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THE EFFECT OF THE ANION IN THE FERTILISER ON THE ANION AND CATION CONTENT OF PERENNIAL RYEGRASS [1]

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SUMMARY

The results are discussed of a pot culture experiment on the effect on the mineral composition of perennial ryegrass of a replacement of nitrate in the fertiliser by chloride, phosphate and sulphate. Starting from the cation-anion ratio in the plants, which appears to be independent of the composition of the fertiliser, information is given on the effect of a chloride dressing on the cation content in the herbage of which the order of magnitude was comparable to the effect of nitrate in the fertiliser.

INTRODUCTION

On studying the effect of nitrate fertilisation on the mineral composition of perennial ryegrass (DIJKSHOORN, 1957) it was found that the increase in the nitrogen content of the grass was accompanied by an increase in the cation content and a decrease in the content of the Cl + S + P anions. When the total anion content was represented by the sum of chlorine, phosphorus, sulphur and nitrogen and the total cation content by potassium, sodium, magnesium and calcium, it was found that the cation-anion ratio was practically independent of the use of feritliser, as was to be expected from the principle of constant cation-anion ratio formulated by BEAR (1950).

Although the increase in the nitrogen content was accompanied by a decrease in the content of the Cl + S + P anion fraction, it was found that this anion antagonism was unable to prevent a certain rise in the total anion content with an increasing nitrogen content. Starting from the assumption that the cation-anion ratio is not subject to change, then the increase in the cation content is due to this increase in the anion content. Consequently the cation supplied with the nitrates in the fertiliser was not the cause of this increase, although the nature of this cation did determine the extent to which it could contribute to increase the cation content of the plants. Hence the said effect of nitrate represents the effect of an anion which causes a considerable increase in the anion content of the plants as a result of the greater amount taken up from the fertiliser. A similar effect may therefore also be expected from fertilising with anions such as chloride, phosphate and sulphate, provided sufficient amounts of these anions are taken up from the fertiliser to bring about a distinct increase in the anion content of the plants.

Considerable changes in the content as a result of an application of ferti-

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liser are above all possible in the case of an element which is not essential to growth, and moreover on account of its properties is readily taken up and transported in the plant. If only a small amount of such an element is available there can only be a small uptake, even if the plant produces a large amount of dry matter. In this case the result is a very low content. If the element is added in a fertiliser the dry matter production is unchanged, but when the dressing is suffficiently heavy the uptake may increase very considerably, resulting in a proportionate increase in the content. This type of behaviour is exhibited by the chloride anion.

The phosphate and sulphate anions are essential to growth. Consequently very low contents of these elements do not occur, as when the uptake drops below a certain level there is also a decrease in the dry matter production. It is also found that when the content is sufficiently high to make growth independent on fertilisation, an extra supply of these anions produces an effect on the content thereof which is relatively smaller than that encountered in the case of chloride and nitrogen. This is related to the fact that phosphate and sulphate are absorbed and transported in the plant with relatively greater difficulty than the chloride ion. When a soil is used containing a sufficient quantity of essential elements to permit normal growth, but of which the chloride is not high, it may be expected that a chloride dressing will have a greater effect on the mineral composition of the plants than a phosphate or sulphate dressing.

Experimental

In order to observe the effect of chloride dressings on the cation and anion content in the grass, in the experiment discussed here the effect was investigated of adding to the soil equivalent amounts of chloride, monophosphate and sulphate. In order to keep the cation supply unchanged as well as to compare directly the effect of adding the anions with the effect of nitrate, in each series of dressings the starting-point was an addition of 40 mg equivalents of potassium nitrate per pot. In each successive member of the series a greater equivalent part of the potassium nitrate was replaced by the potassium salt of one of the above-mentioned anions, while the last pots in each series were given no nitrate, but only 40 mg equivalents of potassium chloride, potassium sulphate or potassium monophosphate. Thus each fertilisation series contains per pot a constant potassium dressing of 40 mg equivalents, a dressing of the corresponding anion rising from nil to 40 mg equivalents, and a nitrate dressing falling from 40 to nil mg equivalents.

Use was made of a sandy soil having a moderate nitrogen and chloride content. In the manner previously described, the prepared pots were planted with perennial ryegrass which after three days was clipped at a height of approximately 3 cm above the soil. After remaining in the greenhouse for four weeks, the pots being brought up to weight daily with de-mineralised water, the herbage produced by regrowth was collected by clipping to the original height. The dry matter yield was 11 gm in the case of the pots not dressed with nitrate, and increased to 15 gm in the case of the heaviest nitrate dressing. In the case of the pots dressed with equal amounts of nitrate the same yield was found in the three series, so that the choice of the other potassium salt had no effect on the yield.

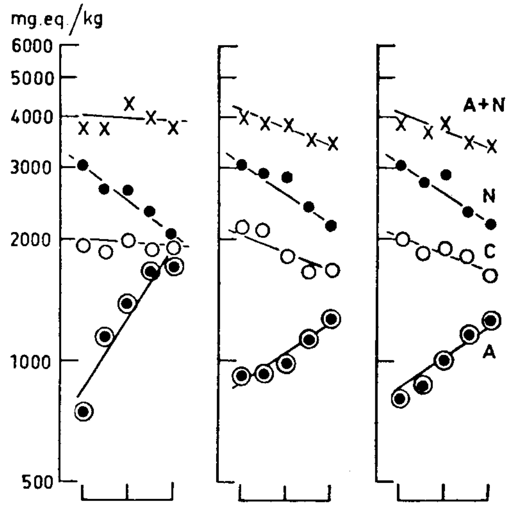

FIG. 1a ANION CONTENT A = Cl + S + P, CATION CONTENT C = K + Na + Mg + Ca, KJELDAHL NITROGEN CONTENT N AND TOTAL ANION CONTENT A + N, IN MG EQUIVALENTS PER KG OF DRY MATTER PRODUCED IN THE CHLORIDE SERIES (LEFT-HAND GRAPH), IN THE PHOSPHATE SERIES (MIDDLE GRAPH) AND IN THE SULPHATE SERIES (RIGHT-HAND GRAPH). Abscis : compare figure 1b.

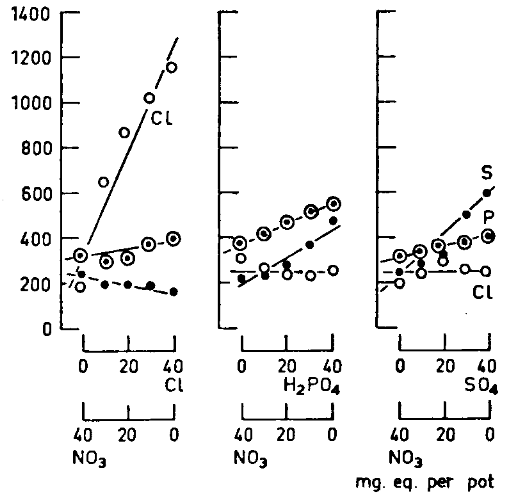

FIG. 1b CHLORINE, PHOSPHORUS AND SULPHUR CONTENTS IN MG EQUIVALENTS PER KG OF DRY SAMPLE. THE ABSCIS INDICATES INCREASING AMOUNTS OF THE ANION SUPPLIED IN EACH SERIES IN MG EQUIVALENTS PER POT AND THE CORRESPONDINGLY DECREASING AMOUNTS OF NITRATE, ADDED IN THE FERTILISING MIXTURE OF POTASSIUM SALTS.

DISCUSSION

The contents found in the samples are plotted in Figs. 1a and 1b against the number of mg equivalents of chloride, phosphate or sulphate present in the fertiliser. The left-hand graphs relate to the chloride series, the middle graphs to the phosphate and the right-hand graphs to the sulphate series. The abscissa shows both the amount of the anion investigated and the amount of nitrate used in the fertiliser. The effect of increasing amounts of chloride, phosphate and sulphate should be read from left to right in the corresponding graphs, while the effect of increasing amounts of nitrate is shown in the graphs from right to left.

Fig. 1a shows the trend of the anion fraction A (= Cl + S + P), the cations C (K + Na + Mg + Ca), the Kjeldahl nitrogen content N and the total anion content A + N, in mg equivalents per kg dry matter, depending on the composition of the fertiliser. In these graphs use is again made of a logarithmic scale in order to indicate constant ratios by means of parallel lines.

A more detailed consideration of the effect of increasing amounts of nitrate in the phosphate and sulphate series (viz. reading from right to left) shows that this effect is reflected in an increase in the nitrogen content, the total anion content A + N, and the cation content C. The content of the anion fraction A decreases with increasing nitrate fertilisation. Taking into account the relatively large degree of error to which this type of experiment is subject, the trend of the total cation content C and the total anion content A + N is best indicated by two paralled lines drawn in the graphs through the corresponding plots. The position of these lines corresponds to a cation-anion ratio of 0.5, and the same slope indicates that this ratio is not clearly dependent on the composition of the fertiliser.

Hence this result exactly corresponds to the effect of an increasing nitrate dressing, previously found by DIJKSHOORN (1957). Although in this case the increase nitrate dressing involves at the same time a decreasing phosphate or sulphate dressing, the main effect is entirely determined by nitrate. Moreover a closer inspection of the graphs reveals that the result of these two series may be regarded as identical. Whether the nitrate in the fertiliser is replaced by phosphate or sulphate, the trend of the total cation and anion content of the plants resulting from the replacement is not demonstrably affected by the choice of these anions.

The results of the chloride series show a somewhat different pattern. The effect of increasing amounts of nitrate in the fertiliser is only clearly reflected in the increasing nitrogen content. Its trend as a result of the dressing differs hardly at all from that of the other series. Apparently, however, the cation content C and the total anion content A + N are less dependent on the composition of the fertiliser.

When nitrate is entirely replaced by chloride, i.e. over the whole fertilisation range, the nitrogen content in the plants decreases by about 1000 mg equivalents per kg of dry matter; this is approximately equal to its decrease in the other series. The increase in the anion fraction A accompanying this replacement is greater in the chloride series and in this case is also about 1000 mg equivalents per kg of dry matter. Consequently when nitrate is replaced by chloride there is little variation in the value of the total anion content A + N and this anion content in the chloride series is substantially independent of the composition of the fertiliser.

The values for the total cation and anion content of the first member of the chloride series are somewhat low, as appears from a comparison with the values for the first member of the other two series which also relate to a dressing with 40 mg equivalents of nitrate and are consequently identical. Taking this into account, the trend of the cation content (C) and the total anion content (A + N) is represented by the two parallel lines made in the graph by the corresponding plots. These lines show that in the chloride series as well the dry matter produced has a cation-anion ratio of 0.5 which is independent of the fertiliser.

Hence the smaller dependence of the cation content of the plants in the chloride series on the composition of the fertiliser is due to the fact that there is no decrease in the total anion content such as generally occurs with a decreasing nitrogen content, since owing to the ready uptake of the chloride from the fertiliser a corresponding increase is effected in the anion fraction A. The nitrate effect is disguised by chloride as numerically both anions give rise to corresponding effects in the mineral balance.

In the chloride series the decrease in the nitrogen content is approximately equal to the increase in the anion fraction A. Although nitrate and chloride are both monovalent anions and both may be considered as ions which are readily taken up by the plant, this quantitative correspondence in the effect on the composition of the plant is noticeable. It is probable that this corresponding effect on the anion content is determined by a limit in the anion increase which nitrate and chloride are both easily able to satisfy, but as a result of which their effect is limited in a numerically equivalent manner.

The occurrence of antagonism, in which a rise in the content of one of the elements of the group is accompanied by a fall in the content of one or more of the remaining elements of the group, usually provides an indication as to whether a limit has been reached in the content of a group of elements such as the anions. This prevents the limit from being exceeded when as a result of a fertilisation the content of one of the anions shows an increase which could lead to such an effect by itself. An example of such an antagonism is the decrease in the anion fraction A with increasing nitrogen content. This decrease is, of course, also determined by the fact that an increasing amount of nitrate in the fertiliser is accompanied by a decreasing supply of one of the anions occurring in the anion fraction A. In the chloride series this effect of the supply even predominates, but in the phosphate and sulphate series the nitrate effect is predominant.

In Fig. 1b the contents of the individual anions of the fraction A are shown separately. In the series in which the nitrate effect predominates, i.e. the phosphate and sulphate series, it appears that when the nitrate dressing is increased (i.e. from right to left in the graphs) there is also a decrease in the content of the anion which does not occur in the dressing, i.e. sulphur in the phosphate series and phosphorus in the sulphate series.

In the chloride series this effect is only encountered in the case of phosphorus. In this series the sulphur content decreases with increasing chlorine content and decreasing nitrogen content in the plant. Hence the increasing supply of chloride causes both a great increase in the anion fraction A and an antagonistic suppression of the sulphur content. That the antagonism is reflected in the sulphur content and not in the phosphorus content is related to the fact that of the chloride, phosphate and sulphate anions it is the sulphate anion that is most difficult for the plant to absorb and transport. Hence a large increase in the chloride uptake will interfere in the first instance with the sulphate uptake.

The occurrence of these antagonisms among the anions shows that both in the case of the greater chloride uptake and the greater nitrate uptake a resistance is set up against an excessive anion content. It is therefore probable that the correspondence in the magnitude of the effect of nitrate and chloride on the total cation and total anion content in the plant is determined by this limit in the anion content. The specific properties of these anions only agree insofar as both can be absorbed with sufficient ease in order to bring about this limit in the anion content.

An important aspect of the plant nutriment is the manner in which such a limit is effected in the anion content. In reviewing the results of Fig. 1 it is noticeable that the anion antagonism with a low nitrogen level, i.e. on the right-hand side of the graphs, is only clear in the case of the chloride series, being shown in the form of the above-mentioned divergent trend in the sulphur content. In this series a high cation content of approximately 2000 mg equivalents per kg of dry matter also occurs in this fertilisation range. One consequence of BEAR's rule regarding the relationship between cations and anions is that a limit in the content of the two categories is already given when either the cations or the anions show a limited uptake. Although in general it is difficult to deduce from the observations which group of elements is primarily limited by the plant in the uptake, it would seem that for the time being experiences mostly agree with the assumption of a limited cation uptake of which the content does not exceed a value of 2000 mg equivalents. Starting from a cation-anion ration of 0.5, a total anion content could occur of which the value does not exceed 4000 mg equivalents. When this content has been reached additional amounts are either difficult to take up from a fertiliser, or their uptake is accompanied by greater antagonistic effects among the anions.

REFERENCES

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