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A NOTE ON THE CATION-ANION RELATIONSHIPS IN PERENNIAL RYEGRASS

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SUMMARY

The effect of a fertilization with the nitrates of the potassium, sodium, magnesium and calcium cations on the mineral composition of perennial ryegrass was studied in a pot culture experiment.

Regardless of the cation selected, the effect of the nitrate applied was manifested in an increase in the nitrogen and the cation contents and in a lowering of the chlorine, sulphur and phosphorus contents. The cation – anion relationship, including the nitrogen content as a monovalent anion, was found to be independent of the fertilization.

When potassium and sodium nitrate were supplied in the fertilizer the increase in the cation content was found to have been almost entirely due to an increase in the content of these cations. When magnesium and calcium nitrate were applied these cations proved incapable of providing the increased cation uptake at a sufficient rate, so that as a result of the nitrate available there was also an increase in the contents of the cations which had not been provided in the fertilizer.

INTRODUCTION

The literature bearing on the subject contains repeated references to the relationship between the cation uptake and the uptake of the other elements in the growing plant. In order to be able to interpret observations on the uptake of the cations it is also essential to study the simultaneous uptake of the other elements.

The question arises as to which elements should be included in these observations. If we may disregard such specific deficits of other elements as interfere with growth it would be sufficient to confine our attention to the group of macro-elements, viz. potassium, sodium, magnesium, calcium, chlorine, sulphur, phosphorus and nitrogen that occur in quantities of from 50 to 3000 mg equivalents per kg dry matter produced and thus represent substantially quantitatively the amount of mineral components absorbed. Although appreciable amounts of silica may occur in grass it is found that a satisfactory picture may be obtained when this element is omitted.

In general the rule formulated by BEAR (1950) for the cation and anion uptake is an excellent aid to the interpretation of the effects of fertilization.

BEAR starts from the assumption that there must be a balance between the amount of cations and anions, both expressed in electrochemical equivalents, that are absorbed by the growing plant. As a result of this balance the ratio of the total cation content to the total anion content in the plant material produced will not systematically depend on all kinds of factors but be determined by the plant. Whereas the plant's mineral composition may vary with varying amounts of the different elements supplied, the elements available will be absorbed in such a way as not to affect this ratio.

One advantage of Bear's postulate is that assumptions regarding the presence or absence of a constant total cation content are related to the anion level in the plant, and this gives us a better picture of the mineral uptake.

Experimental

In this paper Bear's rule is demonstrated by a fertilization experiment with the nitrates of the four cations potassium, sodium, magnesium and calcium. A sandy soil was utilized for the pot culture experiment, but as similar effects may be observed with any type of soil we shall not give any further description of it. The only fertilizer applied to the soil was measured charges of 1 N solutions of the nitrates, each nitrate comprising a series of from 0 to 40 mg equivalents per pot. The pots were uniformly planted with perennial ryegrass that was clipped after three days. Four weeks afterwards the herbage yield was harvested by cutting off to the original height, and its composition was examined.

As a result of the nitrate fertilization the dry matter yield increased from 10 grams to 14 grams per pot, while the nitrogen content of the dry matter produced increased from 2.9% to 4.5% N over the entire fertilizer range. As regards the effect of nitrogen on the yield and the nitrogen content, there was no difference between any of the series of the four nitrates employed.

Discussion

In Fig. 1a the composition of the dry matter from the four series of fertilizations is plotted against the amount of nitrogen in the fertilizer. The graph shows the magnitude of the total cation content (C), the anion fraction Cl + S + P (A), and this anion fraction plus the nitrogen content (A + N), nitrogen being represented as monovalent.

The data are plotted on a logarithmic scale so that the occurrence of constant ratios may be readily seen in the form of parallel lines.

The figure shows the essential part of the effect on the mineral composition of a nitrogen fertilizer in the form of a nitrate, or more properly speaking, the effect of an increasing nitrogen content in the plant caused by an uptake in the form of nitrate. The Cl + S + P anion fraction decreases with increasing fertilization and the total cation content increases. If the nitrogen content is added to the anion fraction this total anion content (A + N) increases also. The trend of the total cation and anion content may be represented by two parallel lines which, allowing for the relatively high margin of error which these combined magnitudes have in this type of experiment, are in substantial agreement with the observations.

The resultant picture, which is to be regarded as the same for the four series, shows the nitrate effect of the fertilization. The cation-anion ratio is

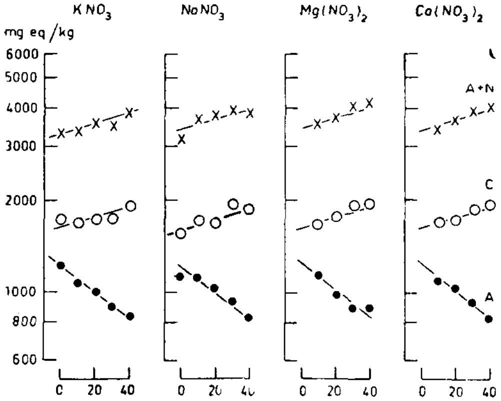

FIG. 1a ANION CONTENT $A = Cl + S + P$, CATION CONTENT $C = K + Na + Mg + Ca$ AND TOTAL ANION CONTENT, $A + N$, IN MG EQUIVALENTS PER KG DRY MATTER PRODUCED, PLOTTED AGAINST THE AMOUNT OF NITRATE APPLIED, SHOWN ABOVE THE GRAPHS, IN MG EQUIVALENTS PER POT CONTAINING 5 KG OF SOIL.

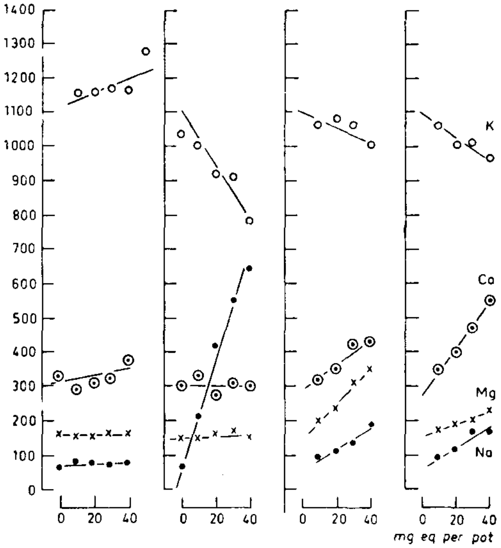

FIG. 1b POTASSIUM, SODIUM, MAGNESIUM AND CALCIUM CONTENTS IN MG EQUIVALENTS PER KG DRY MATTER PRODUCED. ABSCISSA : FERTILIZATION IN MG EQ. PER POT WITH THE NITRATE SHOWN ABOVE THE GRAPHS, VIZ. POTASSIUM, SODIUM, MAGNESIUM AND CALCIUM RESPECTIVELY READING FROM LEFT TO RIGHT.

independent of the amount of fertilizer applied (the lines for C and A + N are parallel) and does not differ in the four series (the lines show the same distance in each series). It is clear that in none of the series was there an element deficiency capable of disturbing these relationships.

The contents of the individual cations are plotted in Fig. 1b on a linear scale, as in this case the quantities are more important than the ratios.

What is first of all noticeable is the steep gradient of the sodium line in the sodium series. In comparison the potassium line in the potassium series is much less steep. Although in this result the sodium uptake seems greater than the potassium uptake, the actual difference is insignificant, bearing in mind the increase in the yield. The increase in the uptake (yield × content) of potassium was calculated as $+0.17$ (± 0.05) and that of sodium $+0.22$ (± 0.01) mg equivalents per mg equivalent utilized in the soil.

In the latter case, viz. in the sodium series, the potassium uptake calculated from the yield and content was found to be independent of the fertilization. Consequently as the yield increases owing to the application of nitrate there is a greater decrease in the potassium content than is the case with magnesium and calcium nitrate in the last two series. This is because in these two series there is, in fact, an increase in the potassium uptake, calculated from yield and content. In these cases, however, this increase is not great enough to prevent a certain decrease in the potassium content as the yield increases. The decrease in potassium content is therefore greater in the sodium series than in the calcium and magnesium series because sodium also becomes available as the nitrate supply increases. As sodium can be absorbed with relative ease by perennial ryegrass, in this case there is less reason for a rise in the potassium uptake as the yield increases. Sodium, which is readily absorbed, is itself sufficiently able to supply the cation requirement which increases with the nitrate level. In the potassium and sodium series there is no increase in the magnesium and calcium contents as the amount of fertilizer is increased. In this case, therefore, the increase in the total cation content is almost entirely due to the cation supplied at the same time, and the two ions, potassium and sodium, are both equally powerful in this respect.

A consideration of the magnesium and calcium nitrate series shows that there is a marked increase in the sodium content and the content of the unsupplied alkaline earth cation, in addition to the increase in the content of the cation supplied.

This shows that magnesium and calcium, being cations which are less readily absorbed, are incapable of providing, at an adequate rate, the required increase in the cation uptake. Consequently the cation requirement is now also supplied by an increase in the uptake of the cations of which the availability remains the same as they do not occur in the fertilizer.

Consideration of the uptake, calculated from the yield and content, leads, by way of comparison, to the same conclusions. Table 1 shows only the effect of the nitrate application on the total cation and anion uptake, as this represents the essential reaction to the fertilization. This effect is determined by calculating the uptake of all observations (yield multiplied by the content) and then calculating the regression of the uptake in mg equivalents on the fertilization in mg equivalents of the nitrate applied.

Table 1 Increase in the uptake of the cations, the anion fraction A = Cl + S + P, and of nitrogen in mg equivalents per mg equivalent of nitrate applied to the soil.

	Potassium nitrate	Sodium nitrate	Magnesium nitrate	Calcium nitrate
Cations	+ 0.25 ± 0.07	+ 0.24 ± 0.03	+ 0.24 ± 0.08	+ 0.26 ± 0.02
Anions A	+ 0.01 ± 0.06	— 0.03 ± 0.02	— 0.03 ± 0.04	— 0.03 ± 0.04
Nitrogen	+ 0.56 ± 0.11	+ 0.49 ± 0.04	+ 0.54 ± 0.12	+ 0.62 ± 0.03

The values listed in the table show that per mg equivalent used in the fertilization the nitrogen uptake increases by an average of 0.55 mg equivalents and the total cation uptake by 0.25 mg equivalents, while the fertilization effects no change in the uptake of the anion fraction. The mean yield was 12 grams dry matter and the increase in the yield resulting from fertilization + 0.09 (± 0.02) grams dry matter per mg equivalent of nitrate applied. Consequently the content of the Cl + S + P anion fraction decreases with increasing yield. It is interesting to observe that owing to the increase in the nitrate available there is no increase in the uptake of the Cl + S + P anion fraction with increasing yield. Thus the plant shows a preference for the nitrate and does not therefore take up any further amount of the other anions.

As the data show, quantitatively the increase in the nitrogen uptake is considerable, being about twice as great as the increase in the cation uptake. This demonstrates the important share taken by nitrate in the cation uptake.

Except, however, for the important part played by nitrate in nutrition as a result of which the yield may be influenced and the uptake also increases accordingly, this property is not a specific feature of nitrate but may be observed in the case of any anion that is readily absorbed. An indication of this has already been found in the past in the case of chloride (DIJKSHOORN and 'T HART, 1957).

It can be seen from the data given in table 1 that the cation uptake shows an increase that is approximately half the increase in the nitrogen uptake, while Fig. 1a shows that the cation and anion relationship (C/A + N) is about 0.5. The plant apparently maintains this ratio as the uptake changes following fertilization, and owing to the great increase in the nitrate uptake there is, so to speak, no room room left for an expansion of uptake of the Cl + S + P anions.

On the face of it it would perhaps seem too schematic to postulate the anion function of the nitrate ion and to compare this ion with a metabolically inert ion such as chloride. A great part of the nitrate is rapidly converted by the metabolic process into organic, non-ionic nitrogen. But is should not be forgotten that by whatever mechanism nitrate in the plant is reduced it must always correspond to an equation of the type $NO_3^- + 8\,H^+ + He^-$ $\longrightarrow 2\,H_2O + NH_3 + OH^-$, so that no anion is lost in this conversion. It is possible, of course, for the plant to pass on to the medium again, via the roots, a part of the hydroxyl formed, which may be in the form of bicarbonate, for example. In this case an extra quantity of anion would be taken up as a result of exchange and this may lead to a cation-anion ratio < 1.

REFERENCES

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