checked that no fertilizer had been applied. About 50 kg of soil was taken from the plough horizon (top 10-20cm). The soil was removed from the four corners and from the centre of the field and thoroughly mixed.

(d) All information thought likely to be of any use later on was recorded. This information included name of the place, distance from the main road or from Holetta town, altitude, slope, the crops grown in the area, the soil colour, the local name of the cultivars collected, the time taken by the cultivar to complete its life cycle as reported by the farmers, sowing and harvesting periods, number of rows in a head, the preferred use (injera, tella, kollo, etc.), the colour of the seeds.

(e) Heads of ripened cultivars were obtained from each locality and mounted on herbarium sheets after drying.

4.2 PROCEDURE USED FOR SELECTION OF CULTIVARS

In this work only cultivars that were easily distinguishable by morphological characteristics were considered. In all cases the dominant cultivar in a farmer's barley field was taken to represent that field. Attempts were made to find the scientific names of the cultivars studied. Unfortunately, identification keys and knowledgeable persons in this field have not been encountered so far. Considering the meagre scientific knowledge on Ethiopian barleys, it is in fact, likely that many of these cultivars have not been described. Within the area investigated there could possibly be many genuine cultivars not included here. Therefore, it must be noted that only those cultivars that happened to be clearly distinguishable by morphological characters not subject to environmental fluctuations including fertility, density and size of ear, colour of the grain and husk, and the size of the awn (Carlson and Horne, 1962) were used to supplement the information gained from the peasants. This helped to eastablish that those studied are really different cultivars. The failure to find the scientific names of each cultivar has dictated the use of local names which may not have universality throughout the country. Even thus, most of these local names are also found in Endashaw's (1979) enumbration of frequent varieties indicating a high degree of consistency in the local names.

4.3 PROCEDURE USED IN SOIL ANALYSES

For most of these, procedures given by Jackson (1962), Dewis and Freitas (1970) and Allen et al. (1976) were followed.

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

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

c. pH was determined in a 1:1 soil : distilled water mixture with a portable Bechman model chem-mate pH meter.

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

e. Soil textural analysis was made by the soil hydrometer method (Bouyoucos method) after pretreatment with 9% hydrogen peroxide and 5% sodium hexametaphosphate. The critical times, according to Stock's Law, were fourty-seven seconds and six-hours and thirty minutes for the settlement of sand and silt respectively.

f. Exchangeable cations were removed by leaching with 1N ammonium acetate solution at pH7 and Na, K, Ca, Mg were determined using an atomic absorption spectrophotometer series 2, Unicam SP 90A. Readings were taken at 589nm for sodium, 766.5nm for potassium, 422.7nm for calcium and 285.2nm for magnesium.

g. Total nitrogen was determined using the Kjeldahl digestion method with copper sulphate selenium mixture as a catalyst. The sample was digested with concentrated sulphuric acid to convert all the 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 boric acid was then back titrated with 0.01N sulphuric acid until the blue colour of bromocresol-methyl red indicator just disappeared and became pink.

h. Calcium carbonate was determined using Collin's Calcimeter for soil analysis. The method is based on carbondioxide evolution when dilute hydrochloric acid is added to a sample of soil. Since most of the carbonate in soils usually exists in the form of calcium carbonate, the amount of carbonate is determined and extrapolated to calcium carbonate.

i. The available phosphorus was extracted with 0.5M sodium bicarbonate ($NaHCO_3$) at pH 8.5. The suspension was shaken on a rotary mechanical shaker for 30 minutes and immediately filtered using a phosphorus free filter paper, and discarding the first few drops. Since all the soils had pH below 6.5 the method given by Olsen et al. was used. 2.5 ml of 1N sulphuric acid was added to reduce the pH. 0.5 ml ammonium molybdate and 0.2 ml of the reducing agent, 0.1M stannous chloride, were mixed and added. The chlorostannous reduced molybdophosphoric blue colour was developed and the absorbance read at 720nm using a spectrophotometer series 2, Unicum SP 600.

4.4 PROCEDURE USED IN THE POT EXPERIMENTS

The soils brought from the various barley fields were left for air drying. Small portions (100g) were then taken from each sample and dried at 100°C for 24 hours in an oven. Upon reweighing it became possible to calculate the percentage of water for each soil type. Eighteen black plastic bags (pots) eaoh with a diameter of 16cm, giving a soil surface area of 201.14 sq.cm per pot, were prepared for each of the nine soil types. This gave a total of 162 (=18 X 9) pots. Each bag was folded and in it an amount equivalent to 2kg of "dry soil" was placed. The soils were placed in line according to the alphabetical order of the name of the place they were obtained from; i.e. Bedi, Berfeta 1, Berfeta 2, Foeta, North of Holetta, Suba Road, Wachacha 1, Wachacha 2, Welmera Choke. This insured that all the pots containing the same soil type were placed next to each other. One barley cultivar was sown in each of two pots of each soil type. A square card with 5 holes, one at each corner and one in the centre, was used and 2 seeds were placed in eaoh hole. The pots were split into two identical groups, each group containing each cultivar - soil type combination in the same order. The pots in each group were numbered starting from Bedi soil and going all the way through to Welmera Choke soil. Those pots bearing identical numbers from the two groups thus contained the same soil type and the same cultivar. All those in one group were allocated to different positions in one block according to a set of random numbers. A different set of random numbers was used to assign positions to the pots in the second block. Hence, the experiment was set up in a randomized complete block design in two replications. The shape and size of the greenhouse (A.A.U., Arat Kilo) allowed for three rows in twenty seven columns in each replicate (block). To avoid edge effects extra bags with soils and barley cultivars of any type were put surrounding the experimental ones.

After the emergence of seedlings only one healthy seedling was left per hole and the rest discarded. This gave five plants per pot. Sowing date was December 26/1979 and harvesting date was April 26/1980. Throughout the experimental period only distilled water was provided as visually seen needed by the soil and weeds were removed by hand where-ever they appeared.

A case of attack by aphids was recognized at an early stage and malathine was applied. At a time when most of the plants were about to mature leaf rust broke out. This was counteracted by spraying with plantvax..

The daily temperature range between maximum and minimum in the greenhouse varied from 10°C to 34°C, the average daily range of variation being 26.56°C. The average daily temperature over the growing period was 25.05°C. The relative humidity on average varied from 60% to 100%.

Various growth parameters were recorded as follows:

a. The number of seeds which germinated were counted at 24 hours intervals.

b. Individual plant height were measured in centimeters at 10 day intervals from the soil surface to the maximum height attained by the leaves held vertical. This measurement was taken on the 20th, 30th, 40th, 50th, 60th and 70th days after sowing.

c. Number of leaves per individual plants were counted at the same time as for height measurements.

d. Individual plant culm diameter was measured at the third internode with an improvised cardboard mm guage (Evans, 1972) at 70 days after sowing.

e. The plants were harvested at 123 days after sowing. Virtually all the plants had matured then. Information recorded at harvesting included number of plants per pot which had headed, seeded, or remained blind. Plant height and number of leaves at harvesting were also recorded. The harvested material was then chopped up and oven dried (105°C for 2 hours) (Evans, 1972; Allen et al., 1976), transferred to a dessicator for cooling and weighed to determine the total above ground dry matter production per pot with five plants.

5. R E S U L T S

5.1 . DATA REDUCTION

Initially measurements and counting of characters were made on individual plants. Later on mean values for all growth parameters considered in this work were computed per treatment. In some cases still further reduction of data was made to obtain the mean values for the two blocks The resulting data are presented as follows.

TABLE 2. AVERAGE PLANT HEIGHT IN CENTIMETRES

CULTIVAR	BALEME											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	21.0	15.0	25.6	24.6	27.0	27.4	28.0	30.0	29.2	33.0	30.4	36.6
BERFETA 1	27.4	21.4	29.0	30.6	29.2	31.6	30.0	37.0	31.2	43.4	32.0	45.2
BERFETA 2	18.8	15.3	23.0	32.2	25.6	37.2	34.0	42.4	34.2	43.0	34.2	43.0
FOETA	22.2	25.0	27.8	35.0	38.6	46.0	48.2	55.6	51.0	56.6	53.8	57.6
NORTH OF HOLETTA	26.4	21.0	27.2	42.6	37.6	45.6	40.5	47.8	47.0	50.8	54.2	54.2
SUBA ROAD	23.6	21.2	32.4	41.0	41.2	46.0	49.0	50.0	52.0	51.2	54.2	51.8
WACHACHA 1	15.6	22.2	21.0	30.2	23.4	33.4	24.0	37.6	28.0	39.0	30.0	41.0
WACHACHA 2	17.8	13.3	22.4	32.6	34.4	40.6	45.0	45.0	46.0	47.0	49.6	50.2
WELMERA CHOKE	21.4	21.0	27.6	42.2	36.2	45.4	40.4	50.0	48.2	52.1	53.0	55.0

TABLE 2 (Cont'd)

CULTIVAR	KESELE											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	25.0	18.5	26.8	36.2	30.6	42.2	32.0	43.0	33.0	44.1	33.0	44.8
BERFETA 1	24.8	18.0	26.2	25.2	32.0	28.2	36.2	35.2	37.8	36.0	38.0	37.4
BERFETA 2	25.0	22.0	29.6	33.2	40.4	35.0	44.0	36.0	45.0	37.0	47.8	37.0
FOETA	25.4	24.4	36.2	44.8	37.6	46.2	40.8	47.0	46.2	47.0	52.0	47.4
NORTH OF HOLETTA	20.1	24.0	25.2	37.0	39.0	45.4	43.0	50.0	44.0	50.0	45.4	50.4
SUBA ROAD	30.0	21.8	30.8	34.8	43.6	41.2	49.2	48.6	53.4	51.0	54.8	52.6
WACHACHA 1	25.6	17.6	27.4	27.8	34.2	33.8	38.2	34.6	38.8	35.0	40.0	35.2
WACHACHA 2	25.0	17.4	30.6	32.6	38.2	40.6	43.4	42.4	44.2	43.0	45.4	43.4
WELMERA CHOKE	25.4	24.4	30.0	39.2	34.0	42.2	39.0	47.6	44.8	48.0	47.6	48.4

TABLE 2 (Cont'd)

CULTIVAR	NETCH GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	21.8	16.2	26.6	26.8	32.8	33.2	34.4	39.6	35.0	44.6	35.6	46.0
BERFETA 1	19.4	19.0	27.2	33.6	28.2	39.0	30.0	39.4	35.2	39.6	37.6	39.8
BERFETA 2	13.8	30.4	25.5	41.8	37.7	46.2	40.0	52.2	43.8	55.5	45.5	57.8
FOETA	26.6	16.8	31.8	36.4	39.0	40.4	43.0	47.0	47.0	47.0	53.4	47.4
NORTH OF HOLETTA	23.4	19.2	28.0	30.8	38.6	43.0	46.0	49.6	51.0	50.2	54.0	51.4
SUBA ROAD	24.8	14.0	30.8	37.8	37.6	44.0	45.0	48.0	49.2	49.4	52.6	49.8
WACHACHA 1	27.6	16.2	31.0	24.8	32.2	28.0	34.0	35.0	42.0	37.6	43.2	38.4
WACHACHA 2	23.9	18.6	28.8	38.4	37.8	45.8	44.8	48.2	53.0	49.6	57.6	50.2
WELMERA CHOKE	28.6	19.0	31.2	37.0	37.4	42.2	42.0	47.6	49.0	48.0	55.0	48.4

TABLE 2 (Cont'd)

CULTIVAR	SEMERETA											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	27.6	17.2	29.0	33.2	34.2	38.4	43.0	47.0	50.0	51.4	55.[illegible]	54.2
BERFETA 1	22.4	18.2	24.8	32.2	33.4	39.4	39.0	46.2	48.2	50.2	55.6	56.4
BERFETA 2	28.6	21.0	29.6	39.0	38.8	46.4	43.6	52.0	56.0	57.8	63.2	64.2
FOETA	26.8	27.0	35.0	41.4	43.8	47.0	50.0	53.2	55.0	58.0	61.8	65.2
NORTH OF HOLETTA	27.4	27.0	28.2	41.0	37.6	45.6	47.0	53.0	53.2	58.2	60.8	64.4
SUBA ROAD	22.8	20.0	28.6	32.6	37.8	36.4	44.6	49.0	50.8	55.0	65.0	60.8
WACHACHA 1	17.0	22.2	23.0	33.2	26.8	37.2	35.0	40.6	41.3	53.0	44.0	55.8
WACHACHA 2	21.0	21.7	27.6	38.4	32.2	43.2	42.4	48.0	52.0	57.5	57.0	67.6
WELMERA CHOKE	25.2	22.0	28.0	35.4	44.4	43.0	51.6	49.0	57.0	52.4	63.6	57.6

TABLE 2 (Cont'd)

CULTIVAR	ENAT NETCH GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	9.2	13.7	18.8	23.2	23.8	28.6	25.8	30.0	27.0	32.2	28.0	33.4
BERFETA 1	13.6	10.0	25.2	19.4	27.6	26.4	29.6	29.6	31.4	30.0	32.4	30.0
BERFETA 2	16.5	9.5	26.4	33.4	37.0	48.4	42.0	54.2	45.2	56.8	47.4	59.2
FOETA	16.2	12.9	27.2	34.8	42.2	45.8	45.0	51.4	46.0	54.4	46.6	56.4
NORTH OF HOLETTA	10.2	8.8	26.8	31.0	40.2	44.2	47.0	46.5	47.8	47.6	48.0	48.0
SUBA ROAD	13.2	10.5	27.8	32.6	39.8	41.4	45.0	49.2	51.8	50.8	54.2	51.4
WACHACHA 1	12.6	6.4	23.8	19.2	28.4	29.6	30.0	34.4	35.0	39.6	38.0	42.8
WACHACHA 2	12.2	12.9	29.0	24.2	34.2	40.2	38.8	48.6	45.0	50.0	47.2	51.2
WELMERA CHOKE	13.0	9.6	24.8	28.4	38.2	33.8	40.0	39.6	43.2	40.0	45.0	40.2

TABLE 2 (Cont'd)

CULTIVAR	KEYE GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	24.5	20.5	30.4	35.8	36.0	42.2	40.2	43.5	43.0	44.4	44.6	45.2
BERFETA 1	23.4	16.0	31.8	31.2	35.6	44.4	39.0	45.0	39.0	46.0	39.2	47.0
BERFETA 2	25.6	24.6	33.2	37.8	40.4	47.4	45.2	53.6	54.0	58.2	56.6	60.6
FOETA	26.2	21.2	31.6	39.6	39.2	45.6	45.0	51.0	48.2	54.8	51.2	57.0
NORTH OF HOLETTA	23.2	21.6	30.8	46.0	41.4	49.2	48.0	55.2	52.2	58.4	54.0	63.8
SUBA ROAD	27.3	20.2	36.0	38.8	41.0	41.0	47.4	47.4	52.0	53.2	54.[illegible]	56.0
WACHACHA 1	21.3	17.4	25.6	25.4	30.6	35.6	33.0	44.0	37.0	42.2	37.2	42.8
WACHACHA 2	28.5	18.5	33.4	29.8	38.4	37.8	46.0	40.2	56.0	42.8	58.4	43.0
WELMERA CHOKE	28.4	9.6	34.8	28.4	37.4	33.8	46.0	39.6	49.2	40.0	51.2	40.2

TABLE 2 (Cont'd)

CULTIVAR	M C U G A											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	19.2	16.0	21.8	27.8	26.4	31.0	28.6	32.2	29.0	33.0	30.0	33.6
BERFETA 1	21.7	11.0	23.6	20.4	26.6	28.2	28.0	32.4	30.0	33.0	33.0	33.0
BERFETA 2	19.4	15.0	19.6	34.4	31.0	43.8	36.0	45.0	37.0	47.0	37.4	50.0
FOETA	22.2	20.8	29.2	37.0	39.2	43.6	44.0	50.6	45.6	54.0	47.2	58.0
NORTH OF HOLETTA	23.2	18.5	26.8	36.0	39.0	43.6	32.0	51.6	45.0	56.0	49.0	62.6
SUBA ROAD	23.6	19.4	34.0	35.2	42.6	41.4	48.0	48.6	51.4	49.0	54.0	49.0
WACHACHA 1	22.8	9.3	26.6	21.4	27.6	31.6	29.2	38.4	31.0	46.4	33.2	49.2
WACHACHA 2	22.6	16.2	26.0	33.6	33.4	46.0	40.0	46.4	42.0	48.0	44.2	48.6
WELMERA CHOKE	23.4	18.0	28.6	31.2	36.6	33.0	45.4	34.0	47.8	34.2	50.2	34.6

TABLE 2 (Cont'd)

CULTIVAR	SENEF–KOLLO											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPES / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	21.2	21.2	25.4	36.2	33.6	43.6	39.4	44.0	40.0	44.2	41.2	44.4
BERFETA 1	23.2	13.3	24.2	30.2	32.2	37.2	34.0	38.0	35.0	38.6	36.4	39.0
BERFETA 2	19.4	19.6	19.6	39.4	31.0	42.2	36.0	43.2	37.0	44.0	37.4	44.4
FOETA	28.0	20.8	29.2	42.8	39.2	44.0	46.0	49.4	48.4	56.0	51.8	60.4
NORTH OF HOLETTA	21.6	20.1	28.6	40.2	38.6	45.2	46.4	49.4	47.0	57.0	48.0	64.6
WACHACHA 1	16.6	15.6	22.8	29.0	33.0	33.8	37.0	34.6	38.2	35.0	39.6	35.0
WACHACHA 2	22.7	17.4	29.6	37.4	32.2	42.2	35.0	45.6	37.0	47.8	38.2	49.0
WELMERA CHOKE	26.2	18.6	30.0	37.8	38.8	45.6	47.0	48.6	49.0	48.8	50.4	49.0
SUBA ROAD	26.4	19.2	28.0	40.2	33.8	45.6	39.0	50.2	40.2	52.0	41.5	53.4

TABLE 3. AVERAGE LEAF NUMBER

CULTIVAR	BALEME											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.0	2.0	3.2	3.4	3.6	4.0	5.0	5.0	5.6	6.0	7.8	7.0
BERFETA 1	2.0	2.8	3.0	4.0	3.6	4.4	4.4	5.4	5.6	6.2	6.8	6.4
BERFETA 2	2.0	2.8	3.4	5.0	4.4	5.6	5.0	6.2	5.2	7.0	5.8	7.6
FOETA	2.0	3.0	4.4	4.0	5.4	5.0	6.8	6.8	7.6	7.2	9.0	8.0
NORTH OF HOLETTA	2.0	3.0	4.0	5.0	5.0	6.0	6.0	6.8	7.6	8.0	8.8	9.0
SUBA ROAD	2.0	3.0	4.2	5.0	5.0	5.8	6.0	6.8	7.4	8.6	9.0	10.0
WACHACHA 1	2.0	2.2	3.2	4.0	3.6	4.2	5.0	5.0	5.6	6.2	6.2	8.2
WACHACHA 2	2.0	2.2	3.4	4.2	4.6	5.2	6.8	6.0	7.0	7.4	8.2	8.4
WELMERA CHOKE	2.0	3.0	4.6	4.8	5.4	5.6	7.0	6.8	7.6	7.6	8.4	9.0

TABLE 3.(Cont'd)

CULTIVAR	KESELE											
DAYS AFTER SOWING	20		30		40		50		60		70	
BLOCK / SOIL TYPE	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.0	3.0	4.6	4.0	4.8	4.6	6.0	5.8	6.2	6.6	7.0	8.4
BERFETA 1	2.0	2.6	3.8	3.5	4.8	5.0	6.0	6.0	6.2	7.0	6.6	7.8
BERFETA 2	2.8	2.8	4.8	4.0	5.6	5.4	6.6	6.0	7.8	6.4	8.4	7.2
FOETA	2.0	2.8	4.0	5.0	5.0	5.0	6.6	6.6	7.0	8.2	7.8	9.2
NORTH OF HOLETTA	2.0	2.8	4.0	4.6	5.0	6.0	6.0	7.0	7.0	8.0	7.6	9.0
SUBA ROAD	2.6	2.8	5.0	4.8	6.0	5.6	6.8	6.8	7.8	7.4	9.0	8.2
WACHACHA 1	2.0	2.0	4.0	4.0	5.0	4.6	6.0	5.8	7.0	6.8	8.0	8.0
WACBACHA 2	2.2	3.0	4.0	4.0	5.0	5.0	5.8	5.8	7.6	7.6	8.0	7.8
WELMERA CHOKE	2.4	3.0	4.0	4.4	5.0	5.0	6.2	6.2	7.2	7.0	8.2	8.0

TABLE 3 (Cont'd)

CULTIVAR	NETCH GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.0	2.4	3.8	3.6	4.4	4.4	5.8	5.4	6.0	6.8	6.4	8.4
BERFETA 1	2.6	2.8	3.8	4.2	4.8	4.6	5.8	5.8	6.4	7.2	7.8	8.9
BERFETA 2	2.6	3.0	4.2	5.0	6.0	6.0	7.0	7.4	8.0	8.2	8.8	9.0
FOETA	3.0	3.0	4.8	4.8	5.6	6.0	6.4	6.6	7.6	7.8	9.0	9.2
NORTH OF HOLETTA	2.4	2.8	4.6	5.0	4.8	5.2	5.8	6.8	6.2	7.8	8.0	9.0
SUBA ROAD	2.6	2.6	4.6	4.6	6.0	5.6	6.6	7.0	7.6	8.4	9.2	9.0
WACHACHA 1	2.4	2.8	4.0	3.6	4.6	4.4	5.8	5.6	7.0	6.6	9.8	8.0
WACHACHA 2	2.2	3.0	4.2	5.0	5.0	5.8	5.6	6.2	7.8	7.6	9.0	8.0
WELMERA CHOKE	2.2	2.8	4.0	4.8	5.2	5.6	6.4	6.8	7.6	7.8	9.0	9.0

TABLE 3 (Cont'd)

CULTIVAR	SEMERETA											
DAYS AFTER SOWING	20		30		40		50		60		70	
BLOCK / SOIL TYPE	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.6	2.4	5.0	4.0	5.2	5.0	6.0	6.0	7.0	7.2	9.0	9.0
BERFETA 1	2.0	2.0	3.8	4.0	5.0	5.4	6.4	6.2	7.4	8.0	9.0	9.0
BERFETA 2	2.6	3.0	5.0	5.0	6.9	6.4	7.0	7.8	8.4	8.6	9.0	9.0
FOETA	2.6	3.0	4.8	5.0	5.6	6.0	6.4	7.0	8.0	8.2	9.0	9.0
NORTH OF HOLETTA	3.0	3.0	5.0	5.4	6.0	6.6	7.2	8.0	8.4	8.6	9.0	9.0
SUBA ROAD	2.8	2.8	5.0	4.4	6.0	6.0	6.0	7.2	7.8	8.0	9.0	9.0
WACHACHA 1	2.0	3.0	3.8	4.0	4.6	5.2	5.8	6.2	6.8	7.0	8.4	8.0
WACHACHA 2	2.2	3.0	4.0	5.0	5.0	6.0	5.8	7.4	6.8	8.0	9.0	9.2
WELMERA CHOKE	2.6	3.0	4.8	5.0	5.4	5.8	6.8	7.0	7.8	7.6	10.0	8.0

TABLE 3. (Cont'd)

CULTIVAR	ENAT NETCH GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	1.8	2.0	3.2	3.0	5.0	3.0	5.2	4.4	5.6	5.0	5.6	5.4
BERFETA 1	2.0	2.0	3.4	3.0	3.4	3.8	4.6	4.8	5.8	6.0	6.2	6.2
BERFETA 2	2.2	2.0	4.0	4.0	5.0	5.0	6.8	6.2	7.8	7.8	8.2	8.6
FOETA	2.0	2.0	4.2	4.2	5.0	5.4	6.0	6.4	7.2	8.6	8.8	9.0
NORTH OF HOLETTA	2.0	1.8	3.6	4.4	4.6	5.0	5.8	6.4	6.8	7.2	7.8	8.4
SUBA ROAD	2.0	2.4	4.0	4.2	4.4	5.6	5.6	7.2	6.0	7.8	7.2	8.4
WACHACHA 1	1.8	1.6	3.2	3.0	3.6	3.4	5.2	4.6	6.0	6.2	7.0	7.0
WACHACHA 2	1.8	2.0	3.2	3.6	3.8	4.6	5.6	6.0	7.0	7.0	8.0	7.6
WELMERA CHOKE	2.0	2.4	3.8	3.4	5.0	5.4	6.6	6.2	7.8	7.0	9.0	8.0

TABLE 3 (Cont'd)

CULTIVAR	KEYE GEBS											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE / BLOCK	1	2	1	2	1	2	1	2	1	2	I	2
BEDI	2.2	3.0	4.0	4.0	4.4	4.0	5.8	5.6	6.0	6.0	7.6	8.4
BERFETA 1	2.8	2.4	4.0	4.0	4.4	4.8	5.0	6.6	6.8	7.0	8.0	8.6
BERFETA 2	2.6	3.0	5.0	5.0	5.8	6.2	7.0	7.8	8.6	8.2	9.8	8.6
FCETA	2.6	3.0	5.0	4.6	5.8	5.0	6.6	6.2	6.8	7.8	7.0	9.2
NORTH OF HOLETTA	2.0	3.0	4.0	5.0	5.6	5.8	6.0	6.6	7.6	8.2	9.0	9.4
SUBA ROAD	2.2	2.8	5.0	5.0	5.2	6.0	6.6	7.0	7.6	8.0	8.8	8.6
WACHACHA 1	2.0	2.6	3.0	4.0	4.0	4.4	5.2	5.6	6.8	7.0	8.0	8.2
WACHACHA 2	2.4	3.0	4.0	4.0	5.0	5.0	6.2	6.0	7.0	6.8	9.0	8.4
WELMERA CHOKE	2.2	3.0	4.2	4.6	5.2	5.4	7.0	6.6	8.2	7.8	10.0	9.4

TABLE 3 (Cont'd)

CULTIVAR	MOUGA											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE / BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.0	2.2	3.2	3.6	3.8	3.8	4.4	5.0	4.8	5.8	5.0	6.2
BERFETA 1	2.0	2.0	3.2	3.2	4.2	4.0	4.8	5.6	5.6	6.4	6.8	7.0
B RFETA 2	2.0	2.2	3.4	4.2	4.2	5.0	5.0	6.8	6.0	7.2	7.4	8.2
FOETA	2.2	3.0	4.0	4.4	5.0	5.2	6.2	6.4	7.4	7.8	7.8	8.4
NORTH OF HOLETTA	2.8	2.2	4.0	4.2	5.0	5.4	5.6	6.4	7.0	7.6	8.2	9.0
SUBA RCAD	2.2	2.4	4.2	4.0	5.2	5.0	6.6	6.8	7.4	7.8	8.0	8.6
WACHACHA 1	2.0	2.0	3.8	3.0	4.2	3.8	5.4	5.2	6.4	7.0	7.4	8.4
WACHACHA 2	2.0	2.2	4.0	4.4	4.4	5.0	5.4	6.2	7.2	7.0	8.2	7.6
WELMERA CHOKE	2.2	2.6	4.0	4.0	5.0	4.8	6.0	6.0	7.0	6.6	8.2	7.4

TABLE 3 (Cont'd)

CULTIVAR	SENEF - KOLLO											
DAYS AFTER SOWING	20		30		40		50		60		70	
SOIL TYPE \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.0	3.0	4.0	4.0	4.6	4.8	5.2	6.0	6.4	7.0	7.0	8.0
BERFETA 1	2.0	2.8	4.0	4.0	4.8	4.4	6.0	5.8	7.0	7.0	7.6	7.6
BERFETA 2	2.8	3.0	4.6	5.0	5.6	6.0	6.4	7.6	8.2	8.8	9.4	10.0
FOETA	2.8	3.0	4.8	5.0	5.0	5.8	6.2	6.8	7.8	8.2	8.6	9.0
NORTH OF HOLETTA	2.0	3.0	4.6	5.0	5.0	6.6	6.0	7.0	7.0	8.0	8.0	10.0
SUBA ROAD	2.2	2.8	5.0	5.0	6.0	5.0	7.0	6.8	7.6	7.8	9.5	9.6
WACHACHA 1	2.0	2.4	4.0	4.0	4.0	4.6	5.0	6.0	6.0	6.4	7.0	7.4
WACHACHA 2	2.6	3.0	4.0	5.0	5.0	5.6	6.0	7.2	7.0	8.0	8.6	10.0
WELMERA CHOKE	2.2	3.0	4.2	5.0	5.0	5.8	6.2	7.0	7.6	8.0	9.0	9.4

TABLE 4. ABOVE GROUND DRY WEIGHT IN GRAMS PER POT OF FIVE PLANTS

CULTIVAR	DALEME		KESELE		NETCH GEBS		SEMERETA		ENAT NETCH GEBS		KEYE GEBS		MOUGA		SENEF KOLLO	
SOIL TYPE \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	2.3	2.5	1.5	1.4	1.1	1.5	1.6	1.0	0.8	0.8	1.6	1.2	0.7	1.0	1.2	1.3
BERFETA 1	0.7	1.1	1.5	1.3	1.8	1.4	1.3	1.5	1.0	1.1	1.8	1.3	1.3	0.8	1.2	1.2
BERFETA 2	1.8	1.4	3.6	2.3	3.6	3.4	3.4	3.6	3.5	3.0	3.9	4.4	2.1	2.5	3.0	5.2
FOETA	3.2	3.7	3.1	3.0	3.5	2.8	5.2	4.0	3.3	3.5	3.5	4.0	4.4	3.7	4.5	4.2
NORTH OF HOLETTA	4.6	3.1	3.6	3.4	3.8	3.0	4.3	4.2	3.2	3.4	3.0	4.3	3.0	2.5	3.4	4.2
SUBA ROAD	4.2	3.3	4.3	3.9	4.2	3.2	3.9	2.6	3.2	3.0	3.1	2.6	3.2	2.7	2.5	3.4
WACHACHA 1	1.3	1.2	2.4	2.0	2.5	1.7	1.4	1.8	1.9	1.0	1.8	1.7	1.4	1.3	1.3	1.4
WACHACHA 2	2.3	2.2	2.9	2.5	3.2	2.5	2.5	4.0	2.9	2.5	3.6	2.1	2.3	3.0	2.5	3.2
WELMERA CHOKE	3.5	2.8	3.3	2.9	3.7	3.2	3.5	2.3	2.4	1.4	3.5	2.9	2.7	2.2	3.1	2.6

TABLE 5. AVERAGE CULM DIAMETER AT THE THIRD INTERNODE IN MILLIMETRES: 70 DAYS AFTER SOWING

CULTIVAR	BALEME		KESELE		NETCH GEBS		SEMERETA		ENAT NETCH GEBS		KEYE GEBS		MOUGA		SENEF KOLLO	
SOIL TYPE \ BLOCK	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
BEDI	1.95	2.25	2.25	2.15	1.76	2.05	1.47	1.66	1.86	1.86	2.05	2.25	1.56	1.37	1.95	1.95
BERFETA 1	1.76	1.95	2.25	1.95	1.86	2.34	1.76	1.95	1.76	1.95	2.25	1.95	2.05	2.05	[illegible]	1.95
BERFETA 2	2.05	2.25	2.34	2.34	2.54	2.54	2.25	2.44	2.34	2.54	2.25	2.54	2.15	2.64	2.54	2.44
FOETA	2.54	3.03	2.64	2.64	3.03	2.54	2.54	2.44	2.83	2.34	2.74	2.83	3.22	2.54	3.03	2.74
NORTH OF HOLETTA	2.15	2.34	2.25	2.64	2.34	2.44	2.44	2.44	2.44	2.44	2.34	2.54	2.44	2.34	2.25	2.74
SUBA ROAD	2.05	2.83	2.25	2.54	2.64	2.54	2.05	1.95	2.54	2.54	2.34	2.15	2.34	2.44	2.44	2.74
WACHACHA 1	1.86	1.95	1.95	1.95	2.05	2.15	1.56	1.95	1.47	1.95	2.05	2.05	1.66	1.95	1.95	1.95
WACHACHA 2	2.15	2.34	2.44	2.15	2.44	2.34	1.86	2.25	2.25	2.25	2.54	2.05	2.34	2.44	2.05	2.34
WELMERA CHOKE	2.05	2.54	2.34	2.44	2.44	2.44	1.86	1.95	2.34	1.76	1.95	2.15	2.15	1.76	2.05	2.05

TABLE 6. RESULTS OF SOIL ANALYSES

A. COLOUR TEST AND MECHANICAL ANALYSIS

SOIL TYPES	SOIL COLOUR		MECHANICAL ANALYSIS			
	DRY SOIL	MOIST SOIL	% Sand	% Silt	% Clay	TEXTURAL CLASS
BEDI	10 YR $\frac{5}{4}$ Yellowish brown	7.5 YR $\frac{4}{2}$ Dark brown	30.5	45.5	24.0	LOAM
BERFETA 1	5 YR $\frac{4}{4}$ Reddish brown	5 YR $\frac{3}{4}$ Dark reddish brown	38.0	32.0	30.0	CLAY LOAM
BERFETA 2	7.5 YR $\frac{4}{2}$ Dark brown	7.5 YR $\frac{3}{4}$ Dark brown	16.5	40.5	43.0	SILT CLAY
FOETA	7.5 YR $\frac{3}{2}$ Dark brown	5 YR $\frac{2}{2}$ Dark reddish brown	24.0	42.0	34.0	CLAY SILT
NORTH OF HOLETTA	10 YR $\frac{5}{4}$ Yellowish brown	7.5 YR $\frac{4}{2}$ Dark brown	31.0	41.0	28.0	LOAM
SUBA ROAD	7.5 YR $\frac{4}{4}$ Dark brown	7.5 YR $\frac{3}{2}$ Dark brown	40.0	44.0	16.0	LOAM
WACHACHA 1	5 YR $\frac{4}{2}$ Dark reddish grey	5 YR $\frac{3}{2}$ Dark reddish brown	38.0	40.0	22.0	CLAY LOAM
WACHACHA 2	7.5 YR $\frac{4}{2}$ Dark brown	5 YR $\frac{2}{2}$ Dark reddish brown	26.0	40.0	34.0	LOAM
WELMERA CHOKE	7.5 YR $\frac{4}{4}$ Dark brown	7.5 YR $\frac{3}{2}$ Dark brown	25.0	32.5	42.5	CLAY

TABLE 6. (Cont'd)

B. CHEMICAL ANALYSES

SOIL TYPES	pH	ELECTRICAL CONDUCTIVITY m mhos / cm	EXCHANGEABLE CATIONS m eq /100gdry soil					Mg/Ca	% $CaCo_3$	% Total N	mg P_2O_5 /kg
			Na	K	Ca	Mg	Sum				
BEDI	4.53 Strongly acid	14.960	0.05	0.76	5.28	0.25	6.34	0.05	0.0805	0.27	12.37
BERFETA 1	5.53 Strongly acid	19.720	0.02	0.83	13.29	2.37	16.51	0.18	0.0268	0.20	2.29
BERFETA 2	6.05 Slightly acid	27.200	0.03	0.88	22.0	4.37	27.28	0.20	0.0298	0.26	31.14
FOETA	4.78 Strongly acid	52.360	0.66	0.72	22.0	4.00	27.38	0.18	0.0298	0.22	22.21
NORTH OF HOLETTA	5.48 Strongly acid	12.036	0.03	0.86	11.44	0.69	13.03	0.06	0.1341	0.22	9.62
SUBA ROAD	5.98 Medium acid	18.360	0.01	0.86	13.99	1.88	16.74	0.13	0.1371	0.23	67.33
WACHACHA 1	5.80 Medium acid	14.280	0.06	0.75	10.56	1.18	12.55	0.11	0.0179	0.11	below detection
WACHACHA 2	5.80 Medium acid	15.640	0.07	0.83	19.18	3.55	23.63	0.19	0.0179	0.23	3.37
WELMERA CHOKE	5.98 Medium acid	23.120	0.05	0.89	14.17	1.71	16.82	0.12	0.0805	0.24	53.59

5.2. STATISTICAL TREATMENT OF DATA

a. Variance analysis following Sokal and Rohlf (1969); Little and Hills (1978) was conducted on six growth characters. The procedure for model I two way analysis of variance 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 7.

b. In order to determine the cultivars that performed significantly higher or lower on each soil 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 tables 8 and 9.

c. The coefficients of variability (CV) of each cultivar was calculated (Steel and Torrie, 1960 and 1976). These results are given in table 10.

d. Spearman's rank correlations between dry weight ranks and some soil analytical results were made.

TABLE 7. ANALYSIS OF VARIANCE.

CHARACTER		TOTAL ABOVE GROUND DRY WEIGHT (g) / 5 PLANTS			AVERAGE NUMBER OF LEAVES 70 DAYS AFTER SOWING			AVERAGE CULM DIAMETER 70 DAYS AFTER SOWING		
SOURCE OF VARIATION	df	SS	MS	Fs	SS	MS	Fs	SS	MS	Fs
CULTIVARS	7	6.92	0.99	4.13****	31.44	4.99	11.51*****	1.15	0.16	4.00*****
SOILS	8	118.74	14.84	61.83*****	45.75	5.72	14.67*****	10.06	1.26	31.50*****
INTERACTION CULT. X SOIL	56	24.31	0.43	1.79***	33.74	0.60	1.54**	2.12	0.04	1.00 NS
ERROR (WITH IN GROUP VARIATION)	72	17.35	0.24		28.19	0.39		3.13	0.04	
TOTAL	143	157.32			139.11			16.46		

NS = NOT SIGNIFICANT

df = DEGREE OF FREEDOM

SS = SUM OF SQUARES

MS = MEAN SQUARES

Fs = VARIANCE RATIO

** = SIGNIFICANT AT 10% LEVEL

*** = " " 5% "

**** = " " 1% "

***** = " " 0.5% "

TABLE 7 (Cont'd)

CHARACTER	AVERAGE PLANTS HEIGHT 20 DAYS AFTER SOWING				AVERAGE PLANT HEIGHT 40 DAYS AFTER SOWING			AVERAGE CHANGE IN HEIGHT PER DAY (Cm.) BETWEEN THE 20th & 40th days after sowing		
SOURCE OF VARIATION	df	SS	MS	Fs	SS	MS	Fs	SS	MS	Fs
CULTIVARS	7	1733.65	247.66	13.50*****	353.69	50.53	2.40***	2.47	0.39	3.00****
SOILS	8	316.24	39.53	2.15***	2334.31	291.79	13.84*****	3.05	0.38	2.92****
INTERACTION CULT. X SOIL	56	404.27	7.22	0.39 NS	869.36	15.52	0.74 NS	2.52	0.05	0.38 NS
ERROR (WINTH IN GROUP VARIATION)	72	1321.09	18.35		1518.40	21.09		9.33	0.13	
TOTAL	143	3775.25			5075.76			17.63		

NS = NOT SIGNIFICANT
df = DEGREE OF FREEDOM
SS = SUM OF SQUARES
MS = MEAN SQUARES
Fs - VARIANCE RATIO

** = SIGNIFICANT AT 10% LEVEL
*** = " " 5% "
**** = " " 1% "
***** = " " 0.5 % "

TABLE 8. CULTIVARS RANKED ON DRY MATTER PRODUCTION ACCORDING TO SOIL TYPES *

RANK	BEDI SOIL	BERFETA 1 SOIL	BERFETA 2 SOIL	FOETA SOIL	NORTH OF HOLETTA SOIL	SUBA ROAD SOIL	WACHACHA 1 SOIL	WACHACHA 2 SOIL	WELMERA CHOKE SOIL
1	BALEME a	NETCH GEBS a	KEYE GEBS a	SEMERETA a	SEMERETA a	KESELE a	KESELE a	SEMERETA a	NETCH GEBS a
2	KESELE ab	KEYE GEBS a	SENEF-KOLLO a	SENEF-KOLLO ab	BALEME a	BALEME ab	NETCH GEBS ab	KEYE GEBS ab	KEYE GEBS a
3	KEYE GEBS ab	KESELE ab	NETCH GEBS ab	MOUGA abc	SENEF-KOLLO a	NETCH GEBS ab	KEYE GEBS ab	NETCH GEBS ab	KESELE a
4	NETCH GEBS b	SEMERETA ab	SEMERETA ab	KEYE GEBS abc	KEYE GEBS ab	SEMERETA ab	SEMERETA ab	SENEF-KOLLO ab	BALEME ab
5	SEMERETA b	SENEF-KOLLO ab	ENAT NETCH GEBS ab	BALEME abc	KESELE ab	ENAT NETCH GEBS ab	ENAT NETCH GEBS ab	ENAT NETCH GEBS ab	SEMERETA ab
6	SENEF-KOLLO b	MOUGA ab	KESELE ab	ENAT NETCH GEBS abc	NETCH GEBS ab	SENEF-KOLLO b	SENEF-KOLLO b	KESELE ab	SENEF-KOLLO ab
7	MOUGA b	ENAT NETCH GEBS ab	MOUGA ab	NETCH GEBS bc	ENAT NETCH GEBS ab	MOUGA b	MOUGA b	MOUGA ab	MOUGA ab
8	ENAT NETCH GEBS b	BALEME b	BALEME b	KESELE c	MOUGA b	KEYE GEBS b	BALEME b	BALEME b	ENAT NETCH GEBS b

* (i) Cultivars having different letter or letters below them are significantly different from each other at 5% probability level.

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

TABLE 9. PAIRS OF CULTIVARS SHOWING SIGNIFICANT VARIATION IN MEAN DRY WEIGHT WHEN ANALYZED BY DUNCAN'S MULTIPLE - RANGE TEST AT 5% PROBABILITY LEVEL.

SOIL TYPES	CULTIVARS SHOWING HIGH VALUES	CULTIVARS SHOWING LOW VALUES	OBSERVED DIFFERENCE	CRITICAL DIFFERENCE
BEDI	BALEME	ENAT NETCH GEBS	[illegible].6	1.11
	"	MOUGA	1.55	1.10
	"	SENEF-KOLLO	1.15	1.08
	"	NETCH GEBS	1.10	1.06
	"	SEMERETA	1.10	1.06
BERFETA 1	NETCH GEBS	BALEME	0.70	0.58
	KEYE GEBS	"	0.65	0.57
BERFETA 2	KEYE GEBS	BALEME	2.55	1.98
	SENEF-KOLLO	"	2.50	1.96
FOETA	SEMERETA	KESELE	1.55	1.30
	"	NETCH GEBS	1.45	1.28
	SENEF-KOLLO	KESELE	1.30	1.28
NORTH OF HOLETTA	SEMERETA	MOUGA	1.50	1.02
	BALEME	"	1.10	1.01
	SENEF-KOLLO	"	1.05	1.00
SUBA ROAD	KESELE	KEYE GEBS	1.25	1.06
	"	MOUGA	1.15	1.04
	"	SENEF-KOLLO	1.15	1.04
WACHACHA 1	KESELE	BALEME	0.95	0.83
	"	MOUGA	0.85	0.81
	"	SENEF-KOLLO	0.85	0.81
WACHACHA 2	SEMERETA	BALEME	1.00	0.62
WELMERA CHOKE	NETCH GEBS	ENAT NETCH GEBS	1.55	1.11
	KEYE GEBS	" " "	1.30	1.10
	KESELE	" " "	1.20	1.08

TABLE 10. COEFFICIENTS OF VARIABILITY CALCULATED FROM MEASUREMENTS MADE ON DIFFERENT SOILS (%).

CULTIVARS \ CHARACTER	1	2	3	4	5	6
BALEME	43.78	12.84	16.75	15.40	18.20	38.66
KESELE	33.15	5.37	9.15	7.77	9.28	19.01
NETCH GEBS	32.14	6.80	11.84	7.96	11.73	25.16
SEMERETA	41.97	3.08	13.69	11.92	15.41	13.20
ENAT NETCH GEBS	44.42	14.91	15.75	13.66	20.64	26.89
KEYE GEBS	36.31	7.30	10.31	10.12	9.02	16.32
MOUGA	45.25	11.76	18.95	11.81	16.43	25.19
SENEF-KOLLO	44.99	10.61	15.16	14.71	8.21	9.27

1 = total above ground dry weight in grams per five plants

2 = Average number of leaves, 70 days after sowing

3 = " culm diameter, 70 " " "

4 = " plant height, 20 " " "

5 = " " " , 40 " " "

6 = " change in plant height per day, between the 20th and 40th days after sowing.

5.3 GROWTH RATE ANALYSIS

In order to compare the growth pattern of each cultivar, the mean relative growth rates were calculated. Various indices of plant growth analysis have been developed by a number of workers in the general field of plant physiology. Reference can be made to Bloch (1961), Evans (1972), Leopold and Kriedemann (1975), Banniseter (1976), Hunt

(1978) and McCollum(1979). The mean relative growth rate is one of these indices commonly used for the assessment of a plant's growth over a period of time. It is defined as follows:-

$$\bar{R} = \frac{\log e\ W_2 - \log e\ W_1}{T_2 - T_1}$$

Where $\bar{R}$ = Mean relative growth rate; W_2 = Weight at time 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 logarithsms

It can be computed from plant growth parameters eg. height, width, weight and number of parts recorded at any two times separated by a specified interval during the actively growing period of the plant (Evans, 1972; Hunt, 1978). Since it is the rate of change of, say weight, it is usually given in weight per weight per time (Hunt, 1978); but, McCollum (1979) recommends its expression as percent per day and this is what has been followed here.

In order to evaluate the growth activities of the eight cultivars of barley the mean relative growth rate was calculated from plant height measurements for the following two stages:

a. For the period between the 20th and 70th days after sowing (Table 11).
b. For the period between the 2 to 3 leaf stage, which was 20 days after sowing except for Enat Netch Gebs on Bedi, Wachacha 1 and Wachacha 2 soils and Kesele on Wachacha 1 soil treatment where it was later than 20 days after sowing and the 5 leaf stage. ___ this was done in order to compare the relative mean growth rates at comparable physiological conditions. ___ (Table 12).

TABLE 11. MEAN RELATIVE GROWTH RATES AS PERCENT PER DAY BETWEEN THE 20th AND 70th DAYS AFTER SOWING

SOIL TYPES \ CULTIVAR	BALEME	KESELE	NETCH GEBS GEBS	SEMERETA	ENAT NETCH GEBS	KEYE GEBS	MOUGA	SENEF-KOLLO
BEDI	1.24	1.16	1.54	1.80	1.90	1.38	1.10	1.42
BERFETA 1	0.88	1.14	1.46	2.04	1.92	1.56	1.40	1.44
BERFETA 2	1.58	1.18	1.68	1.88	2.84	1.70	1.76	1.42
FOETA	1.90	1.42	1.68	1.70	2.52	1.64	1.78	1.68
NNORTH OF HOLETTA	1.56	1.48	1.80	1.68	3.24	1.94	2.02	1.98
SUBA ROAD	1.72	1.46	2.12	2.24	2.98	1.68	1.78	1.46
WACHACHA 1	1.14	1.12	1.24	1.86	2.90	1.44	1.84	1.68
WACHACHA 2	2.32	1.48	1.86	2.10	2.74	1.54	1.62	1.52
WELMERA CHOKE	1.88	1.30	1.50	1.88	2.66	1.36	1.44	1.60

TABLE 12. MEAN RELATIVE GROWTH RATES AS PERCENT PER DAY BETWEEN THE 2 – 3 AND THE 5 LEAF STAGES

CULTIVAR / SOIL TYPES	BALEME	KESELE	NETCH GEBS	SEMERETA	ENAT NETCH GEBS	KEYE GEBS	MOUGA	SENEF-KOLLO
BEDI	1.60	2.32	2.59	2.47	2.28	2.35	1.40	2.56
BERFETA 1	1.07	2.10	2.64	2.90	3.03	2.92	2.03	2.83
BERFETA 2	2.95	2.47	4.15	4.50	5.10	4.40	3.64	3.69
FOETA	3.56	2.65	4.42	3.27	5.68	3.29	3.16	3.02
NORTH OF HOLETTA	3.20	3.44	3.25	2.56	6.86	3.61	3.47	4.15
SUBA ROAD	3.87	2.45	6.60	3.67	6.10	4.18	3.53	4.50
WACHACHA 1	1.63	2.35	1.58	2.45	3.94	2.26	2.50	2.88
WACHACHA 2	4.35	3.10	3.39	3.20	4.68	2.45	3.22	3.60
WELMERA CHOKE	3.09	2.15	2.53	3.40	6.11	2.36	2.52	3.60

6. DISCUSSION

6.1 THE GROWTH OF THE PLANTS IN THE GREENHOUSE

It must be noted that the conditions that were prevailing in the greenhouse (temperature, humidity, closed environmental conditions and limited rooting space) were all unnatural for the crop. The essense of this experiment was to see how each cultivar responded to the different soil types when other environmental conditions were identical. It was observed that most of the cultivars, except Semereta, showed very poor grain development. Some plants produced heads with awns but without seeds, some produced only awns at the tips of the shoot, some headed but the heads remained blind (did not emerge from the boot) and a few did not reach heading stage at all, i.e. they remained in a juvenile stage.

Bannister (1976) states that extreme temperatures cause both physical damage and physiological disturbances. The upper limit of temperature tolerance for biological activities is about 50°C when proteins become denatured (Leopold and Kriedemann, 1975). It is also known that on a sunny day some plant organs (eg. leaves) can be at higher temperature (up to 18.4°C) than the air temperature (Bannister, 1976). Endashaw (1976) quoting different sources reported that greenhouse temperatures greater than 15°C occasionally result in an undesirably high accumulation of nitrites in soils. He also pointed out that bacterial populations tend to decrease with increasing temperature.

The observations made on the experimental plants showed that vegetative stages were quite normal except for the absence of tillers in the greater majority of cultivars. It is known that under controlled environmental conditions it was found that 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 (Russel, 1973; Downs, 1975). While dealing with the physiological aspects of dryland farming, Arnon (1975) pointed out that high temperatures above a critical value may be detrimental. He illustrated this claim with the observation that growth retardation and difficulties in fertilization occurred even in heat loving crops, eg, maize and Sorghum around 45°C. Mesfin et al. (1978) studied the eco-physiology of noog (Guizotia abyssinica) and reported that high temperatures (27° and 33°C) resulted in failure of flowering although normal vegetative growth was observed. It is known that (Nuttonson, 1957) extreme temperatures adversely affect pollination and specifically that high temperatures during the heading stage or between heading and ripening, especially if accompanied by hot winds, cause serious hazards in the development of both vegetative and reproductive parts in barley.

In light of the reports just cited and considering that the experiments were carried out in the dry (sunny) season at an altitude (Addis Ababa) lower than most of the sites from which the cultivars were collected it is easy to attribute the failure of normal ripening of the cultivars to high temperature. These results indicate that Semereta, besides being fast maturing is also, compared to the others, high temperature tolerant. This conclusion agrees fairly well with the field observations in that this cultivar has a wide distribution in the comparatively warmer and lower areas (eg. Berfeta, on the road to Suba, North of Holetta) and also it is grown as a "belg" crop along the Suba road when conditions turn out to be favourable.

6.2 GERMINATION PERIOD

Since germination is also one important property that could influence the success of cultivars, the time each cultivar took to germinate was recorded. The results are given in Table 13.

TABLE 13. AVERAGE GERMINATION PERIOD

No.	CULTIVAR	GERMINATION PERIOD IN DAYS*	RANK, STARTING WITH THE FASTEST
1	BALEME	3.39	2
2	KESELE	3.39	2
3	NETCH GEBS	3.72	4
4	SEMERETA	3.17	1
5	ENAT NETCH GEBS	7.83	7
6	KEYE GEBS	3.44	3
7	MOUGA	4.44	6
8	SENEF-KOLLO	4.00	5

* each figure represents the average of 180 (9 X 10 X 2) seeds sown.

From table 13 above it can be seen that Semereta is a fast germinating cultivar. Later observations also revealed that it is quick maturing as it was the first of the cultivars to head and ripen.

Enat Netch Gebs was the slowest to germinate. It also proved to be the fastest in mean relative growth rate and was not tha last of the group to mature. On the other hand Mouga happened to be the slowest in mean growth rate and in maturity. Lexander (1963) working with spring wheat varieties found that early ripening varieties are also rapidly germinating; late varieties having prolonged dormant stages because they contain more inhibitor complex substances than early ones.

Differential germination period for different cultivars of barley has been reported by Nuttonson (1957). As can be seen from the table (13) all except one cultivar germinated before five days,which is very fast. This could have been due to the temperature of the greenhouse resulting in optimum soil conditions for germination or possibly that these cultivars being adapted to tropical conditions are extremely quick germinating. The two high altitude cultivars, Enat Netch Gebs and Mouga, that showed delayed germination may have developed this property as a result of adaptive variation which ultimately resulted in slow physiological activities suitable for cooler areas. This suggests that physiological activities related to germination are genetically controlled rather than being immediate responses to environmental changes. In studies of this sort one must make sure that the grains to be sown are collected during one growingseason, from completely ripened plants and also kept under identical storage conditions after collection. It must be stressed that the above conclusions were based on peasant harvested seeds that had been stored under the differing conditions that the peasants use.

6.3 DISCUSSION OF THE PERFORMANCES OF CULTIVARS IN THE GREENHOUSE

Casual observations as well as recorded growth parameters including plant height, leaf number, culm diameter and dryweight showed that there are variations among treatment responses. The following discussion is based on Tables 2-12. Analysis of variance (Sokal and Rohlf, 1969) was made on six growth parameters; this is shown in Table 7. From this table the following major conclusions can be drawn.

a. There are significant variations in the performance of barley in the different soils, all the six barley characters showing variations based on the differences among the soils significant at 5% or smaller probability levels.

b. The performance of barley also shows significant variations depending on the cultivars, all the six barley characters showing variations based on cultivar differences significant at 5% or smaller probability levels.

c. There are some significant interactions between the soil types and cultivars manifested in some of the barley characters.

Before going into a discussion of the differences observed among cultivars, it seems logical to discuss what a cultivar is in order to establish that it is indeed cultivars that are being handled in this study. A complete discussion of what a cultivar is and the techniques used in cultivar identification is, however, beyond the scope of this project. As applied in agriculture the term cultivar (variety) is a subdivision of species, but it is not equivalent to the "variety" of the taxonomist. It is simply taken to mean an agronomic unit possessing certain characteristics which separate it from other agronomic units of the same species (Carlson and Horne, 1962). Clapham and Almgard (1978) have briefly discussed the international convention of 1961 under which a cultivar is registered. According to these authors a cultivar has to be distinguishable from other cultivars known at the day of application for registration by at least one important characteristic and has to be sufficiently homogeneous and stable with regard to its essential characteristics. It has been reported that most cultivars are distinguishable by morphological characteristics. If it becomes difficult to identify them in this manner, they can be identified by biochemical techniques (Almgard and Norman, 1970 ; Almgard and Landegren, 1974; Almgard and Clapham, 1975 and 1977; Clapham and Almgard, 1978).

In the Ethiopian farmers' fields there usually occur a population of various "kinds". Which of the "kinds" are genuine cultivars remains debatable. In the literature this mixed population is referred to as a composite population (Hailu and Pinto, 1977). In a field where such various "kinds" are found mixed, there usually occurs a dominant "kind" whose local name usually represents the whole composite population. This dominant "kind" is so distinctive as to fully qualify as a cultivar according to the international convention discussed above. In this study, the following cultivars were used in the greenhouse experiments.

B A L E M E

This cultivar exceeded only two other cultivars in total dry matter production. In this discussion by total dry matter is meant the sum of above ground dry matter produced by one cultivar on the different soils where it grew in the greenhouse. The highest production for Baleme, which was excelled only by Semereta, was on North of Holetta soil. It was more than fourtimes greater than the lowest production for the cultivar, which was on Berfeta 1 soil. It produced the highest of all the cultivars on Bedi soil, from where it had been collected, and the lowest of all of them on Berfeta 1 and 2 soils. Its culms grew thickest on Suba Road soil and thinnest on Berfeta 1 soil. The highest leaf number was on Suba Road soil where as the lowest was on Berfeta 1 soil. The mean relative growth rate was highest on Wachacha 2 soil and lowest on Berfeta 1 soil. On the whole it showed fairly high coefficients of variability for all characters considered. It headed without seeding on soils of North of Holetta, Bedi, Foeta, Wachacha 1 and Wachacha 2. The best growth, as indicated by the combination of the parameters quantified, was observed on Foeta, North of Holetta, Suba Road and Wachacha 2 soils where as stunted growth was observed on Berfeta 1 and Berfeta 2 soils.

K E S E L E

This cultivar was fifth in total dry matter production with the highest being on Suba Road soil and the lowest on Berfeta 1 soil. Its production on Suba Road and Wachacha 1 soils was the highest of all the cultivars. Its production on Welmera Choke soil, from where the cultivar was collected, was excelled by Netch Gebs and Keye Gebs. The thickest culms for this cultivar were observed on Foeta soil whereas it was the opposite on Wachacha 1 soil. Leaf number was highest on Suba Road soil and lowest on Berfeta 1 soil. The highest mean relative growth rate was observed on North of Holetta soil while the lowest was observed on Berfeta 1 soil. It had low coefficients of variability. It produced seedless heads on Suba Road, Welmera Choke, North of Holetta and Berfeta 2 soils. Observations showed luxuriant growth on Foeta, North of Holetta, Suba Road and Wachacha 2 soils, but stunted growth on soils of Berfeta 1 and Bedi. However, it was the cultivar that performed next best to Baleme on Bedi soil.

NETCH GEBS

This was the cultivar that produced the third highest total dry matter. The highest production for the cultivar, which was excelled only by Kesele, was on Suba Road soil and its lowest was on Bedi soil. It produced the highest of all the cultivars on Berfeta 1 soil. Its production on North of Holetta soil, from where it had been collected, was excelled by all cultivars except Enat Netch Gebs and Mouga. It showed high values of culm diameter on many soils, the highest being on Foeta soil and the lowest on Bedi soils. Leaf number was highest on Foeta and Suba Road soils and lowest on Bedi soil. Its mean relative growth rate was highest on Suba Road soil and lowest on Wachacha 1 soil. Its coefficient of variability for dry matter production was the lowest of all cultivars. It headed on all soils except Bedi and Wachacha 1, with a few seeds on Suba Road and Berfeta 2 soils. Overall this cultivar grew well on soils of Foeta, Berfeta 2, North of Holetta and Welmera Choke. The poorest growth was on Bedi soil.

S E M E R E T A

Besides being the overall highest producer of total dry matter, it produced the highest of all the cultivars on Foeta, North of Holetta and Wachacha 2 soils. It produced its highest on Foeta soil and its lowest; which was less than one-third of its highest, on Bedi soil. On the whole, it had the thinnest culms, which were thickest on Foeta soil and thinnest on Bedi soil. On Suba Road soil, from which the cultivar had been collected, its production was the fourth highest. The highest value for mean relative growth rate was, however, on this soil and on Berfeta 2 soil, whereas its lowest was on Wachacha 1 soil. It had fairly high coefficients of variability. The variation in leaf number was very small for this cultivar. Even the very poorly developed plants had needle-like leaves whose total number did not vary much from those of well developed plants. This cultivar matured the fastest of all the cultivars, and it set seeds on all soils. The heads and seeds were extremely poor on Bedi and Berfeta 1 soils. The growth of this cultivar on Foeta, Suba Road, North of Holetta, Berfeta 2, Wachacha 2 and Welmera Choke soils was good. Stunted growth with thin and weak lodging shoots was observed on Bedi soil and to a less extent on Berfeta 1 soil.

E N A T N E T C H G E B S

In total dry matter production this cultivar was exceeded by all other cultivars except Mouga. Its highest dry weight, which was higher only than that of Mouga, was on North of Holetta soil while its lowest, which was the lowest of all the cultivars for the soil was on Bedi soil. On Wachacha 2 soil, from where it had been collected, its production was the fifth highest of the cultivars. The plants showed the highest value for culm diameter on Suba Road and lowest on Berfeta 1 soil. Leaf number was highly variable, the highest being on Foeta soil and the lowest on Bedi soil. This was the cultivar that had the highest mean relative growth rate, which was highest on North of Holetta soil and lowest on Bedi soil. The variability as indicated by all characters considered was high, being the highest of all for plant height at 40 days after sowing and for leaf number at 70 days after sowing. It headed on Foeta, North of Holetta, Suba Road, Wachacha 1 and 2 soils but no seeds were produced. All plants remained at a juvenile stage on Bedi and Berfeta 1 soils. This cultivar showed fairly good growth on soils of Foeta, North of Holetta, Berfeta 2 and Suba Road and stunted growth on Bedi and Berfeta 1 soil.

K E Y E G E B S

Keye Gebs stood second in total dry matter production with its highest, which was also the highest of all the cultivars; on Berfeta 2 soil, from where it had been collected, and its lowest, which was the third highest of all cultivars on Bedi soil. Plants with the thickest culms were observed on Suba Road where as those with the thinnest ones occurred on Wachacha 1 soil. It had the most leaves on Welmera Choke and the fewest on Bedi and Berfeta 1 soils. The highest value for mean relative growth rate was on Berfeta 2 soil and the lowest on Bedi soil. It showed low variability on the whole. Overall growth of this cultivar was good on Berfeta 2, Foeta, North of Holetta and Welmera Choke soils.

M O U G A

This cultivar had the lowest dry matter production. Its highest which was excelled only by Semereta and Senef-Kollo, was on Foeta soil, from where it had been collected, and its lowest, which was higher than that of Enat Netch Gebs only, was on Bedi soil. Its lowest production compared with the other cultivars was on North of Holetta soil. It developed thick culmed plants on soils of Foeta, Suba Road and Berfeta 2 but it failed to develop even nodes on Bedi soil. It produced its highest number of leaves on North of Holetta soil and its lowest number of leaves on Bedi soil. Its mean relative growth rate was highest on North of Holetta and Berfeta 2 soils and lowest on Bedi soil. It had the highest coefficient of variability on dry matter production, and high values for the other quantified characters. Its growth on soils of Foeta, Suba Road, North of Holetta and Wachacha 2 was good whereas it was stunted on Bedi and Berfeta 1 soils.

S E N E F - K O L L O

It produced the fourth largest total dry matter with its highest, excelled only by Semereta, on Foeta soil and its lowest, the fifth highest for the soil, on Berfeta 1 soil, from where it had been collected. The largest value for culm diameter was on Foeta soil and its smallest on Berfeta 1 soil. Leaf number was highest on Berfeta 2 soil and lowest on Wachacha 1 soil. The mean relative growth rate was highest on Suba Road and lowest on Bedi soil. Its coefficient of variability was the second highest for dry matter production. It headed with the formation of a few poor seeds on soils of Berfeta 2, Foeta, North of Holetta, Wachacha 2 and Welemera Choke. These were also the soils on which it had grown best. The poorest growths were on Berfeta 1 and Bedi soils.

There are clear differences between these cultivars although all of these observed differences are not significant. Cultivars that showed significant variations in dry matter production are indicated in Tables 8 and 9.

It was observed that a given cultivar performed better on certain soils than others. On a soil that one cultivar performed well, some other cultivar performed badly. In general, some soils were good for most cultivars and others were bad. It appeared that each of these cultivars has different soils that suit it and there are also some soils on which some cultivars would be unsuitable. Before one can conclude about the reasons behind the differences in the performances of these cultivars a discussion on the different soils on which the cultivars were grown in the greenhouse becomes necessary.

6.4 DISCUSSION OF THE RESULTS OF SOIL ANALYSES

As indicated under materials and methods (section 4), the soils on which the cultivars were grown by the peasants were analyzed both as to their mechanical composition and chemical contents. The results are shown in Table 6. From this table it can be seen that the soils are dark brown to dark reddish brown when they are moist. Most of the lower altitude soils contain higher clay percentage with the exception of Suba Road soil, which showed the lowest clay content of all the soils. The pH values ranged from 4.53 to 6.05 which puts all of them in the acidic range. Exchangeable potassium did not show much variation and in all cases it was well above the critical level (0.45 meq / 100g of soil) and above exchangeable sodium. Exchangeable calcium, magnesium and phosphorus showed wide variations. The highest value of exchangeable phosphorus (for Suba Road soil) was over 60 times greater than the lowest value (for Wachacha 1 soil). These results agree with those of Murphy (1968) for soils of the general area.

Considering the low pH which must indicate low cation content, the long history of cultivation that this area must have experienced, the rugged topography and heavy rainfall it receives which make for easy nutrients translocation both through leaching and soil erosion, the nutrients analyzed in this study can not be high enough to be toxic. The abundance of the oxides of iron (Gezahegne, 1979) and the low pH values obtained provide good indications of the age and the conditions under which these soils have developed. In soil genesis the formation of the oxides and hydroxides of iron and aluminium is known to occur under tropical conditions when the soil is exposed to the sum and leaching is intensified by heavy rains (Tisdale, 1966; Buchman and Brady, 1969; Etheringthon, 1975). The variations among the soils with regards to their nutrients is, therefore, best viewed as indicating various degrees of nutrient depletion. The following discussion of the various soils is based on the results shown in Table 6.

BEDI SOIL

This soil was collected from an area in which the parent rock is trachybasalt. Its textural class (loam) qualifies it as a good soil. Its total nitrogen content was the highest of all the soils. In exchangeable potassium and electrical conductivity it was low, exceeding only two other soils. It was the fifth of the group in available phosphorus. Its calcium carbonate content was excelled by two other soils. Exchangeable sodium, calcium, magnesium, the ratio of magnesium to calcium and pH were low; the last four being the lowest for all the soils.

The Bedi Plateau, by virtue of being a sub-station of the Institute of Agricultural Research (I.A.R.), has been studied for the past few years and the results confirm that the problems of acidity and low exchangeable cations and phosphorus are acute. The soils, which have developed on the oldest rock in the area (Gezahegne, 1979) are also the oldest of the soils (Science and Technology Commission,

1979) and have, therefore, a porous Kaolinitic clay mineral in the subsoil with the worst consequences of vertical leaching which has produced strongly acidic conditions (Asnakew, personal communication). Asnakew further pointed out that the files of the I.A.R. (Holetta) show that analysis of the soils of Bedi area made outside of Ethiopia confirmed that the level of available phosphorus is low due to a high fixation to the insoluble iron and aluminium phosphates even though total phosphorus was not low. It is known that (Buckman and Brady, 1969) in most strongly acidic soils the concentration of iron and aluminium ions greatly exceeds that of the soluble form of phosphate ion (H_2PO_4) resulting in insoluble compounds. The determinations made abroad also showed that the possibility of aluminium toxicity is high in this soil. Thompson and Troeh (1978) reported that aluminium toxicity occurred in barley at pH below 5 when the crop was grown in culture solutions. The results of these soil analyses (Table 6) showed that this soil is the lowest of the group in the sum of exchangeable cations, which was about half of the next lowest (Wachacha 1 soil), although electrical conductivity was fairly high. The high conductivity might have happened due to the contribution from exchangeable heavy metals (eg. aluminium, manganese). This fact coupled with the low pH, well below 5, makes heavy metal toxicity a possibility. The possibility of low microbial activity as a result of low pH, favouring slow rates of nutrient release (Buchman and Brady, 1969) is also high. Although this soil appears to be good in its air and water relations and nitrogen content, which is a consequence of fallowing (I.A.R., 1977), the above mentioned problems limit production of crops making it a soil of low fertility (Science and Technology Commission, 1979). Therefore, the barley cultivars that grow on this soil must be at least moderately tolerant to these problems. It is for this reason that the total dry matter production of the barley cultivars in the greenhouse experiments was the second lowest of all the soils.

BERFETA 1 SOIL

The parent rock for this soil is porphyritic pyroxene basalt. The ease with which it weathers is great. This soil is second in its sand content, third in ratio of exchangeable magnesium to calcium, fourth in electrical conductivity and fifth in exchangeable potassium. Its content of total exchangeable cations and its pH were the sixth highest of the group. Although this soil originated from the same parent rock as that of Foeta, it had a lower exchangeable sodium, calcium, magnesium and total nitrogen. It showed the second highest value for calcium carbonate. The available phosphorus was also second to last, being excelled over 30 times by Suba Road soil and about 10 times by Foeta soil. Welmera Coke soil which had been derived from a similar parent rock was less acidic and had the second highest available phosphorus. The major factor causing low available phosphorus and also limited supply of exchangeable bases and as a consequence limiting growth appears to be acidity. The colour of this soil, which is reddish brown, the low exchangeable sodium, which is very low for a soil derived from pyroxene basalt (Sorrel and Sandstrom, 1973) indicating the intensity of leaching which, in fact, becomes more evident when compared with those of Foeta and Welmera Choke soils, the pH and the other properties (Table 6) are indicative of its typical oxisol nature (Etheringthon, 1975; Science and Technology Commission, 1979). A few of the possible limiting factors of plant growth on this soil are heavy metal toxicity and low nutrient availability, eespecially phosphorus due to fixation on clay particles forming insoluble compounds (eg. Calcium phosphate). Like the previous soil this is also a soil of low fertility. The barley cultivars that can grow successfully on this soil must be only those that can tolerate these problems. The low fertility status of this soil was reflected by the fact that the total dry matter produced by the barley cultivars grown on this soil in the greenhouse experiments was the lowest for all soils.

BERFETA 2 SOIL

This soil is derived from porphyritic olivine basalt. It has a number of attributes that make it suitable for plant growth. Its clay content, pH, exchangeable calcium, magnesium and the ratio of magnesium to calcium make it the best of all the soils. It is the second best in electrical conductivity, total nitrogen, exchangeable potassium, sum of exchangeable cations and the third best in available phosphorus. The low content of exchangeable sodium observed indicates that there has been considerable leaching although not as intense as that of Berfeta 1 soil. Since the results of soil analyses showed higher values for some of the desirable plant nutrients for this soil than for most of the soils, it would be expected to show better growth of barley cultivars than most soils. The results of the greenhouse experiments (Table 4) showed that the total dry weight of barley cultivars grown on this soil was the fourth highest for all the soils.

FOETA SOIL

This soil is derived from a parent rock of porphyritic pyroxene basalt. This is also a soil with a number of attributes that make it favourable for plant growth. It had the highest values for electrical conductivity, exchangeable sodium, calcium and sum of exchangeable cations. Its exchangeable magnesium was the second highest and its exchangeable phosphorus the fourth highest. The high value for exchangeable sodium indicates that leaching has not been intense. This conclusion is in line with the claim of the farmers that this area had been cleared of its forest vegetation relatively recently. Visual observation showed that it was the soil in which more carbondioxide bubbled off when hydrogen peroxide was added as a pretreatment to destroy the organic matter of the soil for mechanical analysis. This observation gives an indication that the organic matter content of this soil is high. The prevalence of low pH and high exchangeable cations indicates that there must exist organic acids contributing to the acidity and facilitating nutrient release. According to Buckman and Brady (1969), this happens due to complex formation by organic acids and humus with iron and aluminium. It showed the smallest value for exchangeable potassium; this was, however, above the critical level. Olivine basalts, from which this soil is derived, being the youngest rocks are low in their potassium content (Sorrel and Sandstrom, 1973). As shown by most of the nutrients this soil is of reasonably high fertility, rendering it suitable for plant growth. In fact, the dry matter produced by the barley cultivars grown on this soil in the greenhouse experiments was the highest for all the soils.

NORTH OF HOLETTA SOIL

The parent rock for this soil is aphanitic basalt, which is an intermediate between basic and acidic rocks (Gezahegne, 1979). This soil is of a loamy texture with higher values of clay and sand than Bedi soil, which belongs to the same textural class. It is second to Suba Road soil in calcium carbonate content and the third highest in its content of exchangeable potassium. In available phosphorus this soil is the sixth best. Other properties of this soil had very low scores (Table 6). However, its content of exchangeable calcium, magnesium and sum of exchangeable cations was about two times greater than that of Bedi soil. From the data alone it is hard to classify this soil as a poor or a fertile soil. The total dry matter production of the barley cultivars grown on this soil in the greenhouse experiments was, however, the second highest for all the soils.

SUBA ROAD SOIL

The identity of the parent rock for this soil is uncertain as a result of failure to spot exactly the site from where the soil was collected on a geological map of Welmera. In the general area of the site porphyritic pyroxene basalts and trachybasalts occur almost intermingled. Therefore, it would require the collection of some rocks to help its identification or a visit with a geologist. Whatever the parent rock is, this soil showed a number of disirable attributes for plant growth on analyses. Besides being a loam soil in texture it had the highest sand content (40%) making it suitable for barley dultivation if water is not limiting (Thakur, 1975). It ranked first in available phosphorus and calcium carbonate and was the second best in pH. It had the third highest value for exchangeable potassium and the fifth highest value for exchangeable calcium, magnesium, sum of exchangeable cations and electrical conductivity. This soil showed the smallest values for clay content (16%) and exchangeable sodium, which to some extent is indicative of intense leaching. The over all properties of this soil as revealed by the analytical results shown in Table 6 and discussed here identify it as one of the few soils with adequate quantities of the desirable plant nutrients. It is, therefore, expected to support good plant growth. The total dry matter produced by the barley cultivars grown on this soil in the greenhouse experiments was the third highest for all the soils.

WACHACHA 1 SOIL

This soil was collected from an area of trachytic parent rock covering the whole Wachacha mountain. When viewed with respect to its textural composition it appeared to be among the best of the group, its pH being the third best. Nevertheless, most of its other properties had low scores, being the lowest for total nitrogen, exchangeable phosphorus which was in fact below detection with the method used here, and calcium carbonate. Trachytes being derivatives of igneous rocks of the quartz rich acidic magmas, are rocks not easily weathered (Etheringthon, 1975; Thompson and Troeh, 1978). The low level of available phosphorus observed for this soil and for Wachacha 2 soil, also collected from a farm adjacent to Wachacha 1 and having the same parent rock, is probably due to the slow rates of decomposition of parent rock (Science and Technology Commission, 1979) which is aggravated by the rapid removal by crop plants of the available form of phosphorus. In addition tothis the high degree of vertical as well as horizontal leaching much intensified by the steep slopes would also further reduce the phosphorus by translocation. The porous nature of the soils of this area manifested by their low clay content would also increase internal drainage and hence leaching from the plough horizon. In the greenhouse experiments discussed above purplish leaves showing deficiency of phosphorus were observed on the experimental barley plants grown on Wachacha 1 soil. A fact that holds true for other soils as well and worth nothing here is that soils derived from igneous rocks are prone to be deficient in phosphorus. This low level of phosphorus was manifested by poor development of tillers, those few developed being weak in most of the experimental plants. This soil is also identified as a poor soil, It is unsuitable for crops except those that are tolerant particularly to low levels of available phosphorus. It was for this reason that the total dry weight produced by barley cultivars grown on this soil in the greenhouse experiments was so low that it was the third from the last for all the soils. The farmers claimed that Wachacha 1 soil is poor and grew cultivars, eg. Kete and Oshonkollo, which they thought were low in nutrient demands.

WACHACHA 2 SOIL

This loamy soil was also collected from a trachytic parent rock. It showed identical values for pH and calcium carbonate to that of the adjacent farm soil discussed above, i.e. Wachacha 1. Other properties, however, showed considerable differences in that this soil was the second best in exchangeable sodium and the ratio of magnesium to calcium and the third best in the sum of exchangeable cations. Even though the available phosphorus was higher than that of Wachacha 1 soil it was low, being the seventh highest. Wachacha 2 soil is claimed by the peasants to have been brought under cultivation relatively recently compared with that of Wachacha 1. It is claimed to be good for growing Enat Netch Gebs, the chief crop for "injera" and one believed by the peasants to be higher in its nutrient demands than Kete and Oshonkollo, which are of secondary use to the peasants. Many of the properties discussed above make this among the fertile soils. It is thus expected to be fairly suitable for the growth of barley. The total dry matter produced by the barley cultivars grown on this soil in the greenhouse experiments was the sixth highest for all the soils.

WELMERA CHOKE SOIL

The parent rock for this soil is basic porphyritic pyroxene basalt. Its fast weathering behaviour is indicated by the high clay content, the second highest of all the soils. Welmera Choke soil was the best in exchangeable potassium, the second best in pH and available phosphorus, the third best in electrical conductivity and the fourth best in exchangeable potassium, calcium and total exchangeable cations. The possible problems of this soil are water logging and low magnesium to calcium ratio. Being among the good soils of the group it is expected to be favourable for barley cultivars. This actually became evident in that the barley cultivars grown on this soil in the greenhouse experiments produced the fifth highest total dry matter.

6.5 GENERAL DISCUSSION

The pattern of barley cultivar distribution in Welmera is so complex that a satisfactory explanation can only be given if different studies are made and interpreted critically. It was for this reason that field observations and analyses were carried out. A general overall view of the results makes it obvious that the distribution of barley cultivars within the areacovered is to a large extent governed by edaphic factors. Other factors which presumably influence the distribution of some of these cultivars within the same area are climatic and socio-economic. The climatic factor appears to governthe restriction of some cultivars, eg. Mouga and Enat Netch Gebs, to the tops of high mountains and others, eg. Semereta,to areas low down. On the other hand there are cultivars, eg. Kesele, which is grown in the lower areas and in Wachacha, that do not have climatic barriers within Welmera.

In the following discussion, which is based on data given in Tables 2 - 6 and 8 - 10 and discussions made with barley farmers in Welmera, attempts have been made to interpret the complex phenomenon of soil type and cultivar distributions by combining all relevant information made available through observations, discussions, experiments and analyses.

Soil analytical results showed wide variations among the soils as did plant performances. The question of how exactly the plant performances and soil factors varied was analyzed using Spearman's rank correlation (Little and Hills, 1978),

$$r_s = 1 - \frac{6 \sum di^2}{(n-1)\ n\ (n+1)}$$

Where r_s = Spearman's rank correlation,

$\sum di^2$ = sum of the squared differences between rank based on dry weight of barley produced by the soils and the value of the specific factor of the soils,

n = size of the group ranked. Values for r_s are shown in Table 14.

TABLE 14. RANK CORRELATION BETWEEN DRY WEIGHTS OF BARLEY AND VARIOUS EDAPHIC FACTORS

No.	EDAPHIC FACTORS	r_s
1	Sand Content	-0.70**
2	Clay Content	-0.42
3	Silt Content	0.43
4	Average rank of ranks of sand and clay	-0.17
5	pH	0.10
6	Electrical Conductivity	0.27

TABLE 14. (Cont'd)

No.	EDAPHIC FACTORS	r_s
7	Total nitrogen	0.10
8	Calcium carbonate	0.49
9	Available phosphorus	0.45
10	Sum of Exchangeable cations	0.52
11	Exchangeable potassium	0.12
12	" calcium	0.53
13	" magnesium	0.17
14	" sodium	-0.03
15	Ratio of Magnesium to calcium	0.33
16	Average rank of ranks of available P and Ca	0.68**
17	" " " " " " P and Mg	0.53
18	" " " " " " P and pH	0.76**
19	Average rank of ranks of available P and Silt	0.51
20	" " " " " " P, Ca and Mg	0.58*
21	" " " " " " P, Ca, Mg and Silt	0.63*
22	" " " " " " P, Ca, Mg and pH	0.50
23	" " " " " " P, Ca, $\frac{Mg}{Ca}$ and pH	0.42
24	" " " " " " P, Ca and $\frac{Mg}{Ca}$ and	0.70**
25	" " " " " " P, Ca, $\frac{Mg}{Ca}$, pH and Silt	0.75**
26	" " " " " " P, Ca, Mg, pH and Silt	0.68**
27	" " " " " " P, Ca, $\frac{Mg}{Ca}$, pH and Silt	0.53
28	" " " " " Calcium Carbonate and Clay	0.61*
29	" " " " " " " and Silt	0.41
30	" " " " " available Ca and Clay	0.43

TABLE 14. (Cont'd)

No.	EDAPHIC FACTORS	r_s
31	Average rank of ranks of available Ca and Sand	0.06
32	" " " " " " Ca and Silt	0.68**
33	" " " " " " Ca and pH	0.28
34	" " " " " " pH and Silt	0.05
35	" " " " " " P, Ca, $\frac{Mg}{Ca}$, and Silt	0.60*
36	" " " " " " P, Ca, pH and Silt	0.65*
37	" " " " " " P and N	0.33

* = Significant at 10% probability level

** = Significant at 5% probability level

The values of rank correlation coefficients shown in Table 14 were low for single nutrients. The virtual lack of statistical significance of the correlations for any of the nutrients taken separately is actually to be expected since it is known that plant growth depends not on single factors but on a multitude of factors that usually interact strongly (Kelley, 1948). The highest positive correlations were for those edaphic factors that would be expected to interact among one another. Neither pH alone nor phosphorus alone had high correlation with dry weights of barley. The average rank of the ranks based on these two edaphic factors, however, correlated at 5% significance level of probability with the dry weights of barley. A number of such strong correlations can be seen in Table 14.

Both sand content and clay content when taken separately showed high correlations with the dry weights of barley. The coefficient of correlation based on the average rank of their ranks, however, was much smaller than either of their coefficients of correlation. Sand and clay, therefore appear to have antagonistic effects on dry weight production of barley though both reduce it.

The nutrients that had low correlation values with the dry weights of barley, eg. total nitrogen, exchangeable potassium, exchangeable magnesium were presumably in concentrations above what could limit growth given the other soil conditions, and this is probably as true in the field as in the greenhouse.

Those edaphic factors that showed high correlations with dry weights, individually or when taken in combination with other factors are presumably factors that were limiting the performance of barley in the greenhouse experiments. It is among the factors that have strongly correlated with the total dry weights, i.e. of the barley cultivars added together that one would expect to find specific edaphic factors which influence the performance of individual barley cultivars both in the greenhouse and in the field.

The total dry weight of barley produced on a given soil in the greenhouse experiments was divided by the total number of cultivars (8) that produced it. The resulting average values of production for the different soils were used to place the different soils according to their relative levels of fertility on the vertical axis of a graph. The dry weights produced by a specific cultivar on the different soils were placed along the horizontal axis. The position of each soil was marked on the graph based on these two axes. The cultivar whose production of dryweight 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° 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 vertical 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 for the horizontal axis will be greater than that of the vertical axis; the point then lies to the right of the horizontal line. If on the other hand it produces less than average, the vertical value will be greater shifting the point to the left of (above) 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 2-9. From these graphs it became possible to see those cultivars that performed higher or lower than average for the given level of soil fertility. It is the combined effect of different edaphic factors that are usually responsible for the performances of species or varieties (Kelley, 1948).

Some of these edaphic factors could be among those not determined in this study. Nevertheless, attempts were made to identify from among those edaphic factors analyzed the ones that look as if they would be responsible for the obseved performance of the cultivars of barley in Welmera soils.

For Figures 2-9:

F = Foeta Soil
BF2 = Berfeta 2 Soil
W1 = Wachacha 1 Soil
N.H. = North of Holetta Soil
W.C. = Welmera Choke Soil.
BD = Bedi Soil
S.R. = Suba Road Soil
W2 = Wachacha 2 Soil
BF1 = Berfeta 1 Soil

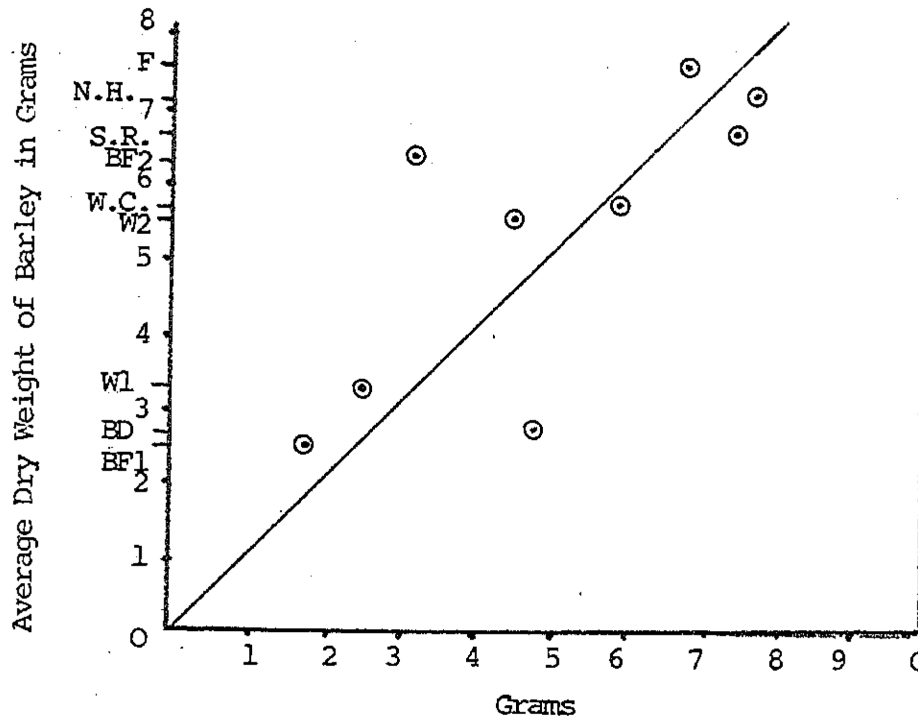

Figure 2. Graph of Average Dry Weight of Barley against Dry Weight of Baleme.

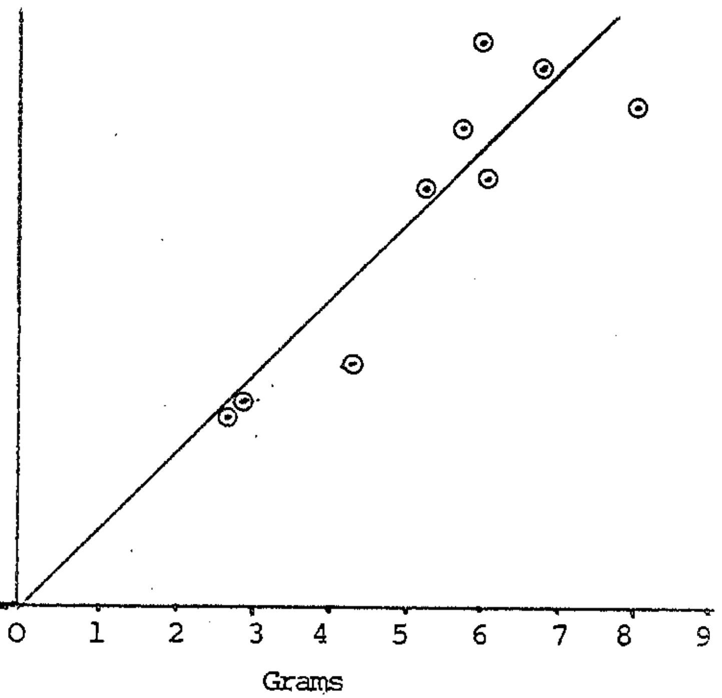

Figure 3. Graph of Average Dry Weight of Barley against Dry Weight of Kesele.

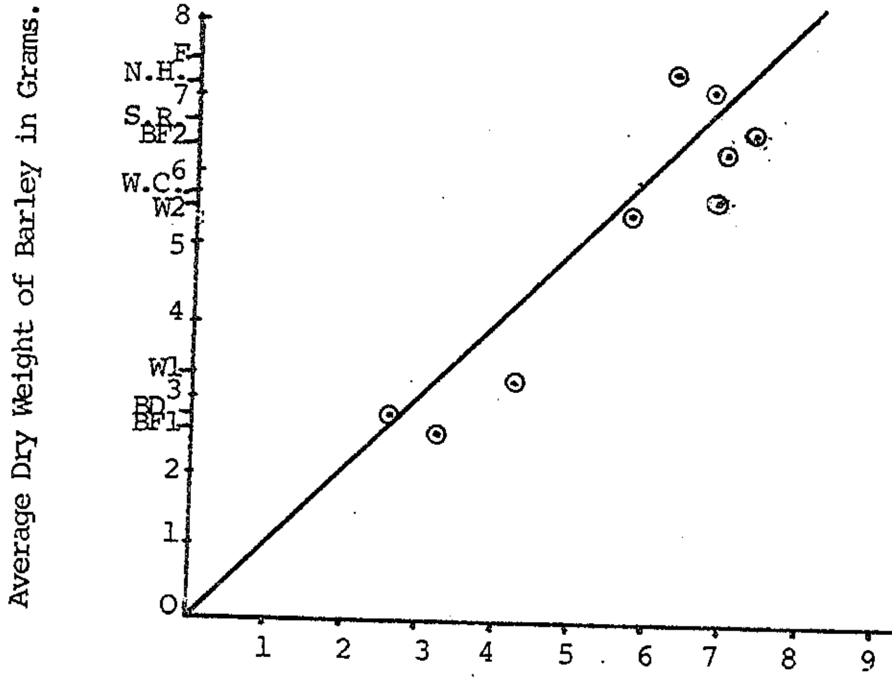

Figure 4. Graph of Average Dry Weight of Barley against Dry Weight of Netch Gebs.

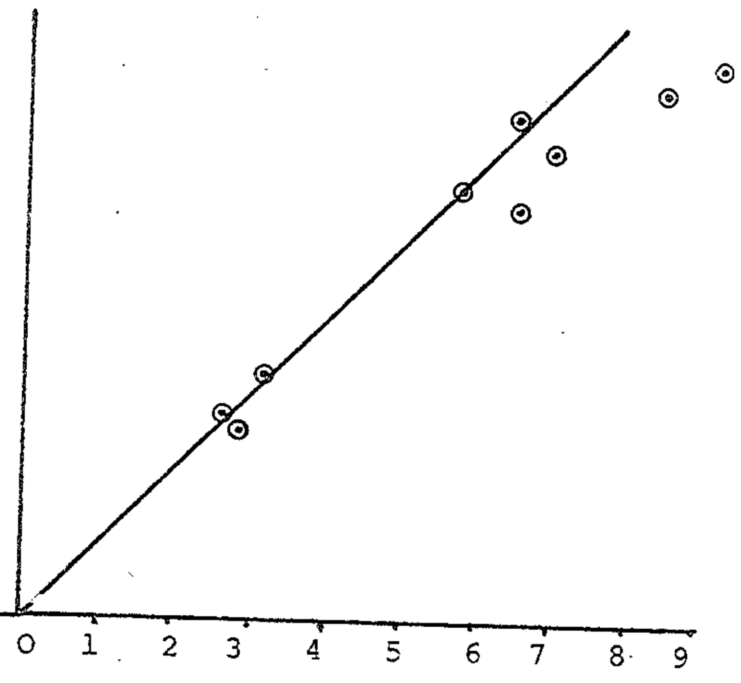

Figure 5. Graph of Average Dry Weight of Barley against Dry Weight of Semereta.

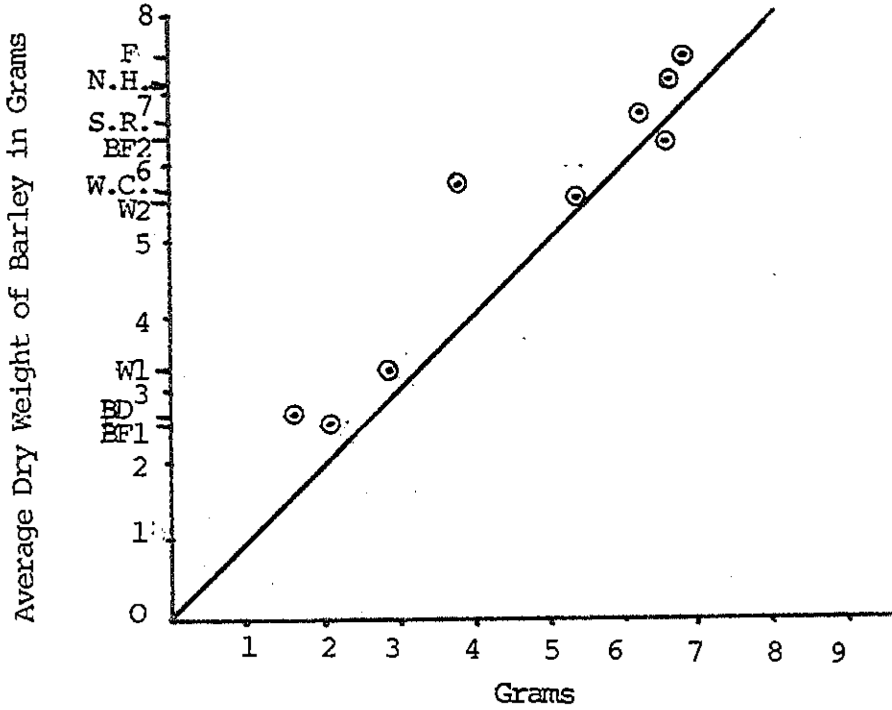

Figure 6. Graph of Average Dry Weight of Barley against Dry Weight of Enat Netch Gebs.

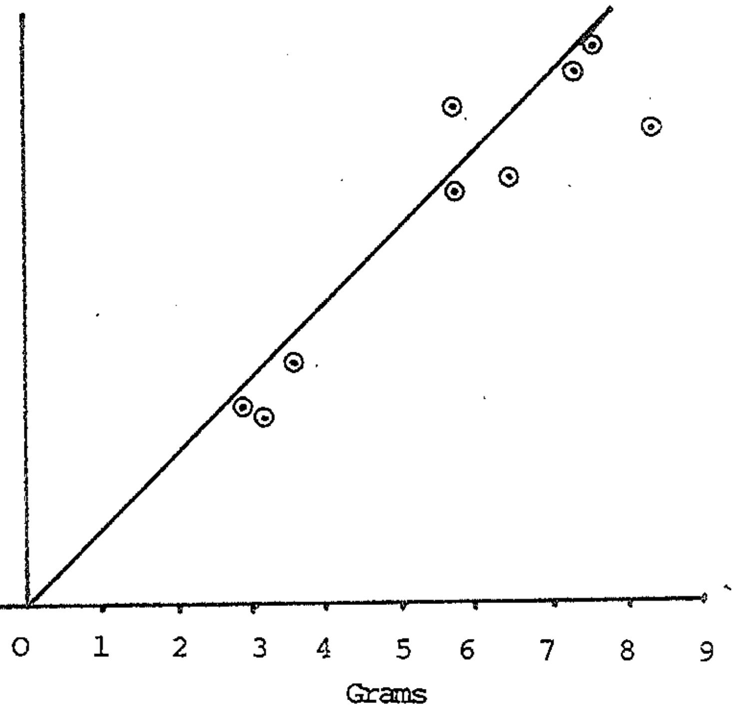

Figure 7. Graph of Average Dry Weight of Barley against Dry Weight of Keye Gebs.

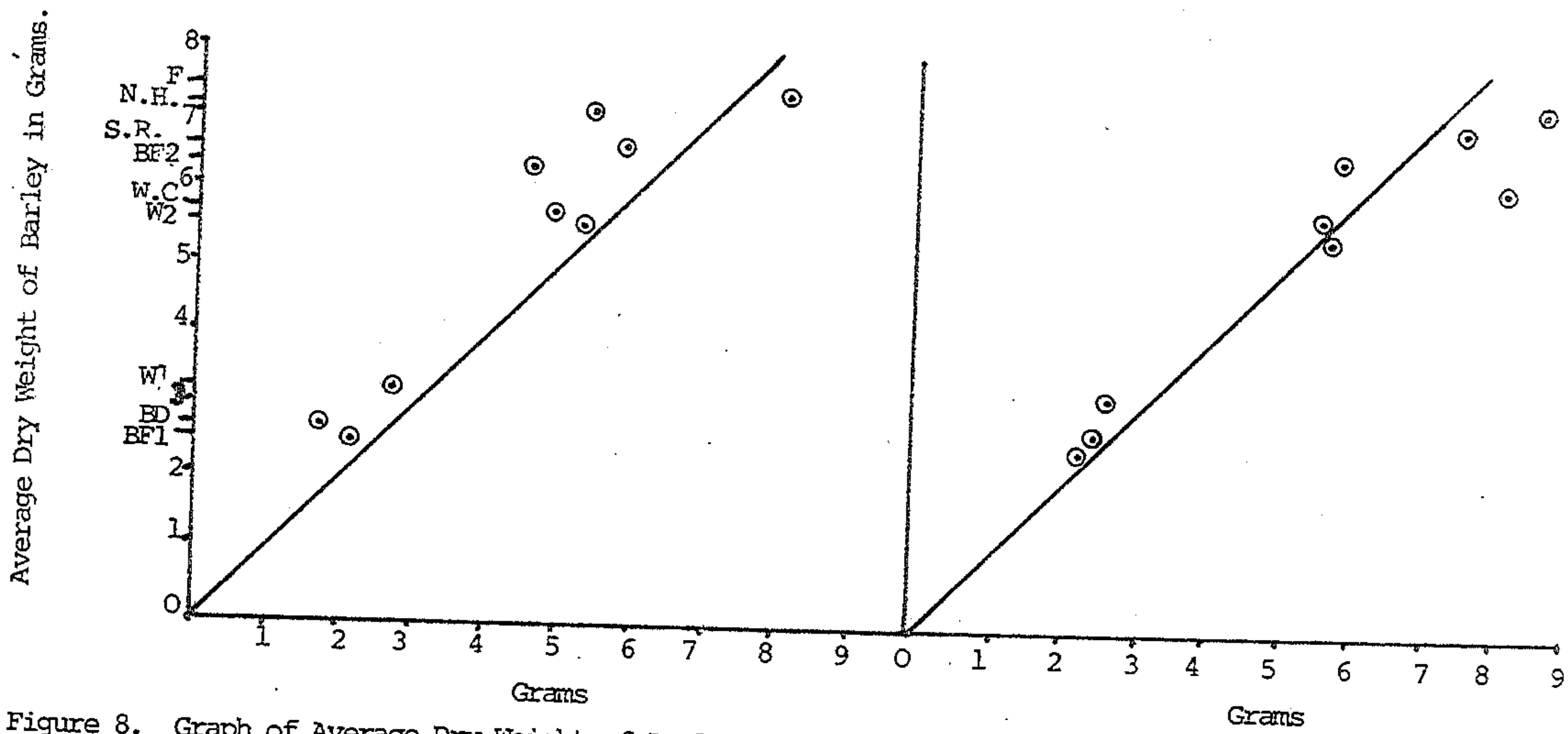

Figure 8. Graph of Average Dry Weight of Barley against Dry Weight of Mouga.

Figure 9. Graph of Average Dry Weight of Barley against Dry Weight of Senef-Kollo.

Baleme performed above average on Bedi, Suba Road, North of Holetta and Welmera Choke soils. These four soils had the highest calcium carbonate contents. Of these four soils the dry weight of Baleme was only slightly above average on Welmera Choke soil. The clay contents of Bedi, Suba Road and North of Holetta soils are low, North of Holetta which has the highest of the three having only 28% , while that of Welmera Choke is the second highest of all the soils, i.e. 42.5%. It, therefore looks that it is a soil low in clay and high in calcium carbonate that Baleme requires. Obviously the need for calcium carbonate is not for raising pH since Bedi soil has the lowest pH of the soils. Calcium carbonate was estimated using a Collin's Calcimeter. In this the carbondioxide evolved is used to estimate the carbonate. At this low pH, it is conceivable that much of the carbonate comes from salts other than calcium carbonate, perhaps from ferrous carbonate (Etheringthon, 1975).

Baleme's dry weight on Berfeta 2 soil deviated the most to the left of the average for the cultivar. This soil has low calcium carbonate, though not the lowest, but it also has the highest clay content of the soils.

Kesele performed highest above average on Suba Road and Wachacha 1 soils. These soils had the lowest clay contents and the highest sand contents. It appeared that this cultivar requires a soil with low clay and high sand contents. There seems to exist a certain balance between sand and clay content of soils that would create optimum growing conditions for this cultivar. Berfeta 1 soil had also sand content equal to that of Wachacha 1 soil but it had higher clay content than Suba Road and Wachacha 1 soils. But Kesele's performance on Berfeta 1 soil was only average. This cultivar was observed grown by the farmers on Wachacha 1, mixed with other cultivars, and on Welmera Choke, also mixed but dominating. Welmera Choke has the second highest clay content of the experimental soils. It appeared that the decision of the peasants to grow this cultivar in Welmera Choke is not in accordance with its requirements as far as clay is concerned. This cultivar performed better than all other cultivars, except Netch Gebs and Keye Gebs, on Welmera Choke soil. This shows that a cultivar is assigned to a farm not necessarily because the farm is the best for its production, but because the cultivar even if not performing at its best, is one of the best producers in that farm. The worst performance of the cultivar was on Foeta soil. The reason for this is not clear.

Netch Gebs performed above average on all soils except Bedi, North of Holetta and Foeta soils. These soils had the lowest pH values. Its best performances were on Welmera Choke and Wachacha 1 soils, which had higher pH than those on which it performed least. These soils are almost the same in their colour when dry, the only difference being in the Chroma. On the three soils with the highest pH and the highest available phosphorus, i.e. Berfeta 2, Welmera Choke and Suba Road soils the cultivar performed average or a little above average. The low performance of this cultivar on soils of Foeta, Bedi and North of Holetta suggests that it is probably sensitive to low pH. Since plants are not affected by pH *per se*, then it is probable that the cultivar is sensitive to heavy metal toxicity.

Semereta's production deviated to the right most on Foeta, North of Holetta and Wachacha 2 soils. It appeared that this cultivar, responds to the cummulative effect of various edaphic factors as it formed a high positive correlation (0.89) in performance with the overall performance of barley. It was the cultivar in which the overall fertility levels of the soils as assessed through the performance of all the cultivars together was shown by its performance. Soil clay content was plotted against Semereta dry weight deviation from the diagonal in the graph of average dry weight produced by all barley cultivars against Semereta production on the different soils. The graph of this deviation against clay content is given in Figure 10. As this graph shows the cultivar produced well above average on soils with clay contents above 26%. On soils in which the clay content was lower the dry matter production of Semereta is also lower than average. Foeta, North of Holetta and Wachacha 2 soils on which this cultivar performed best had clay contents of 34%, 28% and 34% respectively. On soils of high clay content, eg. Welmera Choke and Berfeta 2 soils there is an indication that the performance of Semereta is reduced, that for Welmera Choke in fact being only average. An increase in clay beyond the optimum, therefore, seems to be associated with a decrease in Semereta's performance. As a cultivar that requires the best growing conditions as indicated by its correlation with the total performance of all cultivars added up, it requires optimum physical conditions in the soils for best performance.

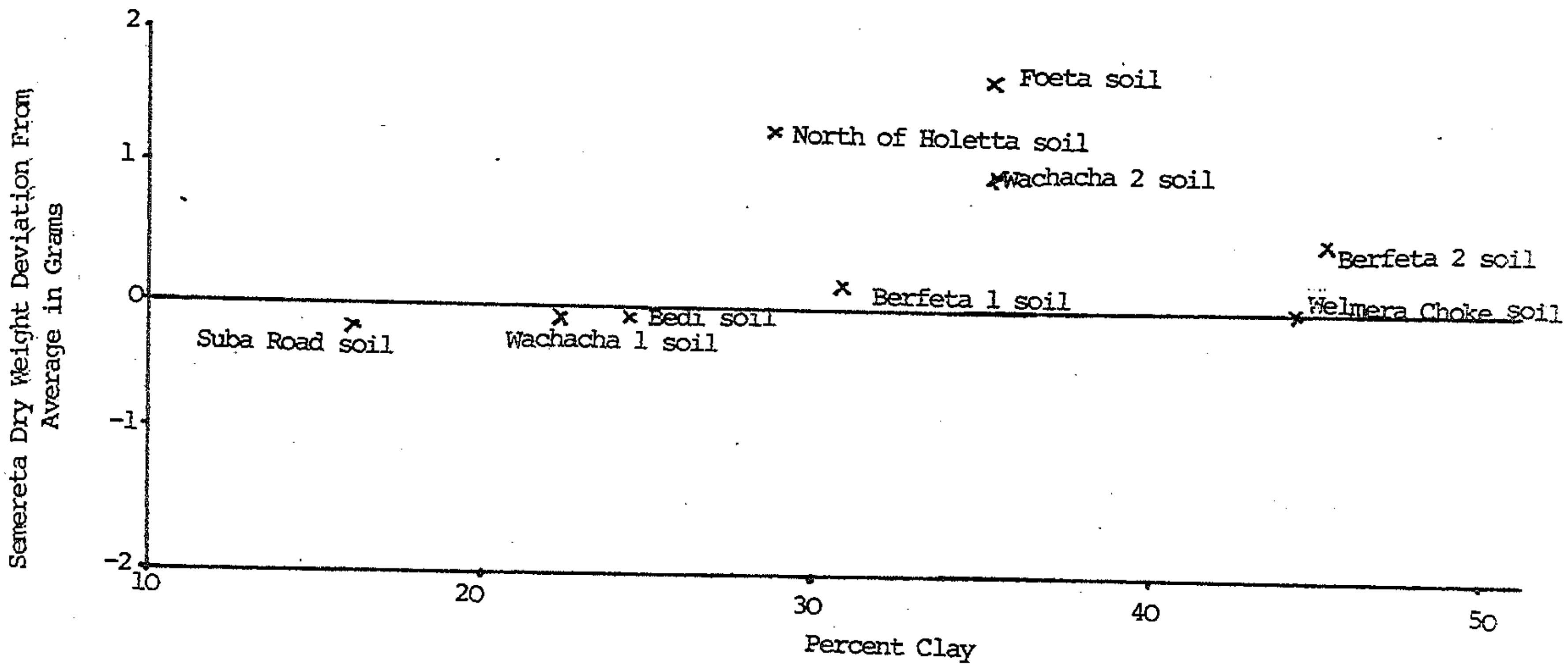

Figure 10. Graph of Semereta Dry Weight Deviation from Average Barley Dry Weight Against Soil Clay Content.

Under conditions of medium clay contents in the soil both air and water balance and nutrient availability would be optimal for growth as is true of most plants. Semereta, therefore, presumably being sensitive to both soil physical and chemical conditions behaved as an indicatoer of overall fertility of soils.

Enat Netch Gebs performed below average on all soils except Berfeta 2 soil where it performed a little above average. Its two best performances were on Berfeta 2 and Wachacha 2 soils. These two soils which are identical in colour when dry and nearly so in silt contents had the highest ratios of magnesium to calcium, 0.20 for Berfeta 2 soil and 0.19 for Wachacha 2 soil. Its least performances were on Bedi and Welmera Choke soils. These soils had the same amount of exchangeable sodium and calcium carbonate. The ratio of magnesium to calcium for these two soils were low, being the lowest of all for Bedi soil. It appeared that soils with high proportion of exchangeable magnesium to exchangeable calcium are suitable for the growth of this cultivar.

Keye Gebs performed above average on all soils with the exception of Suba Road soil. It deviated most to the right on Berfeta 2 and Welmera Choke soils both of which had the highest clay contents, the highest pH and the highest available potassium. Its performance on Berfeta 2 soil deviated more markedly to the right than the others. This soil besides having the highest pH, the highest clay content, the highest exchangeable magnesium and the highest ratio of magnesium to calcium, has the second highest total exchangeable cations and the third highest available phosphorus. Keye Gebs performed much below average on Suba Road soil which has the lowest clay content and the lowest exchangeable sodium. This cultivar was encountered under wide cultivation by the farmers in Berfeta. The farmers claimed that the cultivar does best on soils recently cleared of their natural vegetation. Both from the experimental results and the information of the peasants it looks as if this cultivar prefers soils that are rich in nutrients.

Mouga performed below average on all soils with the exception of Foeta. Though below average its next best performance was on Wachacha 2 soil. Foeta and Wachacha 2 soils had the same clay contents (34%), high values of exchangeable cations, of which, for sodium they had the highest values. The high values of exchangeable cations, and especially of sodium presumably indicate a state of not very heavy leaching. Its lowest performance was on Berfeta 2 soil which had low exchangeable sodium, though not the lowest. This cultivar was seen grown by the peasants in Foeta and Wachacha on farms that had steep slopes. It looks as if this cultivar has some preference for rich soils that are well drained. Its nutrient requirements are probably higher than that of Keye Gebs since unlike the latter, it performed above average only in the soil with the highest fertility status, i.e. Foeta soil.

Senef-Kollo showed the highest of its above average values on Berfeta 2 and Foeta soils. These soils had the highest values for exchangeable calcium, magnesium and sum of exchangeable cations.

Its lowest performances were on Suba Road, Wachacha 1 and Bedi soils. Suba Road and Wachacha 1 soils had the lowest clay contents. Wachacha 1 and Bedi soils had the lowest exchangeable cations. It appears that the performance of this cultivar is much influenced by the total exchangeable cations in general, but exchangeable calcium and magnesium in particular.

The cultivar that performed the best was identified for each of the soils. The soil on which a cultivar performed its best was also identified. This made it possible to identify the few cases 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. This was true of Semereta on Foeta soil, Keye Gebs on Berefta 2 soil and Kesele on Suba Road soil. These three soil cultivar pairs appeared completely compatible. Considering only edaphic factors it can be safely concluded that it would be more rewarding than other combinations if these three pairs of soils and cultivars were matched as indicated by the results. The reason why Semereta is not grown in Foeta appears to be two fold. The first is probably the limitation imposed by climatic factors; Foeta, which is about 3,000 metres, may be too cold for Semereta. The fact that Semereta produced heads that set seeds whereas Mouga produced a few seedless heads and many plants that did not head at all under the specific greenhouse conditions suggests that Semereta probably does well in warmer areas, and Mouga in cooler areas. The second reason may be the fact that Semereta is two-rowed and has a short head making its grain yield presumably much lower than that of Mouga even when Mouga's dry matter production is lower. As counted in samples collected from the Welmera area the average grain per head for Semereta is 20 and that for Mouga is 60. A high coefficient of variability indicates a high yielding cultivar (Steel and Torrie, 1960 and 1976). From Table 10, it can be seen that the C.V. for Mouga is high, and, though it is based only on dry matter productivity the grain yields are presumably in line with this.

Again the soil on which each cultivar performed the least was identified. The cultivar that performed least on each soil was also identified. This helped to identify the few cases where the poorest performance of a cultivar on a given soil was also the poorest for the cultivar. This was the case for Baleme on Berfeta 1 soil and Enat Netch Gebs on Bedi soil. This suggested a complete incompatibility between these respective soils and cultivars. Baleme and Enat Netch Gebs had not been encountered in areas from where these respective soils of their poorest performances were collected. The cultivation of Baleme on Berfeta 1 soil and Enat Netch Gebs on Bedi soil, even if climatio factors did not limit would be a real disaster in production. In fact the peasants cultivate only Baleme on Bedi soil because other cultivars have proved to be unsuitable.

These being the two extremes, i.e. highly compatible and completely incompatible, other soil-cultivar pairs appeared to be of intermediate grades. The practice of the peasants has to be viewed against the fact that their interests are on grain yield which might deviate from dry matter yield. This is even more likely in barley in that grain yield depends on different factors, eg. number of rows on a head, density and length of ear, other factors of agronomic interest eg. diseases associated with localities.

A fact suggesting that the mechanisms of adaptive variation have had a strong impact on the evolution of these cultivars can be evident from Tables 8 and 9 which are summarized here. Those cultivars that performed significantly higher on a certain soil were either cultivars grown by the peasants on that particular soil, i.e. Baleme on Bedi soil, Keye Gebs on Berfeta 2 soil and Kesele on Welmera Choke soil, or else they are cultivars grown nearer to the area from where the particular soil had been collected, as was the case with Netch Gebs on Welmera Choke and Berfeta 2 soils, Senef-Kollo on Berfeta 2 soil, Semereta on North of Holetta soil, Kesele on Suba Road soil and Wachacha 1 soil. Exceptions to these were, however, the significantly better performance of Semereta on Foeta and Wachacha 2 soils, Keye Gebs on Welmera Choke soil and Senef-Kollo on Foeta soil. Senef-Kollo produced quite a good number of plants with heads that set seeds in the greenhouse experiments. The climatic reason presumed for not growing Semereta in Foeta is probably also true of Senef-Kollo. The reason why Semereta is not grown in Wachacha could probably be climatic, since Wachacha is at about the same altitude (3000m) as that of Foeta, on the one hand and soci-economic on the other; i.e. Enat Netch Gebs that is widely cultivated in Wachacha probably yields more grains than Semereta as it was counted in samples collected from Welmera area that it has 72 grains per head on average. The C.V. values for dry matter given in Table 10 showed higher values for Enat Netch Gebs than those for Semereta. These facts suggest that besides the climatic reason there is also an economic reason for not cultivating Semereta in Wachacha. The reason why Keye Gebs is not grown in Welmera Choke is not clear. With the exception of Mouga on Wachacha, which was excelled significantly by Kesele and Senef-Kollo on Suba Road, which was excelled significantly by Kesele all those cultivars excelled significantly by other cultivars are those which are normally not grown by the farmers in those areas.

The peasants in Welmera through many generations of practice, which presumably had its ups and downs, have managed to fit the cultivars of their barley to the soils they thought were appropriate. This was based on pure empirical knowledge. Undoubtedly it had demanded ages of experiences both with the soils and the cultivars.

Nevertheless, in areas in which the climatic barrier does not operate, it seems that there are cultivars that can perform better than those used by the peasants, eg. Semereta on North of Holetta soil, Kesele on Suba Road soil, Keye Gebs on Welemera Choke soil, Netch Gebs on Welmera Choke and Berfeta 1 soils. This, however, requires more investigation before it is accepted. The way it is being handled by the peasants might be the best choice. The sort of investigations that would help to find out the exact state of affairs would be to conduct similar experiments as done in the greenhouse in the different sites preferably for a number of years.

The results showed that even farms which were very close to one another had wide differences in overall properties. This is evident from analytical results (Table 6) and pot experiments (Tables 2-5). To cite a few of the differences, Wachacha 1 and 2 soils taken from literally adjacent farms showed wide differences in nutrient contents, plant growth and dry weights of barley cultivars grown on them. Berfeta 1 and 2 soils were collected from farms that were situated not far from each other but showed wide differences both in nutrient availability and plant performances. These conclusions agree with the farmers attitudes towards these soils. Infact, it is their major reason for allocating cultivars and some times even different crops including broad beans, peas, barley and wheat to their farms. This becomes understandable if one recalls the findings of Alexander (1961) which confirmed that not only adjacent farms, even a single farm could be situated on several soil types. These differences in turn influence the plants that grow on them. That barley varieties could also respond differentially to different soils is implied from studies on fertilizer responses. Hailu (1973) working with other cultivars of barley showed that cultivars could respond differentially to various levels of fertilizer application. Such intraspecific variations have been reported for many species when grown on the same soils under identical conditions. These include Avena sativa (Mn and Mg), Beta vulgaris (K,P,N), Zea mays (N), Lolium perenne (N), Hordeum vulgare (Sr) and a number of others (Epstein, 1972). Most of these conclusions were reached through experiments with plants grown in soil and evidence exists in favour of the fact that there are genetically controlled nutritional differences among varieties. In acid soils, high concentrations of heavy metals (Al, Mn, Zn) are known to occur. Varietal differences in sensitivity to these metals as well as to the resulting soil deficiencies have been observed within *Gossypium hirsutum*, *Gossypium barbadense*, *Lolium species* and *Medicago species* (Epstein, 1972). Although different mechanisms can be employed by different species and varieties, they are generally believed to be differences in the rate of absorption and translocation of specific elements, efficiency of metabolic utilization and tolerance to high concentrations of an element in the medium (Epstein, 1972). The occurrence of edaphic ecotypes among cultivated species is regarded to be a good promise for agriculture in that it becomes possible to fit crops to the appropriate soils or to select among the edaphic ecotypes those which yield most for each unit of fertilizer applied (Goodman, 1969, Brown and Jones, 1977). This practice not only minimizes the use of fertilizers but also avoids their massive use.

In general, the differential responses observed among these cultivars of barley to the same soil strongly suggest that there are genetically controlled differences among the cultivars included in this study. It is highly probable that these differences are differences in their responses to levels of cationic nutrients, available phosphorus and heavy metal toxicity including aluminium, manganese and zinc. However, further investigation through sand or water culture experiments is needed for confirmation.

All the seeds used in this study were subjected to different levels of soil fertility in the previous harvests. Those that were harvested from the fertile soils, eg. Foeta, Berfeta 2 and Wachacha 2, might have accumulated nutrients that would sustain them for at least one growing season (Evans,1972). This possibility might have obscured the actual deficiencies in some of the soils. If that had happened in this study, repeated trials would show wider differences among soils and cultivars than those seen now. The fertility status of particularly poor soils might have been over estimated. The direct implication of this is that trials of this sort have to be conducted for a number of years before a full picture of the magnitude of contrasts between the poorest and the richest of the soils emerges. These contrasts, however, can only be greater and not smaller than those observed in this study.

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