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To the Graduate Council:

I am submitting herewith a thesis written by T. Seshagiri Rao entitled "Ionic Concentration of Soil Water Held at Different Tensions". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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IONIC CONCENTRATION OF SOIL WATER

HELD AT DIFFERENT TENSIONS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

T. Seshagiri Rao

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CHAPTER I

INTRODUCTION

Water is indispensable for all life processes. In many instances water is the limiting factor for crop production. Not only farmers and agronomists are interested in problems relating to soil moisture, but ecologists, engineers, hydrologists and others are also interested in soil moisture. All have needed a practical way of measuring soil moisture each with a definite purpose peculiar to the problems each faces. Consequently, a number of methods of measuring soil moisture are available.

Soil moisture modifies the properties of the soil in a number of ways. Excess and deficit of moisture create problems which are not only entirely different but which require use of radically different management skills. One aspect of the effect of moisture deficit was studied and reported in this thesis.

The object of the investigation was to find out how the ionic concentration of moisture films changed due to a change in the energy with which such films were held.

CHAPTER II

REVIEW OF LITERATURE

Water is such a commonplace substance that many of its properties are taken for granted, and it is assumed that those properties will be more or less constant under all conditions. This is not, however, completely true. The properties of water are altered to a considerable extent by substances dissolved in it and by colloids with which it is associated.

The composition of water is simple but still it is a fairly complicated substance. In scientific terminology water is an asymmetrical molecule. The centers of gravities of positive and negative charges do not coincide. Due to this electrical imbalance water behaves like a charged body having a dipole. Hence it is a polar substance. It possesses a relatively high degree of reactivity, has a high dielectric constant and is a strong ionizing solvent. The dissociation of water is very small and yet it is sufficient to bring about a variety of chemical reactions such as hydration, hydrolysis and others all of which are involved to some extent in soil behavior (10, 14).

In the soil, water is present in pore space in the form of thick films whose movement is chiefly governed by gravitational force and also present in the form of thin films around the soil particles whose movement is governed by inter-facial forces such as surface tension. Briggs and his associates (3, 4) developed

the concept of capillary-tube hypothesis which considered the soil to be constituted of numerous capillaries of varying dimensions. Bouyoucos (5, 7) suggested a "new" classification of soil moisture and for the first time introduced the concept of "unfree" water. Buckingham (9) introduced the concept of using energy relationships to characterize soil-moisture phenomena. According to this concept the amount of water in the soil is a function of the energy with which water is held. The energy necessary to remove water from the soil is a continuous function of soil moisture.

The introduction of the more fundamental energy concepts in soil-water relationships has helped considerably to explain the movement especially of unsaturated flow. Due to the attraction of the soil for water molecules, the latter are held by the soil with a certain force. As the soil contains increasingly greater amounts of water, less energy is required to remove such water. But as the moisture content in the soil decreases, more energy is required to remove such water. Thus, at low moisture contents the soil holds water with a relatively greater force. As the thickness of moisture films decreases the physical and chemical properties of water will change.

Bouyoucos (5, 6) found from the freezing point and dilatometer methods that a portion of water in the soil did not freeze at all even at the extreme low temperature of -78°C . He concluded from his experiments that all water in the soil does not exist in the same condition. He defined water which did not freeze even at low temperature as "unfree" water. Mattson (18) also studied

the form and properties of water adsorbed on clay surfaces. Although he did not appear to accept the "unfree" water concept, he explained the phenomenon in terms of Donnan distribution.

Buehrer and Rose (10) have discussed the properties of "bound" water. It has been found that bound water possesses a number of unusual properties as contrasted with those of liquid water in its normal state. Buehrer and Rose defined bound water as that "water which fails to freeze at -3°C " and continued to state that "bound water must be looked upon as that portion of the total water present in a soil which is held by forces of electrostatic orientation or by capillarity, or in chemical combination, so that the properties which characterize free water have been markedly reduced in magnitude". Thus, bound water was found to have a dielectric constant of only 2.2 as compared with a value of 81 for free water. "Its low dielectric constant indicates a greatly reduced polarity and therefore its solvent power and dissociating action on salts and other substances must be considerably less than that of pure water." (10)

Anderson and Low (1), in recent years, studied the density of water adsorbed by Lithium-, Sodium-, and Potassium-Bentonite. They found that the density of water decreased continuously as the clay surface was approached. At distances of about $10\text{ \AA}$, the densities of water on Li-, Na-, and K-Bentonite were 0.975, 0.972 and 0.981 respectively. Their data also showed that the density of the water structure was less than that of pure water up to distances greater than $60\text{ \AA}$ but not exceeding $86\text{ \AA}$.

The studies cited show that the activity of water and hence its polarity is definitely decreased when it becomes associated with the active surfaces of the colloidal particles by way of sorption, chemical combination or electrostatic attraction.

The soil solution is one of the chief sources of nutrients to plants. Jenny's root contact exchange theory has not replaced this concept but has only supplemented it. The concentration of the soil solution at any given moment is a result of the equilibrium conditions existing in the soil as a result of the Mass Action effect. The concentration is not always the same. Research has shown that there is no such thing as a definite or true soil solution. Evaporation and plant growth continually alter the water content of the soil. This in turn affects the characteristics of soil solution films both qualitatively and quantitatively. Hence the composition of the solution films present in soils changes more or less continually.

It is generally believed that the solution around or in immediate contact with the soil particles is more concentrated than the mass of the solution. This is largely based on the application of the theoretical principles of adsorption by soil colloids, but Bouyoucos (8) presented experimental evidence to the contrary. By adding KCl solution to quartz flour he obtained a lower freezing point depression which he considered evidence that the solution surrounding the particles was more dilute than the bulk of the solution. In fact he used the dilatometer technique to identify

and determine "unfree" water which has reduced solvent power.

Mattson (18) distinguished two kinds of solutions surrounding clay micelle and classified them as micellar solution and the outside solution. From an application of the Donnan distribution of ions between the micellar and the outside solution, he predicted that the micellar solution would be less concentrated with respect to free electrolytes than the outside or intermicellar solution. Thus he reported the greater chloride concentration in the solution phase than in the diffuse ion swarm-layer surrounding the colloidal particle.

Drachev and Aleksandrova (12) noticed an increase in soluble potassium and phosphate when the moisture was increased. The concentration of calcium and nitrate decreased with an increase in soil moisture.

Martin and Christie (17) studied the water-soluble constituents of two soils of very different type, namely, sandy loam and silty clay loam, at four moisture contents. In both the soils there was a tendency for the depression of nitrate and potassium at moisture contents approaching the air-dry condition. The nitrate disappeared in sandy loam under excess water and potassium, calcium, and magnesium were also decidedly depressed.

Kelley (16) studied the effect of dilution on the water-soluble and exchangeable bases of alkali soils in its relation to the salt tolerance of plants. Dilution affected the amounts of water-soluble sodium more than water-soluble calcium and magnesium.

He found no marked effect of dilution on chloride and nitrate whereas the amounts of bicarbonate and sulphate were markedly decreased by dilution.

Eaton and Sokoloff (13) found differences in proportion as well as absolute amounts of constituents in 1:5 aqueous extracts of soils and in displaced soil solutions. They found that in 3 saline calcareous soils the dissolved calcium and magnesium decreased on dilution. They explained this on the basis of cation-exchange reaction which takes place when the water-soil ratio is increased. In this exchange, calcium enters the adsorbing complex and sodium is liberated. They called this process "dilution effect". They also obtained significant decreases in dissolved chloride in 3 soils on increasing moisture content from field moisture to 500%. Eaton and Sokoloff explained the decrease in chloride "as a result of 'unfree' water in which chloride salts were insoluble or less soluble than in ordinary water, so that chloride would become more concentrated in the 'free' water; with increasing moisture content the percentage of unfree water of the total moisture would be decreased and accompanied by a decrease in chlorides on the oven-dry basis".

Davis (11) found greater sodium chloride concentration in the external phase than in the suspension of a bentonite-NaCl system.

Reitemeier (20) studied the effect of moisture content on the dissolved and exchangeable ions of soils of arid regions. Dissolved ions of six soils were determined at four moisture contents,

field moisture, saturation percentage, 200% and 500%. The ions included calcium, magnesium, ammonium, potassium, carbonate-bicarbonate, sulphate, chloride, nitrate and phosphate. He noticed changes in soluble contents of all ions in all soils as a consequence of dilution. Potassium, sodium, ammonium, carbonate, bicarbonate, phosphate and sulphate increased in all soils with corresponding increases in moisture content. Calcium and magnesium increased in four soils and decreased continuously in one. He attributed the increases in these eight ions to ion-exchange and solution of solid compounds by additional amounts of water. The decreases in calcium and magnesium have been explained as a result of "dilution effect". Chlorides and nitrates decreased continuously in all soils. Reitemeier explained these anion decreases as a possible result of the existence of unfree water, negative adsorption of monovalent anions in neutral and alkaline soils, or a combination of the two mechanisms.

Mattson and Wiklander (19) have postulated that "negative adsorption" of anions may be due to either the existence of unfree water which does not act as a solvent or to a Donnan distribution of anions between the ion swarm layer of a colloidal particle and its external phase.

Reviewing the earlier work on the effect of moisture content on the soluble salts of various soils, Reitemeier (20) has summarized as follows. "In virtually all cases, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, phosphate and silicate

increased on dilution". Total nitrate may decrease or increase slightly. The usual net effect of increasing moisture is an increase in total dissolved salts."

Richards and Reitemeier (21), discussing the reliability of the pressure-membrane method for extraction of soil solution, hypothesized that due to the surface activity of soil colloids in which the exchanges of cations and possibly anions are involved, ionic concentration gradients are possibly established over finite distances from the surface of the finer soil particles. At each moisture content a solution is obtained which is representative of that condition. They found in general that the soil solution extracted by the pressure-membrane procedure remained constant in composition during the extraction. However, they point out that though the moisture film removed by these several methods is of homogeneous composition, the unremoved portion may be affected by the colloidal forces. They hinted that a possible answer, at least in part, might be found for the above question by a further application of the pressure-membrane technique involving the "fractional stepwise extraction" of solution at increasing moisture tensions. The work presented in this thesis makes an attempt to find an answer to this question.

CHAPTER III

METHODS AND PROCEDURES

The cations in the soil solutions of soils of different textures at various soil-moisture tensions were determined after extracting the soil solution by the pressure-membrane technique. The study was conducted at the Soil and Crop Laboratory, College of Agriculture, University of Tennessee, Knoxville, during 1959-1960.

The following soils of different textures were selected for study:

1. Sequatchie sandy loam
2. Sequatchie loam
3. Egam clay loam
4. Emory silty clay loam

The soil samples were collected in and around the Agricultural Experiment Station, Knoxville, and represent surface 6 inch layers.

The soils were dried, and passed through a 2 mm sieve. Sub-samples of each of the four soils were separately treated with normal solutions of calcium chloride, potassium chloride and sodium chloride to replace the cations, and the respective Ca-soil, K-soil and Na-soil were prepared. These prepared soils were used for the purpose of extracting soil solutions.

Pressure-membrane apparatus has been widely used in soil-moisture studies. The details of the manipulations are described by Richards (22, 23). However, certain salient points pertaining

to the study are given below.

An amount of 250 gms of Ca-soil was placed in the pressure-membrane apparatus and the soil was pressed gently and firmly to insure uniform contact with the membrane. Distilled water was then added to saturate the soil and allowed to remain for 3 to 4 hours to make sure that the soil was thoroughly wetted. Excess water was removed by a pipette. The soil was then subjected to increasing pressures in a stepwise fashion. At the start a pressure of one atmosphere was applied. After the end of 12 hours the extract that collected was removed, volume noted and the calcium content determined by the Beckman D U Flame Spectrophotometer. The pressure was then increased successively to 3, 7, and 15 atmospheres and the extracts were collected at the end of every 12 hour period, measured and analyzed as before. Similar extractions were carried out using K-soil and Na-soil each textural class of soils and the concentrations of the cations were determined as before. Distilled water was used for the extraction in order to avoid complications due to the interactions of the ions in tap water.

Similar extractions were carried out from all the different soils using neutral normal ammonium acetate as the extracting liquid. The extracts were analyzed as before. The cellophane membrane was soaked in the extracting liquid, ammonium acetate in this case.

Amounts of moisture in the soils at the same tensions at which extractions were done, were also determined by the pressure-membrane apparatus as described by Richards (23).

The analytical procedures for calcium, potassium, and sodium are given in Appendix A.

CHAPTER IV

RESULTS AND DISCUSSION

The data regarding the quantity of soil solution obtained by applying pressures from all the soils are presented in Appendix B.

The object of the study was to find out how the concentrations of the moisture films varied due to changes in the energy with which such films were held. Different soils and extractants might modify any concentration changes arising because of increasing tension.

So the results are discussed separately to evaluate the effects due to soils, extractants and tension although the dominant factor of influence in all these cases is soil-moisture tension. The extracting liquids used will be simply referred to as water medium and ammonium acetate medium for the sake of brevity.

The Relation Between the Pressure and the Radius of Curvature of the Moisture Film

The excess pressure on the concave side of a liquid film is dependent on the radius of curvature of the surface and on the surface tension of the liquid. This can be calculated by the following equation:

$$P = \frac{2v}{r}$$

where P = Pressure inside the film in dynes per sq. cm.

v = surface tension of water in dynes per cm. at 20° C.

r = radius of curvature of the water film in cms.

Since the applied pressure and surface tensions were known, the radii of curvature of the moisture films at the various pressures were calculated and are presented in Table I.

The Effect of Soil-Moisture Tension on the Ionic Concentration of Soil Solution

Water medium: The results are presented in Table II and are shown graphically in figures 1 through 7.

Data from Table II were statistically analyzed and correlation coefficients were calculated between concentration and soil-moisture tension. Correlation coefficients for the limited data may not be too reliable, nevertheless, they have been calculated for giving a more definite idea of various relationships than would be possible by mere visual comparison. The results are presented in Table III.

Calcium. A negative correlation of concentration with tension was observed. As the soil-moisture tension increased the concentration of the calcium in the extracted soil-solution decreased. This showed that the unremoved portion of the moisture film was less and less concentrated. The value of the negative correlation increased numerically with the textural change in the soil from coarse to fine.

Potassium. The concentration of potassium like the concentration of calcium also decreased with increased tension except in loam soil.

Sodium. Except in clay loam there was a positive correlation which indicated that the concentration of the unremoved moisture

TABLE I

THE RELATION BETWEEN TENSION AND THE RADIUS OF
CURVATURE OF THE MOISTURE FILM

Pressure Atmospheres	Radius of Curvature of the Moisture Film in Angstroms
1	14000
3	4700
7	2000
15	960

TABLE II

IONIC CONCENTRATION IN PPM OF WATER EXTRACTS BETWEEN
DIFFERENT TENSIONS FROM SOILS OF FOUR TEXTURES

Soil Texture	Soil-moisture Tension Range in Atmospheres	Calcium	Potassium	Sodium
		<i>Soil</i>	<i>Soil</i>	<i>Soil</i>
Sandy loam	0 - 1	22.5	162.5	132.5
	1 - 3	28.8	157.5	112.5
	3 - 7	27.5	137.5	160.0
	7 -15	22.5	130.0	190.0
Loam	0 - 1	25.0	166.0	133.0
	1 - 3	25.0	135.0	122.5
	3 - 7	22.5	160.0	210.0
	7 -15	22.5	160.0	245.0
Clay loam	0 - 1	33.8	190.0	220.0
	1 - 3	25.0	151.3	155.0
	3 - 7	21.2	132.5	145.0
	7 -15	18.7	137.5	125.0
Silty clay loam	0 - 1	31.3	195.0	160.0
	1 - 3	25.0	175.0	185.0
	3 - 7	22.5	177.5	185.0
	7 -15	16.3	172.5	180.0

TABLE III

CORRELATION COEFFICIENTS BETWEEN TENSION
AND CONCENTRATION IN WATER MEDIUM

Soil Texture	Calcium	Potassium	Sodium
Sandy loam	-0.31	-0.94	+0.88
Loam	-0.84	+0.21	+0.93
Clay loam	-0.85	-0.70	-0.81
Silty clay loam	-0.95	-0.69	+0.43

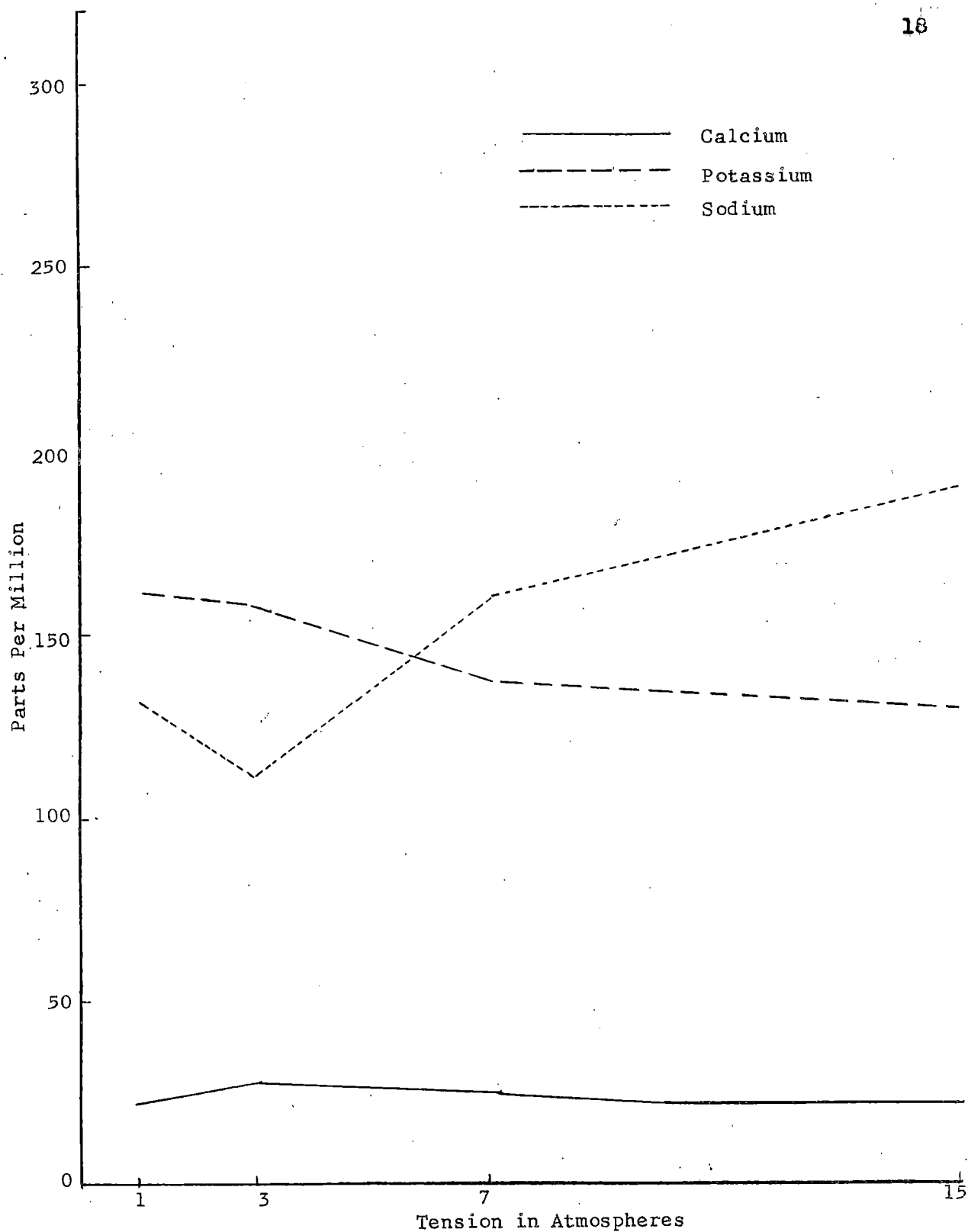


Figure 1--The cation concentration in water extracts obtained between different pressures from a Sequatchie sandy loam.

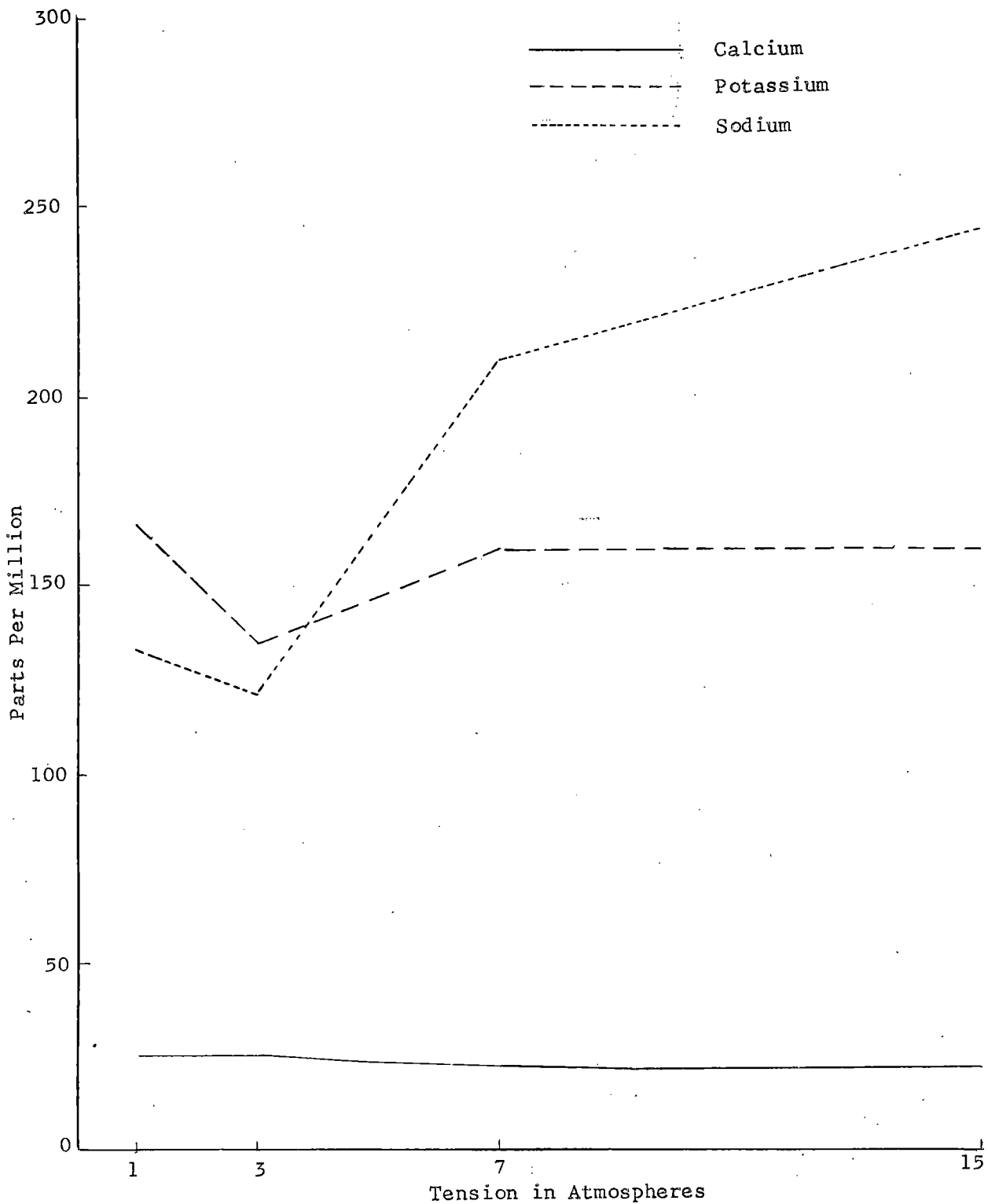


Figure 2--The cation concentration in water extracts obtained between different pressures from a Sequatchie loam.

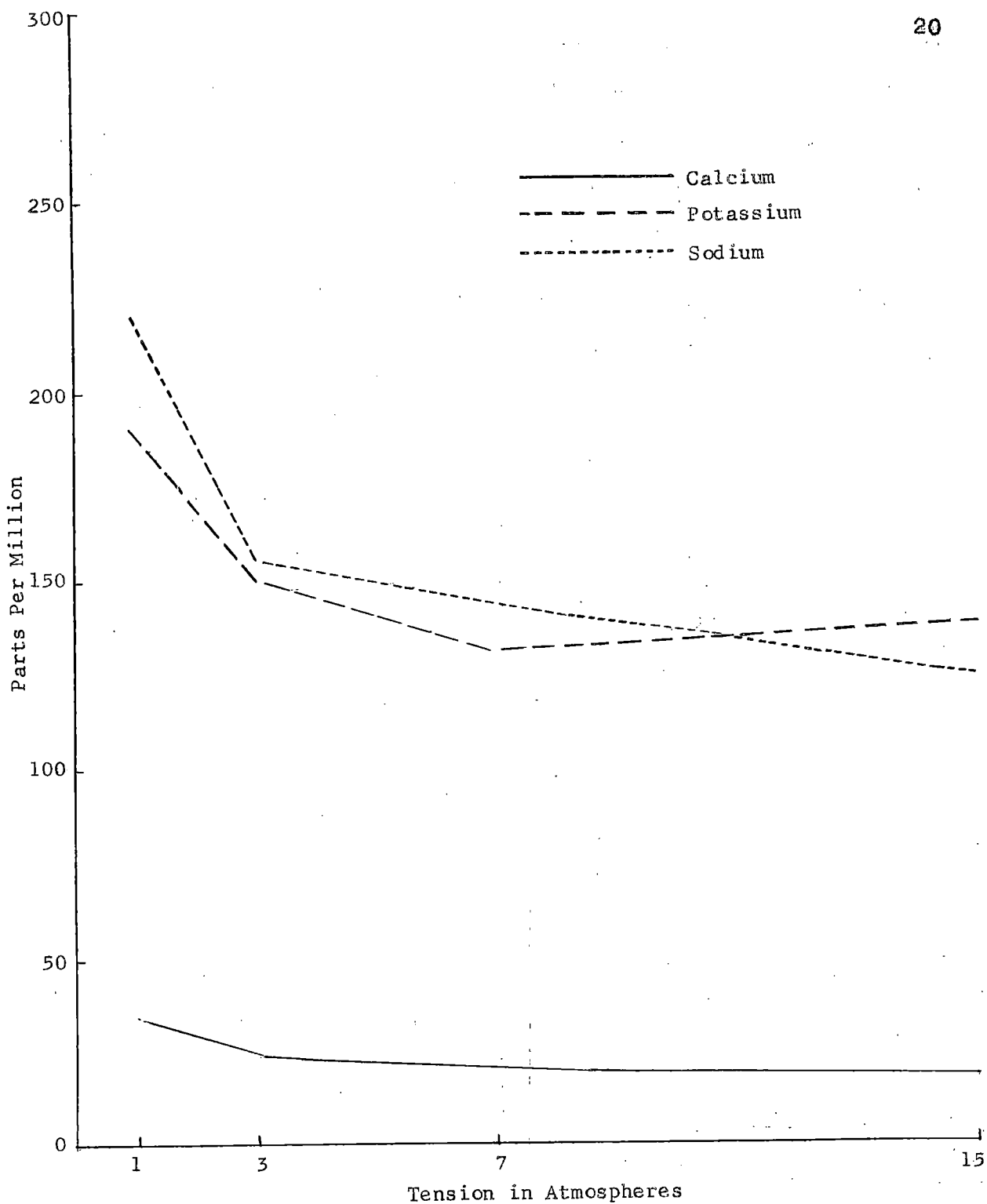


Figure 3--The cation concentration in water extracts obtained between different pressures from an Egam clay loam.

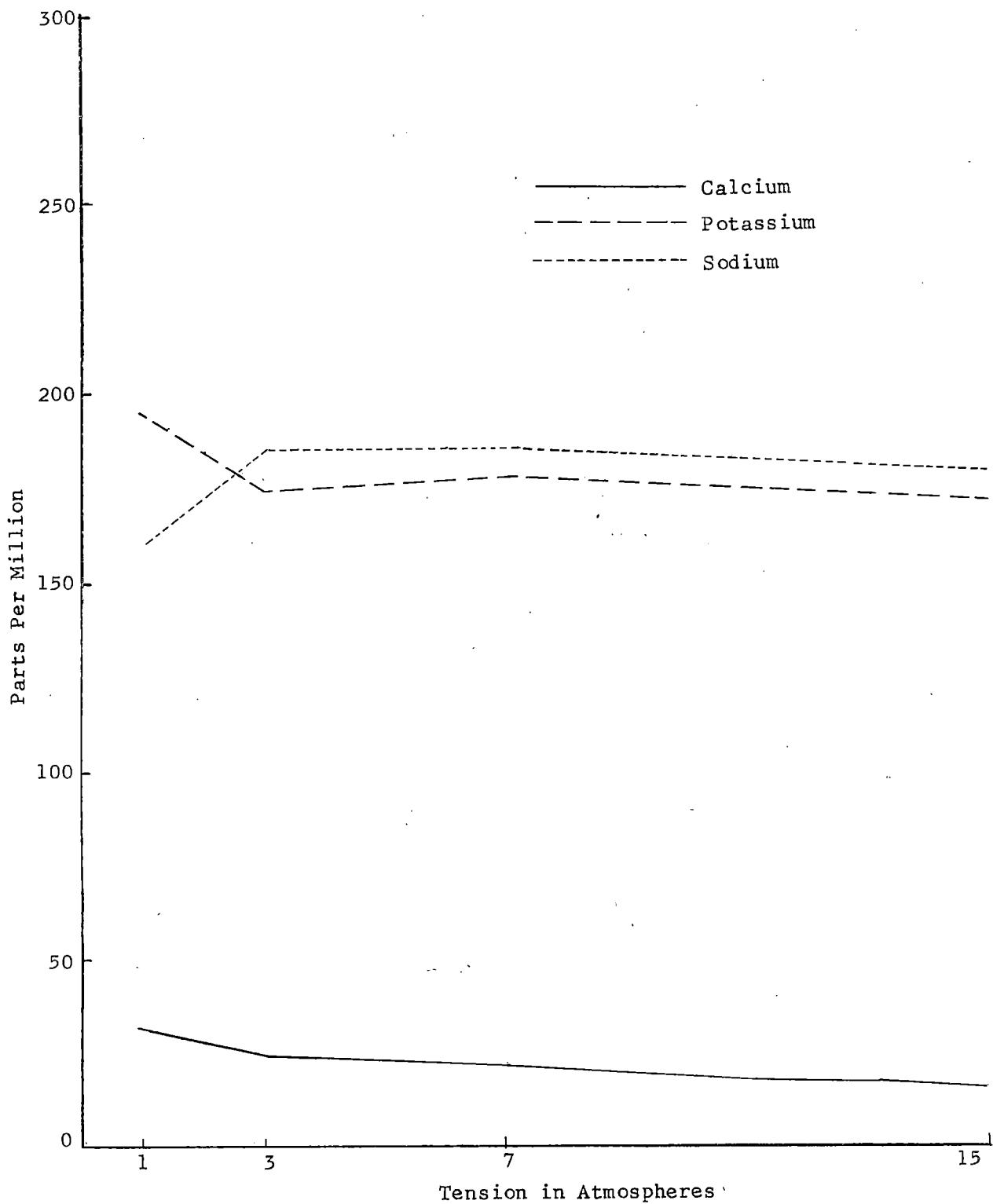


Figure 4--The cation concentration in water extracts obtained between different pressures from an Emory silty clay loam.

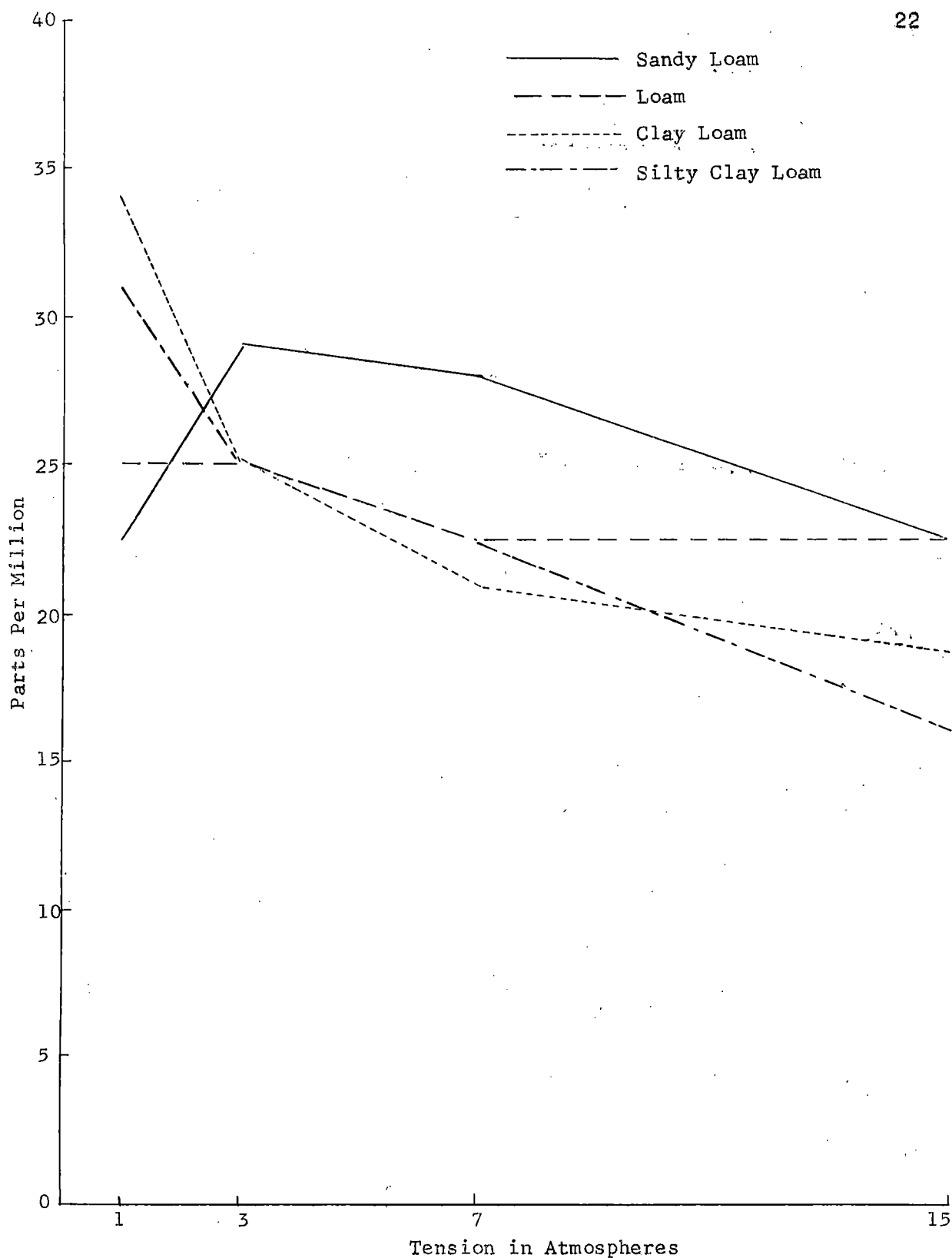


Figure 5--The calcium concentration in water extracts obtained between different pressures from all soils studied.

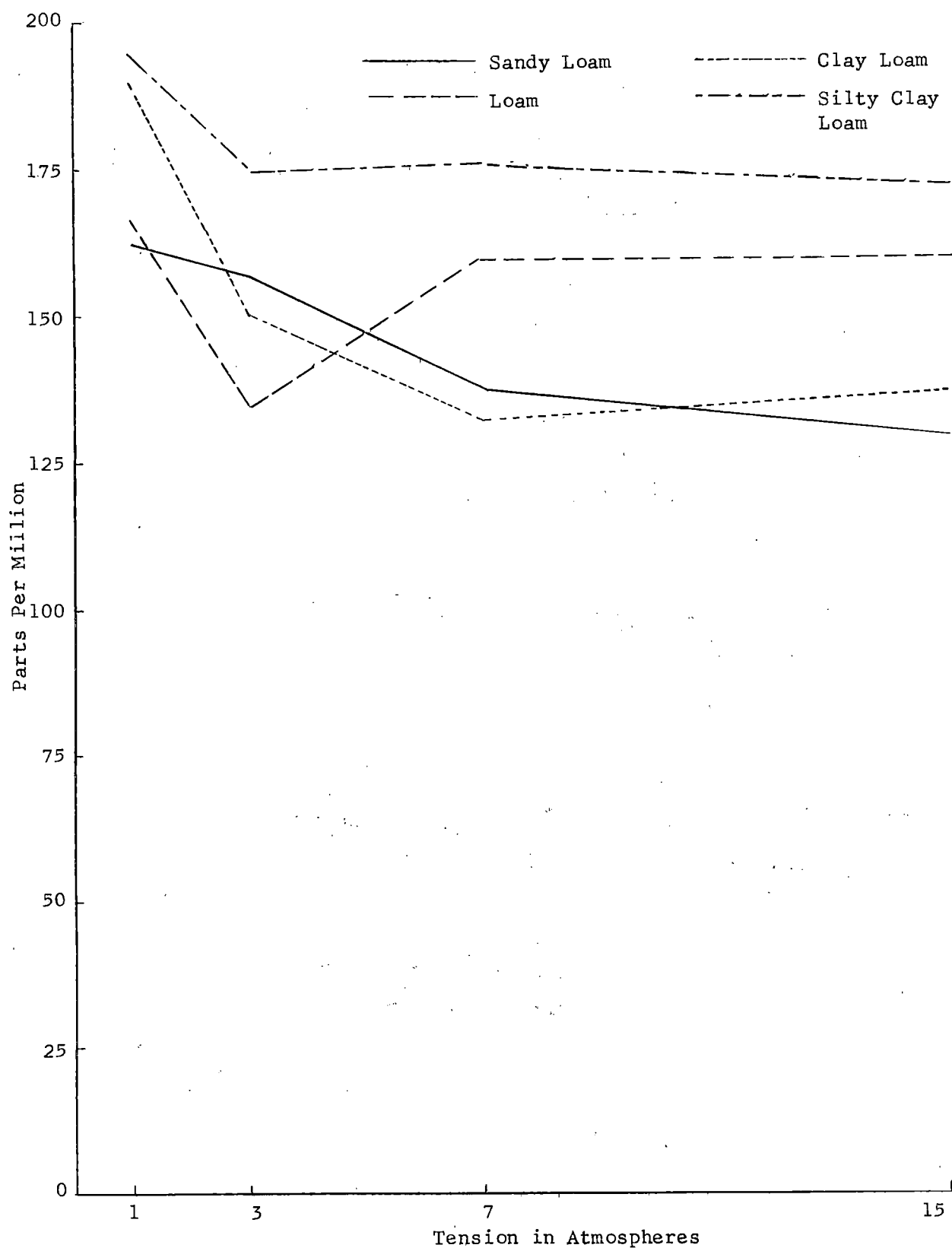


Figure 6--The potassium concentration in water extracts obtained between different pressures from all soils studied.

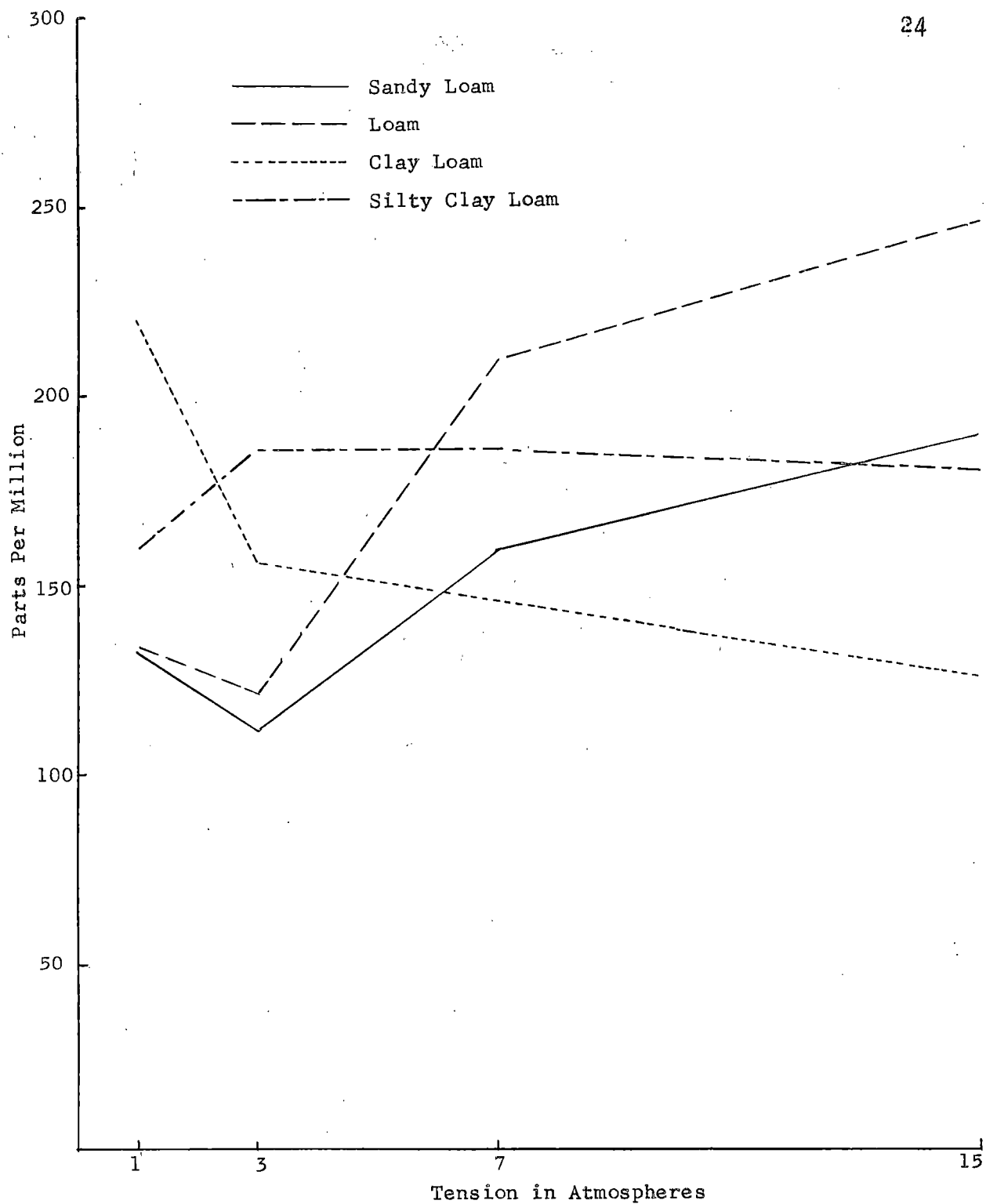


Figure 7--The sodium concentration in water extracts obtained between different pressures from all soils studied.

film increased with tension.

Ammonium acetate medium: Results are given in Table IV and presented graphically in figures 8 through 14. Correlation coefficients have also been calculated and are given in Table V.

A negative correlation was observed in all soils and for all the three cations. The degree of correlation increased as the texture of the soil changed from coarse to fine.

The relation of tension and concentration was similar in both the extracting liquids with the exception of sodium.

Reitemeier (20) extracted soil solution from a sample of Hesperia sandy loam at the liquid point (upper plastic limit) by the pressure-membrane method and analyzed the solution in six fractions. He noticed decreased concentration in the latter part of the extraction and indicated that as an evidence that the "outer" soil solution was more concentrated than that nearer the soil particle.

The results presented are in conformity with the concept of bound water or unfree water. As the soil-moisture tension increases, the thickness of the moisture film decreases. Water present under such high tension is regarded as bound or unfree. It has been found that such water has a lower solvent power. The amount of adsorbing surface present in a soil also determines the amount of bound water present under the prevailing conditions. Thus in finer textured soils the amount of bound water present would be more than in sandy soils at the same tension. So the decrease in concentration would be greater in the finer textured

TABLE IV

IONIC CONCENTRATION IN PPM OF AMMONIUM ACETATE EXTRACTS
BETWEEN DIFFERENT TENSIONS FROM SOILS OF FOUR TEXTURES

Soil Texture	Soil-moisture Tension Range in	Calcium	Potassium	Sodium
	Atmospheres			
Sandy loam	0 - 1	1550	1950	1950
	1 - 3	1150	725	600
	3 - 7	1150	875	625
	7 -15	1275	825	675
Loam	0 - 1	2050	2450	1575
	1 - 3	1275	1000	1100
	3 - 7	1250	1000	925
	7 -15	1150	775	675
Clay loam	0 - 1	3000	2500	2200
	1 - 3	1375	2150	1350
	3 - 7	1200	1825	1175
	7 -15	1050	1450	875
Silty clay loam	0 - 1	2000	3300	2150
	1 - 3	1225	1550	1100
	3 - 7	1300	1875	1025
	7 -15	1150	1050	675

TABLE V

CORRELATION COEFFICIENTS BETWEEN TENSION AND CONCENTRATION
IN AMMONIUM ACETATE MEDIUM

Soil Texture	Calcium	Potassium	Sodium
Sandy loam	-0.33	-0.55	-0.55
Loam	-0.69	-0.69	-0.89
Clay loam	-0.70	-0.97	-0.83
Silty clay loam	-0.67	-0.77	-0.80

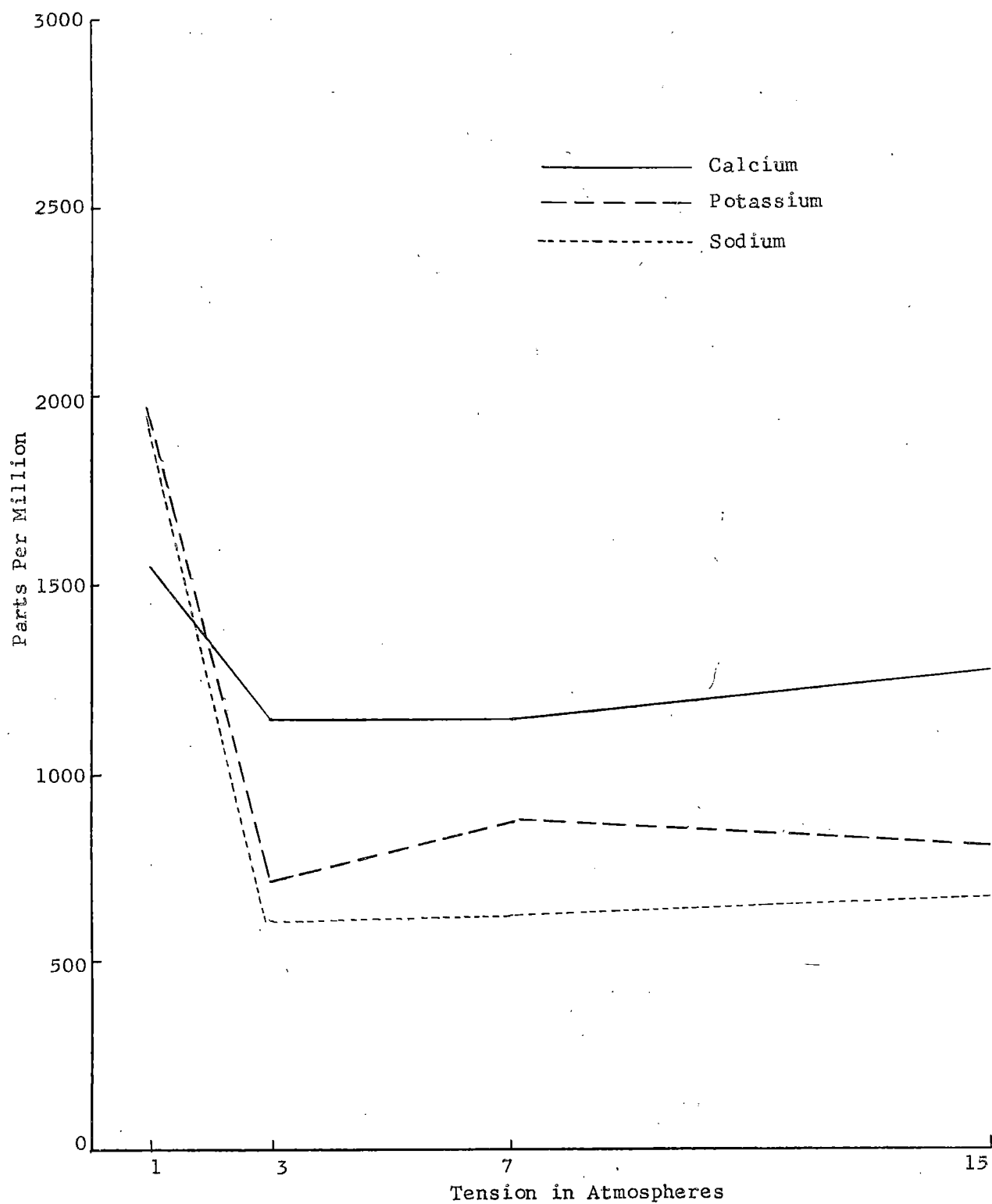


Figure 8--The cation concentration in ammonium acetate extracts obtained between different pressures from a Sequatchie sandy loam.

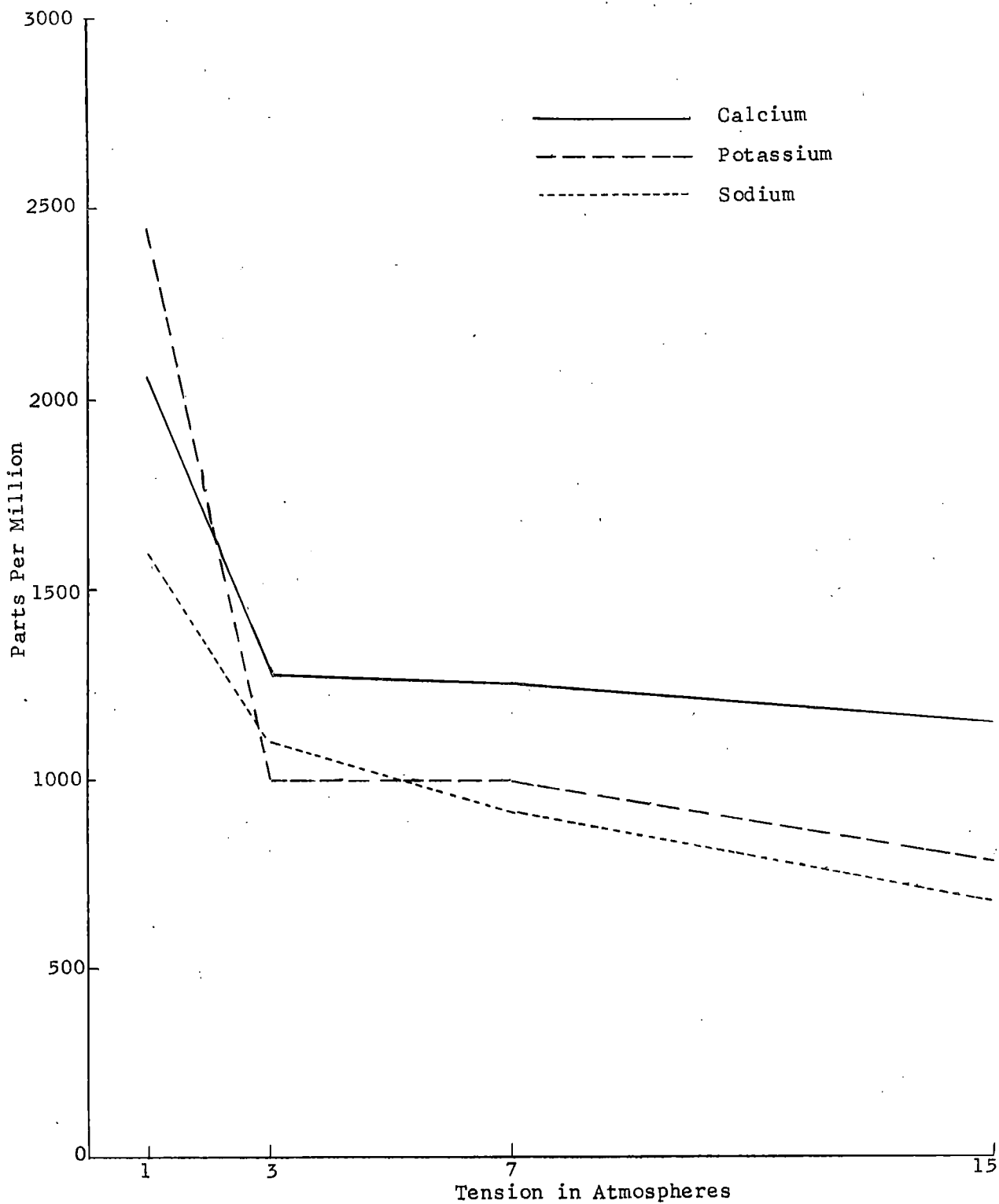


Figure 9--The cation concentration in ammonium acetate extracts obtained between different pressures from a Sequatchie loam.

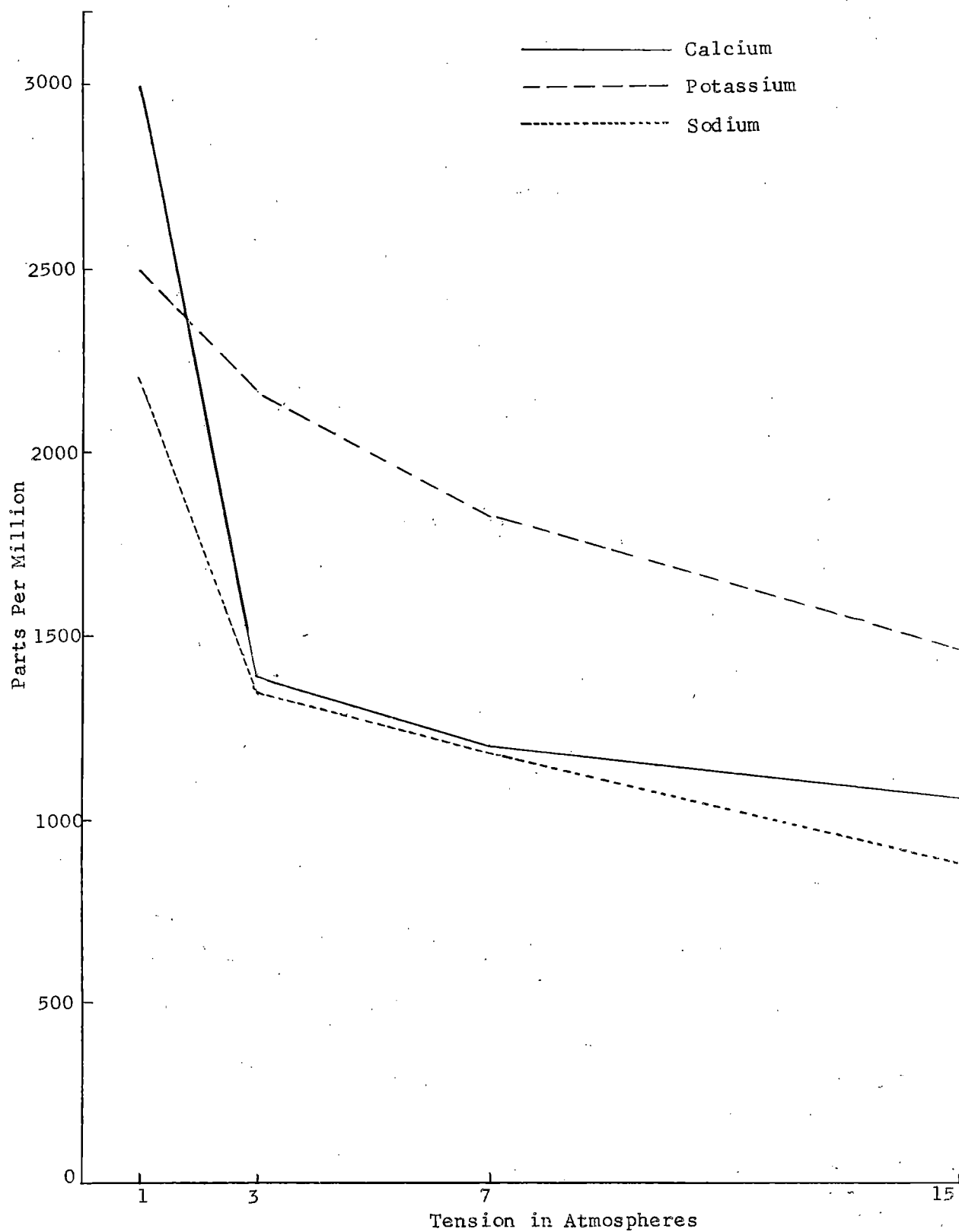


Figure 10--The cation concentration in ammonium acetate extracts obtained between different pressures from an Egam clay loam.

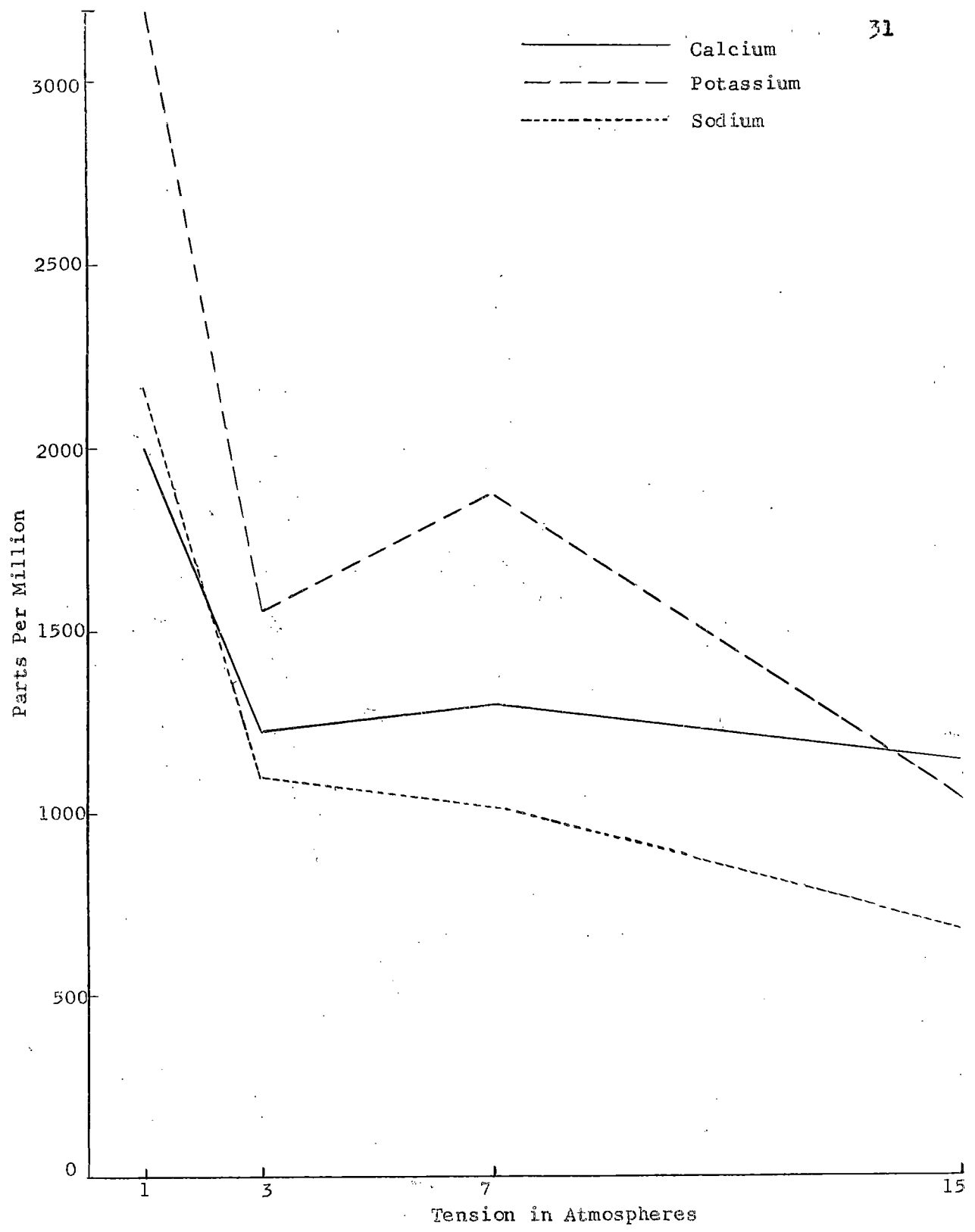


Figure 11--The cation concentration in ammonium acetate extracts obtained between different pressures from an Emory silty clay loam.

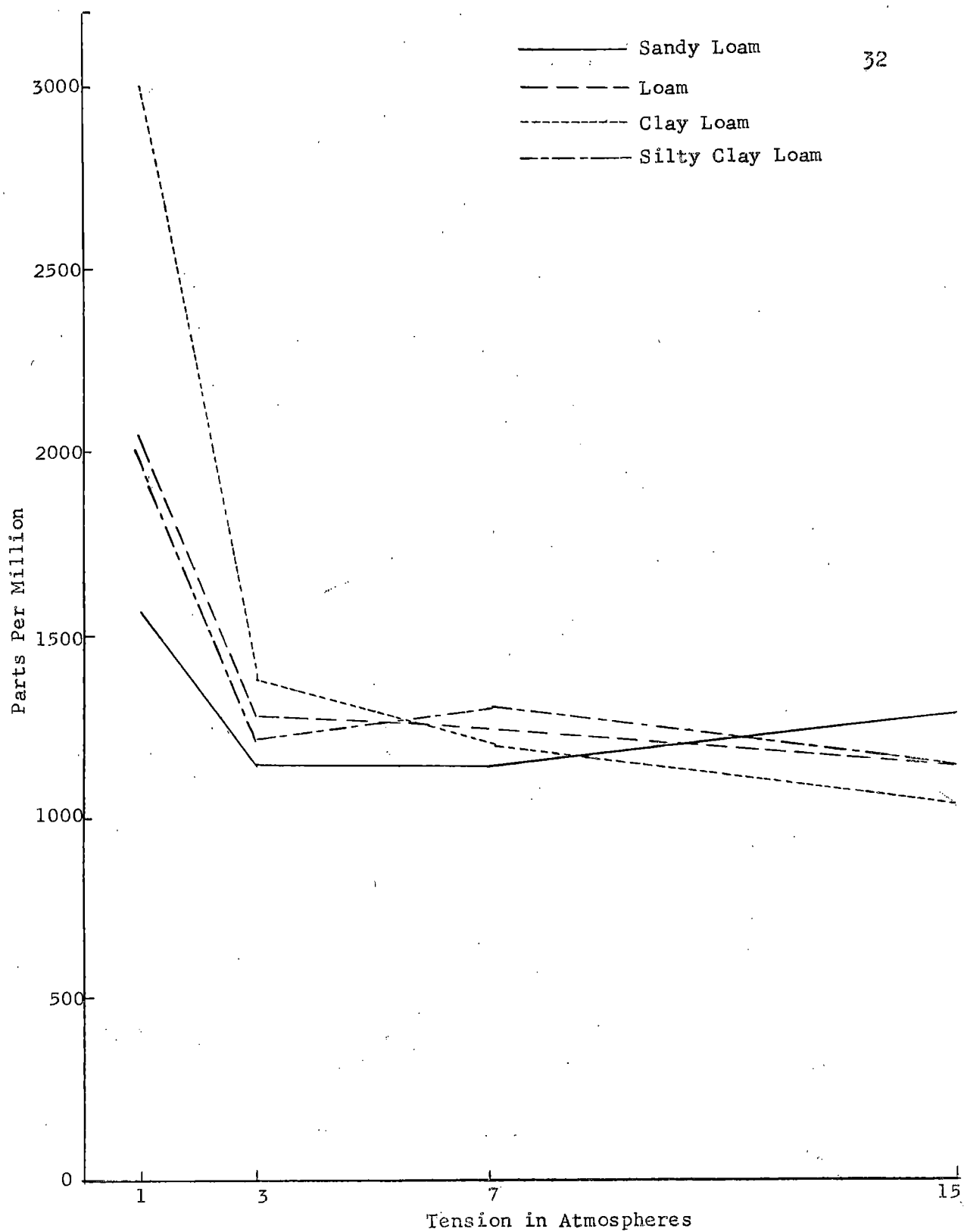


Figure 12--The calcium concentration in ammonium acetate extracts obtained between different pressures from all soils studied.

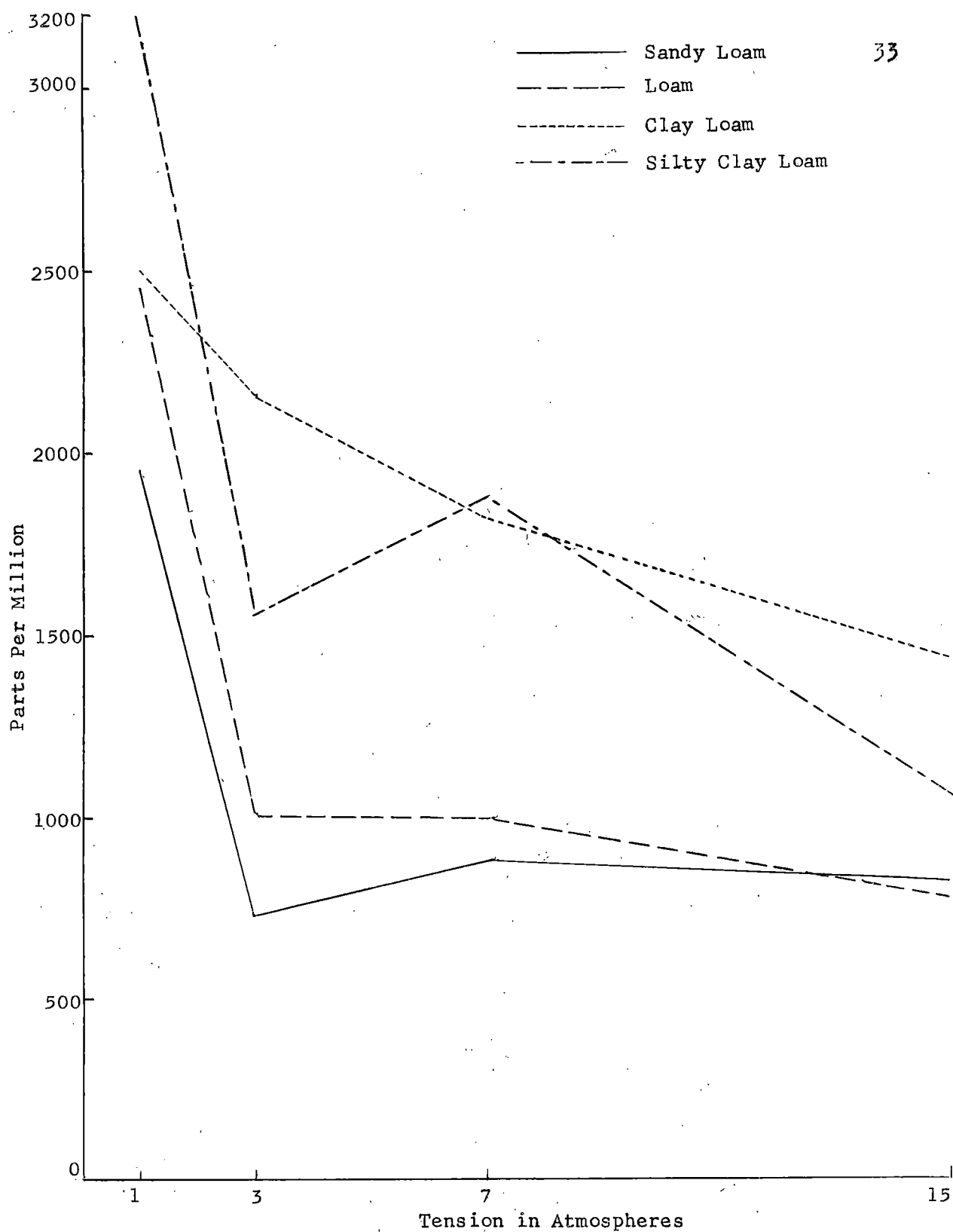


Figure 13--The potassium concentration in ammonium acetate extracts obtained between different pressures from all soils studied.

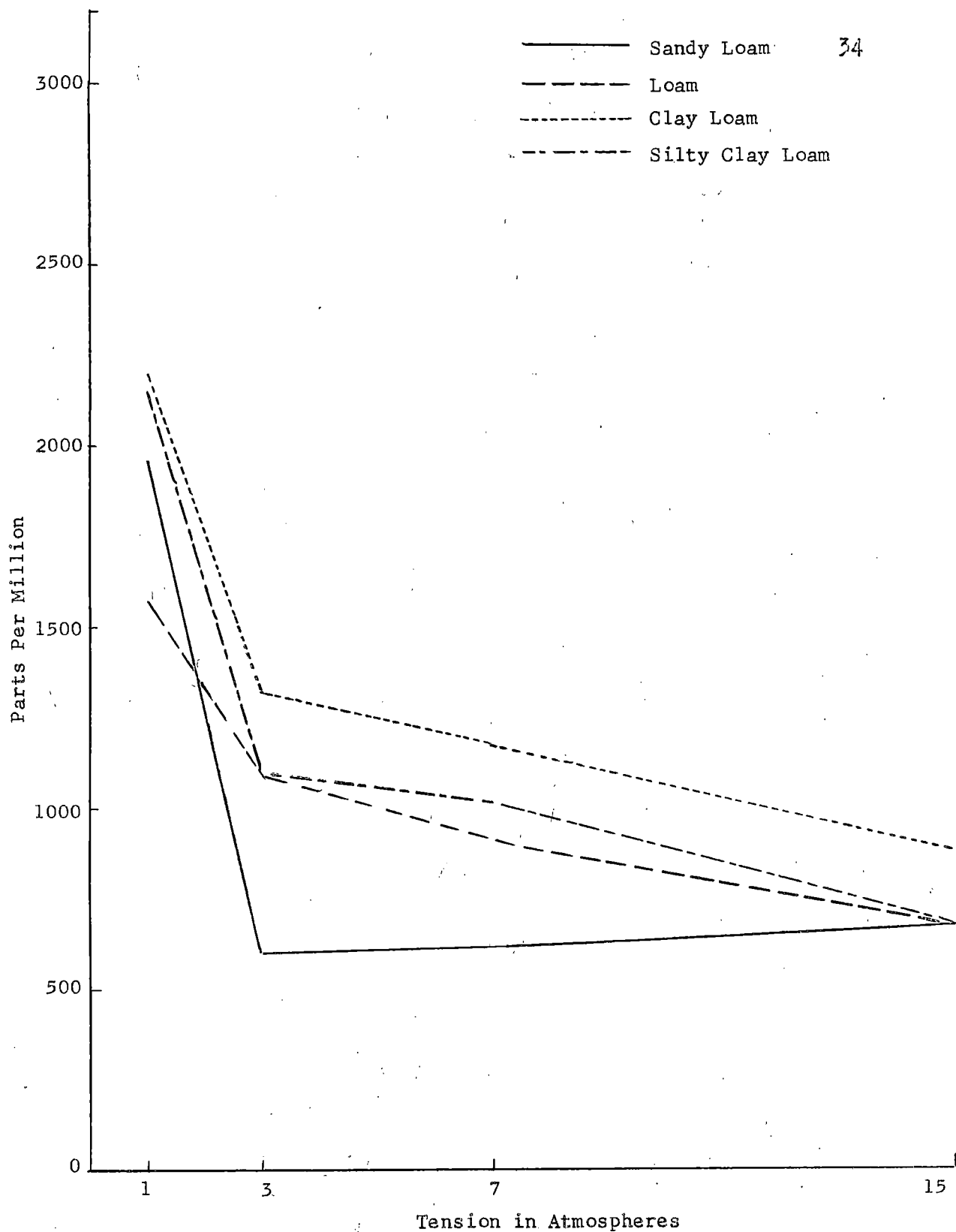


Figure 14--The sodium concentration in ammonium acetate extracts obtained between different pressures from all soils studied.

soils than in coarse and medium textured soils. The low negative correlations obtained in the coarser textured soils in this study indicates that even the low amount of water present in them has considerable solvent power and therefore is in a higher free energy state.

Comparison of Changes in the Concentrations of the Cations in the Two Extracting Liquids

The changes in the concentrations as they occurred with decreasing thickness of the moisture films were compared by calculating correlation coefficients between the cations in water medium and the cations in ammonium acetate medium, first, separately for each soil and second, for all soils considered together. The data are presented in Table VI.

Calcium. Except in sandy loam, there was a positive correlation in all the other cases. The changes in the concentration of calcium with increasing tension were same in both the extracting liquids. In this case also the correlation increased numerically as the texture of the soil progressively changed to a finer texture.

When all the soils were considered together the correlation was positive indicating that for both the solvents the concentration of the liquid nearer the adsorbing surface was less and less concentrated. Both the solvents gave similar results.

Potassium. In all the soils taken separately and together the correlation was positive indicating the similar effects of both

TABLE VI

CORRELATION COEFFICIENTS BETWEEN THE CATIONS
IN THE TWO EXTRACTING LIQUIDS

Soil Texture	Ca in Water vs Ca in Ammonium Acetate	K in Water vs K in Ammonium Acetate	Na in Water vs Na in Ammonium Acetate
Sandy loam	-0.79	+0.59	-0.27
Loam	+0.64	+0.46	-0.82
Clay loam	+0.97	+0.87	+0.99
Silty Clay loam	+0.86	+0.99	-0.88
All the soils considered together	+0.69	+0.60	-0.33

the solvents as noticed with one exception in the case of calcium.

Sodium. It was pointed out earlier that except in clay loam the concentration changes with increasing tensions in all other soils differed in respect to the solvent used. There was a positive correlation between tension and concentration when water was the extractant and the reverse when ammonium acetate was the extractant. However, in clay loam there was a negative correlation in both cases.

Thus in the cases of calcium with one exception and potassium in all the soils and sodium in clay loam both solvents had similar effects.

The Effect of Soil-Moisture Tension on the Concentration of the Soil Solution of All the Soils Considered Together

In order to keep the soil factor constant and assess the effect due to tension all the soils were considered together. This may be called tension effect. Thus correlation coefficients were calculated between tension and concentration in all the soils considered together and presented in Table VII.

Calcium. The negative correlations in both cases showed that irrespective of the soil or the extractant used, the concentration of the moisture film also decreased as the thickness of the moisture film decreased.

Potassium. The negative correlation in both cases in the case of potassium showed the same trend as in calcium.

TABLE VII

CORRELATION COEFFICIENTS BETWEEN TENSION AND CONCENTRATION
(ALL THE SOILS CONSIDERED TOGETHER)

Extractant	Calcium	Potassium	Sodium
Water	-0.69	-0.41	+0.34
Ammonium acetate	-0.55	-0.59	-0.69

Sodium. There was positive correlation in water medium and negative correlation in ammonium acetate medium.

The correlation coefficients of the three cations in the two extractants revealed an interesting trend. When water was the extractant the greatest concentration decrease (highest negative correlation coefficient) of the unremoved portion of the moisture film occurred in the case of calcium followed by potassium and sodium. However, sodium concentration increased. This trend was reversed in the ammonium acetate medium. Sodium showed the greatest concentration decrease followed by potassium and calcium.

Tension and Soil-Moisture Relationships

The data regarding the moisture content of the soils at various tensions are given in Table VIII, and the relation between amount of soil moisture and soil-moisture tensions are presented graphically in figures 15 through 18.

In all four texturally different soil types the moisture content in the Ca-soils at the different tensions was higher than moisture content at equal tensions in the Na- and K-soils.

Thomas (24) studied the effect of various replaceable bases on the vapor pressure curves and found that the K-, Na- and NH_4 -saturated soils adsorbed less water than H- and Ca-saturated samples at low vapor pressure. He attributed the peculiar behavior of sodium to the greater dispersion and swelling at higher moisture contents.

Baver (2) has presented data in which the hygroscopicity

TABLE VIII

MOISTURE CONTAINED IN THE SOILS AT VARIOUS TENSIONS
RESULTS EXPRESSED AS PERCENTAGE ON OVEN DRY BASIS

Soil Texture	Soil-moisture Tension in Atmospheres	Ca-soil	K-soil	Na-soil
Sandy loam	1	22.4	19.4	19.4
	3	10.8	9.0	10.1
	7	6.8	6.4	6.4
	15	5.3	4.5	5.2
Loam	1	24.7	24.6	25.5
	3	12.7	11.0	11.8
	7	8.0	7.6	7.8
	15	7.0	5.3	5.7
Clay loam	1	38.2	33.1	37.1
	3	23.5	21.7	22.5
	7	15.8	15.4	16.1
	15	12.6	10.9	11.8
Silty clay loam	1	27.0	23.3	24.2
	3	15.3	13.2	13.7
	7	10.3	9.7	9.9
	15	8.5	8.0	8.4

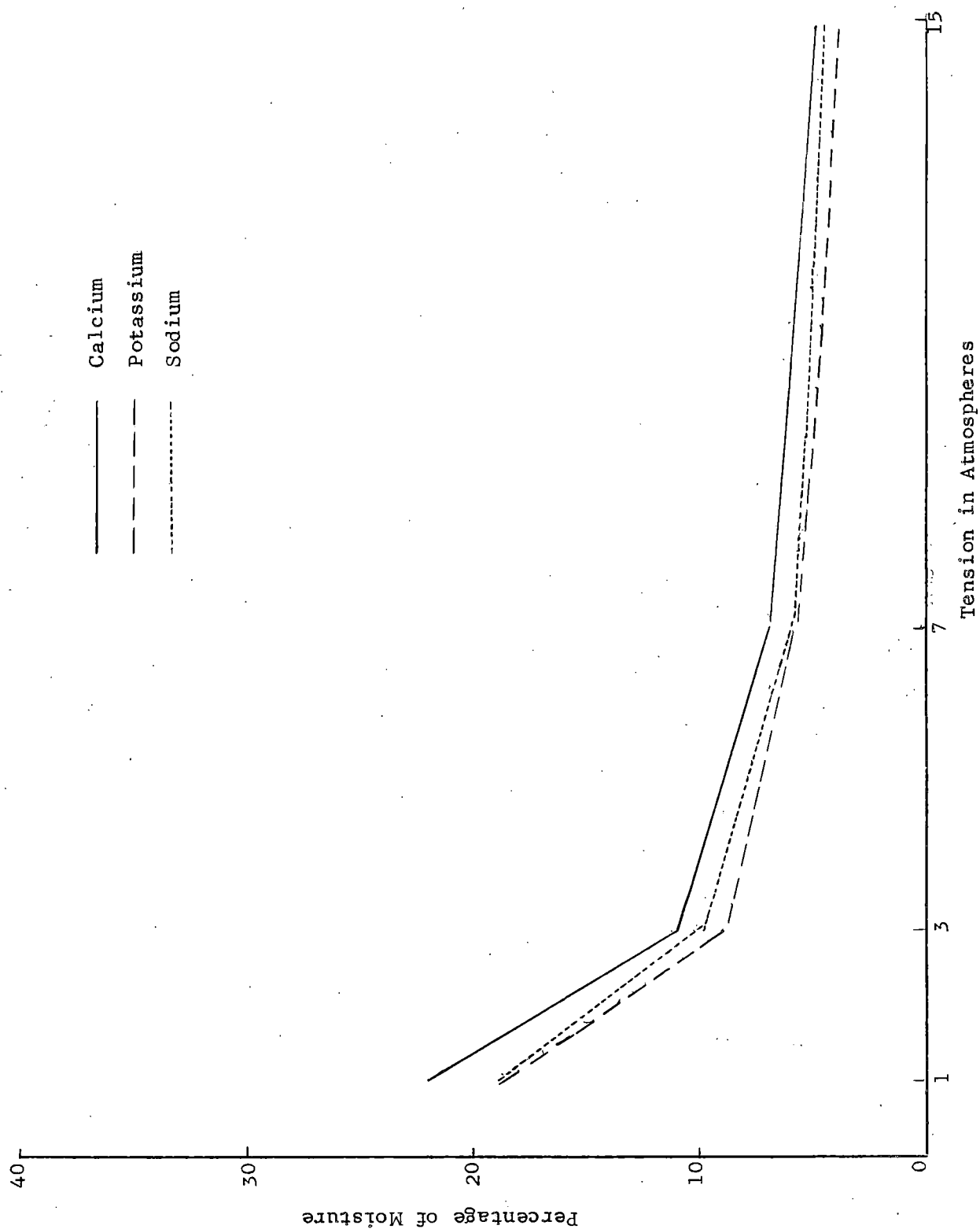


Figure 15--The moisture release curves for sandy loam saturated with different cations.

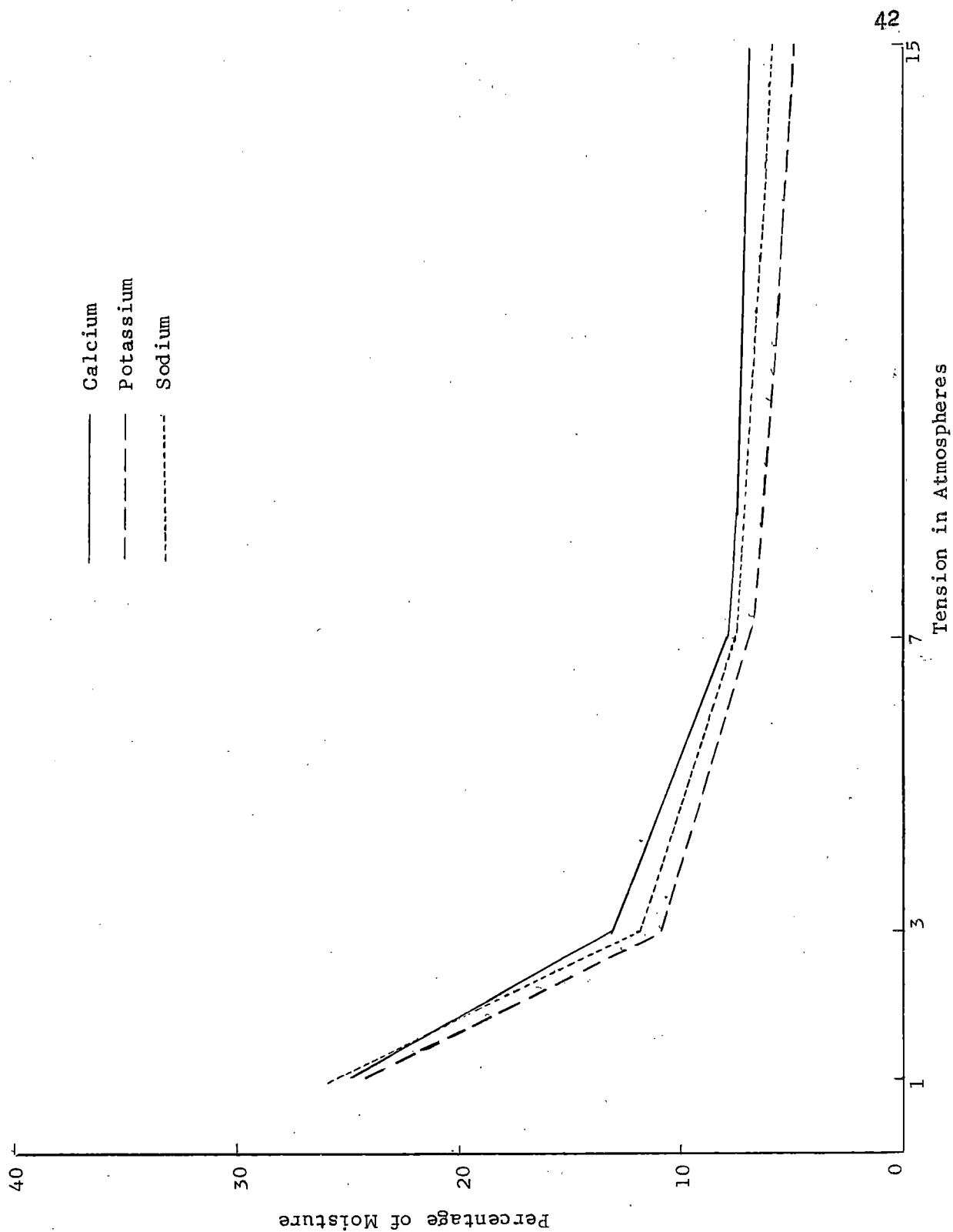


Figure 16--The moisture release curves for loam saturated with different cations.

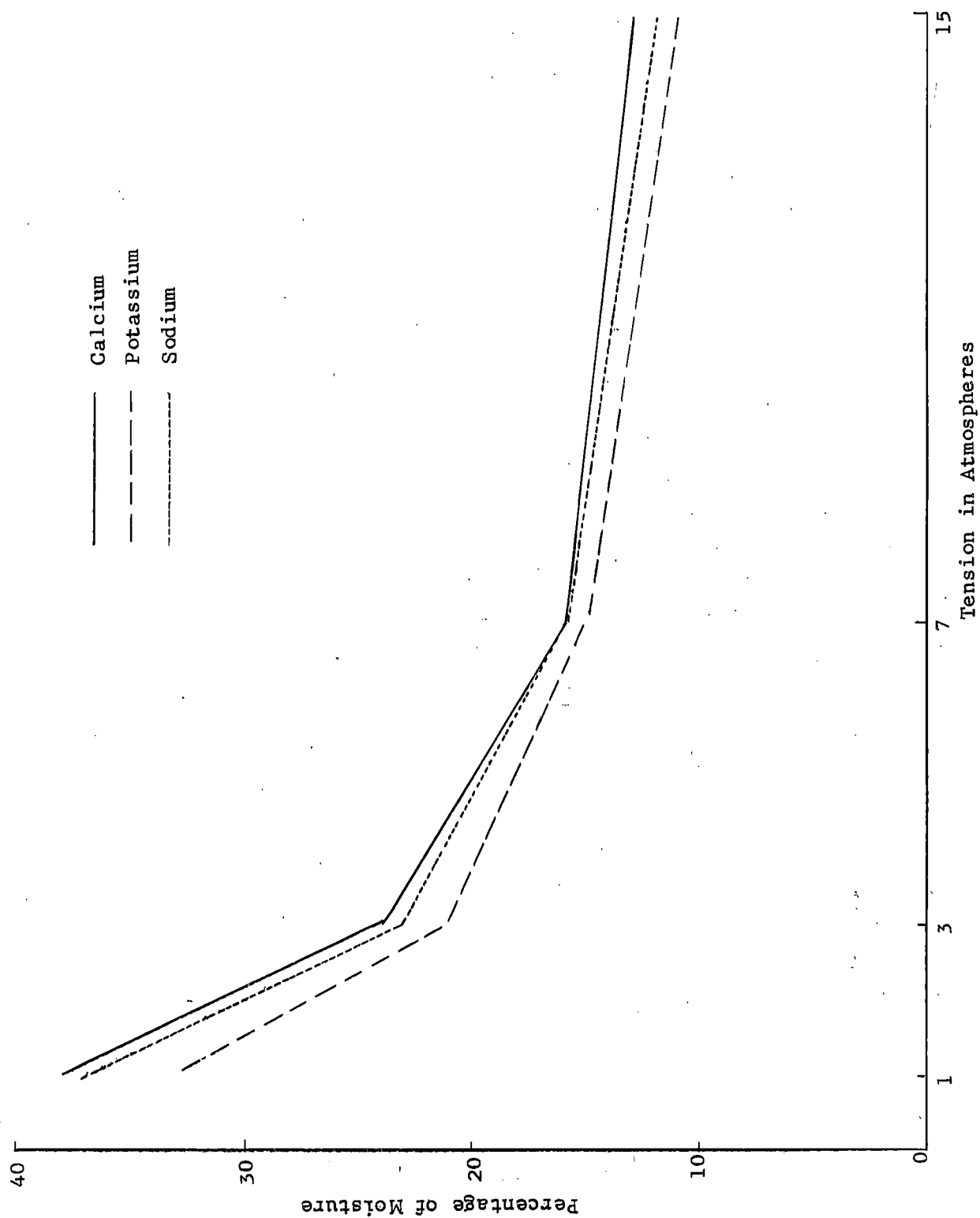


Figure 17--The moisture release curves for clay loam saturated with different cations.

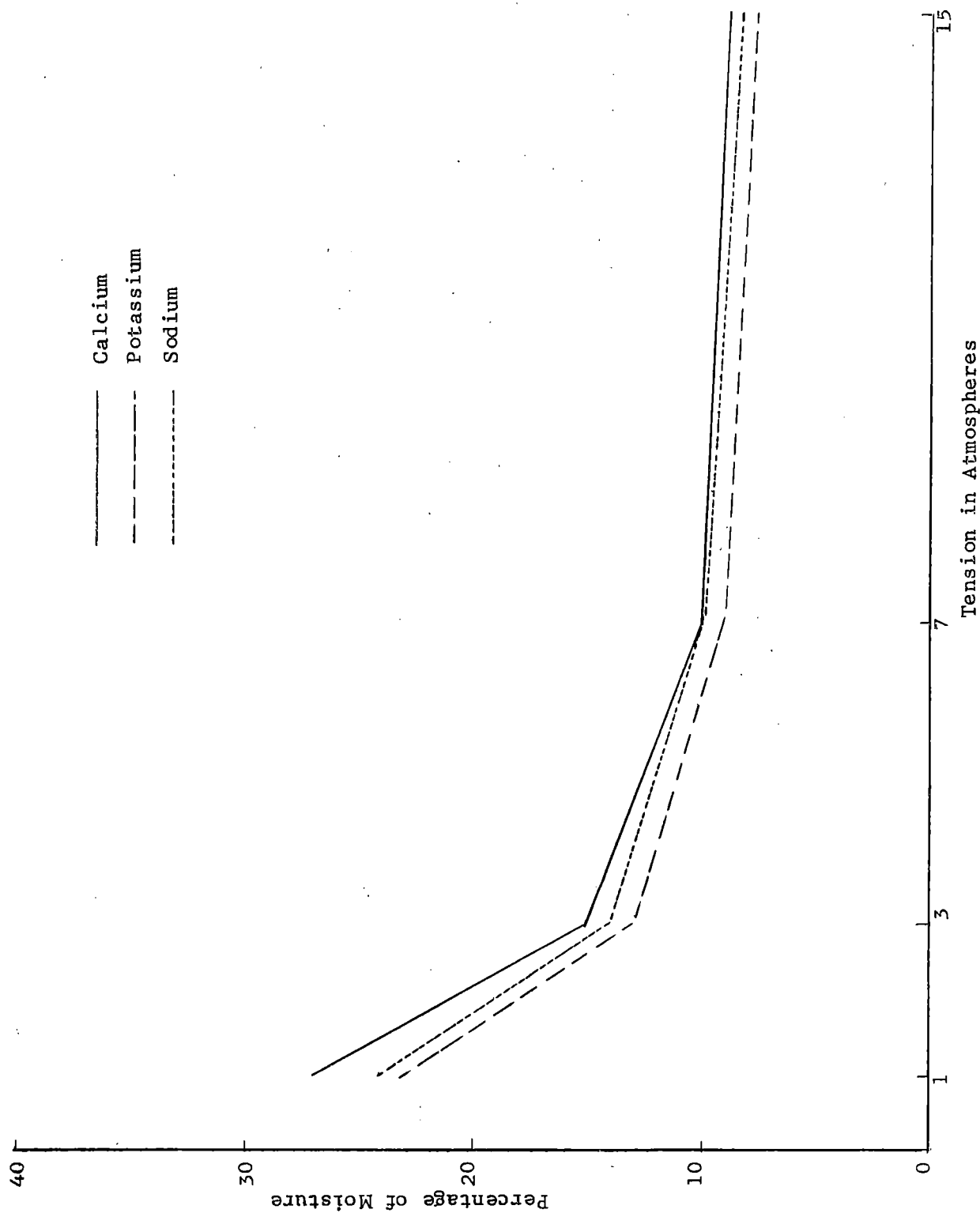
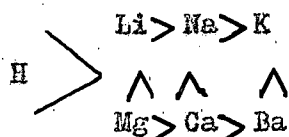


Figure 18--The moisture release curves for silty clay loam saturated with different cations.

increased according to the following series at 99.8% relative humidity: $\text{Li} > \text{Na} > \text{H} > \text{Ba} > \text{Ca} > \text{K}$ and at a relative humidity of 74.9% according to the following series: $\text{H} > \text{Ca} > \text{Li} > \text{Na} > \text{Ba} > \text{K}$. "The peculiar behavior of the sodium ions is explained on the basis that at low vapor pressures the dehydrated Na-clay contains a large number of pores that are too small for the entrance of water molecules. Ca-clay, on the other hand, is more open and is able to absorb more water. At higher vapor pressures, the Na-clay swells and greater amounts of water are adsorbed than in the Ca-system." (2).

Jenny (15) considers the relative size of the ion as a contributing factor in the hydration of aluminosilicates. According to Jenny there are cavities present which are filled by the adsorbed ions and water molecules. The amount of space in one cavity available to water molecules depends on the number and size of the ions within the cavity. If the ion has smaller crystal lattice radii, the amount of space available for water molecules is greater.

Hence according to Jenny's concept the hydration of different clays would occur as follows:



Results in Table VIII show that hydration occurred in the order $\text{Ca} > \text{Na} > \text{K}$. This order is in agreement with Jenny's concept.

CHAPTER V

SUMMARY

Ionic concentration of soil water held at different tensions was determined after extraction of the soil solution by the pressure-membrane technique. Four soils of different textures i.e. sandy loam, loam, clay loam and silty clay loam were selected.

Soil solutions were extracted at 1, 3, 7, and 15 atmospheres.

Distilled water and neutral normal ammonium acetate were used as the extracting liquids.

The results were:

1) The ionic concentration of soil water extract decreased as the thickness of the moisture film decreased with increasing soil-moisture tension.

2) The results in general conform to the concept of bound water or unfree water present at the adsorbing surface which is reported to have considerably reduced solvent power compared to free water.

3) A greater decrease in concentration which may have been caused by a larger quantity of bound water occurred in clay loam and silty clay loam. The larger quantity of bound water may perhaps be due to their higher colloidal content.

4) In all the soils and in both solvents the concentrations of calcium and potassium in the extracted soil solution decreased with increasing soil-moisture tension.

5) The concentration of sodium decreased in all the soils in ammonium acetate medium whereas it decreased in clay loam alone in water medium.

6) In all the different textural classes, moisture in the Ca-soils, especially at high tension, was always higher than in the Na-soils and K-soils.

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LITERATURE CITED

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APPENDIX A

APPENDIX A

FLAME SPECTROPHOTOMETRIC ANALYSIS OF THE EXTRACTS

Standard solutions of Calcium, Potassium and Sodium as chlorides were prepared in two media: 1) 0.05 HCl and 2) Neutral normal ammonium acetate. Analytical reagents were used in this study. Separate calibration curves for the standard solutions were prepared by using Beckman DU Flame spectrophotometer equipped with a photomultiplier attachment. The following wave lengths of 4227, 7665 and 5893 Angstroms were used for calcium, potassium and sodium respectively.

Analysis of the Extract

Water medium: A calculated amount of 4 N. HCl was added to the extract to bring the normality of the extract to 0.05. A small portion of this extract was used to determine the cations by the spectrophotometer. From the reading obtained the concentration was directly read off the calibration curves prepared earlier.

Ammonium acetate medium: A small portion of the extract was used directly to determine the cations and the concentration found as in the water medium.

APPENDIX B

APPENDIX B

MILLILITERS OF SOIL SOLUTION OBTAINED AT
VARIOUS PRESSURES FROM ALL THE SOILS

Soil Texture	Soil-moisture Tension Range in Atmosphere	Water Medium			Ammonium Acetate Medium		
		Ca	K	Na	Ca	K	Na
Sandy loam	0 - 1	84.0	80.0	66.0	69.0	61.0	72.0
	1 - 3	9.0	6.5	19.0	18.0	17.0	18.0
	3 - 7	7.5	7.0	9.0	8.0	7.5	12.0
	7 -15	5.0	7.0	6.0	6.0	5.0	5.5
Loam	0 - 1	82.0	87.0	83.0	66.0	71.0	88.0
	1 - 3	15.0	11.0	13.0	20.0	20.0	10.0
	3 - 7	9.5	8.0	7.5	11.0	7.5	7.5
	7 -15	7.5	7.5	6.0	6.0	6.0	5.0
Clay loam	0 - 1	94.0	82.0	81.0	72.0	69.0	84.0
	1 - 3	24.5	11.0	16.0	24.0	26.0	17.0
	3 - 7	18.0	18.0	13.0	19.0	17.0	10.0
	7 -15	11.0	12.5	14.0	6.5	6.0	5.5
Silty clay loam	0 - 1	72.0	78.5	74.0	68.0	82.0	69.0
	1 - 3	19.5	9.5	19.5	22.0	17.0	17.5
	3 - 7	9.5	7.5	7.5	9.0	7.0	8.0
	7 -15	7.0	6.5	7.0	5.0	5.0	4.5