# THE EFFECT OF GYPSUM ON THE GROWTH
# OF MILLET PLANTS

By

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Bachelor of Science

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1964

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1975

THE EFFECT OF GYPSUM ON THE GROWTH

OF MILLET PLANTS

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## ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to Professor Lester W. Reed, major adviser, for his assistance, guidance and encouragement throughout the course work and preparation of this thesis. Appreciation is also extended to the author's graduate committee--Dr. Ralph S. Matlock, Dr. Billy B. Tucker, and Dr. Eddie D. Basler--for their suggestions and assistance.

The author wishes to express his gratitude to the Department of Agronomy of Oklahoma State University for the facilities used in this study.

The author is grateful to his parents and other members of his family and especially to his wife for constant encouragement, patience and support during his graduate study at Oklahoma State University.

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# CHAPTER I

## INTRODUCTION

Millions of acres of land has been damaged due to salinization which directly or indirectly removes arable land from cultivation. The need of more and more food for human consumption is increasing day by day posing a challenge to the agricultural scientists to meet the demand of food for the growing population. Among one of the many unfavorable conditions that man is facing in todays agriculture, is gypsiferous soils which have posed an ever increasing problem throughout the world and more so in southwestern parts of the United States of America. Though gypsum ($CaSO_4.2H_2O$) has proved to be very useful in correcting alkali soils, the presence of gypsum in very large quantities in soil may be toxic to the growth of plants.

The research reported here is an attempt to demonstrate the effects of high levels of gypsum on the growth of plants and to determine if gypsum in large amounts in soil could be detected by plant analysis.

## CHAPTER II

## LITERATURE REVIEW

Gypsum ($CaSO_4.2H_2O$) is found in many soils of the arid regions, in amounts ranging from traces to several percent. In some soils, gypsum is present in the sedimentary deposits from which the soil was derived, whereas, in other soils the gypsum is formed by the combination and precipitation of calcium and sulfate during salinization. Information regarding the gypsum content of alkali soils is important, because it usually determines whether the application of chemical amendments will be required for reclamation. Also, the presence of considerable amounts of gypsum in the soil might permit the use of an irrigation water having an unfavorably high sodium content.

Studies by Reitemeier (33) and others show that at least three factors other than the solubility of gypsum may influence the amounts of calcium and sulfate extracted from gypsiferous soils. They are:

1. The solubility of calcium salts other than gypsum;
2. Exchange reactions in which soluble calcium replaces other cations, such as sodium and magnesium; and
3. The solubility of sulfate salts from sources other than gypsum.

Many soils owe their distinctive character to the fact that they contain excessive concentrations of either soluble salts or exchangeable sodium or both. For agricultural purposes, such soils are regarded as a class of problem soils that requires special remedial measures and management practices. Soluble salts produce harmful effects to plants by increasing the degree of saturation of the soil solution and by increasing the degree of saturation of the exchange materials in the soil with exchangeable sodium. The latter effect occurs when the soluble constituents consists largely of sodium salts and is of a more permanent nature than the salt content of the soil solution, since exchangeable sodium usually persists after the soluble salts are removed.

The soluble salts that occur in soils consists mostly of various proportions of the cations sodium, calcium and magnesium and the anions chloride and sulfate. Saline soils occur for the most part in regions of arid or semi-arid climate. Restricted drainage is a factor that usually contributes to the salinization of soils and may involve the presence of a high groundwater table or low permeability of the soil. The high groundwater table is often related to topography. The term saline is used in connection with soils for which the conductivity of the saturation extract is more than 4 m mhos/cm at 25$^{o}$C and the exchangeable sodium percentage is less than 15. Ordinarily the pH is less than 8.5. Saline soils are often recognized by the presence of white crusts of salts on the soil surface. Soil salinity may occur in soils having distinctly developed profile characteristics or in undifferentiated soil material such as alluvium.

The electrical conductivity of the saturation extracts of saline soils is in excess of 4 m mhos/cm and an SAR less than 15. In no case does the pH reading exceed 8.5. Chloride and sulfate are the principal soluble anions present in these soils and the bicarbonate content is relatively low, and carbonate is absent. The soluble-sodium salt content exceeds calcium plus magnesium somewhat, but the SAR is not high and gypsum and alkaline - earth carbonates are common constituents of saline soils. As shown by the values for the electrical conductivity of the saturation extracts, the salinity levels are sufficiently high to affect adversely the growth of most plants. Reclamation of these soils will require leaching only, providing drainage is adequate.

A field of crop plants growing on saline soil usually contain barren spots and stunted growth of the plants with considerable variability in size, and often the foliage has a deep blue-green color, but these features are not necessarily an indication of salinity. The extent and frequency of bare spots in many areas may be taken as an index of the concentration of salt in the soil. In as much as most plants are more sensitive to salinity during germination than in later stages of growth, barren spots are more indicative of salinity around the seed during germination than they are of the general salinity status of the soil profile.

There are many regions where plants may develop an intense chlorosis because of certain soil conditions. Often the causes of chlorosis are not fully understood, but this condition is frequently associated with the use of irrigation waters of high bicarbonate content. Some species of plants develop characteristic necrotic leaves when grown on saline soil.

Numerous laboratory experiments with sand and water cultures have demonstrated the close relationship between plant growth and the osmotic pressure of the culture solution. On a weight or equivalent basis, chloride salts are generally more inhibitory to the growth of plants than sulfate salts, but this difference tends to disappear when concentrations are expressed on an osmotic basis. These relationships indicate that it is the total concentration of solute particles (ions) in the solution rather than their chemical nature which is mainly responsible for the inhibitory effects of saline solutions on the growth of crop plants.

It should be recognized that toxicity so defined need not involve a direct effect of the salts or ions, or on the surface membranes of plant tissues. Frequently, toxicity may be caused, in part, at least, through effects on the uptake or metabolism of essential nutrient elements. Ions that are frequently found in excess in saline soils include chloride, sulfate, bicarbonate, sodium, calcium and magnesium. It appears that differences in plant tolerance to excessive concentrations of ions in the substrate are related, in some degree, to specific selectivity in ion absorption and nutrient requirements of the plants (19).

Ayers and Hayward (4) measured the effects of soil salinity on seed germination on several crop plants by adjusting to various degrees of salinity by additions of NaCl and observed that soil salinity may affect the germination of seeds in two ways:

i) By decreasing the ease with which seeds may take up water and thereby decreasing the rate of water entry; and

ii) By facilitating the intake of ions in sufficient amounts to be toxic.

Bower and Turk (7) are of the opinion that one of the possible causes of poor plant growth on soils highly saturated with exchangeable sodium is the inability of the plant to obtain an adequate supply of calcium. Calcium chloride was more toxic to barley than sodium chloride when compared on an equal osmotic basis(26). Smirnov (43) in an experiment with flax on a podsol soil reported excess calcium to cause the greatest decrease in yield as compared with sodium and potassium. Plants grown on soils containing calcium carbonate often have saps of high pH values which reduce iron solubility and mobility.

Russian workers (31) attribute lack of growth on soils of high replaceable sodium percentages to be due to lack of calcium and report that replaceable magnesium lowers the threshold of sodium toxicity, as also does organic matter and calcium and magnesium carbonates. In experiments with alfalfa in soils of various Ca/K ratios, the Ca/K ratio in the plant was found to correlate with that in the soil. Peech and Bradfield (32) reported on the Ca-K relationship in soils and plants and concluded that plants absorb large amounts of potassium because large amounts are available and that large amounts of available potassium decrease calcium absorption.

Cation exchange can be represented by equations similar to those employed for chemical reactions in solutions. For example, the reaction between calcium saturated soil and sodium chloride solutions may be written:

$Ca\ X_2 + 2\ NaCl \rightleftharpoons 2\ Na\ X + CaCl_2$, where X designates the soil exchange complex.

The use of cation-exchange equations for expressing the relationship between the soluble and exchangeable cations in soils of arid regions involves inherent difficulties. Moreover, there are no accurate methods available for determining exchangeable calcium and magnesium in soils containing alkaline earth carbonates and gypsum. Two cation ratios: designated as the sodium-adsorption-ratio (SAR) and potassium-adsorption-ratio (PAR), are employed for discussing the equilibrium relation between soluble and exchangeable cations. The sodium-adsorption-ratio and potassium-adsorption-ratios are defined as $Na^+/\sqrt{Ca^{++} + Mg^{++}/2}$, $K^+/\sqrt{Ca^{++} + Mg^{++}/2}$, respectively, where $Na^+$, $K^+$, $Ca^{++}$ and $Mg^{++}$ refer to the concentrations of the designated soluble cations expressed in milliequivalents per liter (19).

Kelley (23) emphasizes the importance of calcium as an essential element for the growth of plants in addition to nitrogen, phosphorus, and potassium, etc. The importance of calcium may be considered from the standpoint of soil acidity, plant growth, phosphate availability, soil structure, soil formation, alkali soils, and the use of fertilizers. Soil acidity was thought to be due to soluble substances, chiefly organic, however, we now know that this is only a minor aspect of the question. The acid substances of soils are, for the most part, not soluble in the ordinary sense, rather they are colloidal in nature and they are both organic and inorganic. Non-saline neutral soils are usually approximately calcium saturated, that is, calcium is the dominant exchangeable cation. Under leaching conditions, the calcium becomes replaced by H ions from the surface of the colloidal particles. In consequence, these particles (clay) become acid.

An inadequate supply of calcium in acid soils is often an important factor in the growth of legumes. When grown on such soils, those species of legumes that normally absorb relatively large amounts of calcium are often found to contain somewhat subnormal amounts of calcium. Certain important microbiological soil processes are also adversely affected by an inadequate soil calcium supply and by soil acidity. Calcium also affects the growth of plants through its influence on the absorption of other elements. Within certain limits, an inverse relationship has been found between the absorption of calcium and potassium by plants. Calcium affects toxicity caused by high concentrations of magnesium and sodium probably largely because of its influence on the absorption of these elements. Through its effects from the pH of the soil, $CaCO_3$ may also reduce the solubility of iron in the soil as to produce chlorosis in several different species of plants.

The state of granulation of the colloids of a soil markedly influences the "tilth" of the soil. The kind and relative proportions of the different cations that are combined with, or absorbed on the surface of, the colloidal particles, largely determine the state of granulation of the soil. Calcium-saturated colloids are usually not highly dispersed, rather they tend to form aggregates. The state of aggregation of soil colloids is closely related to the "tilth" of the soil.

As long as the upper horizons of a soil contain $CaCO_3$, the dominant exchangeable cation of a non-saline soil will be calcium. Under this condition pronounced segregation of the particles of the soil, with the consequent development of dense subsoil horizons, does not take place, because Ca-saturated colloids are not highly dispersed, but under the leaching condition of humid regions, $CaCO_3$ is gradually dissolved and leached out of the soil. This is followed by the replacement of calcium by H ions from the colloids with the consequent production of a dispersed condition of the colloids.

Just as H ions replace calcium from soil colloids under humid conditions, with the formation of an acid condition in the soil, sodium tends to replace calcium under arid conditions, with the formation of alkaline conditions. The replacement of calcium by sodium incident to the accumulation of a high concentration of sodium salts leads directly to significant changes in the physical, chemical and biological conditions of the soil. The sodium-saturated-exchange substances become highly dispersed when leached, and they undergo hydrolysis with the formation of sodium hydroxide. The net result is a condition extremely unfavorable, both physically and chemically, to plant growth. Just as in the case of acid soils, the remedy for sodium soil is calcium. Soluble calcium is able to replace the sodium, thus converting the colloids into a state of calcium saturation, which leads to biologically favorable physical and chemical conditions in the soil (23).

Erdman (14) studied the effect of gypsum on Iowa soils. He conducted two experiments wherein the first was to determine the chemical and bacterial effects of gypsum on Iowa soils. The Shelby loam, having only 525 pounds of total phosphorus per acre, showed the largest amount of water-soluble phosphorus of any of the soils. With this soil the 200-pound gypsum treatment caused a slight increase in water-soluble phosphorus, whereas the 20,000 pound treatment decreased the solubility. With the Marshall silt loam the small application of gypsum increased slightly the solubility of the soil phosphorus while the heavy treatment had no effect. Neither of the gypsum treatments exerted any effect on the phosphorus of the Carrington loam. The 200-pound gypsum treatment increased water-soluble phosphorus of the Webster loam, but the difference was too small to be significant. Considering all of his results, it is evident that the heavy application of gypsum had no effect on the content of water-soluble phosphorus of these soils while the 200-pound treatment gave a slight, though unmistakable, increase in all the soils studied except the Carrington loam. The water-soluble potassium obtained from the 200-pound gypsum treatment was less in all the soils, except one, than that extracted from the untreated soils. The excessive gypsum treatment brought about a decided increase in the solubility of the potassium, in each soil type studied, the amount of potassium in the water extracts varying with the type of soil. In the second experiment the effect of gypsum on phosphorus and potassium, was determined on a neutral Carrington loam. Gypsum was added to this soil with or without $CaCO_3$. It was concluded that gypsum in small amounts may increase the solubility of the phosphorus and potassium in some soils. In others, no effect may appear.

Shedd (42) studied the influence of sulfur and gypsum on the solubility of potassium in Kentucky soils. In the majority of treatments without $CaCO_3$, the amount of K soluble in $NH_4NO_3$ solution was larger than the combined amount obtained by distilled $H_2O$ and 0.2 N $HNO_3$, whereas with this base present, it was less. Moreover, with the same solvent, when $CaCO_3$ was present in the treatment, the K obtained was generally less than that extracted from the untreated soil.

Vanschaik (46) in a study on the influence of adsorbed sodium and gypsum content on permeability of glacial till soils concluded that the permeability of glacial till soils having mainly montmorillonite in the clay fraction was negligible when the exchangeable sodium percentage (ESP) exceeded 15 to 20%. Relatively higher permeability values were obtained in soils containing gypsum, but water transmission through such soils was negligible above ESP of 30 to 35%.

Scot and et al. (39) in a study on the problem soils in southern New South Wales emphasizes that application of gypsum to Na-clay soils gave improved flocculation, leading to greater water infiltration and better seedling emergence. Mahmoud, et al. (27) in a pot experiment concluded that applying gypsum to an alkali clay soil in appropriate amounts to replace exchangeable Na in a clay complex gave faster and better results than applying the corresponding amounts of sulfur. Total microbial flora, azotobacter, nitrifiers and aerobic cellulose decomposers increased in number, while spores of aerobic spore formers, streptomycetes and clostridia decreased as reclamation proceeded. Cultivation of such reclaimed soils benefited the microbial flora. Plant vigor, which was regarded as an index of the improvement of physio-chemical and biological properties of soil due to reclamation was better with gypsum applied high rates of 8, 12.1 and 9.68 ton/faddan (1 faddan = 1.038 acre) was better than lower rates.

Sandhu and Bhumbla (38) studied the effect of different organic materials and gypsum on soil structure. Addition of sugarcane trash, alone and with gypsum, significantly improved aggregation (into greater than 0.25 mm particles) non-capillary porosity, hydraulic conductivity, volume weight, and other physical properties of a silty clay loam soil. The effects persisted for more than six months. Rice husks residue produced some improvement but was much less effective than sugarcane trash.

Abrol and Bhumbla (1) studied salt leaching in a highly saline-sodic soil wherein the effect of continuous and intermittently ponded water, with or without the application of gypsum, was studied on the leaching (redistribution) of salts in a highly saline-sodic soil. The results of 42 days leaching tests showed that whereas gypsum greatly enhanced leaching of salts, intermittent ponding had no particular advantage over continuous ponding treatments. This is ascribed to the low permeability of sodic soils resulting in water movement in unsaturated conditions even in continuously ponded treatments. Apart from increased depth of salt leaching in gypsum treated plots, the salts underwent considerable dispersion and were distributed to a greater soil depth. This resulted from changes in the pore size distribution and resulting velocity distribution within water flowing through soil pores. Chaudry and Warkentin (9) have shown the relative ease of replacement of Na from clay minerals in the following order: attapulgite > kaolinite > halloysite > illite > montmorillonite.

Ririe, Toth and Bear (35) studied the movement of CaO, $CaCO_3$, $Ca(OH)_2$, $CaCO_3.MgCO_3$, $Ca(OH)_2$ + MgO, MgO and $CaSO_4.2H_2O$ in Norton silt loam and Sassafras sandy loam, soils of widely different characteristics. The materials were incorporated into the top 3 inches of soil at rates equivalent to the H in the exchange complex of the entire 7½ inch soil column. In both soils, the Ca of $CaSO_4.2H_2O$ was lost more rapidly than that from any of the liming materials. Whereas the K losses from both soils were increased by the use of $CaSO_4.2H_2O$. Loss of Na was repressed on both soils by use of $CaSO_4.2H_2O$, however, loss of Mg increased.

Bridge and Tunny (8) investigated the pore-space relation and swelling properties of natural clods from the A and B horizons of a clay soil using a saran resin coating technique. Three treatments were applied to the clods; first, wetting with distilled water; second, wetting with saturated gypsum solution; and third, wetting with distilled water following gypsum treatment of a field at the rate of 15 metric tons/ha. Results showed that gypsum treatment limited the amount of swelling in the clods, gypsum treatment in the field being as effective as treatment with saturated gypsum solution. This effect is attributed to the replacement of $Na^+$ by $Ca^{++}$ on the clay exchange sites rather than to changes in the electrolyte concentration within the clods. Gypsum treatment improved the air filled pore space in clods from the B horizon with a 59% pore content; at moisture contents between 0.1 bar and 15 bars the air filled pore space ranged from 3 to 7% by volume in the untreated clods and from 5 to 12% by volume in the gypsum-treated clods.

Ankist (2) applied gypsum at 7 - 10 ton/ha to a moderately columnar, finely columnar and a crusted solonetz soil. The treatment did not effect the solubility (in 1% $(NH_4)_2SO_4$) of soil P or of applied phosphate P. The decrease produced by gypsum in the P content of an aqueous extract was not accompanied by a decrease in millet yield or by decreased removal of P by the millet in a pot experiment. The decrease in the solubility of soil P in water must decrease leaching of P into the lower horizons, and this is important during irrigation.

Hernando, Sanchez Conde and Contreras (20) in a experiment with a gypsum soil with moisture maintained at levels of 15 - 100% of field capacity, a $H_2O$ level of 80% field capacity gave best growth of wheat and maize. Nutrient uptake was about the same at moisture contents of 30 and 60%. The moisture content had more effect on the growth of wheat than of maize. When gypsum was added to the soil to bring $CaSO_4$ contents to 25, 50 and 75% and moisture was kept at 20, 60 and 80%, the higher $CaSO_4$ contents caused smaller growth of maize, especially at 80% moisture. Wheat appeared to show minimum growth at 25% gypsum content at the various moisture levels. For a given moisture level, loss of moisture from plants decreased as gypsum level rose. Sen and Taneja (40) found that moisture retention in sandy loam of pH 7.2, treated with different organic manures was unaffected by the application of gypsum. In such soils gypsum might depress nitrification when organic matter like farm manure was present, with large quantities of low-N manure denitrification might be induced by heavy applications of gypsum. There were large increases in N in soils receiving heavy manuring from leguminous plant material plus 1 ton/acre gypsum. Gypsum reduced N loss in soils receiving large applications of legume litter.

Boekel (6) says that application of lime, $CaSO_4$, sulfur or sugar factory lime improved the structure of heavy clay soils and attributes the beneficial effects were due to an increase of the Ca-ion concentration in the soil solution and varied according to the solubility of the amendment. The slightly soluble $CaSO_4$ produced a quick action of short duration because the Ca ions are rapidly leached away; sugar factory lime has a more lasting effect and acts more quickly than ordinary lime; the solubility of marl and similar materials is too low to have any marked effect other than on soil pH.

Martin, Vlamis and Stice (28) carried out an experiment by broadcasting and discing into a serpentine soil 1 to 8 tons/acre of $CaSO_4$ and found a considerable increase in yields of barley hay and oat vetch hay in the second and up to the fourth season after application. Yield increases occured where the Ca saturation of the soil in the surface 6 inches was increased to above 16 - 20% as compared with 8 - 10% in untreated plots.

Tsai, Lee and Shen (45) in a lime experiment applied Ca-containing materials to a deep-plowed field and paddy rice field and found that Ca-containing materials tended to increase the yield of sugarcane and the effect of gypsum was similar to that of lime, but inferior to that of sugar factory filter cake.

Sharma, Fehranbacher and Jones (41) says that under the humid-temperate climatic conditions of Illinois, the high Na content of natric horizons can be reduced and corn yields on natric soils can be increased greatly by mixing high rates of gypsum with soil to a depth of 90 cm and installing tile at the 90 cm depth with no more than about 9 or 10 m spacing to carry the sodium out of the profile in drainage water.

A number of field experiments were done to determine the effect of gypsum on different crops grown on various soil types by Erdman (13, 14) in a study of gypsum effect on various crops and he concluded that in the first place it is quite apparent from both the chemical data and field work that the soil type plays a prominent part in the effects of gypsum on soils. The smaller application of gypsum did not have any effect on ammonification and nitrification, while the larger amounts were slightly unfavorable to these bacterial processes. The results on carbon dioxide production shows that gypsum did not hasten the decomposition of the soil organic matter except perhaps, in a highly basic soil. In the field experiments, gypsum proved favorable on the clover and small grain crops in several instances. Gypsum at the rate of 200 pounds per acre exerted a distinctly beneficial effect on the production of alfalfa hay.

Arzani (3) in a field experiment applied gypsum at 240 kg/ha in the late autumn which gave a total hay yield of 22764 kg/ha in the following season and sulfur at 4.46 kg/ha gave a yield of 20639 kg/ha, compared with 18236 kg/ha from the control. Ca applied as $CaCO_3$ at 6.97 and 13.94 kg/ha gave seed yields of 124 and 117 kg/ha, respectively, compared with 98 kg/ha from the control. $CaCO_3$ application increased absorption of N, P and Ca, gypsum increased absorption of K and sulfur increased P absorption.

Hallhock and Garren (18) studied the pod breakdown, yield and grade of Virginia type peanuts and concluded that above normal rates of $CaSO_4$ up to 3090 kg/ha reduced pod breakdown in Arachis hypogeae. The incidence of pod breakdown was significantly lower in pods that contained about

0.2% Ca or more than in those containing 0.15% Ca.

Mostafa and Ulrich (30) used electrical conductivity of the culture solution to serve as a control for the determination of the calcium ionic activity coefficient. Both the calcium concentration and its activity in culture solution were monitored as the plants were growing. Sugar beet plants at low external calcium supply developed calcium deficiency symptoms even though the calcium in solution as measured by its concentration or activity was still relatively high.

Vlamis (47) studied the growth of lettuce and barley as influenced by degree of calcium saturation of soil, wherein gypsum treatments were added to the complete N, P and K nutrients. As a further test, additional pots were leached separately with single-salt solutions of $CaSO_4$, $MgSO_4$ and $K_2SO_4$. After removal of the excess salts with water, each pot received the standard amounts of nutrients. The yields of lettuce were increased by the addition of gypsum or by leaching with $CaSO_4$ in conjugation with the N, P, K nutrients. The increase in amount of growth and the improvement in appearance of the plants grown on soils treated with gypsum or leached with $CaSO_4$ pointed to a Ca deficiency or a Mg toxicity, or possibly both.

Salonen, et al. (37) studied gypsum as a constituent of a multinutrient fertilizer. In pot experiments with oats on five different soils, inclusion of gypsum in a granulated fertilizer mixture of diammonium phosphate and potash salts gave highly significant yield increases.

Loveday and Scotter (25) used small pots in an open greenhouse to study the emergence response of clover to dissolved $CaSO_4$ on soils covering a wide range of clay and exchangeable Na levels. The most significant effect of $CaSO_4$ treatment was a delay in the air drying of the surface soil, due to improved moisture transmission from beneath. Relationships between emergence and response to $CaSO_4$ on the one hand and clay content and ESP on the other were a reflection of the relationship of these soil properties to porosity and moisture transmission.

Grinchenko, Shelkar and Ponomareva (17) showed that application of 1 - 3 cwt/acre raw gypsum powder at time of sowing increased pod protein of pea by 3 - 18% and pea-chaff protein by 17 - 85 %. 10 kg/ha of superphosphate increased pod protein by 38 - 71 %. Protein content of seeds was increased by 18 - 32 % by gypsum and 23 - 26 % by superphosphate. Grinchenko et al. (16) in a similar experiment found out that application of 1 - 3 quintals/ha of gypsum or sugar-factory lime increased the root yield of sugar beet by 22 - 28 q/ha and yields of grain by 3.5 q/ha and also improved grain quality.

Downey (11, 12) designed an experiment to study the effect of gypsum and drought stress on growth, water status and yield with maize (*Zea mays*, L.). Gypsum and no-stress conditions stimulated tiller production so that the final effective plant densities were above optimum. The no-stress treatments produced large amounts of dry matter but this was channeled into sterile tillers rather than into grain. Rixon (36) similarly has shown a complex interaction between nitrogen and gypsum; stimulated tillering may be due to increased availability of nitrogen, with the improved aeration that follows gypsum application.

Fried and Peech (15) conducted an experiment to investigate whether calcium deficiency or some other factor associated with soil acidity is the primary cause of poor plant growth on acid soils by comparing the effects of gypsum and lime on plant growth and chemical composition.

They concluded that the plants grown on limed soils absorbed much more calcium and gave much higher yields than those grown on gypsum-treated soils despite the higher concentration of calcium in soil solution in the gypsum treated soils. This indicated that the poor growth of plants on acid soils is not necessarily due to the lack of an adequate supply of calcium, but that the response of crops to lime on acid soils is quite complex, involving several contributing factors such as toxicity of manganese, iron and aluminum, the relative significance of which probably varies with different crops and soils.

Khosla, Dargan, Abrol and Bhumbla (24) carried out an experiment with a saline-sodic soil containing high amounts of carbonate and bicarbonate applied gypsum at 0.0, 13.5 and 27.0 tons/ha incorporated into the soil at depths of 10, 20 and 30 cm. The effect of treatments on soil properties and yield of barley, rice and wheat grown in succession were studied. When gypsum was mixed at greater soil depths, the yields were lowered. Only barley yielded higher when gypsum at 27.0 ton/ha was mixed at a depth of 20 cm than at a depth of 10 cm. Gypsum was less effective in improving the soil physical and physio-chemical properties when mixed at greater soil depths, and less of the calcium was available for plant growth. The rice crop was highly effective in reducing the soil pH and electrical conductivity, irrespective of the treatments.

Bhumbla and Poonia (5) in a pot experiment evaluated the effect of exchangeable-sodium percentage (ESP) on the availability of Ca from added $CaSO_4.2H_2O$ and $CaCO_3$ to barley (Hordeum vulgare, L.), dhaincha (Sesbania cannabina (Retz.) Pers.) and maize (Zea mays, L.). The content of Ca from added gypsum was maximum in barley followed by dhaincha and maize.

Subbiah and Singh (44) evaluated the efficiency of gypsum as a source of sulfur to oilseed crops. Groundnut (*Arachis hypogeae*, L.), mustard (*Brassica juncea*, L. var. Sarson Prain) and soy bean (*Glycine max*, L. Men.) were grown in pots under greenhouse conditions on soils deficient in available sulfur. Gypsum was as efficient as other standard sulfur sources such as ammonium sulfate and sodium sulfate.

CHAPTER III

MATERIALS AND METHODS

The effect of gypsum ($CaSO_4.2H_2O$) on growth of millet plants (Millex - 23) was studied at four gypsum treatment levels and a check treatment which received no gypsum. The experiment was conducted at the Oklahoma State University Controlled Environmental Research Laboratory in a growth chamber. The treatments of the experiment were arranged in a completely randomized design. There were four replications and five treatments including the check.

Port silt loam soil (Cumulic Haplustoll) was collected from the West Agronomy farm and pulverized to 20 mesh. Twenty #10 sheet iron cans lined with plastic bags were filled with 3 kg of soil in each pot.

TREATMENTS:

1. Fertilizer:

   (a) 0.4 gm $NH_4NO_3$ per pot as a solution.

   (b) 0.4 gm $Ca(H_2PO_4)_2$ per pot as a solution.

2. Gypsum

   (a) None (Check)

   (b) 0.1% Gypsum 3 gm/pot

   (c) 1.0% Gypsum 30 gm/pot

   (d) 5.0% Gypsum 150 gm/pot

   (e) 10.0% Gypsum 300 gm/pot

The above treatments of fertilizers and gypsum were thoroughly mixed with soil in the pot and 20 seeds of millex - 23 (Panicum miliaceum, L.) per pot were sown on January 29, 1975 and thinned to 10 seedlings after germination and finally to 5 plants in each pot. After sowing, the pots were immediately watered to field capacity. This was done by assuming 50% of the bulk of the soil as pore space and about 50% of the pore space as the saturation volume at field capacity. No provision for drainage was made. All the 20 pots were arranged in a completely randomized design in the growth chamber and the pots received twelve hour day light and twelve hour night with a $75^{o}C$ temperature during day hours and $65^{o}C$ temperature during the night hours. The pots were checked every day for pot weight and water added whenever the pot weight fell by 25% of that added.

The 20 pots were harvested after 45 days on March 15, 1975. The height of each plant in all the twenty pots were measured in inches and the wet weight of the five plants in each pot were also measured in grams. The above plant samples collected were oven dried and weighed for dry weight. Subsequently, all the twenty samples were ground for plant analysis.

The above experiment was repeated during the summer months of 1975 using the Clairemont sandy loam (Typic Ustifluvent) and planted as described above. The 20 pots were arranged in the growth chamber in a completely randomized design. The plants were harvested after 45 days on July 7, 1975. The wet weight was measured and the plant samples oven dried for dry weight and the samples ground for plant analysis.

The 20 plant samples of Experiment I were analyzed for % calcium and magnesium using the Atomic Absorption Spectrophotometer. One gram of the plant sample was weighed and 10 ml of (3 parts of $HNO_3$

and 1 part of $HClO_4$) was added and left to digest for 24 hours and then heated until $HClO_4$ completed the digestion. After the digestion was completed the contents were washed with distilled water into a 25 ml volumetric flask and contents brought up to volume. The samples were read on the Atomic Absorption Spectrophotometer by using Ca and Mg lamps. The readings were compared to standards and the % Ca and Mg calculated.

The 20 plant samples of Experiment II also were analyzed for Ca, Mg, K and Na by the above procedure and the % Ca, Mg, K and Na calculated.

# CHAPTER IV

## RESULTS AND DISCUSSION

Erdman (14) who worked on oats showed the results of the effect of application of gypsum on oats as shown in Table XII. The gypsum treatments had practically no effect on the growth of oats. Slight gains were noted in the case of the 500 and 1000 pound gypsum treatments with lime, but these were too small to be significant.

In another experiment Erdman applied 200 pounds of gypsum which gave an increase of 11.9 bushels of oats per acre over the average of the two check plots. The plot receiving lime alone was low and therefore no comparison can be made between it and the three plots receiving lime and gypsum. In another experiment gypsum caused a noticeable increase in the yield of oats. The 200 pound application gave a gain of 8.2 bushels of oats; 500 pounds gave a gain of 4.8 bushels, while the plot receiving the large application of gypsum showed an increase of 15 bushels per acre when compared with the first check plot. The plot with 500 pounds of gypsum and lime showed an increase of 10.9 bushels per acre over the plot receiving lime alone while the 200 and 1000 pound gypsum treatment with lime showed only small increases.

The results of the experiment reported here showing the effect of gypsum on yield composition of plants are given in the Table XIII. In the Experiment I there is a gradual increase in height, wet and dry weight of the plants as the treatment level of gypsum increased from

TABLE I

ANALYSIS OF VARIANCE FOR VARIABLE HEIGHT OF MILLET PLANTS IN EXPERIMENT I

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 29.169 | 15.766** | 0.0001 |
| Linear | 1 | 83.260 | 45.003** | 0.0001 |
| Quadratic | 1 | 21.163 | 11.439** | 0.0041 |
| Residual | 2 | 6.126 | 3.311 | 0.0633 |
| Error | 15 | 1.850 | | |

**Significant at .01 level of probability.

TABLE II

ANALYSIS OF VARIANCE FOR VARIABLE WET WEIGHT OF MILLET PLANTS IN EXPERIMENT I

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 94.487 | 3.665* | 0.0280 |
| Linear | 1 | 137.171 | 5.32* | 0.0358 |
| Quadratic | 1 | 72.738 | 2.82 | 0.1137 |
| Residual | 2 | 84.020 | 3.26 | 0.0656 |
| Error | 15 | 25.779 | | |

*Significant at .05 level of probability.

none (check) to 10% gypsum. An analysis of variance was done on these variables and the Linear and Quadratic effects studied. The AOV on height shows a small error variance and there is a quadratic curve (Figure 1). The AOV on height indicates a difference in growth of the plant height due to the difference in the treatments. It also indicates a linear (upward) and quadratic effect in the growth of the plant height due to the increase in gypsum level. The graph of height versus treatment levels shows no significant increase in plant height after 5% gypsum level. It is observed that for every increase in 1 kg of the gypsum the plant height increased to 5/10 th of an inch.

In a study of the wet weight of the millet plants harvested, the plant wet weight increased as the treatment level of gypsum increased. The AOV indicates a linear (horizontal) trend in the wet weight due to the increase in gypsum level. The quadratic trend was not significant. It showed that as the level of gypsum increased so did the wet weight of the harvested plants. The line was fairly linear or straight and the quadratic effect was very small (Figure 2). For every increase in 1 kg of the gypsum, the wet weight increased by 7/10 th of a gram.

The dry weight of the plants showed a significant increase in weight, proportionate to the increase in treatment levels of gypsum. Here the error variance was very small and the analysis indicates that there is a linear trend (upwards) and the curvature is quadratic (Figure 3). As the gypsum level increases the dry weight of the plants also increases linearly and quadratically. Above the 5% gypsum level there was not much difference in dry weight of the plants.

The results of plant yield in Experiment II are shown in Table XIII. The linear effect was very small and the data fits a quadratic response

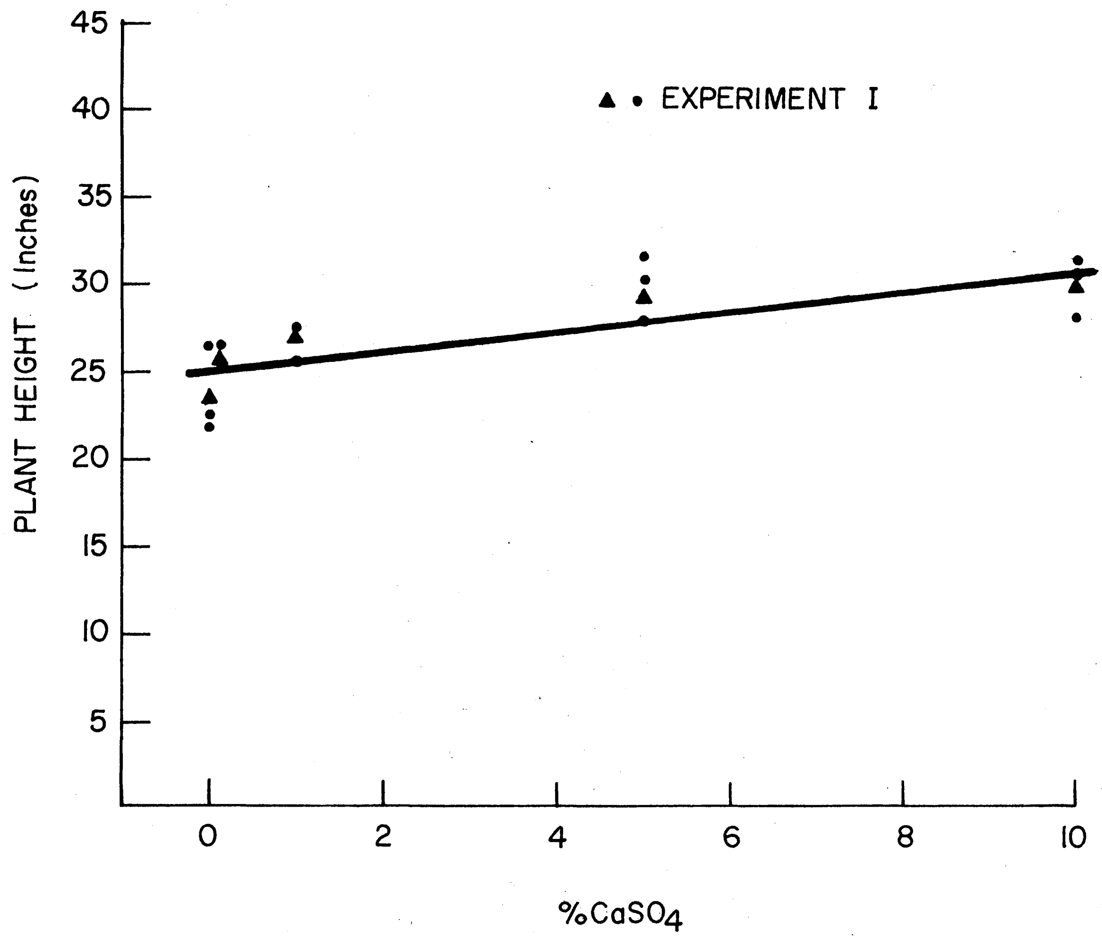


Figure 1. Height Response Curve for Experiment I

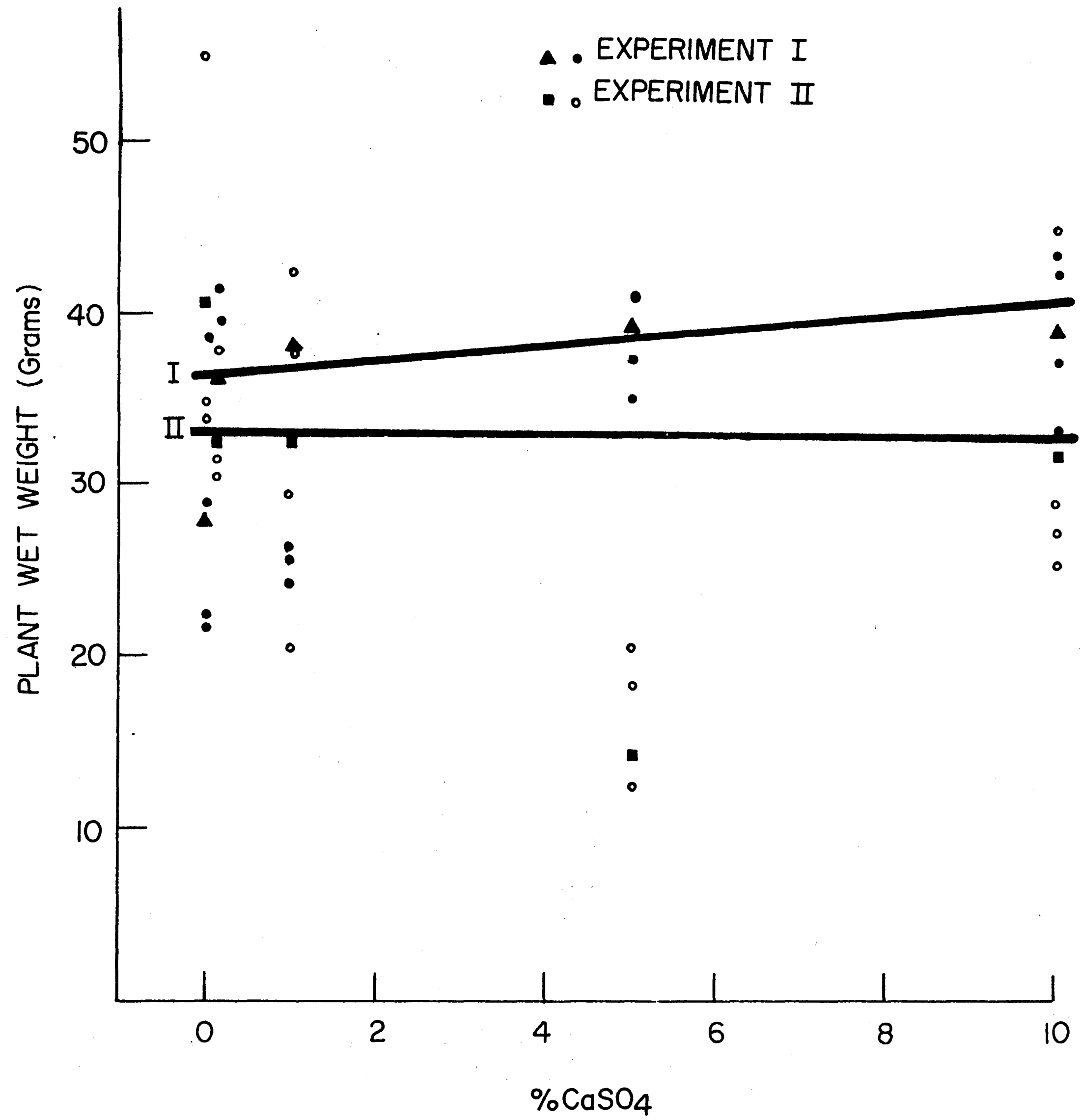


Figure 2. Wet Weight Response Curve for Experiment I and II

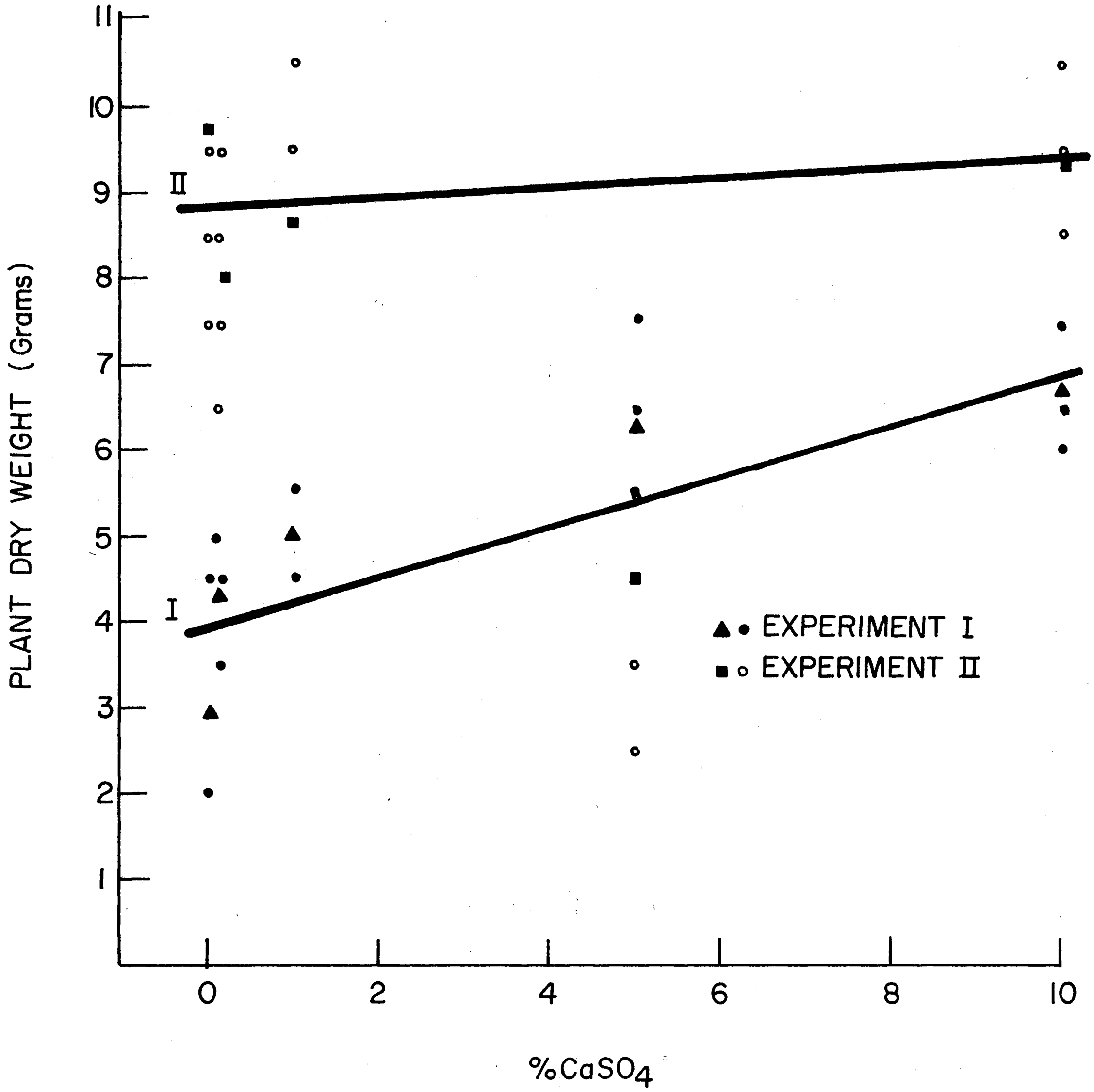


Figure 3. Dry Weight Response Curve for Experiment I and II

TABLE III

ANALYSIS OF VARIANCE FOR VARIABLE DRY WEIGHT OF MILLET PLANTS IN EXPERIMENT I

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 9.281 | 13.418** | 0.0002 |
| Linear | 1 | 27.121 | 39.211** | 0.0001 |
| Quadratic | 1 | 5.065 | 7.323* | 0.0163 |
| Residual | 2 | 2.469 | 3.570 | 0.0529 |
| Error | 15 | 0.691 | | |

*Significant at .05 level of probability.
**Significant at .01 level of probability.

TABLE IV

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE Ca OF MILLET PLANTS IN EXPERIMENT I

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 0.005 | 10.195** | 0.0005 |
| Linear | 1 | 0.015 | 29.067** | 0.0001 |
| Quadratic | 1 | 0.003 | 6.637* | 0.0211 |
| Residual | 2 | 0.001 | 2.537 | 0.1111 |
| Error | 15 | 0.0005 | | |

*Significant at .05 level of probability.
**Significant at .01 level of probability.

TABLE V

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE Mg
OF MILLET PLANTS IN EXPERIMENT I

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 0.002 | 2.871 | 0.0593 |
| Linear | 1 | 0.004 | 4.957* | 0.0417 |
| Quadratic | 1 | 0.005 | 0.582 | 0.4572 |
| Residual | 2 | 0.002 | 2.973 | 0.0805 |
| Error | 15 | 0.0009 | | |

*Significant at .05 level of probability.

TABLE VI

ANALYSIS OF VARIANCE FOR VARIABLE DRY WEIGHT
OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 17.425 | 5.531** | 0.0063 |
| Linear | 1 | 1.378 | 0.437 | 0.5184 |
| Quadratic | 1 | 57.616 | 18.291** | 0.0007 |
| Residual | 2 | 5.352 | 1.699 | 0.2152 |
| Error | 15 | 3.150 | | |

**Significant at .01 level of probability.

TABLE VII

ANALYSIS OF VARIANCE FOR VARIABLE WET WEIGHT
OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 393.800 | 5.553** | 0.0063 |
| Linear | 1 | 224.160 | 3.160 | 0.0957 |
| Quadratic | 1 | 1213.396 | 17.110** | 0.0009 |
| Residual | 2 | 69.321 | 0.970 | 0.5964 |
| Error | 15 | 70.916 | | |

**Significant at .01 level of probability.

TABLE VIII

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE Ca
OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 0.029 | 1.295 | 0.3157 |
| Linear | 1 | 0.004 | 0.201 | 0.6601 |
| Quadratic | 1 | 0.091 | 4.092 | 0.0613 |
| Residual | 2 | 0.009 | 0.444 | 0.6543 |
| Error | 15 | 0.022 | | |

curve. The average wet weight of the plants decreased in treatment 2 where the level of gypsum treatment was 0.1% and was fairly constant in all the other treatment levels including the 10% gypsum treatment. Figure 3 shows that the dry weight of the above plants have the same effect but there is a slight increase in dry weight between the 5% level and the 10% level.

The results of the plant composition of Experiment I in response to Ca and Mg is shown in Table XIV. A glance at the % Ca in the plants reveal that as the gypsum level was increased the % Ca in the plants decreased gradually. The Analysis of Variance predicts that there is linear as well as quadratic effect in the % Ca present in the plants (Figure 4). The error variance is small and shows that as the gypsum level increases the % Ca in plants decreases. The linear trend was downwards and the curvature was quadratic. There was not much difference in % Ca above the 5% gypsum level. The % Mg in the above plants the analysis shows a linear trend downwards. As the gypsum level increased, the % Mg content in the plants remained fairly constant.

In Experiment II, the results of which are shown in Table XIV, the quadratic effect was significant and the linear trend was not significant. The % Ca content in the plants remained about the same as the gypsum level increased (Figure 4).

The % Mg content in the plants also remained constant as the gypsum level increased. The linear effect was not significant while the quadratic effect was significant.

The % K in the plants remained the same as the gypsum treatment increased. The analysis of variance showed no significant linear and quadratic trend in K due to the different gypsum level (Figure 5).

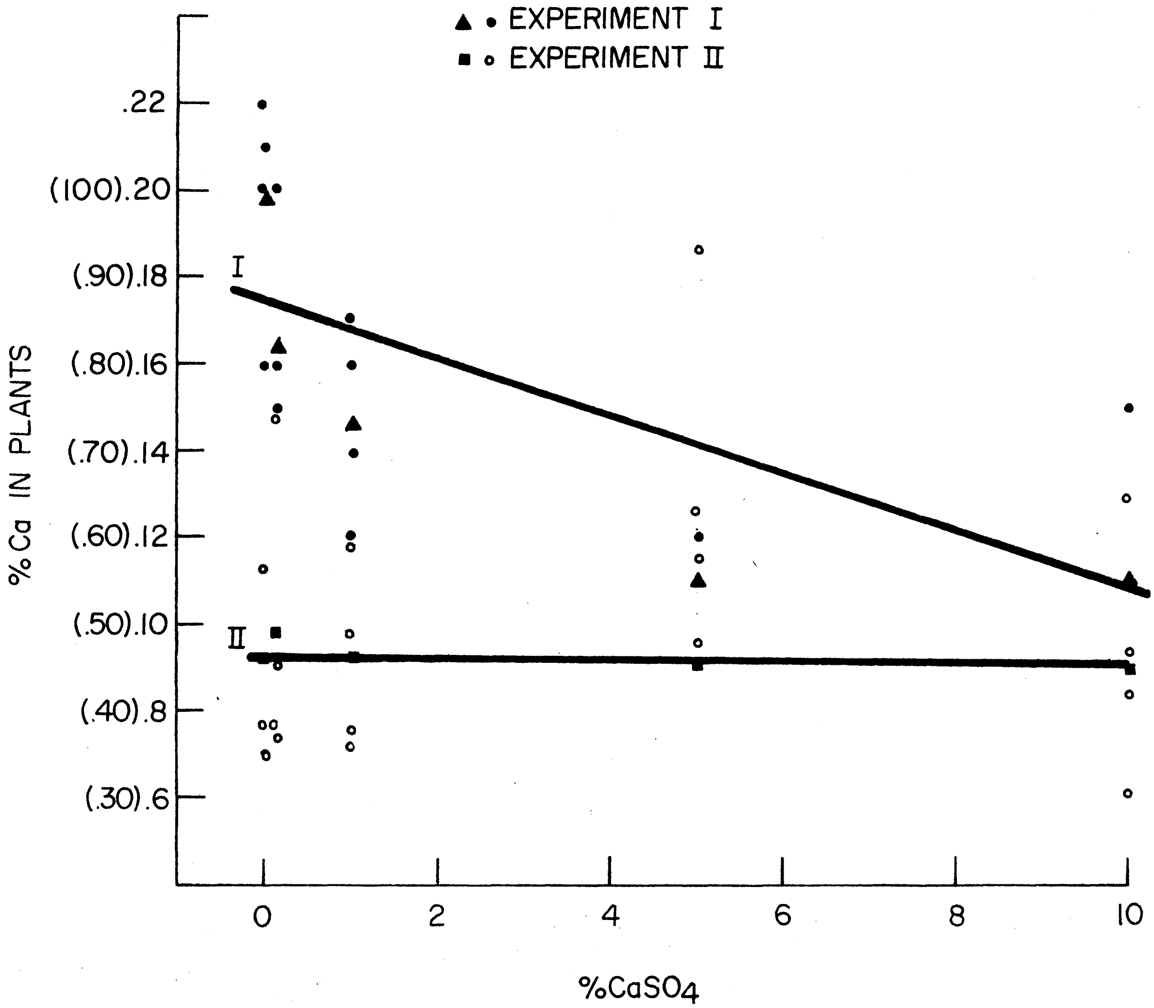


Figure 4. % Ca (in Plants) Response Curve for Experiment I and II

TABLE IX

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE Mg OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 0.022 | 1.956 | 0.1529 |
| Linear | 1 | 0.002 | 0.204 | 0.6575 |
| Quadratic | 1 | 0.070 | 6.149* | 0.0255 |
| Residual | 2 | 0.008 | 0.734 | 0.5002 |
| Error | 15 | 0.011 | | |

*Significant at .05 level of probability.

TABLE X

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE K OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 0.247 | 0.794 | 0.5483 |
| Linear | 1 | 0.764 | 2.456 | 0.1379 |
| Quadratic | 1 | 0.122 | 0.394 | 0.5396 |
| Residual | 2 | 0.051 | 0.164 | 0.8502 |
| Error | 15 | 0.311 | | |

TABLE XI

ANALYSIS OF VARIANCE FOR VARIABLE PERCENTAGE Na OF MILLET PLANTS IN EXPERIMENT II

| Source | df | M.S. | F Value | OSL |
|---|---|---|---|---|
| Treatments | 4 | 6.500000 | 1.875 | 0.1668 |
| Linear | 1 | 0.000011 | 3.293 | 0.0896 |
| Quadratic | 1 | 0.000009 | 2.791 | 0.1155 |
| Residual | 2 | 0.000002 | 0.707 | 0.5123 |
| Error | 15 | 3.466666 | | |

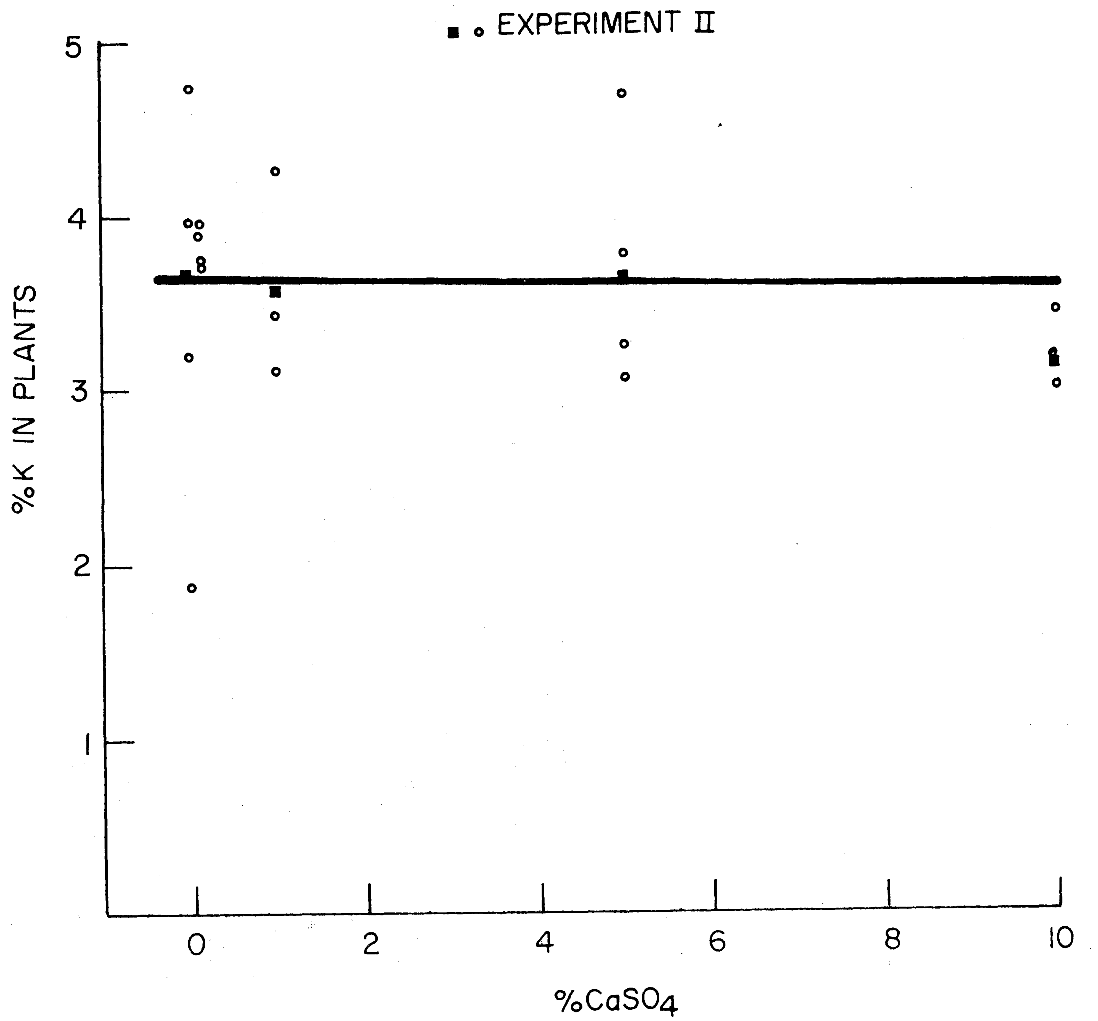


Figure 5. % K (in Plants) Response Curve for Experiment II

The % Na also remained the same as the gypsum level increased. The AOV indicates no linear and quadratic trend.

In general, Ca absorption and plant growth increases as the gypsum treatment increased. The amount of Ca necessary for optimum growth varies with plant species, but is generally higher for montmorillonitic than for kaolinitic clays.

Several investigators have shown that the availability of Mg and K also increases with the degree of base saturation, the soil ratio of Ca:K and Ca:Mg remaining constant as saturation is increased. Chu and Turk (10) found the K and Mg content of oats and rye grown on a bentonite-sand mixtures increased several fold as degree of base saturation rose from 20 to 80 percent. Raising K and Mg levels of the substrate by increasing the exchange capacity (adding more clay at the same degree of saturation) resulted in much smaller increases in the contents of these cations in the plants.

Although it is generally found that increasing the degree of saturation of a given ion increases its availability to plants, still a large number of studies have shown the availability of one ion to be greatly effected by the associated ions on the exchange complex. The complementary ion principle Jenny and Ayers (21) accounts for such findings. According to this, the exchangeability, and presumably the availability, of an exchangeable ion is greater the more strongly absorbed are the other exchangeable ions, the so called complementary ions. Thus, a given exchangeable cation, K for example, would be considered more available when the complementary ion is strongly adsorbed Ca, than when it is weakly adsorbed Na.

Thus, the data in the experiment shows that the growth of the millet plants was much better on the gypsum treated soils than the check soil which received no gypsum at all.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

An experiment was conducted in a growth chamber in the Oklahoma State University Controlled Environmental Research Laboratory, to find the effect of gypsum on the growth of millet plants (Millex - 23). The soil used for the purpose was Port silt loam (Cumulic Haplustoll) from the Agronomy farm. The above experiment was repeated during the summer months of 1975 using Clairemont sandy loam (Typic Ustifluvent) and the variety Sudax-millet. The treatments were (1) of Fertilizers and (2) Gypsum.

1. Fertilizer:

   (a) 0.4 gm $NH_4NO_3$ per pot as a solution.

   (b) 0.4 gm Ca $(H_2PO_4)_2$ per pot as a solution.

2. Gypsum:

   (a) None (Check)

   (b) 0.1% gypsum 3 gm/pot

   (c) 1.0% gypsum 30 gm/pot

   (d) 5.0% gypsum 150 gm/pot

   (e) 10.0% gypsum 300 gm/pot

The plants were harvested after 45 days and the yield and growth determined. After drying, the plants were analyzed for percentage Ca, Mg, K and Na.

Application of gypsum on Port silt loam and Clairemont sandy loams even at highest level of gypsum treatment, at the rate of 10% (w/w) in the above experiment showed a marked increase in height of the plants, wet and dry weights of the plants as compared to the non-treated plants.

The increase in height of the plants was gradual and showed a linear effect with a curvature of quadratic type. The wet weight and dry weight of the plants had similar effects and increased as the treatment level of gypsum increased. But it was not the same in Experiment II for variable wet and dry weight where the quadratic effect was highly significant.

It could be concluded that the high levels of gypsum had no toxic effect on the growth of millet plants even at the highest rate of gypsum at 10%. Instead the plants showed an increased growth in the gypsum treated pots. This could be attributed to the influence of gypsum on the soil properties. The improved soil structure might have improved soil water absorption and soil aeration leading to improved flocculation and better emergence of seedlings.

Erdman (14) used excessive quantities of gypsum and found that there was a marked increase in the amount of water soluble potassium in all the soils studied. This could have also happened in this experiment.

Whereas in the plant analysis composition the % Ca was higher in the plants grown in untreated soil than treated soil and showed a linear downward trend. The curve was quadratic and tells that the decrease in % Ca in treated plants was gradual but whereas in the Experiment II though the trend is downwards, the % Ca in treated plants is almost the same but less than the check.

The % Mg was higher in plants grown on untreated soil and decreased as the gypsum treatment increased, though Experiment II showed fairly constant % Mg among the treatments. The quadratic effect was between the check and the 1% treatment level.

The % K and Na in Experiment II exhibited the same trend throughout between the check and the treatments.

Thus, in general it could be concluded from the plant analysis that there was no change in Ca, Mg, K and Na in the millet plants due to increase in gypsum levels.

The question is, why do the millet plants contain low Ca in spite of high amounts of $CaSO_4.2H_2O$ treatments in the pots?

In a study by Subbiah and Singh (44) on the efficiency of gypsum as a source of sulphur to oilseed crops it was determined that though gypsum contains Ca as one of the constituents, gypsum proved a poor source of Ca and most of the calcium present in the plant was derived from the soil itself rather than from the fertilizer source. This low utilization of Ca may be attributed to either a high Ca pool already in the soil or to the low availability of Ca from the gypsum source, or both. Their investigation showed that gypsum was a poor supplier of Ca and its efficacy was only because of its sulfur content. Several workers have shown that gypsum is a poor source of calcium. Fried and Peech (15) found that the lime was superior to gypsum in supplying calcium to alfalfa. Ririe and Toth (34) used radioactive calcium in carbonate, sulfate and phosphate forms and found that calcium was most available to alfalfa as carbonate and least available as sulfate.

Kanwar and Chawla (22), from pot experiments on a sodic soil with graded doses of gypsum, reported that application of gypsum in quantities higher than 30% of gypsum requirement was not necessary.

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TABLE XII

THE EFFECT OF GYPSUM ON YIELD OF OATS PER ACRE

| Plot No. | Treatment | Carrington Loam Ames (bu.) | Fort Dodge (bu.) | Eldora (bu.) |
|---|---|---|---|---|
| 1. | Check | 44.2 | 52.4 | 48.3 |
| 2. | 200 lbs. Gypsum | 44.2 | 66.0 | 56.5 |
| 3. | 500 lbs. Gypsum | 46.6 | 56.5 | 53.1 |
| 4. | 1000 lbs. Gypsum | 46.3 | 51.0 | 63.3 |
| 5. | 200 lbs. Gypsum and lime | 44.5 | 57.8 | 57.8 |
| 6. | 500 lbs. Gypsum and lime | 46.6 | 57.8 | 65.3 |
| 7. | 1000 lbs. Gypsum and lime | 49.0 | 61.9 | 55.1 |
| 8. | Lime | 47.6 | 46.9 | 54.1 |
| 9. | Check | 44.2 | 55.8 | 61.9 |

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TABLE XIII

EFFECT OF GYPSUM ON GROWTH OF MILLET PLANTS (YIELD COMPOSITION)

| Pot No. | Treatments | EXPERIMENT I Avg. Height of 5 Plts (inches) | EXPERIMENT I Avg. Wet-Wt. of 5 Plts (grams) | EXPERIMENT I Avg. Dry-Wt. of 5 Plts (grams) | EXPERIMENT II Avg. Wet-Wt. of 5 Plts (grams) | EXPERIMENT II Avg. Dry-Wt. of 5 Plts (grams) |
|---|---|---|---|---|---|---|
| 1. | 1 | 26.15 | 38.5 | 4.5 | 40.5 | 9.5 |
| 2. | (Check) | 23.30 | 29.0 | 3.0 | 33.5 | 8.5 |
| 3. | | 21.80 | 21.5 | 2.0 | 55.5 | 13.5 |
| 4. | | 22.60 | 22.5 | 2.0 | 34.5 | 7.5 |
| 1. | 2 | 24.70 | 39.5 | 5.0 | 31.5 | 9.5 |
| 2. | 0.1% | 26.20 | 41.5 | 4.5 | 37.5 | 8.5 |
| 3. | (Gypsum) | 25.59 | 32.5 | 4.0 | 30.5 | 7.5 |
| 4. | | 25.76 | 30.5 | 3.5 | 31.5 | 6.5 |
| 1. | 3 | 25.75 | 38.5 | 4.5 | 20.5 | 5.5 |
| 2. | 1% | 27.80 | 41.0 | 5.5 | 42.5 | 9.5 |
| 3. | (Gypsum) | 27.35 | 35.0 | 4.5 | 37.5 | 10.5 |
| 4. | | 27.65 | 37.5 | 5.5 | 29.5 | 9.5 |
| 1. | 4 | 27.60 | 36.5 | 5.5 | 14.5 | 3.5 |
| 2. | 5% | 29.29 | 38.5 | 6.5 | 18.5 | 5.5 |
| 3. | (Gypsum) | 31.40 | 44.5 | 7.5 | 20.5 | 5.5 |
| 4. | | 30.05 | 39.5 | 5.5 | 12.5 | 2.5 |
| 1. | 5 | 28.06 | 33.5 | 6.0 | 25.5 | 85. |
| 2. | 10% | 30.45 | 37.5 | 6.5 | 29.5 | 8.5 |
| 3. | (Gypsum) | 31.24 | 43.5 | 7.5 | 27.5 | 9.5 |
| 4. | | 29.53 | 42.5 | 6.5 | 45.5 | 10.5 |

TABLE XIV

EFFECT OF GYPSUM ON GROWTH OF MILLET PLANTS (PLANT COMPOSITION)

| Pot No. | Treatments | EXPERIMENT I % Ca | EXPERIMENT I % Mg | EXPERIMENT II % Ca | EXPERIMENT II % Mg | EXPERIMENT II % K | EXPERIMENT II % Na |
|---|---|---|---|---|---|---|---|
| 1. | 1 | 0.16 | 0.19 | 0.38 | 0.38 | 3.19 | 0.015 |
| 2. | (Check) | 0.20 | 0.26 | 0.35 | 0.48 | 3.96 | 0.017 |
| 3. | | 0.22 | 0.28 | 0.56 | 0.51 | 2.88 | 0.011 |
| 4. | | 0.21 | 0.29 | 0.56 | 0.65 | 4.79 | 0.017 |
| 1. | 2 | 0.15 | 0.16 | 0.45 | 0.63 | 3.71 | 0.012 |
| 2. | 0.1% | 0.15 | 0.20 | 0.74 | 0.63 | 3.96 | 0.012 |
| 3. | (Gypsum) | 0.16 | 0.21 | 0.37 | 0.41 | 3.74 | 0.015 |
| 4. | | 0.20 | 0.24 | 0.38 | 0.45 | 3.87 | 0.015 |
| 1. | 3 | 0.17 | 0.22 | 0.59 | 0.63 | 4.29 | 0.017 |
| 2. | 1% | 0.12 | 0.17 | 0.36 | 0.44 | 3.60 | 0.015 |
| 3. | (Gypsum) | 0.16 | 0.24 | 0.38 | 0.41 | 3.13 | 0.011 |
| 4. | | 0.14 | 0.21 | 0.49 | 0.49 | 3.46 | 0.015 |
| 1. | 4 | 0.12 | 0.21 | 0.58 | 0.64 | 4.70 | 0.015 |
| 2. | 5% | 0.12 | 0.20 | 0.48 | 0.53 | 3.76 | 0.015 |
| 3. | (Gypsum) | 0.11 | 0.18 | 0.63 | 0.57 | 3.24 | 0.015 |
| 4. | | 0.11 | 0.20 | 0.93 | 0.84 | 3.08 | 0.015 |
| 1. | 5 | 0.11 | 0.20 | 0.65 | 0.50 | 3.46 | 0.012 |
| 2. | 10% | 0.9 | 0.20 | 0.47 | 0.42 | 3.03 | 0.012 |
| 3. | (Gypsum) | 0.9 | 0.15 | 0.42 | 0.47 | 3.03 | 0.012 |
| 4. | | 0.15 | 0.20 | 0.31 | 0.39 | 3.19 | 0.012 |

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