NUTRIENT REQUIREMENT STUDY OF SOME BARLEY CULTIVARS FROM WELMERA.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE		Page
A11.	Average number of spikelets per ear.....	108
A12.	Grain yield in grams per pot............	109
A13.	Root dry weight in grams per pot........	110
A14.	Shoot:Root ratios of dry weights per pot................................	111
A15.	Leaf blade chemical composition in percent............................	112
A16.	Analysis of variance - Significance (F-Test)...........................	116

LIST OF FIGURES

ABSTRACT

This thesis presents a study on the nutrient requirements of four barley (Hordeum vulgare L.) cultivars cultivated in Welmera.

The cultivars were grown in two randomized complete blocks in sand culture at four levels each of P (0,0.5,3 and 5.5 mg.eq), and Ca (0,2,8 and 14 mg.eq.) factorialy combined.

Several growth parameters were determined and leaf nutrient contents analysed. The resulting data were subjected to an analysis of variance.

The results showed that there are treatment effects on the growth responses of barley, and differential response of cultivars to treatments.

Phosphorus had a significant effect on all the growth parameters. Phosphorus levels as low as 0.5 mg.eq. were able to produce significantly high effects on shoot and root dry-weights, culm diameter and blade area of all cultivars. Shoot:root dry-weight ratios of Nech Gebs and Semereta were also significantly affected by P concentration of 0.5 mg.eq. Significantly higher yields for ear dry-weight, grain weight, and ear and tiller number per plant occured at 3 mg.eq. of P.

The effects of calcium were relatively less pronounced than that of phosphorus. Root dry-weight, shoot: root dry-weight ratio, blade area, and grain weight of all cultivars were significantly affected by calcium application. These significances,

however, were obtained only at higher levels of phosphorus in solution. Ca-application had no significant effect at lower levels of phosphorus (i.e 0 and 0.5 mg.eq.) in solution.

Significant differences between leaf nutrient contents were observed only for certain cultivars. Thus, significant treatment effect on % Ca content of leaves was observed only for Keye Gebs. Percent N content of Enat Nech Gebs and Nech Gebs leaves showed significant differences, while the same effect for % Mg content of leaves was observed only for Enat Nech Gebs and Semereta. There were no significant variations in % P content of any of the cultivars.

Deficiency symptoms were observed in all cultivars at the lower P levels (i.e 0 and 0.5 mg.eq.) irrespective of Ca level in solution. Older leaves of Keye Gebs and Semereta were purplish in color while those of Enat Nech Gebs and Nech Gebs were yellowish green. These symptoms were taken to indicate P-deficiency.

Of the four cultivars studied, Semereta had the highest mean relative growth rate followed by Keye Gebs, Nech Gebs and Enat Nech Gebs respectively.

Morphological differences as a result of treatment effects were also observed among the cultivars. Semereta had significantly higher grain yield, ear and tiller number per plant, and ear dry-weight than the other cultivars. On the other hand, it had significantly lower root and blade dry-weights.

Semereta also performed better than any of the other cultivars at very low phosphorus concentrations in solution.

INTRODUCTION

The growth of plants, from seed to maturity, has gained the attention of thoughtful men for ages and is still doing so today.

Bould and Hewitt (1963) trace speculations on the factors that control plant growth to Roman times and even earlier. The fact that "there was an extensive literature on agriculture in Roman times, which maintained a pre-eminent position until comparatively recently" is also reported by Russell (1973).

The experimental study of plant nutrition was first given serious consideration by Nicholas of Cusa in the first half of the 15th century who suggested that plants absorb constituents from the soil by some process related to water uptake (Hewitt and Smith, 1974).

The classical willow tree (<u>Salix</u> Sp.) experiment by Van Helmont 1577-1644 (Bould and Hewitt, 1963) was another quest done to unravel the mystries of plant growth. The search for plant nutrients extends from such simple experiments of early days to present day investigations which comprise a wide array of disciplines.

A brief historical account of plant nutrition is given by Bould and Hewitt (1963), Epstein (1972), Russell (1973) Hewitt and Smith (1974).

Many centuries of observations and investigations lapsed before we gained a general understanding of the mineral nutrition of plants. However, it is very difficult, even today, to state without any doubt, what the quantitative and qualitative mineral requirements of plants are.

It is possible to examine in detail the nutrient requirements of a given species under various conditions, but because of the immense amount of labour involved it will never be feasible to establish that a particular element is universally essential to all plants under all possible conditions (Sutcliffe and Baker, 1978). This statement, according to these workers, is substantiated by the fact that the mineral requirements of only less then 100 species have been studied in detail out of an estimated 200,000 species of flowering plants alone.

The term nutrient requirement has been used in the literature in varying and often very diffuse senses (Ingestad, 1971). In any discussion of the mineral requirements of plants, it has almost become customary to start with the listing of certain mineral elements which are considered essential to all plants. At the present there are eighteen elements considered essential to plants (Jackson, 1976). These are C,H,O,P,K,N,S,Ca,Fe,Mg, Mn,Cu,B,Zn,Co,Mo,Cl, and Na. The essentiality of a nutrient for plants is judged by the following three criteri (Hewitt, 1963): 1) the plant cannot complete its life cycle without the particular element, 2) its effect must be specific and not fulfilled completely by any other element, and 3) its effect on the plant must be direct.

Some aspects of mineral nutrition, including accounts on the recognition of essential elements, are given wide coverage by Hoagland (1932, 1933), Steward (1935), Richards (1944) and Chapman (1945).

Although a uniformity in the mineral requirements of plants is frequently implied in discussions of plant nutrition, that there is no such uniformity is discussed by Gerloff (1963).

It is true that plants have a basic requirement for mineral elements. But different species take up different amounts and different proportions of nutrients, the exact amount taken up depending on the soil conditions (Russell, 1973). Awareness of the fact that no two plants are exactly alike in their response to different environmental factors makes the study of comparative nutrient requirements essential. The need for comparing species or ecotypes is emphasized by Chapman (1976) as they may respond differently to the same soil as a result of dissimilar uptake or by having different requirements for mineral nutrients. Furthermore, much more information is needed on the capacity of different plant species and even cultivars within species to dissolve nutrients (Viets, 1980).

Undertaking such work, however, is not an easy task as the processes that govern the growth and development of a plant are diverse and complicated. Therefore, no particular level of one factor should be referred to as the optimum for growth of a species without specifying at least the approximate levels or conditions of the other important components of the environment (Parker, 1946), and no longer can one be satisfied with an overall "best" requirement for plant nutrition (Steward, 1971).

Yields of crop plants are a function not solely of soil fertility but also of a host of other factors: variety, climate, irrigation, cultural practices, length of harvesting season, and damage by insects and disease (Arnon and Hoagland, 1940). Younts (1972) is also of the opinion that it is essentially impossible to predict absolute optimum nutrition levels when consideration must be given to climate, soil, variety, planting date, etc.

As a result, the problem of accounting for variation of yield in terms of growth and development of the crop plant is obviously very complex, for, ultimately it involves the effect of external factors on all the physiological processes and their dependence on internal factors determined by the genetical constitution of the plant (Watson, 1952). Thus, Steward (1963) goes further to suggest that now research be pursued in inorganic nutrition from such genetically determined mineral requirements and genetically determined nutritional levels.

In view of the role individual mineral elements play in the plant, it had become customary at least for sometime, to visualize their importance in terms of their individual and separate actions only. However, it has become increasingly evident that work with a single element is inconclusive (Brown, 1963). Therefore, it would be wise to consider the interaction of mineral elements with each other and with climatic as well as other environmental conditions while undertaking studies on mineral nutrition. This is infact " a still emerging but potentially very important concept" (Steward, 1963). At the moment a large number of publications on interaction describe many applications and experiences in well defined conditions and with regard to particular crops. In this way plant physiology can move, in the area of mineral nutrition, from the unitary, simplistic approaches that were at first appropriate to the recognition of the more wholistic biological concepts that are now necessary (Steward, 1971).

The nutrient status of individual plants and comparisons among those of different species is usually achieved through an examination of their responses and performances over a range of nutrient regimes. Interpretation of results from soil-plant studies often leads to contradictory conclusion, and today, many of the interrelationships involving nutrients in the soil and in the plant remain subjects of controversy (Drake, 1976). No method has been accepted, says Macy (1936) for measuring the quantitative mineral nutrient requirements of plants. However, methods used for evaluating these performances are constantly being developed and improved.

The soil-soil water-root system is complex, and for simplicity water cultures and sand cultures are often used to study plant nutrient requirements (Briggs, 1978). Plant physiologists through studies with water culture techniques, have firmly established certain important facts regarding the mineral nutrition of plants that have a direct bearing on concepts of the soil as a medium for plant growth (Stout and Overstreet, 1950). Artificial media, as alternatives to the soil for crop production as early as the first half of this century had aroused great popular and scientific interest. Arnon and Hoagland (1940) discuss some general questions pertaining to limiting factors for plant growth under natural conditions and show the need for scrutinizing them in detail when different artificial media are compared.

All other factors being constant, plant growth is a function of the two variables of nutrition, intensity and balance, as they are reflected in the composition of leaves when the plants are in the same stages of growth or development (Shear et.al., 1946). According to these workers, any critical change in the accumulation of one or more elements not accompanied by appropriate changes in all of the other nutrient elements will result in an unbalanced nutrition which will be reflected first in decreased growth and later, if the imbalance is intensified, in additional reductions in growth or yield or in the appearance of leaf symptoms or in all three ways. Utilizing the total soluble salts and the proportionate cations and anions contained in the soil saturation extract, Geraldson (1971) also gives an evaluation of the intensity and balance concept.

Hoagland (1920), however, describes an experiment in which solutions of radically different concentrations and salt proportions have not affected the yield of the crop to any important extent. Although Hoagland's intention is not to show that solutions may not inhibit plant growth because of unfavourable balance, he is of the opinion that the range of equally favourable ratios between nutrient salts is a very broad one.

Having recognized the effect on growth of the varying relative proportions of ions in solutions many investigators have resorted to developing appropriate techniques for helping maintain constant concentrations and ratios of salts in nutrient solutions. Different techniques which deal with the preparation of nutrient solutions have been described by Steiner (1961), Asher et.al. (1965), Asher and Ozanne (1967), and Reisenauer (1969).

The composition of nutrient solutions used in nutrition studies is varied. It would seem that many investigators have grown crops in a solution chosen largely at random, and that, where the results have been successful, they have recommended that solution as being specific for the particular crop concerned (Steiner, 1961). Such recommendations of nutrient solutions, however, do not prove that there is not a more suitable solution for the crop at hand.

A survey of the methods and problems of growing plants in artificial nutrient media for the study of nutrient requirements and interrelationships is described in an extensive monograph by Hewitt (1966). Some of the more important details requirring attention when plants are grown in culture media and the simplest methods for studying nutrient requirements are also outlined by Hewitt and Smith (1974).

The action of the essential elements in the growth processes of higher plants has sometimes been revealed by a study of the visible or anatomical effects that result from mineral deficiencies or by the effects of controlled levels of these elements on the chemical composition of the plants affected (Hewitt, 1963).

The methods used by different laboratories for such studies are based on a few well-established principles, but show an apparently wide range of modifications and innovations which may be confusing (Hewitt and Smith, 1974).

If the concentration of an essential nutrient element in plant tissue drops below a level necessary for optimal growth, the plant is said to be deficient in that element (Epstein, 1972). Deficiencies arising from low mineral concentrations in the growth media will manifest themselves through the development of more or less distinct symptoms. Although these visible deficiency symptoms are helpful in identifying nutrient deficiencies, they can easily be confused with various toxicities and even with the effects of atmospheric pollutants (Treshow, 1970).

Sometimes excessive concentrations of some other elements may so reduce the rate of absorption of a nutrient that the plant becomes deficient in that nutrient (Epstein, 1972; Chapman, 1976). On the other hand, certain metals have been shown to replace others for specific functions in the growth of plants, and thereby mask the deficiency. Strontium for instance, is able to partly relieve the symptoms of calcium deficiency in corn, but it does not contribute to the formation of pectate as does Calcium (Bidwell, 1974).

Hewitt (1944) reports the visual symptoms of mineral deficiencies in crop plants grown in sand cultures and later on elsewhere (1963) describes the morphological, anatomical, chemical and physiological effects of mineral disorders and interactions of the macro-and micro-nutrient elements. A compilation of the deficiency symptoms in barley caused by some mineral deficiencies or excesses is given by Briggs (1978), while Treshow (1970) Epstein (1972) and Bidwell (1974) outline deficiency symptoms of nutrient elements in general.

The adaptation of plants to the mineral status of their habitat means that nutrient deficiencies are not always apparent (Bradshaw, 1976 as quoted by Chapman, 1976). Although visible symptoms should be regarded as just one of several kinds of evidence of deficiency of a given element, several factors combine to introduce considerable uncertainity in diagnosis based on symptomatology (Epstein, 1972). Therefore, mineral deficiencies can probably not be reliably diagnosed from plant appearances alone (Briggs, 1978).

Plant analysis as a means of ascertaining the nutrient content of crops has been used for a very long time. The principles and practices of the mineral analysis of plant tissues is reviewed by Ulrich (1943, 1952), Thomas (1945), Smith (1962), Ulrich and Hills (1967), Cottenie (1980), and Evenhuis and de Waard (1980).

Chemical analysis for available soil nutrients is based on the assumption that plant roots will extract nutrients from the soil in a manner comparable to chemical soil extractants and that there is a relationship between the extractable ions in the soil and their uptake by plants (Bould and Hewitt, 1963).

Plant analyses, according to Tisdale and Nelson (1966), are based on the premise that the amount of a given element in a plant is an indication of the supply of that particular nutrient and as such is directly related to the quantity in the soil. Furthermore, plant analysis is based on the concept that the concentration of a nutrient within the plant at any particular time is an integrated value of all the factors that have influenced the nutrient concentration upto the time the plant sample is taken (Ulrich and Hills, 1967). There is no doubt that the usefulness of plant analysis in this respect is widely recognized. However, plant analysis is not a substitute for a soil test but is most effectively used in conjunction with it (Jones et.al., 1971). These workers add that plant analysis may be used to verify a suspected nutrient element deficiency or to monitor the plant in order to evaluate its nutrient element status. In simplest terms, plant analysis may be viewed as a study of the relationship of the nutrient content of the plant to its growth (Ulrich and Hills, 1967).

However, interpretations of results from plant analysis are not direct and simple. There are various factors working both within and outside the plant that influence these results. Plant composition is in part genetically determined and is influenced by climatic factors (Arnon and Hoagland, 1940). The concentration of minerals vary in different parts of the same healthy plant with age, with the supplies of other elements, between varieties, and with changing growth conditions (Briggs, 1978). Age of plants, nature of taxa, physiological age of leaves, morphological position on plants internutrient effects as well as seasonal variation, season and time of day of sampling, handling of samples, weather conditions and climate have been enumerated by Evenhuis and de Waard

(1980) as having some effects on the actual leaf concentrations. Interactions among ions and their effect on tissue analysis interpretations have been widely discussed by Smith (1962).

A broad knowledge of all the factors involved in the growth of plants is, therefore, essential while interpreting results of plant analysis.

The part of the plant to be used for chemical analysis depends on the type of plant under study, and the objectives of the study in view. As Cottenie (1980) puts it, in mineral analysis, the goal is to find a part of the plant that most clearly reflects by a wide range of content the nutritional status of the plant.

As a research tool, leaf analysis has become more widely used in recent years than ever before (Lundegardh, 1943; Smith, 1962).

Thomas (1945) recognizes two approaches to plant analysis: the old and the modern, and critisizes the former and advocates for the later. The distinction that he draws between the old and modern methods is that the earlier methods were concerned with the quantities of mineral nutrients stored in the mature plant, whereas leaf analysis (the modern approach) is based on the functioning assimilating leaves as the control laboratories of nutrition.

From an *a priori* considerations, it would appear that the entire leaf should be used when the purpose is to determine the relationship of the mineral nutrition to yields (Thomas, 1945). However, different workers have used different parts of the leaf tissue for this purpose. For instance, it was found that phosphorus nutrition of trees is reflected better by the P content of the leaf petioles than by the P content of other parts of the plant (Sato, 1971).

Today, plant analysis as a means to plant nutrient diagnosis has gained popularity among many workers. In fact, leaf analysis offers the only means of applying directly to field work the results of sand-and solution - culture experiments, since the interpretation of nutritional status on the basis of leaf composition is not concerned with the means by which that composition was obtained, but only with the effect on growth of changes in leaf composition (Bould and Hewitt, 1963).

However, to make interpretations from plant analysis more sound and logical, "careful research is needed for each crop to determine which part of the plant is most indicative of the nutrient status of the plant, what field sampling procedure is best, and how often during the season analysis should be made" (Epstein, 1972).

Even with all these considerations, valid conclusions concerning plant responses to mineral nutrients call for the appropriate design of experiments and the collection of the necessary data. The use of statistics and the design of experiments which will permit subsequent statistical analysis of the data are now conspicuous features of the current scene (Steward, 1963).

Plant growth and development are an integral result of many factors operating both within and without the plant, and consequently analyses of growth are complex and consist primarily of emperical relationships among various parameters of growth (Power et.al., 1967).

In growth analysis, it has been customary to consider measurements of different plant characters which are assumed to be related to yield. Records, at intervals, of shoot height, number of tillers per plant, leaf area, stem diameter, and at harvest, ear number and weight per plant, number of grains per ear, weight of 1,000 grains, fresh and dry weight of plants are among the frequently used characters.

Yoshida (1972) classifies plant characters related to yielding ability into two: morphological characters and photosynthetic rate of leaf. He discusses characters such as plant height, leaf angle, tillering habit and panicle growth under the former category.

From whatever point of view it may be considered the growth of a plant as an organism appears as a process of increment in dry weight (West et.al., 1920). According to Watson (1968) growth analysis procedures require only measurements of plant dry weight and leaf area on samples of the crop at intervals throughout its life.

However growth data are obtained, it is always desirable to analyse them in such a way as to estimate growth rates (West et.al., 1920; Erickson, 1976). Relative growth rate provides a convenient integration of the combined performances of the various parts of the plant, and is especially useful when the need arises to compare species and treatment differences on a uniform basis (Hunt, 1978). Interpretation of the results of growth analysis based on relative growth rates, however, should be carried out with considerable care, because "relative growth rates change with time and the rate measured at one stage of growth may not be representative of the plant's response at other times " (Chapman, 1976).

Power et.al., (1967) propose the concepts of net assimilation rate (NAR), leaf area ratio (F), relative growth rate (RGR), and other attributes of growth dependent upon leaf development and dry matter accumulation as among the most promising approaches to growth analysis.

Detailed reviews of the techniques of growth analysis are given by West et.al., (1920), Watson (1952, 1968), Whaley (1961), Power et. al., (1967), Erickson (1976), and Hunt (1978). Radford (1967) gives a detailed account of the growth analysis formulae, and describes all the necessary assumptions involved in their derivation.

The kind of knowledge obtained from the aforementioned types of studies meticulously carried out could be geared towards establishing relationships between crop yields and variations in the environment with the ultimate goal of increasing food production. Developing countries today are being constantly urged to adopt modern agricultural techniques and products to overcome the problem of food shortage. As a result, the use of seeds of high-yielding and disease-resistant crops is spreading fast.

However, the introduction of high yielding varieties has resulted in greater demands on plant nutrients which cannot be met from the inherent soil fertility (FAO, 1980). In other words, promising as they are, the use of high-yielding crops has become highly demanding from the management point of view. As a result, expensive inputs, such as machinery, fertilizers, irrigation and pesticides have become inevitable for the achievement of the high yields. Considering the financial limitations of these countries, profitable economic yields can only be sustained for long on the rational used of such practices.

This in turn calls for constant research on the overall growth characteristics of the crops at hand. Understanding the physiological processes involved in grain production, such as vegetative growth, formation of storage organs, and grain filling, helps determine the best combination of factors (i.e. variety, environment and agronomic practices), and also suggests what improvements can be made to achieve a further increase in grain yield under a given condition (Yoshida, 1972).

One such crop that has currently gained attention is barley. In fact, speaking of communities where potential food shortage is acute, Barghouti and Hadjichristodoulou (1979) suggest that improving barley production and increasing its yield per unit of land, may be considered as a major step in speeding the process of development.

Today, research activities of barley in Ethiopia are not only the reflections of this endeavour, but also responses to the domestic effort needed in improving the crop. Barley comes second, next only to teff, in occupying most of the major crop areas in Ethiopia (Hailu and Pinto, 1977).

More appealing, however, is its high yielding capacity compared to teff or other crops. Hailu and Pinto (1977) given the mean yield of barley and teff as 930 kg/ha and 690 kg/ha respectively, while Birch and Desta (1974) estimate the average yields of 1200 kg/ha for barley and 800 kg/ha for teff. It should be noted here, however, that much of barley seed is husk when compared to teff. Therefore, the above values for barley are expected to decrease when we consider only the consumable portion of the grain.

In spite of cultural practices such as crop rotation and seedbed preparation aimed at maintaining higher crop yields, farmers have been facing many problems which have counteracted their efforts. Some of these are diseases, weeds, harmful insects, problems of soil fertility and conservation.

One of the earliest attempts made to look into these problems by way of making a preliminary assessment of the fertility status of Ethiopian soils in general was to collect and analyse soil samples from different parts of the country.

According to the poineering work of Murphy (1968) of a total 2,200 soil samples analysed, 79% were medium to high in total N, 60.5% medium to high in available P, and over 90% high in available K. His data show adequate amounts of nitrogen and potassium for the Central Highlands, while figures for available phosphorus are low.

According to these findings, which, however, were hardly representative of all the Ethiopian soils, it seemed that there was a severe phosphate dificiency followed by nitrogen deficiency, while potassium was taken to be adequately present. Even when phosphorus is high in the soil, the ability of soils to fix it (Hemwall, 1957; Fried and Shapiro, 1960; Parfitt et.al., 1975) makes phosphorus deficiency highly probable.

Therefore, from Murphy's (1968) work and the similarity of the red soils to each other and the black soils to each other as regards chemical and physical characteristics, it was concluded that practically the whole of the Central Highland area was deficient in nitrogen and phosphorus and likely to show marked responses to the application of nitrogen and phosphorus fertilizers (Birch and Desta, 1974).

Such a recognition seems to have triggered work on fertilizer trials, especially on P and N.

Although reports of field trials carried out before 1966 were few, results indicated responses to nitrogen and phosphorus, especially the later, at widely spread sites but no attempt had been made to systematize the information (Birch and Desta, 1974).

Because of the positive responses of yield to P and N application, fertilizers were established as the primary agricultural inputs. The fact that grains for the market were provided by the small farmers made it essential that these fertilizers be distributed to them so that they could raise their yields. As a result of the impact of fertilizers on agricultural yield, the demand for commercial fertilizers is now mounting.

For instance, according to Louis (1974) the use of diammonium phosphate (DAP) and urea increased considerably during the four years 1970 - 74.

Although there would be no alternative, in the short term, to fertilizer as the principal means to increasing production (Hailu and Pinto, 1977), research must be intensified towards improving varieties, for qualities such as high yielding ability and disease resistance. How much fertilizer to apply and what levels of nutrition in the root zone are most desirable during the growing season are questions that continually confront plant nutritionists and farmers (Younts, 1972). Unless answers are sought to these questions, trying to overcome yield problems only through mere fertilizer application will not be the final solutions. To conduct fertility trials and interpret plant tissue nutrient analyses, we must first understand the growth and nutrient uptake and distribution patterns of the plants, (Jacques et.al., 1975).

Information concerning the ecological distribution and mineral requirement of crops in Ethiopia, in general is meagre. Few attempts that have been made by way of fertilizer trial studies as stated earlier seem to be lacking in well organized and documented results. Where documented data are lacking a full realization of the fertility status of our soils and plant responses to the conditions within the soil become impossible.

Barley, as observed from its cultivation patterns in Welmera is a crop with wide ecological distribution. Both altitudinal and horizontal variation in cultivar composition exist in Welmera. Some cultivars are localized to certain altitudes, while others

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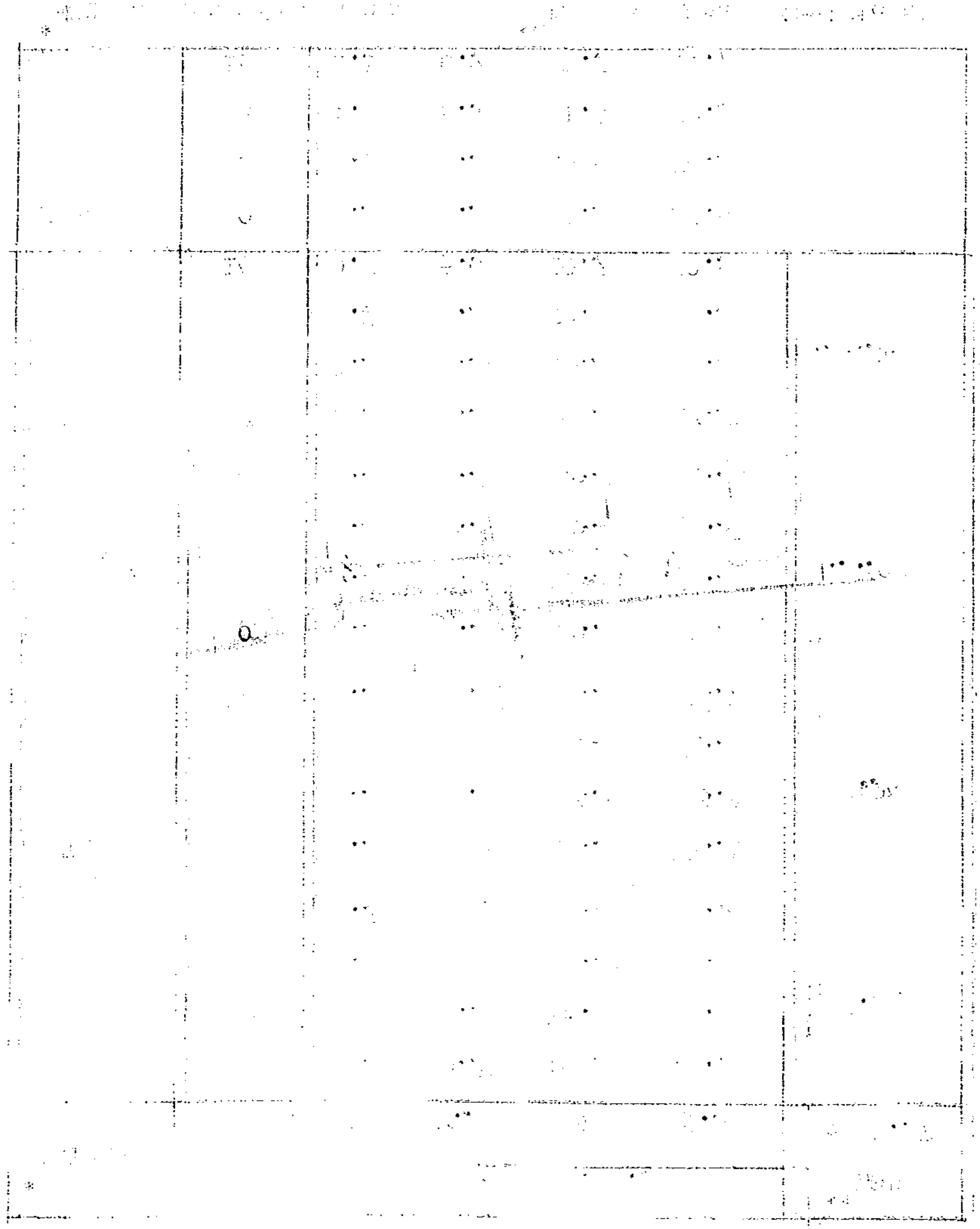

TABLE 11. EFFECT OF P AND Ca APPLICATION ON GRAIN YIELD PER POT

*Cultivar	Ca-rate (mg.eq.)	P-rate (mg.eq.)				**LSD at 0.05
		0	0.5	3	5.5	
ENG	0	-	-	0.75	2.67	
	2	-	0.18	4.90	3.79	2.87
	8	-	1.48	5.25	8.76	
	14	0.07	1.26	12.41	8.94	
KG	0	0.84	-	0.68	2.39	
	2	-	-	6.54	4.23	3.19
	8	0.13	-	7.09	6.50	
	14	-	0.03	8.46	13.10	
NG	0	-	-	1.84	1.55	
	2	-	1.05	3.98	10.24	1.80
	8	0.67	1.80	6.45	7.72	
	14	0.03	-	3.29	9.26	
S	0	0.84	1.76	5.33	10.51	
	2	1.28	4.67	9.02	12.42	4.07
	8	1.33	3.72	12.06	14.68	
	14	0.62	3.23	6.87	12.14	
Mean	0	0.42	0.44	2.15	4.28	
	2	0.49	1.50	6.11	7.62	
	8	0.53	1.75	7.71	9.42	
	14	0.18	1.13	7.73	11.11	

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

**LSD = Least Significant Different

TABLE 12.

Field	Ear dry-weight	Blade dry-weight	S d
1	S a	KG a	
2	NG b	NG a	
3	ENG b	ENG a	
4	KG b	S b	
LSD Level	1%	1%	

Any two values hav

indicated LSD leve

In all the cases, when compared on their overall mean dry-weight yields, Semereta was singled out either as the strongest producer or the weakest producer. It was the number one producer with respect to ear dry-weight yield, tiller number, average number of ears per plant, and grain yield per pot. Semereta stood last with respect to leaf blade area, stem dry-weight, root dry-weight, leaf blade dry-weight, culm diameter and spikelet number.

The mean relative growth rates of all cultivars are seen to be influenced by the various treatments (Table 13). Semereta had the highest overall mean relative growth rate and Enat Nech Gebs had the lowest. Keye Gebs had the second highest relative growth rate and Nech Gebs was the third.

Graphs of plant heights (Figure 2) of all cultivars were more or less the same in shape at the higher levels of phosphorus and calcium (i.e. $Ca_2P_2$and Ca_3P_3). At these levels Keye Gebs had the highest plant height during harvest followed by Nech Gebs, Enat Nech Gebs and Semereta respectively. Marked increases in plant heights at the lowest phosphorus and calcium (i.e. Ca_oP_o) levels occured between the 20^{th} and 30^{th} day, and then almost levelled off upto the 60^{th} day.

Deficiency symptoms were observed in plants grown at all the lower phosphorus levels (i.e. 0 and 0.5 mg.eq.), irrespective of calcium levels in solution. Older leaves of Semereta and Keye Gebs were purplish in color while older

TABLE 13. MEAN RELATIVE GROWTH RATES AS PERCENT PER DAY BETWEEN THE 30th and 60th DAYS AFTER SOWING.

*Cultivar	Ca-rate (mg.eq.)	P-rate (mg.eq.) 0	0.5	3	5.5
ENG	0	0.46	1.18	1.73	1.85
	2	0.41	1.73	1.79	1.76
	8	0.31	1.50	2.21	1.76
	14	0.49	1.39	1.88	1.68
KG	0	0.48	1.34	2.27	2.56
	2	0.59	1.70	2.19	2.45
	8	0.57	1.63	2.28	2.43
	14	0.51	1.41	2.26	2.08
NG	0	0.36	1.59	2.19	2.23
	2	0.30	1.30	2.03	2.30
	8	0.47	1.55	2.13	2.01
	14	0.23	1.75	2.26	1.52
S	0	0.17	1.45	2.31	2.33
	2	0.47	2.15	2.41	2.34
	8	0.56	1.98	2.57	2.25
	14	0.76	1.99	2.49	2.37
Mean	0	0.37	1.39	2.13	2.24
	2	0.44	1.72	2.11	2.21
	8	0.48	1.67	2.30	2.11
	14	0.50	1.64	2.22	1.91

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

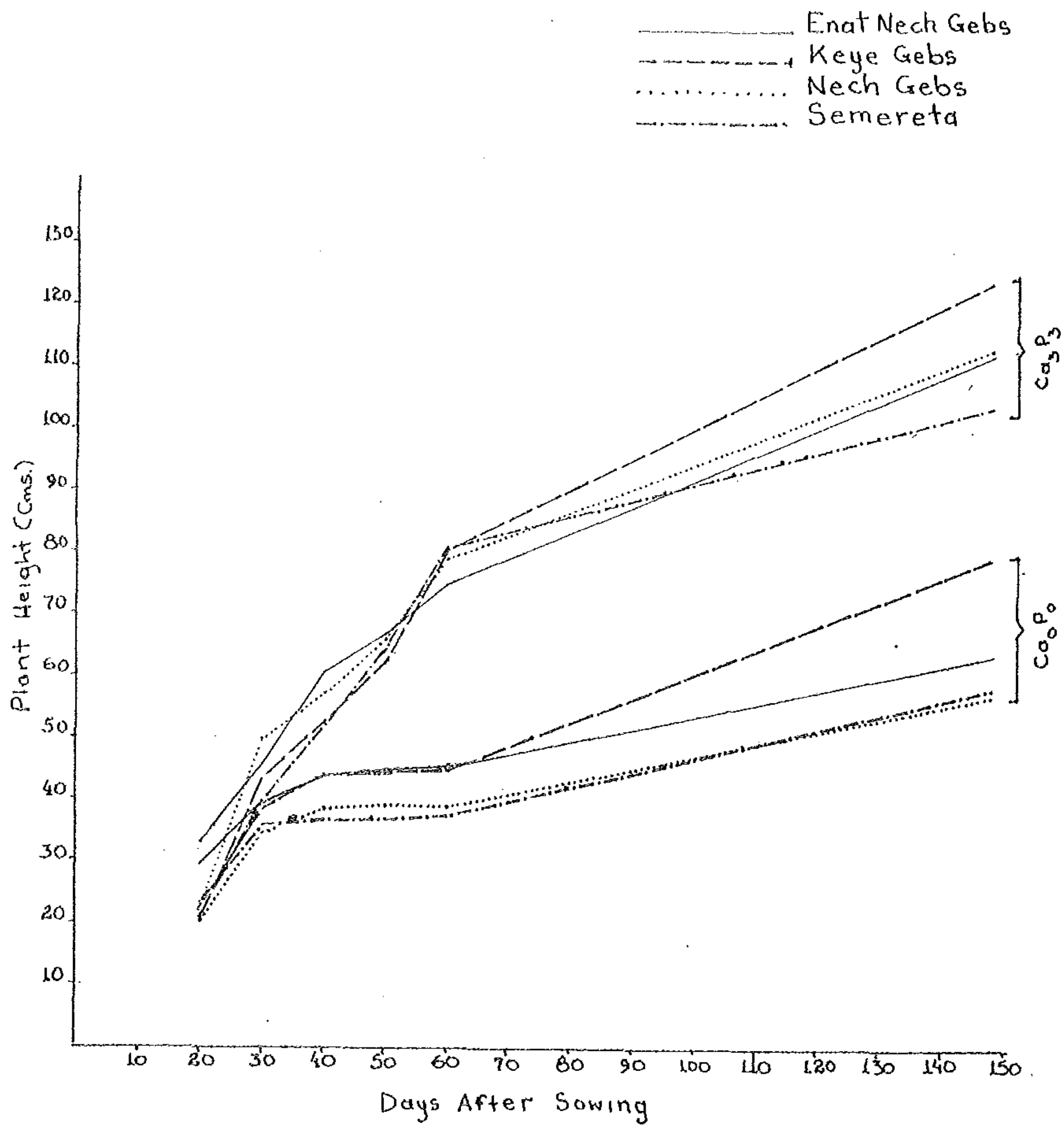

Fig. 2. EFFECT OF Ca_oP_o AND Ca_3P_3 ON PLANT HEIGHT

leaves of Enat Nech Gebs and Nech Gebs were yellowish green in color, and in a few completely yellow. All plants grown at the lower phosphorus levels were very stunted in their growth. No marked variation in vegetative growth was observed with varying levels of calcium.

The chemical composition of the leaf blades of the four cultivars is given in Tables 14 - 17. Calcium and phosphorus applications had no significant effect on the phosphorus content of any of the cultivars (Table 14). However, statistically non-significant higher values for each of the cultivars were obtained with increasing phosphorus levels especially at the lowest Ca - level. Calcium contents of Enat Nech Gebs, Nech Gebs and Semereta leaves show no significant variation while significant variation at 1% probability level is seen in Keye Gebs (Table 15). Phosphorus application had no significant effect on the calcium content of Keye Gebs leaves except at the highest calcium level. At 14 mg.eq. of Ca in solution, phosphorus application significantly decreased Ca-content of Keye Gebs leaves. Calcium application on the other hand significantly increased Ca - contents of Keye Gebs leaves at the lowest level of phosphorus. Although not significant the variation in leaf content of Ca in the other cultivars is similar to that of Keye Gebs.

Phosphorus application significantly decreased the nitrogen contents of Enat Nech Gebs and Nech Gebs at the lower levels of calcium in solution (i.e. 0 and 2 mg.eq.), and significantly increased the N - content of Enat Nech Gebs at the higher levels

TABLE 14. EFFECT OF P and Ca APPLICATION ON % P CONTENT OF LEAVES

*Cultivar	Ca-rate (mg.eq.)	P-rate (mg.eq.) 0	0.5	3	5.5	**LSD at 0.05
ENG	0	0.10	0.30	0.67	0.24	
	2	0.10	0.11	0.19	0.15	***NS
	8	0.66	0.10	0.28	0.16	
	14	0.09	0.15	0.18	0.17	
KG	0	0.14	0.26	0.79	0.14	
	2	0.28	0.54	0.90	0.69	NS
	8	0.50	0.36	0.85	0.60	
	14	0.52	0.77	0.61	0.80	
NG	0	0.62	0.83	1.05	1.76	
	2	0.55	0.47	0.39	1.01	NS
	8	0.23	0.39	0.47	0.85	
	14	0.17	0.25	0.74	0.72	
S	0	0.26	0.37	0.28	0.48	
	2	0.21	0.04	0.30	0.45	NS
	8	0.17	0.13	0.20	0.29	
	14	0.12	0.18	0.17	0.27	

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

**LSD = Least Significant Difference
***NS = Not Significant

TABLE 15. EFFECT OF P and Ca APPLICATION ON % Ca CONTENT OF LEAVES

*Cultivar	Ca-rate (mg.eq.)	P-rate (mg.eq.)				**LSD at 0.05
		0	0.5	3	5.5	
ENG	0	0.94	1.33	1.19	1.24	
	2	0.89	1.29	1.74	2.00	***NS
	8	1.53	1.16	1.75	2.01	
	14	1.74	1.20	1.36	1.23	
KG	0	0.69	0.85	0.88	0.95	
	2	0.84	0.76	1.30	1.00	0.76
	8	1.24	1.06	0.95	1.23	
	14	2.45	0.44	1.17	1.01	
NG	0	0.56	0.92	1.06	1.16	
	2	0.63	1.48	1.02	1.31	NS
	8	1.21	1.23	1.12	1.04	
	14	2.07	1.25	1.32	1.12	
S	0	0.61	1.12	1.08	1.00	
	2	0.67	1.49	1.01	1.18	NS
	8	1.21	0.70	1.19	1.32	
	14	1.97	1.21	0.80	0.88	

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semeneta

**LSD = Least Significant Difference
***NS = Not Significant

of calcium (i.e. 8 and 14 mg.eq.) (Table 16). At lower levels of phosphorus in solution (i.e. 0 and 0.5 mg.eq.) calcium application significantly decreased the nitrogen contents of Enat Nech Gebs and Nech Gebs.

The magnesium content of leaves was significantly affected only in Enat Nech Gebs and Semereta (Table 17). Phosphorus application at the 0.5 mg.eq. level significantly decreased Mg-content of Enat Nech Gebs, and then significantly increased Mg-content at the highest level. These significant variations however, were observed only at 2 mg.eq. of calcium in solution. Phosphorus at 0.5mg.eq. concentration significantly increased Mg-content of Semereta at both the extreme levels of calcium in solution (i.e 0 and 14 mg.eq.). On the other hand phosphorus at higher concentrations significantly decreased Mg-content of Semereta at the two levels of calcium just mentioned.

At the lowest level of phosphorus in solution calcium application significantly increased Mg-content at the 2mg.eq. level and then significantly decreased Mg-content at higher concentrations of calcium in Enat Nech Gebs and Semereta.

TABLE 16. EFFECT OF P and Ca APPLICATION ON % N CONTENT OF LEAVES

*Cultivar	Ca-rate (mg.eq.)	P-rate(mg.eq.) 0	0.5	3	5.5	**LSD at 0.05
ENG	0	4.3	4.2	2.3	3.0	0.90
	2	3.0	3.3	2.4	2.5	
	8	2.3	2.9	3.2	2.5	
	14	2.7	3.4	2.4	2.8	
KG	0	2.7	4.5	3.0	2.8	***NS
	2	1.8	2.3	1.5	1.5	
	8	1.3	1.9	1.6	1.6	
	14	2.2	2.2	1.3	1.7	
NG	0	1.1	1.7	0.7	0.8	0.42
	2	1.0	1.0	0.5	0.7	
	8	0.9	1.1	0.8	0.8	
	14	1.0	1.1	0.8	0.7	
S	0	1.6	0.9	1.2	1.2	NS
	2	0.6	1.3	1.2	1.4	
	8	1.1	2.0	1.4	1.3	
	14	2.4	2.0	1.2	1.5	

* ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

** LSD = Least Significant Difference

*** NS = Not Significant

TABLE 17. EFFECT OF P AND Ca APPLICATION ON % Mg CONTENT OF LEAVES

*Cultivar	Ca-rate (mg.eq.)	P-rate (mg.eq.)				**LSD
ENG	0	0.32	0.49	0.50	0.33	
	2	0.77	0.36	0.54	0.65	0.19
	8	0.38	0.29	0.42	0.48	
	14	0.58	0.41	0.47	0.44	
KG	0	0.29	0.38	0.44	0.43	
	2	0.43	0.35	0.57	0.43	***NS
	8	0.33	0.32	0.38	0.49	
	14	0.46	0.34	0.36	0.30	
NG	0	0.18	0.4[illegible]	0.74	0.47	
	2	0.16	0.56	0.40	0.25	NS
	8	0.26	0.46	0.19	0.32	
	14	0.49	0.43	0.25	0.35	
S	0	0.18	0.59	0.20	0.34	
	2	0.37	0.29	0.35	0.35	0.19
	8	0.24	0.24	0.24	0.18	
	14	0.43	0.68	0.22	0.36	

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

**LSD = Least Significant Difference
***NS = Not Significant

DISCUSSION

This study was undertaken to determine the effects of phosphorus and calcium application on the growth responses and chemical composition of four barley cultivars. Differences in responses if any, among the four cultivars were also looked for.

Response to edaphic factors may be determined in two ways: emperically by growth in different soils, and factor by factor in culture solution (Snaydon and Bradshaw, 1961). It has been mentioned in the introduction that the results of a study of plant responses depend to a large degree on the environment to which the plants have been subjected before and during the treatment.

It is worth mentioning at this point, that the cultivars studied in this work were collected from areas with distinct topographic differences, and other accompanying climatic influences. Enat Nech Gebs seeds were collected at an altitude of 2,950m., Nech Gebs seeds at an altitude of 2,600 m., Keye Gebs seeds at an altitude of 2,500 m., and Semereta seeds at an altitude of 2,400 m.

Apart from the differences in nutrient factors that may exist in the soils of these areas, the influence of heat in the greenhouse during the day, and the difficulty it is likely to cause in the comparison of cultivars should be mentioned at the outset. From the pattern of barley cultivar distribution in Welmera, as stated by Zemede Asfaw (1980), it appears that climatic factors govern the restriction of Enat Nech Gebs to the tops of high mountains and Semereta to areas lower down. The daily minimum - maximum temperatures in the greenhouse during the growth period show fluctuations. The temperature range during this period was 8 - 40°C, with an average maximum temperature of 33°C, and an average minimum temperature of 10.4°C.

Often the suitability of the environment, and with it the success or failure of a species, is determined by the maximum or minimum temperature (Treshow, 1970). Increases in light intensity, while resulting in a higher growth rate, produce several important morphological effects which tend to reduce yield when plants are grown with optimal water and mineral nutrition (Friend, 1966). Since the optimum temperature for maximum metabolic activity varies markedly from species to species and even among populations and individuals of a single species (Treshow, 1970), care must be taken while comparing the overall performance of cultivars such as Enat Nech Gebs and Semereta which are naturally from areas with distinct topographic differences.

It should also be noted that the plants have been affected by disease and aphid attack, and it has been reported that fungus diseases such as powdery mildew can alter the growth of the plant and the rate of photosynthesis (Thorne, 1966).

As the cultivars differ in their growth rates the above factors will have a differential effect on the final yields. It is therefore, with these environmental hazards operating against ideal plant development in mind that the following discussion will be made.

There is a general increase in dry-weight and other measurements with increasing concentrations of phosphorus for all the cultivars studied. The phosphorus concentrations at which most cultivars achieved maximum yield in the study usually varied with calcium concentrations in solution.

Plants supplied with nutrient solutions lacking in calcium achieved significantly increased shoot and root dry-weights at higher concentrations of phosphorus (i.e 3 and 5.5 mg.eq.). When the level of calcium in solution was increased, most plants were able to increase their shoot and root dry-weights significantly at phosphorus concentrations as low as 0.5 mg.eq. Although they are not statistically different, numerically higher shoot and root dry-weights were obtained for most cultivars at higher phosphorus and calcium levels. Since the root depends on the shoot for food, and the shoot inturn depends on the root for mineral and water supply, the above similarity in response in the shoot and the root is to be expected.

The suppression of root development in phosphorus deficient plants in general has been mentioned as limiting to normal plant growth by Treshow (1970) and Russell (1973). As stated earlier mineral and water supply to above ground plant parts depend on the roots, and thus some relationship is expected between roots and shoots. An understanding of the effect of external conditions on root growth is possible only if at the same time attention is paid to shoot growth (Brouwer, 1966), and one parameter which helps in explaining this relationship is the shoot: root ratio. Shoot: root ratios of most cultivars in the present study decreased with diminishing levels of phosphorus in solution.

Responses of growth parameters other than shoot and root dry-weights including grain weights, ear number per plant, spikelet number per head, and tiller number per plant are significantly increased by increases in phosphorus application. The reason for the increase in spikelet number with increasing phosphorus concentrations could be as stated by Afridi et.al. (1978). According to these authors increases in phosphorus result in enhanced cell division in the ear. On the other hand, increase in phosphorus is known to initiate the reproductive phase in many tillers (Russell, 1963; as quoted by Afridi et.al., 1978), and thus could result in increase in ear number per plant. Phosphorus deficiency causes prolonged dormancy of buds, and suppresses tillering (Hewitt and Smith, 1974; Russell, 1973). Thus phosphorus deficiency not only causes reduced ear formation but also results in suppressed tiller formation.

Plant growth can not be accounted for by paying special attention to one or a few of its parts only, because it is a function of the overall performance of the different parts of a plant. Watson (1952, 1968) in his studies on the physiological causes of variation in crop yield concluded that variation in leaf area was the main cause of differences in yield. This becomes evident when one considers the leaf as the site of food synthesis in plants. The larger the photosynthetic area provided by a plant, the better its growth would be. From this standpoint, any environmental factor that tends to affect leaf area is likely to affect dry-weights (Power et.al., 1967; Friend, 1966). However, compared to the other three cultivars, Semereta had a relatively smaller leaf area while it had higher yields in the contrary.

Phosphorus deficiency symptoms were also undoubtedly detected in all cultivars. Older leaves of Semereta and Keye Gebs plants treated with solutions low in phosphorus were purplish in color, indicating P - deficiency. On the other hand, older leaves of Enat Nech Gebs and Nech Gebs were yellowish green in color, and in a few completely yellow. These symptoms were detectable in all the plants grown at lower phosphorus levels (0 and 0.5 mg. eq.) irrespective of calcium concentrations, thus indicating P - deficiency. Hewitt (1944) reports this symptom as being typical in barley, and later on (1963) points out that many of the visible effects of phosphorus deficiency could resemble those which are caused by lack of nitrogen. As a case in point he describes faded yellow- greening in the oldest leaves of lettuce (*Lactuca sativa*) and pea (*Pisum sativum*).

From the results of dry-weights and other growth parameters discussed above, it seems that diminished supplies of phosphorus restrict growth of shoots and roots. Phosphorus is required for the synthesis of adenosine triphosphate and numerous other phosphorylated compounds, its deficiency, therefore, causes immediate and severe disruptions of metabolism and development. It should be borne in mind, however, that excess phosphate over the amount required by the crop sometimes depresses yield. For instance, shoot dry-weight and grain yield of Enat Nech Gebs significantly decreased by very high concentrations of phosphorus at the highest level of calcium in solution. Root dry-weight and ear number of Keye Gebs were also similarly affected. The depressions in dry matter production at the highest phosphorus level could be due to the hastening of the maturation processes and consequent reduction of vegetative growth (Russell, 1973). The mean relative growth rates of the cultivars are also depressed by higher concentrations of phosphorus at higher levels of calcium in solution.

The effect of calcium on the growth of the cultivars, as observed in this study, was not as marked as that of phosphorus. Calcium exerted its influence mostly at higher levels of phosphorus. Certain cultivars, however, uniquely responded to varying levels of calcium in solution. Ear number of Semereta and tiller number of all cultivars were not at all affected by calcium application. Root dry - weights of Nech Gebs and Semereta were significantly de- creased by very high concentrations of calcium at the highest phosphorus level. Blade area of all cultivars were signi- ficantly increased by calcium application at intermediate levels of phosphorus in solution (i.e. 0.5 and 3 mg.eq.). Keye Gebs and Semereta, however, had significantly decreased blade areas at the highest calcium level and phosphorus levels just indicated. Spikelet numbers of most cultivars were signi- ficantly increased by calcium application at lower phosphorus levels. At the lowest phosphorus level in solution culm dia- meters of Keye Gebs and Nech Gebs were significantly decreased by calcium application.

From the general responses of the growth characters ob- served in this study, most cultivars were not affected by calcium applications at the lower phosphorus levels. The fact that all plants treated with nutrient solutions lacking in calcium had normal growth at higher P - levels, however, raises the issue that it is questionable that plants could normally grow without receiving any amount of calcium. According to the rigorous criteria for "essentiality of nutrients" any plant cannot complete its life cycle without a particular essential element. Calcium therefore, cannot be an exception if it is an essential nutrient. The observation made during this study, however, was contrary to this. One or a combination of the following may account for this anomaly: 1) traces of calcium applied as impurities in the chemicals, 2) inadequacy in washing the sand, and 3) inadequacy in the distilling mechanism for the irrigation water used.

Since calcium is a macronutrient, whether normal plant growth could ensue from applications of traces of this element may still raise a dout. However, provided other conditions are favourable, some workers are of the opinion that only a very small amount of calcium is needed for normal plant growth. From work on corn and tobacco plants, which grew well in nutrient solutions with calcium levels lower than 1/50 of that of Hoagland solution, and with a proper balance of micronutrients, Wallace et.al., (1966) concluded that beyond emeliorating toxicities of other ions, the role of calcium in higher plants is that, or nearly that of a micronutrient. Repeated work under varying environmental conditions should be carried out, however, to fully endorse or reject this conclusion.

No typical symptoms that could solely be ascribed to calcium deficiency were observed in the present work. Hewitt (1944) reports to have observed no typical Ca-deficiency in barley leaves, but later on (1963) hints that the characteristic effects of calcium deficiency may occur in may parts of a plant, and also the susceptibility to Ca-deficiency of different tissues may differ in various species. Moreover, the relative sensitivity of calcium affected processes in plants to calcium concentrations in nutrient solutions could be changed for instance, by factors such as the concentration of other cations (Loneragan et al., 1968). Therefore, diagnosis for calcium deficiency not only requires examination of leaves, but also needs the understanding of nutrient balances and the functioning of various processes inside the plant.

Many workers, on the other hand, have shown that calcium deficiency in nutrient solutions has effects on the overall growth of plants, and as a result, there are a large number of experimental and theoretical works which indicate the benefit that calcium gives to plants (True, 1922; Reed and Cummings, 1948; Bradshaw et.al., 1958; Snaydon and Bradshaw, 1961; Wallace et.al., 1966; Jones and Lunt, 1967; Loneragan et.al., 1968; Loneragan and Snowball, 1969). According to these reports a number of factors operating both within and without the plant influence the effect of calcium on different plant processes. Therefore, more refined work on the influence of environmental factors to determine the effects of this nutrient element on crop yield becomes essential. This could be done by taking the nutrients individually, factor by factor in solution along with the complete supply of other nutrients. This way it would be possible to avoid ion interactions arising from different nutrient elements being studied at one time.

The use of plant analysis as a diagnostic tool for assessing the nutritional requirement or status of plants has been discussed in the introduction. The data for the mineral composition of leaf blades, however, do not indicate significant treatment effects for most cultivars.

Different plant species and different parts of a plant are known to show variation in mineral composition. Tissue composition of plants at any one time can be affected by many factors, and as a result intelligent interpretation of tissue analysis requires a broad knowledge of these factors.

In those cultivars for which significant treatment effects were detected, no regular pattern in chemical contents was observed. However, the following generalized observations were evident in all cultivars. Higher phosphorus contents in leaves for all cultivars were obtained at the higher P - levels and lower Ca - levels in solution. On the other hand, higher calcium contents in leaves were obtained at the lowest phosphorus levels but higher calcium levels. Higher N-contents were obtained at lower phosphorus levels irrespective of calcium levels. Relatively higher Mg-contents were detected under the following two circumstances: i) at higher P-levels but lower Ca-levels, and ii) at lower P-levels but higher Ca-levels. However, no correlation was observed between leaf nutrient contents and yields in the present work.

The leaves of plants grown in the absence of phosphorus and calcium had higher contents of these elements that would have been expected. The reason for these high concentrations may lie partially in the quality of the seeds used for the growth of the plants in question. In this type of expriment days Goodman (1969), there is always the possibility that nutrients may be carried over from the parent plants to the progeny seeds, and some might have even accumulated nutrients that would sustain them for at least one growing season (Evans, 1972).

The ability of plants to concentrat K^+ and Ca^{++} in their tissues well above the level of these elements in the external medium is mentioned by Elzam (1971). Various reasons may be given for various elements and plants to explain such cases. It has been reported by Russell (1973), that calcium tends to accumulate in the leaf because as calcium pectate, it constitutes the middle lamellae of the cell walls. Higher concentrations of calcium in leaves than stems have been accounted for by the low mobility of calcium in phloem tissues (Loneragan et.al., 1968). These findings are suggestive of the fact that the proper plant part that best describes the nutritional status of the plants should be identified for efficient utilization of results.

Besides its use in detecting deficiency and revealing nutritional problems, plant analysis also helps in showing reciprocal effects between ions. One such antagonistic effect revealed from the data of leaf composition is the decrease in P-content resulting from increase in calcium supply in solution. The recognition of possible effects of ion interactions is a very important concept in plant nutrition, for in a number of situations it has been established that the minimum amount of an element necessary for normal growth of a plant is not an absolute value, but depends upon the relative amounts of other elements available (Gerloff, 1963).

Wide variation among the cultivars was observed in their ability to take up nutrients from solution. Enat Nech Gebs had the highest nitrogen, calcium and magnesium contents. Keye Gebs had the second highest nitrogen, phosphorus and magnesium contents. Semereta was third in nitrogen and phosphorus, second in calcium and the least in its magnesium contents. Nech Gebs had the highest phosphorus content, and was third in its calcium and magnesium, and had the least nitrogen content in its leaves. Plants grown in nutrient solutions do not absorb the various ions in the proportion in which the ions are present in the growth medium. They rather exert a selective action, absorbing greater portions of some ions than others (Brown 1963). This selectivity in absorption could be manifested uniquely by different plant populations and species. Differences among species in their ability to absorb minerals, particularly in relation to adaptations to different soils have been observed (Langer, 1966).

Knowledge of the pattern of nutrient absorption in different plants is an important concept, because it seems that a number of the quantitative differences in requirements for elements in higher plants are related to variation in capacity for uptake or translocation of elements (Gerloff, 1963). Thus, the variations among cultivars in the present work, as pertains to nutrient contents, may prove vital in determining cultivar distribution provided that significance is established.

The pattern of response to relative growth rates observed in this study had been confirmed from greenhouse observations during the growth period. Semereta was the first cultivar to ripen followed by Keye Gebs. Nech Gebs and Enat Nech Gebs, however, did not show distinct differences between each other as observed in the green house.

Visual observation in the greenhouse also revealed that Semereta had the most stunted vegetative growth, while Enat Nech Gebs and Nech Gebs were well formed with thick stems and large leaves. Grain yields, however, were contrary to these observations.

Considering the altitudinal distribution of the cultivars in Welmera, it is to be expected that Semereta will at least yield better than Enat Nech Gebs, because conditions in the greenhouse relatively simulate those found in the natural habitat of Semereta. Sampling altitudes for the cultivars, as stated earlier, were the lowest for Semereta and increased for Keye Gebs, Nech Gebs, and Enat Nech Gebs respectively.

There was some relationship between response of some growth characters and the increasing or decreasing altitude. Thus tiller number, ear number and grain yield decreased whereas root dry-weights and culm diameter increased in cultivars from higher altitudes. These observations, therefore, are indicative of climatic factors (probably temperature) and edaphic factors as governing factors in cultivar distribution within Welmera.

Morphological differences between plant populations which result from responses to varying edaphic factors are known and believed to be mainly genetically controlled. These differences could also be correlated with factors operating in the growth medium. This is so because closely related populations often differ markedly in their soil preferences indicating that evolution in relation to soil factors has taken place and natural selection has favoured the strongest competitors on each soil type (Goodman, 1969). Such realizations, therefore, are important in that they may help in crop improvement practices. The differential response of the cultivars in the present work is presumably due to their differing genetic constitutions resulting in different physiological variations. This is important because, as stated by Bell and Kirby (1966), crop improvement depends on the availability of adequate genetic variation.

dry-weights, tiller and ear number per plant, and grain yield. This cultivar had also the highest mean relative growth rate, and was the only one to head and produce grains at very low phosphorus levels. If more confirming data are made available through repeated trials, Semereta may be proved as efficient in using phosphorus from very low sources and thus selected as suited to P-deficient soil types.

Morphological variations appearing in closely related plant groups as a result of response to edaphic factors may also catch the eyes of plant breeders. Stiff culms to overcome lodging, and slow relative growth rates to tolerate extreme environmental conditions such as those detected in Enat Nech Gebs may be desirable characters. Differences among cultivars have also been observed in leaf sizes, root and shoot production.

Therefore, it is hoped that these differences in morphological characters will help in identifying desirable characteristics to include in the breeding of high yielding barley cultivars in the future, and select suitable cultivars to different soils of varying nutritional status.

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A P P E N D I X

TABLE A1. AVERAGE PLANT

CULTIVAR		
DAY AFTER SWING	20	
BLOCK TREAT-MENT	1	2
Ca_oP_o	30.4	29.0
Ca_oP_1	28.3	31.7
Ca_oP_2	27.3	29.6
Ca_oP_3	27.7	32.4
Ca_1P_o	28.2	30.9
Ca_1P_1	27.1	26.1
Ca_1P_2	30.1	29.7
Ca_1P_3	30.0	30.6
Ca_2P_o	30.4	29.3
Ca_2P_1	29.6	28.2
Ca_2P_2	29.7	28.9
Ca_2P_3	27.5	28.8
Ca_3P_o	28.2	31.5
Ca_3P_1	26.8	30.5
Ca_3P_2	30.3	29.6
Ca_3P_3	32.8	33.7

TABLE A1. (Cont'd.)

CULTIVAR			
DAYS AFTER SOWING	20		
BLOCK / TREAT-MENT	1	2	
Ca_0P_0	20.6	23.7	37
Ca_0P_1	19.3	17.4	37.
Ca_0P_2	22.8	23.8	41.
Ca_0P_3	20.8	21.2	42
Ca_1P_0	23.2	16.5	39
Ca_1P_1	21.2	18.9	40
Ca_1P_2	25.8	22.1	42
Ca_1P_3	22.2	25.3	39
Ca_2P_0	17.9	21.2	35
Ca_2P_1	19.7	20.5	37
Ca_2P_2	26.0	23.4	38
Ca_2P_3	26.5	25.5	44
Ca_3P_0	21.1	19.8	34
Ca_3P_1	23.9	19.4	37
Ca_3P_2	19.7	24.3	40
Ca_3P_3	22.9	18.8	45

TABLE A1. (Cont'd.)

CULTIVAR			
DAYS AFTER SOWING	20		
BLOCK / TREATMENT	1	2	
Ca_oP_o	19.3	21.5	34
Ca_oP_1	25.6	20.9	3[illegible]
Ca_oP_2	24.8	20.9	42
Ca_oP_3	25.1	16.9	4[illegible]
Ca_1P_o	23.5	24.2	3[illegible]
Ca_1P_1	26.2	19.1	38
Ca_1P_2	17.2	16.5	3[illegible]
Ca_1P_3	25.6	23.4	39
Ca_2P_o	25.9	21.4	3[illegible]
Ca_2P_1	20.0	24.9	3[illegible]
Ca_2P_2	19.3	24.1	39
Ca_2P_3	26.2	22.6	4[illegible]
Ca_3P_o	23.8	20.3	3[illegible]
Ca_3P_1	20.4	22.4	34
Ca_3P_2	22.8	20.2	3[illegible]
Ca_3P_3	22.3	21.8	5[illegible]

TABLE A1. (Cont'd.)

CULTIVAR		
DAYS AFTER SOWING	20	
BLOCK / TREATMENT	1	2
Ca_oP_o	23.9	23.1
Ca_oP_1	24.7	21.3
Ca_oP_2	25.6	22.8
Ca_oP_3	25.5	27.3
Ca_1P_o	27.3	22.9
Ca_1P_1	26.9	27.2
Ca_1P_2	25.4	22.3
Ca_1P_3	26.3	20.7
Ca_2P_o	23.1	23.1
Ca_2P_1	24.0	21.4
Ca_2P_2	22.8	25.8
Ca_2P_3	27.0	18.8
Ca_3P_o	20.9	20.3
Ca_3P_1	24.7	22.9
Ca_3P_2	24.6	28.4
Ca_3P_3	23.5	18.6

TABLE A2. AVERAGE LEAF NU

CULTIVAR			
DAYS AFTER SOWING	20		
BLOCK / TREAT-MENT	1	2	
Ca_oP_o	2.8	2.2	4.
Ca_oP_1	2.4	2.8	3.
Ca_oP_2	3.0	2.6	4.
Ca_oP_3	2.6	2.8	4.
Ca_1P_o	2.2	2.4	3.
Ca_1P_1	3.0	2.2	3.
Ca_1P_2	3.0	2.2	4.
Ca_1P_3	2.8	2.8	4.
Ca_2P_o	2.8	2.4	3.
Ca_2P_1	2.6	2.0	3.
Ca_2P_2	2.8	2.4	4.
Ca_2P_3	3.0	2.8	4.
Ca_3P_o	3.0	2.6	3.
Ca_3P_1	2.2	2.8	3.
Ca_3P_2	2.6	2.2	4.
Ca_3P_3	3.0	2.4	4.

TABLE A2. (Cont'd.)

CULTIVAR			
DAYS AFTER SOWING	20		
BLOCK TREAT-MENT	1	2	
Ca_oP_o	2.4	2.6	3.
Ca_oP_1	2.2	2.0	3.
Ca_oP_2	3.0	2.4	4.
Ca_oP_3	2.8	2.6	4.
Ca_1P_o	3.0	2.2	3.
Ca_1P_1	2.4	2.2	4.
Ca_1P_2	2.8	2.4	4.
Ca_1P_3	3.0	3.0	4.
Ca_2P_o	2.2	2.2	3.
Ca_2P_1	2.6	2.2	3.
Ca_2P_2	3.0	2.0	4.
Ca_2P_3	2.8	2.8	4.
Ca_3P_o	2.2	2.0	3.
Ca_3P_1	2.8	2.0	3.
Ca_3P_2	2.4	2.6	4.
Ca_3P_3	2.4	2.0	4.

TABLE A2. (Cont'd.)

CULTIVAR		
DAYS AFTER SOWING	20	
BLOCK / TREAT-MENT	1	2
Ca_oP_o	2.6	2.4
Ca_oP_1	2.4	2.2
Ca_oP_2	3.0	2.8
Ca_oP_3	3.0	2.2
Ca_1P_o	2.6	2.6
Ca_1P_1	2.6	2.0
Ca_1P_2	2.6	2.4
Ca_1P_3	2.8	2.4
Ca_2P_o	3.0	2.0
Ca_2P_1	2.4	2.4
Ca_2P_2	2.8	2.6
Ca_2P_3	2.6	2.8
Ca_3P_o	2.8	2.2
Ca_3P_1	2.8	2.2
Ca_3P_2	2.4	2.2
Ca_3P_3	2.8	2.6

TABLE A3. AVERAGE CULM DIAMETER AT THE SECOND INTERNODE IN MILIMETERS : 80 DAYS AFTER SOWING.

*CULTIVAR / BLOCK / TREATMENT	ENG		KG		NG		S	
	1	2	1	2	1	2	1	2
Ca_oP_o	2.09	1.96	1.64	1.96	1.53	1.57	1.23	1.13
Ca_oP_1	3.31	2.93	2.64	3.13	3.03	2.50	1.64	1.43
Ca_oP_2	3.95	3.21	3.54	2.95	4.26	3.48	2.62	2.27
Ca_oP_3	4.60	3.54	3.05	3.01	4.23	3.78	2.39	2.56
Ca_1P_o	1.76	1.70	2.58	1.94	1.43	1.45	1.21	1.21
Ca_1P_1	4.23	3.46	3.01	3.19	3.01	3.11	2.03	1.64
Ca_1P_2	4.56	3.66	3.62	3.27	4.50	4.09	3.01	2.17
Ca_1P_3	3.72	2.82	3.58	3.38	3.56	3.95	2.68	2.62
Ca_2P_o	1.84	2.33	1.57	2.19	2.00	1.47	1.17	1.17
Ca_2P_1	3.50	2.52	2.70	3.11	2.68	2.58	1.66	2.13
Ca_2P_2	3.78	3.93	3.91	3.56	4.73	3.54	3.40	2.43
Ca_2P_3	4.93	3.72	4.50	3.83	4.81	3.36	2.46	2.31
Ca_3P_o	2.02	1.98	1.72	1.39	2.07	1.62	1.33	1.21
Ca_3P_1	3.01	2.33	3.13	2.95	3.05	3.05	2.15	1.70
Ca_3P_2	4.77	4.44	3.80	3.97	3.66	3.58	2.76	3.23
Ca_3P_3	4.64	4.44	3.81	3.38	3.99	3.50	2.48	2.31

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A4. AVERAGE BLADE AREA IN SQUARE MILLIMETERS OF THE FIFTH LEAVES: 90 DAYS AFTER SOWING.

*CULTIVAR	ENG		KG		NG		S	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	0.21	0.28	0.16	0.22	0.17	0.16	0.08	0.08
Ca_oP_1	0.34	0.37	0.36	0.40	0.45	0.38	0.18	0.18
Ca_oP_2	0.40	0.48	0.46	0.53	0.54	0.58	0.44	0.42
Ca_oP_3	0.48	0.59	0.57	0.54	0.58	0.65	0.46	0.44
Ca_1P_o	0.17	0.21	0.17	0.24	0.17	0.12	0.08	0.09
Ca_1P_1	0.49	0.49	0.45	0.42	0.38	0.38	0.38	0.33
Ca_1P_2	0.55	0.69	0.51	0.62	0.65	0.71	0.40	0.37
Ca_1P_3	0.50	0.57	0.62	0.53	0.59	0.65	0.48	0.49
Ca_2P_o	0.18	0.12	0.12	0.25	0.17	0.13	0.09	0.08
Ca_2P_1	0.54	0.42	0.44	0.57	0.48	0.42	0.22	0.33
Ca_2P_2	0.71	0.70	0.58	0.67	0.75	0.73	0.51	0.49
Ca_2P_3	0.59	0.55	0.59	0.55	0.63	0.82	0.45	0.53
Ca_3P_o	0.12	0.16	0.13	0.15	0.15	0.17	0.07	0.12
Ca_3P_1	0.40	0.38	0.42	0.29	0.49	0.49	0.20	0.34
Ca_3P_2	0.66	0.67	0.70	0.61	0.78	0.57	0.50	0.51
Ca_3P_3	0.61	0.59	0.66	0.61	0.63	0.67	0.41	0.49

*ENG = Enat Nech Gebs.

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A5. AVERAGE LENGTH : WIDTH RATIO OF THE FIFTH LEAF BLADES: 90 DAYS AFTER SOWING.

*CULTIVAR	ENG		KG		NG		S	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	48.1	45.1	55.0	35.6	58.7	49.7	41.3	48.7
Ca_oP_1	40.6	49.1	52.4	35.0	42.5	48.6	35.2	33.4
Ca_oP_2	42.2	32.0	48.6	36.0	38.2	28.6	37.7	37.5
Ca_oP_3	43.4	30.5	35.5	33.7	32.0	30.8	27.6	35.5
Ca_1P_o	34.9	30.7	53.6	36.3	39.8	33.9	34.1	28.2
Ca_1P_1	44.5	36.1	44.5	40.4	43.0	43.1	36.6	29.8
Ca_1P_2	34.2	31.1	34.9	25.9	31.2	29.9	38.2	49.5
Ca_1P_3	30.4	29.8	36.1	37.1	35.1	27.6	32.0	34.4
Ca_2P_o	41.1	32.3	38.1	43.6	37.7	37.5	30.7	45.5
Ca_2P_1	35.3	34.6	38.4	34.4	37.5	38.9	35.4	31.5
Ca_2P_2	35.9	24.5	31.3	31.3	31.8	27.7	33.7	33.7
Ca_2P_3	34.7	26.2	27.9	35.3	25.7	24.5	40.3	30.6
Ca_3P_o	47.9	37.6	45.7	36.6	43.7	44.9	35.0	42.6
Ca_3P_1	37.7	37.4	46.0	38.9	37.1	38.3	37.0	26.8
Ca_3P_2	31.3	23.0	30.7	26.1	27.5	28.0	33.5	28.4
Ca_3P_3	31.7	26.5	28.5	30.7	29.0	23.6	33.0	34.1

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A6. SHOOT DRY WEIGHT OF THE FIVE PLANTS IN EACH POT IN GRAINS.

*CULTIVAR / BLOCK / TREATMENT	ENG		KG		NG		S	
	1	2	1	2	1	2	1	2
Ca_oP_o	1.7	1.7	0.9	5.6	0.9	1.5	0.4	0.9
Ca_oP_1	3.8	3.5	5.3	8.4	4.2	5.9	4.5	2.4
Ca_oP_2	17.0	15.6	17.9	14.9	14.9	24.3	12.9	20.5
Ca_oP_3	15.1	14.7	18.7	19.4	22.2	19.4	19.1	22.4
Ca_1P_o	2.0	1.3	3.7	1.9	0.5	1.0	0.6	0.7
Ca_1P_1	8.5	9.7	8.4	9.7	7.8	9.1	10.6	8.2
Ca_1P_2	20.2	16.9	22.0	25.5	17.1	21.6	24.3	16.6
Ca_1P_3	17.4	14.1	23.1	24.4	22.7	22.2	19.9	18.6
Ca_2P_o	1.0	1.0	0.9	2.2	1.4	0.9	0.5	0.8
Ca_2P_1	7.9	8.9	7.1	13.5	8.0	7.9	4.6	8.8
Ca_2P_2	12.4	23.6	23.1	23.5	23.5	22.7	15.4	23.7
Ca_2P_3	18.3	22.4	22.7	23.7	25.2	19.1	22.3	24.0
Ca_3P_o	1.0	2.4	1.0	1.0	1.1	1.0	0.6	0.7
Ca_3P_1	7.2	7.3	6.3	7.2	8.2	6.8	6.1	3.9
Ca_3P_2	24.5	27.9	25.2	27.1	19.1	14.6	18.1	23.2
Ca_3P_3	19.5	21.4	23.5	21.9	24.5	21.8	23.0	17.9

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A7. DRY WEIGHT IN GRAIMS OF ABOVE GROUND PARTS PER POT

CULTIVAR	ENAT NECH GEBS							
PLANT PART	EAR		LEAF		STEM		TOTAL	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_0P_0	-	-	0.8	0.8	0.9	0.9	1.7	1.7
Ca_0P_1	-	-	1.9	2.4	1.9	3.1	3.8	5.5
Ca_0P_2	1.2	0.7	4.6	4.7	11.2	10.2	17.0	15.6
Ca_0P_3	0.9	2.4	4.5	4.2	9.7	8.1	15.1	14.7
Ca_1P_0	-	-	0.8	0.5	1.2	0.8	2.0	1.3
Ca_1P_1	0.6	0.3	2.6	3.6	5.3	5.8	8.5	9.7
Ca_1P_2	4.4	2.0	4.6	4.6	11.2	10.3	20.2	16.9
Ca_1P_3	2.7	1.9	4.7	4.2	10.0	8.0	17.4	14.1
Ca_2P_0	-	0.0	0.5	0.3	0.5	0.7	1.0	1.0
Ca_2P_1	0.5	0.9	2.4	2.5	5.0	5.5	7.9	8.9
Ca_2P_2	1.3	5.1	3.8	4.6	7.3	13.9	12.4	23.6
Ca_2P_3	5.7	5.4	3.7	4.7	8.9	12.3	18.3	22.4
Ca_3P_0	0.0	0.2	0.4	0.6	0.6	1.4	1.0	2.4
Ca_3P_1	0.9	0.3	2.4	2.4	3.9	4.6	7.2	7.3
Ca_3P_2	4.9	10.3	5.9	4.4	13.7	4.4	13.2	27.9
Ca_3P_3	5.1	6.0	4.0	5.0	10.4	10.4	19.5	21.4

TABLE A7. (Cont'd)

CULTIVAR	KEYE GEBS							
PLANT PART	EAR		LEAF		STEM		TOTAL	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	-	0.4	0.4	1.8	0.5	3.4	0.9	5.6
Ca_oP_1	-	0.2	2.3	2.6	3.0	5.6	5.3	8.4
Ca_oP_2	1.4	1.2	5.7	4.4	10.8	9.3	17.9	14.9
Ca_oP_3	1.5	2.5	5.4	5.5	11.8	11.4	18.7	19.4
Ca_1P_o	0.0	0.1	1.2	0.6	2.5	1.2	3.7	1.9
Ca_1P_1	0.2	0.4	2.7	3.5	5.5	5.8	8.4	9.7
Ca_1P_2	4.1	5.0	5.0	6.5	12.9	14.0	22.0	25.5
Ca_1P_3	3.3	2.5	5.7	6.2	14.1	14.7	23.1	24.4
Ca_2P_o	0.0	0.3	0.3	0.5	0.6	1.4	0.9	2.2
Ca_2P_1	0.0	0.2	2.4	4.0	4.7	0.3	7.1	13.5
Ca_2P_2	5.2	4.6	4.8	5.5	13.1	13.4	23.1	23.5
Ca_2P_3	3.9	5.6	4.7	4.9	14.1	13.2	22.7	23.7
Ca_3P_o	-	0.0	0.4	0.4	0.6	0.6	1.0	1.0
Ca_3P_1	0.0	0.3	1.8	2.4	4.5	4.5	6.3	7.2
Ca_3P_2	6.2	6.0	4.1	5.2	14.9	15.9	25.2	27.1
Ca_3P_3	3.3	3.6	5.2	5.1	15.0	13.2	23.5	21.9

TABLE A[illegible]. (Cont'd.)

CULTIVAR	NECH GEBS							
PLANT PART	EAR		BLADE		STEM		TOTAL	
BLOCK / TREAT-MENT	1	2	1	2	1	2	1	2
Ca_oP_o	-	0.1	0.7	0.7	0.2	0.7	0.9	1.5
Ca_oP_1	-	0.0	1.9	2.4	2.3	3.5	4.2	5.9
Ca_oP_2	0.7	3.3	4.4	6.5	9.8	14.5	14.9	24.3
Ca_oP_3	1.3	0.9	6.7	5.6	14.2	12.0	22.2	19.4
Ca_1P_o	-	0.0	0.2	0.4	0.3	0.6	0.5	1.0
Ca_1P_1	0.9	0.2	2.2	3.4	4.7	5.5	7.8	9.1
Ca_1P_2	2.7	3.3	4.5	5.0	9.9	13.3	17.1	21.6
Ca_1P_3	5.0	7.0	5.0	4.7	12.7	10.5	22.7	22.2
Ca_2P_o	0.0	0.2	0.3	0.2	1.1	0.5	1.4	0.9
Ca_2P_1	0.5	0.8	2.9	2.4	4.6	4.7	8.0	7.9
Ca_2P_2	5.5	4.4	5.2	5.4	12.8	12.9	23.5	22.7
Ca_2P_3	6.9	3.5	4.6	5.1	13.7	11.0	25.2	19.6
Ca_3P_o	0.0	0.0	0.5	0.4	0.6	0.6	1.1	1.0
Ca_3P_1	0.2	0.1	2.6	2.5	5.4	4.2	8.2	6.8
Ca_3P_2	3.2	1.2	4.8	4.3	11.1	9.1	19.1	14.6
Ca_3P_3	6.3	6.1	4.9	4.4	13.3	11.3	24.5	21.8

TABLE A7. (Cont'd.)

CULTIVAR	SEMERETA							
PLANT PART	EAR		LEAF		STEM		TOTAL	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	0.0	0.1	0.1	0.2	0.3	0.6	0.4	0.9
Ca_oP_1	1.0	0.1	1.2	0.9	2.3	1.4	4.5	2.4
Ca_oP_2	1.8	4.4	3.9	4.8	7.2	11.3	12.9	20.5
Ca_oP_3	5.4	6.4	3.7	4.7	10.0	11.3	19.1	22.4
Ca_1P_o	0.2	0.2	0.1	0.1	0.3	0.4	0.6	0.7
Ca_1P_1	3.5	0.9	2.1	2.2	5.0	5.1	10.6	8.2
Ca_1P_2	9.2	1.9	4.0	4.6	11.1	10.1	24.3	16.6
Ca_1P_3	6.1	7.0	3.9	3.7	9.9	7.9	19.9	18.6
Ca_2P_o	0.1	0.3	0.1	0.1	0.3	0.4	0.5	0.8
Ca_2P_1	1.5	2.0	0.9	1.9	2.2	4.9	4.6	8.8
Ca_2P_2	5.0	8.2	2.7	3.6	7.7	11.9	15.4	23.7
Ca_2P_3	6.9	9.2	3.8	4.2	11.8	19.6	22.2	24.0
Ca_3P_o	0.0	0.0	0.1	0.3	0.5	0.4	0.6	0.7
Ca_3P_1	2.4	0.2	1.0	1.4	2.7	2.3	6.1	3.9
Ca_3P_2	5.6	10.9	3.7	3.0	8.8	9.3	18.1	23.2
Ca_3P_3	8.1	4.7	3.4	3.6	9.5	9.6	23.0	17.9

TABLE A8. AVERAGE TILLER NUMBER PER PLANT

*CULTIVAR / BLOCK / TREATMENT	ENG		KG		NG		S	
	1	2	1	2	1	2	1	2
Ca_oP_o	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0
Ca_oP_1	0.0	1.0	0.0	0.0	0.0	0.8	0.6	0.8
Ca_oP_2	1.0	2.6	2.6	2.0	1.2	4.0	3.0	9.2
Ca_oP_3	1.2	1.2	1.6	3.8	3.5	3.6	4.8	9.8
Ca_1P_o	0.4	0.4	0.0	0.0	0.0	0.6	0.2	0.0
Ca_1P_1	0.2	1.4	0.4	0.6	0.2	1.2	1.6	3.8
Ca_1P_2	1.8	2.4	3.4	3.0	0.8	1.6	4.6	9.4
Ca_1P_3	1.6	2.2	3.8	4.2	3.2	3.2	4.6	5.2
Ca_2P_o	0.0	0.4	0.0	0.0	0.0	0.0	0.2	0.0
Ca_2P_1	0.0	0.2	0.4	1.6	1.0	0.4	1.2	3.8
Ca_2P_2	0.6	2.2	1.6	3.0	1.2	3.2	2.2	7.8
Ca_2P_3	1.4	3.4	3.0	2.4	2.2	3.8	4.8	6.0
Ca_3P_o	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0
Ca_3P_1	0.4	0.4	0.4	0.8	1.0	1.0	1.0	2.0
Ca_3P_2	1.5	3.4	2.8	3.6	1.8	3.2	5.2	3.0
Ca_3P_3	1.4	3.0	3.0	3.2	1.4	3.0	4.8	7.6

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A9. AVERAGE NUMBER OF EARS PER PLANT

*CULTIVAR	ENG		KG		NG		S	
BLOCK / TREAT-MENT	1	2	1	2	1	2	1	2
Ca_oP_o	0.0	0.0	0.0	0.6	0.0	0.2	0.8	0.8
Ca_oP_1	0.0	0.0	0.2	0.6	0.0	0.2	0.8	0.8
Ca_oP_2	1.0	1.0	1.8	1.8	1.4	2.0	2.8	5.4
Ca_oP_3	0.8	1.4	2.2	1.6	1.4	0.8	3.8	5.8
Ca_1P_o	0.0	0.0	0.2	0.4	0.0	0.2	1.2	0.8
Ca_1P_1	0.6	0.6	0.6	0.6	0.8	0.4	1.6	1.2
Ca_1P_2	2.0	1.0	1.8	2.2	1.2	1.8	4.4	3.8
Ca_1P_3	2.0	1.2	2.2	2.6	2.2	2.2	3.6	3.2
Ca_2P_o	0.0	0.6	0.0	0.6	0.4	1.0	1.0	1.0
Ca_2P_1	0.8	1.2	0.4	0.6	0.6	0.4	1.0	2.2
Ca_2P_2	1.0	1.8	2.4	2.6	2.0	2.4	2.4	5.6
Ca_2P_3	1.8	2.8	2.8	2.8	2.4	3.4	6.0	4.0
Ca_3P_o	0.2	0.4	0.9	0.6	0.4	0.2	0.4	0.6
Ca_3P_1	0.6	0.6	0.2	0.6	0.8	0.4	1.2	0.6
Ca_3P_2	1.6	2.8	3.0	3.6	2.0	1.8	3.4	3.6
Ca_3P_3	2.2	2.0	2.8	2.4	2.4	2.8	3.2	5.0

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A10. TOTAL NUMBER OF EARS PER POT AND THEIR DEVELOPMENTAL STAGES DURING HARVEST

CULTIVAR	ENAT NECH GEBS							
HEADING STAGE	H-1		H-2		H-3		H-4	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	-	-	-	-	-	-	-	-
Ca_oP_1	-	-	-	-	-	-	-	-
Ca_oP_2	-	-	-	-	1	1	4	4
Ca_oP_3	-	-	1	1	1	-	2	5
Ca_1P_o	-	-	-	-	-	-	-	-
Ca_1P_1	-	1	-	-	-	-	3	2
Ca_1P_2	-	-	1	-	2	1	7	4
Ca_1P_3	1	-	2	-	-	-	7	6
Ca_2P_o	-	1	-	2	-	-	-	-
Ca_2P_1	1	1	1	-	1	-	1	5
Ca_2P_2	-	-	1	1	-	-	4	8
Ca_2P_3	-	-	-	-	-	-	9	14
Ca_3P_o	-	-	-	-	-	1	1	1
Ca_3P_1	-	-	-	1	-	1	3	1
Ca_3P_2	2	-	1	-	-	-	5	14
Ca_3P_3	-	-	-	-	3	1	8	9

*HEADING STAGES: AFTER BRIGGS (1978)

H-1 = Ear remains inside the boot

H-2 = Awn tips just emerging

H-3 = ¼-½ of the ear emerged

H-4 = Ear Fully emerged

TABLE A10. (Cont'd.)

CULTIVAR	KEYE GEBS							
HEADING STAGE	H-1		H-2		H-3		H-4	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_0P_0	–	–	–	–	–	–	–	3
Ca_0P_1	–	–	–	–	–	3	–	–
Ca_0P_2	–	–	1	–	2	1	6	8
Ca_0P_3	1	–	1	–	1	2	8	6
Ca_1P_0	–	–	–	–	–	–	1	2
Ca_1P_1	1	–	–	–	–	1	2	2
Ca_1P_2	–	–	–	11	–	1	9	9
Ca_1P_3	–	–	2	–	1	–	8	13
Ca_2P_0	–	–	–	–	–	2	–	1
Ca_2P_1	–	–	–	–	1	–	1	3
Ca_2P_2	2.	–	–	2	–	–	10	11
Ca_2P_3	1	1	–	–	1	1	12	12
Ca_3P_0	–	–	–	1	–	–	–	2
Ca_3P_1	–	–	–	–	1	1	–	2
Ca_3P_2	1	–	–	–	2	1	12	17
Ca_3P_3	2	–	–	1	1	1	11	10

TABLE A10. (Cont'd.)

CULTIVAR	NECH GEBS							
HEADING STAGE	H-1		H-2		H-3		H-4	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	–	–	–	–	–	1	–	–
Ca_oP_1	–	1	–	–	–	–	–	–
Ca_oP_2	2	1	–	1	1	1	4	7
Ca_oP_3	1	–	1	–	–	1	5	3
Ca_1P_o	–	–	–	–	–	1	–	–
Ca_1P_1	1	–	1	–	–	1	2	1
Ca_1P_2	1	2	–	–	1	–	4	7
Ca_1P_3	–	1	–	–	–	1	–	9
Ca_2P_o	–	–	–	–	–	–	2	5
Ca_2P_1	–	–	1	–	1	–	1	2
Ca_2P_2	–	–	–	–	1	1	9	11
Ca_2P_3	1	2	–	–	2	1	9	14
Ca_3P_o	–	–	1	–	–	–	1	1
Ca_3P_1	1	–	1	–	–	1	2	–
Ca_3P_2	2	–	–	–	2	3	6	6
Ca_3P_3	2	–	–	1	–	2	10	11

TABLE A10. (Cont'd.)

CULTIVAR	SEMERETA							
HEADING STAGE	H-1		H-2		H-3		H-4	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	-	1	-	-	-	-	4	3
Ca_oP_1	1	-	-	-	1	1	2	3
Ca_oP_2	-	3	-	3	3	2	11	19
Ca_oP_3	-	1	-	2	1	3	18	23
Ca_1P_o	-	-	-	-	1	3	5	1
Ca_1P_1	-	1	-	-	1	3	7	2
Ca_1P_2	1	-	-	2	-	5	21	12
Ca_1P_3	-	-	-	-	3	1	15	15
Ca_2P_o	-	1	-	-	-	-	-	4
Ca_2P_1	-	-	-	-	2	1	3	10
Ca_2P_2	-	3	-	1	2	2	10	22
Ca_2P_3	7	-	2	-	1	8	20	12
Ca_3P_o	-	-	-	-	-	-	8	3
Ca_3P_1	-	-	-	1	-	-	6	2
Ca_3P_2	1	-	1	1	2	-	13	17
Ca_3P_3	-	1	-	2	3	5	13	17

TABLE A11. AVERAGE NUMBER OF SPIKELETS PER EAR

*CULTIVAR	ENG		KG		NG		S	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	0.0	0.0	0.0	12.5	0.0	11.0	4.31	6.0
Ca_oP_1	0.0	0.0	0.0	16.0	0.0	0.0	9.8	5.5
Ca_oP_2	30.5	24.0	22.0	26.4	26.3	34.1	18.4	12.3
Ca_oP_3	26.7	18.2	24.4	25.4	27.4	34.0	13.9	12.1
Ca_1P_o	13.0	0.0	6.0	8.5	0.0	0.0	6.0	3.2
Ca_1P_1	20.3	21.5	22.5	18.3	22.3	10.3	16.0	11.2
Ca_1P_2	27.4	25.0	28.8	30.0	39.0	33.6	15.1	10.4
Ca_1P_3	49.6	21.1	26.2	19.4	38.5	30.6	16.2	15.2
Ca_2P_o	0.0	0.0	0.0	15.5	18.0	8.2	5.0	4.2
Ca_2P_1	15.0	24.8	19.0	14.0	21.0	23.5	11.6	10.4
Ca_2P_2	40.0	23.8	31.0	31.5	36.3	34.8	19.2	12.7
Ca_2P_3	25.7	24.9	28.2	23.2	32.2	24.1	15.4	13.6
Ca_3P_o	[illegible]6.0	[illegible]9.0	[illegible]0.0	[illegible]7.0	[illegible]7.0	11.0	[illegible]3.5	4.7
Ca_3P_1	18.3	14.3	18.0	11.8	25.3	15.0	14.[illegible]	19.5
Ca_3P_2	41.6	24.5	27.4	24.1	30.4	24.6	15.6	14.5
Ca_3P_3	32.8	26.0	33.4	27.8	35.6	30.2	16.5	12.9

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

TABLE A12. GRAIN YIELD PER POT IN GRAMS

*CULTIVAR	ENG		KG		NG		S	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	-	-	-	0.84	-	-	0.38	0.46
Ca_oP_1	-	-	-	-	-	-	1.26	0.50
Ca_oP_2	0.05	0.70	0.00	0.68	0.00	1.84	1.46	3.87
Ca_oP_3	0.16	2.51	0.04	2.35	0.88	0.67	4.98	5.53
Ca_1P_o	-	-	-	-	-	-	0.72	0.56
Ca_1P_1	0.13	0.05	-	-	0.87	0.18	3.67	1.00
Ca_1P_2	3.08	1.82	2.65	3.89	1.67	2.31	8.16	1.85
Ca_1P_3	2.18	1.61	1.86	2.37	3.67	6.57	5.37	7.05
Ca_2P_o	-	-	-	0.13	-	0.67	0.65	0.68
Ca_2P_1	0.73	0.75	-	-	0.62	1.18	1.70	2.02
Ca_2P_2	0.53	4.72	3.77	3.32	3.80	2.65	4.63	7.13
Ca_2P_3	4.90	3.86	1.96	4.54	4.98	2.74	5.84	8.84
Ca_3P_o	-	0.97	-	-	0.03	-	0.98	0.54
Ca_3P_1	0.80	0.46	0.00	0.3	-	-	2.55	0.68
Ca_3P_2	3.54	8.87	4.58	3.88	2.37	0.92	5.21	1.66
Ca_3P_3	3.53	5.41	10.32	2.78	4.12	5.14	7.57	4.57

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

TABLE A13. ROOT DRY WEIGHT IN GRAMS PER POT

CULTIVAR* / BLOCK / TREATMENT	ENG 1	ENG 2	KG 1	KG 2	NG 1	NG 2	S 1	S 2
Ca_oP_o	0.4	0.5	0.2	0.7	0.2	0.4	0.2	0.1
Ca_oP_1	1.5	2.4	0.6	1.1	1.2	1.2	0.6	0.5
Ca_oP_2	4.9	3.6	2.4	2.7	2.5	3.5	1.4	1.6
Ca_oP_3	4.6	3.2	3.3	2.6	4.1	2.7	1.3	1.4
Ca_1P_o	0.9	0.5	0.8	0.4	0.1	0.2	0.3	0.2
Ca_1P_1	2.4	3.5	2.3	1.5	1.9	2.5	1.3	0.7
Ca_1P_2	4.9	3.3	3.3	3.3	4.4	3.9	2.7	1.9
Ca_1P_3	2.5	3.0	4.9	3.0	3.6	2.7	1.8	1.3
Ca_2P_o	0.5	0.4	0.4	0.8	1.0	0.3	0.3	0.2
Ca_2P_1	2.3	3.0	1.5	2.6	1.8	1.4	1.0	1.7
Ca_2P_2	2.1	4.0	3.6	3.0	5.8	3.6	1.8	2.0
Ca_2P_3	3.3	3.1	3.4	2.9	6.0	2.5	2.4	2.5
Ca_3P_o	0.5	0.9	0.3	0.4	0.7	0.3	0.2	0.3
Ca_3P_1	1.1	3.7	0.9	1.7	2.2	2.0	1.0	0.4
Ca_3P_2	4.7	4.4	4.5	3.9	2.6	2.3	1.4	1.5
Ca_3P_3	6.1	4.1	2.9	2.3	3.0	2.6	1.3	1.1

*

ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A14. SHOOT: ROOT RATIOS OF DRY WEIGHTS PER POT

CULTIVAR	ENG		KG		NG		S	
BLOCK / TREATMENT	1	2	1	2	1	2	1	2
Ca_oP_o	4.25	3.40	4.50	8.00	4.50	3.75	2.00	9.00
Ca_oP_1	2.53	2.29	8.83	7.64	3.50	4.92	7.50	4.80
Ca_oP_2	3.47	4.33	7.46	5.52	5.96	6.94	9.21	12.81
Ca_oP_3	3.28	4.59	5.67	7.46	5.41	7.19	14.69	16.00
Ca_1P_o	2.22	2.60	4.63	4.75	5.00	5.00	2.00	3.50
Ca_1P_1	3.54	2.77	3.65	6.47	4.11	3.64	8.15	11.71
Ca_1P_2	4.12	5.12	6.67	7.73	3.89	5.54	9.00	8.74
Ca_1P_3	6.96	4.70	4.71	8.13	6.31	8.22	11.06	12.77
Ca_2P_o	2.00	2.50	2.25	2.75	1.40	3.00	1.63	4.00
Ca_2P_1	3.43	2.97	4.73	5.19	4.44	5.64	4.60	5.18
Ca_2P_2	5.90	5.90	6.42	7.83	4.05	6.31	8.56	11.85
Ca_2P_3	5.55	7.23	6.68	8.17	4.20	7.84	9.29	9.60
Ca_3P_o	2.00	2.67	3.33	2.50	1.43	3.67	3.00	2.33
Ca_3P_1	3.79	1.97	7.00	4.24	3.27	4.10	6.10	9.75
Ca_3P_2	5.21	6.34	5.60	6.95	10.42	8.30	12.93	15.47
Ca_3P_3	3.20	5.22	8.10	9.52	7.30	9.42	17.69	16.27

TABLE A15. LEAF BLADE CHEMICAL COMPOSITION IN PERCENT

ELEMENT	NITROGEN							
*CULTIVAR	ENG		KG		NG		S	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	4.30	4.30	2.40	3.00	1.01	1.23	2.80	0.33
Ca_oP_1	4.30	3.80	4.70	4.20	1.29	2.07	1.18	0.56
Ca_oP_2	2.40	2.20	2.80	3.10	0.62	0.73	0.73	1.68
Ca_oP_3	2.80	3.20	2.60	3.00	0.78	0.90	0.73	1.68
Ca_1P_o	2.80	3.20	2.60	0.95	0.84	1.18	0.45	0.78
Ca_1P_1	3.00	3.50	3.50	1.06	1.01	0.90	0.90	1.68
Ca_1P_2	2.10	2.70	2.25	0.73	0.56	0.50	0.62	1.79
Ca_1P_3	2.30	2.70	2.20	0.78	0.56	0.73	1.12	1.68
Ca_2P_o	1.80	2.80	1.80	0.84	0.84	1.01	1.75	0.44
Ca_2P_1	3.40	2.30	3.10	0.78	1.01	1.12	2.00	2.01
Ca_2P_2	2.90	3.40	2.50	0.78	0.73	0.84	1.45	1.34
Ca_2P_3	2.40	2.60	2.50	0.78	0.56	1.00	1.34	1.34
Ca_3P_o	2.40	2.90	3.00	1.46	0.90	1.06	2.00	2.78
Ca_3P_1	2.90	3.90	3.40	0.95	1.06	1.12	1.90	2.01
Ca_3P_2	2.40	2.30	2.10	0.56	0.67	0.95	1.34	1.12
Ca_3P_3	2.40	3.20	2.55	0.84	0.67	0.67	1.34	1.68

*ENG = Enat Nech Gebs

KG = Keye Gebs

NG = Nech Gebs

S = Semereta

TABLE A15. (Cont'd.)

ELEMENT	PHOSPHORUS							
*CULTIVAR	ENG		KG		NG		S	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_oP_o	0.10	0.10	0.10	0.18	0.93	0.30	0.18	0.33
Ca_oP_1	0.45	0.14	0.18	0.33	1.06	0.60	0.20	0.53
Ca_oP_2	1.21	0.12	0.75	0.82	1.52	0.58	0.34	0.21
Ca_oP_3	0.28	0.19	0.19	0.08	1.98	1.54	0.65	0.30
Ca_1P_o	0.06	0.14	0.20	0.36	0.77	0.32	0.28	0.13
Ca_1P_1	0.08	0.13	0.25	0.82	0.50	0.44	0.03	0.05
Ca_1P_2	0.20	0.17	1.00	0.80	0.54	0.23	0.30	0.30
Ca_1P_3	0.14	0.15	0.16	1.22	1.50	0.51	0.46	0.43
Ca_2P_o	1.21	0.11	0.47	0.52	0.22	0.23	0.23	0.10
Ca_2P_1	0.08	0.11	0.33	0.38	0.54	0.23	0.20	0.06
Ca_2P_2	0.40	0.16	0.76	0.94	0.70	0.23	0.30	0.09
Ca_2P_3	0.19	0.12	0.17	1.02	1.32	0.38	0.36	0.21
Ca_3P_o	0.06	0.12	0.34	0.70	0.14	0.20	0.11	0.12
Ca_3P_1	0.14	0.16	0.51	1.02	0.26	0.23	0.21	0.14
Ca_3P_2	0.19	0.16	0.47	0.74	0.94	0.53	0.31	0.03
Ca_3P_3	0.18	0.16	0.08	1.52	1.24	0.20	0.31	0.22

* ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

TABLE A15. (Cont'd.)

ELEMENT	CALCIUM							
*CULTIVAR	ENG		KG		NG		S	
TREATMENT \ BLOCK	1	2	1	2	1	2	1	2
Ca_0P_0	0.94	0.93	0.70	0.67	0.93	0.19	0.61	0.61
Ca_0P_1	1.14	1.51	0.73	0.97	0.56	1.27	1.61	1.07
Ca_0P_2	1.16	1.22	0.84	0.91	1.04	1.07	1.21	0.95
Ca_0P_3	2.15	0.23	1.07	0.82	1.33	0.99	1.11	0.89
Ca_1P_0	1.26	0.52	0.93	0.74	1.02	0.23	0.66	0.67
Ca_1P_1	1.47	1.11	0.65	0.87	2.07	0.89	1.37	1.60
Ca_1P_2	2.23	1.15	1.77	0.83	1.05	0.99	1.06	0.96
Ca_1P_3	2.27	1.72	1.12	0.87	1.46	1.15	1.30	1.06
Ca_2P_0	1.53	1.53	1.12	1.35	2.39	0.03	1.21	1.21
Ca_2P_1	1.25	1.07	0.03	1.09	1.56	0.90	0.05	1.34
Ca_2P_2	2.43	1.07	0.76	1.14	1.04	1.19	1.25	1.12
Ca_2P_3	3.03	0.98	0.88	1.07	0.99	1.08	1.35	1.28
Ca_3P_0	1.58	1.89	1.73	3.16	2.44	1.69	1.97	1.96
Ca_3P_1	1.89	0.51	0.77	0.10	1.32	1.18	1.34	1.07
Ca_3P_2	1.93	0.79	1.11	1.23	1.58	1.06	0.82	0.78
Ca_3P_3	1.74	0.72	0.97	1.04	1.18	1.05	0.82	0.94

*ENG = Enat Nech Gebs
KG = Keye Gebs
NG = Nech Gebs
S = Semereta

TABLE A16. ANALYSIS OF VARIANCE-SIGNIFICANCE (F-TEST)

No.	Character	Source of Variation		
		Cultivars	Treatments	Interaction
1	Average plant height:			
	-20 days after sowing	***	NS	NS
	-30 " " "	***	***	NS
	-40 " " "	***	***	NS
	-50 " " "	***	***	NS
	-60 " " "	***	***	***
	- During harvest.	***	***	NS
2	Average leaf number:			
	-20 days after sowing	NS	NS	NS
	-30 " " "	***	***	NS
	-40 " " "	***	***	***
	-50 " " "	***	***	***
	-60 " " "	***	***	***
	- During harvest.			
3	Average Culm Diameter:			
	-80 days after sowing	**	**	NS
4	Average Blade Area:			
	-90 days after sowing	*	**	NS
5	Average Length:Width			
	Ratio of leaves	*	***	NS
6	Shoot Dry-Weight	***	***	NS
7	Root Dry-Weight	***	***	**
8	Shoot:Root Dry-Weight			
	Ratio	***	***	***

* = Significant at 10% level

** = " " 5% level

*** = " " 1% level

NS = Not Significant

TABLE A16. (Cont'd.)

No.	Character	Source of Variation		
		Cultivars	Treatments	Interaction
9	Average Tiller Number	***	***	NS
10	Average Ear Number	***	***	***
11	Average Spikelet Number	***	***	NS
12	Stem Dry Weight	***	***	*
13	Leaf Dry Weight	***	***	**
14	Ear Dry Weight	***	***	NS
15	Grain Yield	***	***	NS