Plant and Soil XIX, no. 3 December 1963

RESIDUAL EFFECT OF NITROGEN FERTILIZER ON SUCCEEDING CROPS IN A MODERATE MARINE CLIMATE

by F. VAN DER PAAUW

Institute for Soil Fertility, Groningen, The Netherlands

Residual effects of fertilizers have been observed frequently; those of phosphorus may last several years.

Though the soluble nitrogen in a humid climate is subject to vigorous leaching, recent investigations (Harmsen [5], van der Paauw [9], Baumann [1]) have shown that the value of the amount of soluble nitrogen in the whole rooting zone for the nitrogen supply of the crop should not be underestimated. This amount depends largely on the intensity of rainfall, especially in winter, and on soil properties.

Large residual effects of nitrogen applied to the preceding crop are mentioned in literature (Crowther [2], Jacquot [7], Hunter and Yungen [6], Pearson *et al.*[13]). White, Dumenil and Pesek [14] paid much attention to the problem. Residual effects corresponding to from 0 to 49 per cent with an average of *ca* 25 per cent of the effect of a fresh fertilization (Dumenil [3]) were found for oats or corn succeeding corn. These responses were especially large after dry seasons. Considerable differences in nitrate content in different years were observed in the 6–21 inch depth of soil (White and Pesek [14]).

It is of interest to know whether similar effects also occur under the more humid conditions of western Europe. Information concerning this problem has been derived from a series of long-term experimental fields with varied nitrogen dressing in the moderate marine climate of the Netherlands.

TABLE 1

Data of experimental fields

Exp. field		First year	Soil	Place	Rotation
Pr	934	1947	Reclaimed moor (old)*	Borgercompagnie (Gr.)	Potatoes – rye – oats**
Pr	935	1947	Reclaimed moor (new)*	Emmercompascuum (Dr.)	,, – ,, – ,, **
PO	470	1954	Sand (old)	Heino (Ov.)	,, – ,, – ,,
Pr	1521	1954	Very light marine clay	Hornhuizen (Gr.)	Potatoes – wheat – oats
Z	1795	1954†	Light marine clay	Wilhelminadorp (Z.)	,, – ,, – ,,
Cl	1605	1954	River clay	Randwijk (Gld.)	,, – ,, – ,,
NNH	1806	1955	Light marine clay††	Wieringerwerf (NH.)	,, – ,, – ,,
IB	25	1957	Loam	Ottersum (L.)	,, – ,, – ,,

* humic sandy layer on sub-soil of peat.
** till 1953 potatoes-rye.
† finished in 1960.
†† reclaimed Zuiderzee soil.

EXPERIMENTAL FIELDS

Nine experimental fields were laid out between 1947 and 1957 in different parts and on different soils in the Netherlands. With the exception of one field where the experiment terminated in 1960 the experiments are still being continued.

Potatoes, wheat (on clay and loam) or rye (on sand), and oats are grown in rotation. Experiments in two fields started in 1947; in the first seven years

only potatoes and rye have been grown. Nitrogen is applied in 5 to 6 different amounts from zero to a very high dressing in 2 to 4 replicates.

The different amounts of applied nitrogenous fertilizers are yearly shifted over the plots in such a way as to make the total amount of nitrogen applied to each plot about the same over a period of six years. An advantage of this annual re-arrangement is that cumulative effects are avoided and that possible residual effects of nitrogen applied in the preceding year can be eliminated statistically. However, in this treatise these residual effects are taken into consideration.

PROCEDURE

Residual effects are compared with the effects of a fresh nitrogen fertilization. This comparison is made only as far as nitrogen is governing the yield. The residual effect is expressed as a percentage of the effect of the fresh nitrogen dressing.

An example is given in Fig. 1. Yields have been plotted against the amount of nitrogen applied in the preceding year at different levels of fresh nitrogen dressing. Nitrogen being the limiting factor in the range 0 to 66 kg per ha of fresh nitrogen, the average effect of residual nitrogen is calculated as the percentage of the effect of 66 kg per ha of nitrogen. In this case it amounts to 25 per cent.

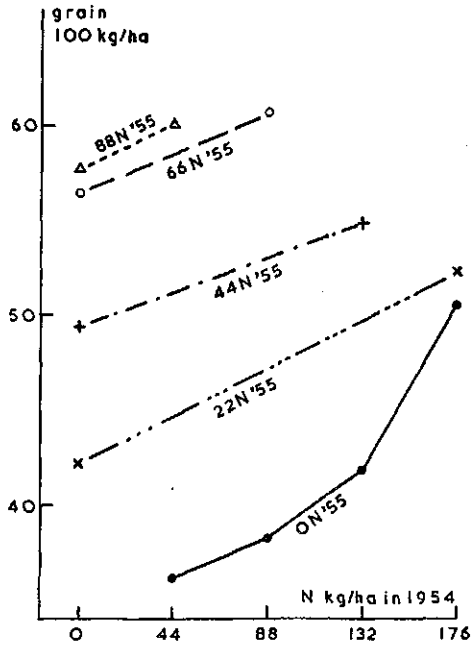

Fig. 1. Relation between nitrogen dressing to preceding crop (potatoes) and yield of wheat freshly dressed with 0 to 88 kg/ha nitrogen on river clay (1955).

On account of the small residual effects single data are inaccurate in many cases. Due to the large number of data significant average results have been obtained. As the differences of the amounts applied to potatoes were the highest, the data obtained with the succeeding rye and wheat crops were found to be the most accurate. Moreover these crops are very sensitive to nitrogen. Conversely, the results obtained with potatoes succeeding oats were the least reliable.

In 11 out of 14 winters (1947/48–1960/61) rainfall was moderate or high amounting to from 200 to 400 mm in the four months period November-February. Very dry winters with about 120 mm of rain occurred in 1948/49 and 1953/54. In 1959/60 rainfall amounted to about 200 mm but the preceding summer and autumn had been extremely dry. Part of rainfall during winter was used for resaturating the soil before leaching occurred. Therefore 1959/60 can be considered a dry winter. In spring soluble nitrogen was still found in the arable layer.

RESULTS

The results have been averaged according to crop and soil (Tables 2 and 3).

A highly significant, average residual effect of 5.6 per cent has been found. This response is decidedly smaller than the average found in drier climates. It must be noticed, however, that rainfall exceeded the normal during the experimental years.

Very significant results were found for rye and wheat (Table 2). Average results for oats and potatoes were similar but not quite significant. Statistical significance was obtained for oats only on sandy soils.

Positive results were also obtained on all soils (Table 3) but significancy was reached in only a few cases.

TABLE 2

Residual effect of nitrogen			
Crop	Number of years	Residual effect in % with standard error	P
All crops	162	5.6 ± 1.32	< 0.001
Rye	29	4.5 ± 0.97	< 0.001
Wheat	34	8.5 ± 2.34	0.001
Oats	40	4.5 ± 2.33	0.06
,, (sand only)	12	5.5 ± 2.23	0.02
,, (clay only)	28	4.1 ± 3.21	0.20
Potatoes	59	5.7 ± 3.02	0.07
,, (sand only)	29	5.1 ± 4.50	0.30
,, (clay only)	30	6.3 ± 4.12	0.10

TABLE 3

Residual effect per experimental field			
Exp. field	Number of years	Residual effect	P
Pr 934	32	5.3 ± 1.84	0.01
Pr 935	29	4.1 ± 2.45	0.10
PO 470	14	5.6 ± 7.38	0.50
Pr 1521	21	2.5 ± 2.89	0.40
Z 1795	18	5.7 ± 3.36	0.10
CI 1605	19	6.9 ± 6.41	0.30
NNH 1806	18	11.0 ± 3.75	0.01
IB 25	11	5.9 ± 3.37	0.10

From 1955 to 1961 significant positive results were obtained only in 1956, 1959, and 1960 amounting to 10.9 ± 3.17, 9.7 ± 4.13, and 16.8 ± 3.66 per cent (P = 0.001, 0.02 and 0.001) respectively.

A more realistic picture of residual effects is obtained by relating these to the amount of fertilizer nitrogen left in the soil. In 130 cases a calculation of this ratio has been realized by means of crop analysis. Instead of an average residual effect of 5,3 per cent (in relation to the amounts dressed) 13,5 per cent was found. It is obvious, however, that a much greater part of the nitrogen applied in the preceding year is not available to the succeeding crop. It is probable that nitrogen has been lost already, partly by leaching, in the preceding season. Another part originally bound in organic form (leaves, roots, weeds, micro-organisms) may have been remineralized before winter and thus also have become susceptible to leaching.

Residual effect as affected by rainfall in winter

Rainfall in November-February is especially responsible for leaching of nitrogen (Fisher [4], Lehr and Veen [8], van der Paauw [9]). The sum of rainfall in these months has been related to the average residual effects (in percentages of effects of equal amounts of fresh fertilizer) in 1955–1961 (Fig. 2).

In spite of the relative inaccurateness of the results there is an indication of a pronounced effect of winter rainfall. It has already been mentioned that the winter of 1960 which induced the highest effect was much drier than indicated by its sum of rainfall.

It may be concluded that higher residual effects than actually

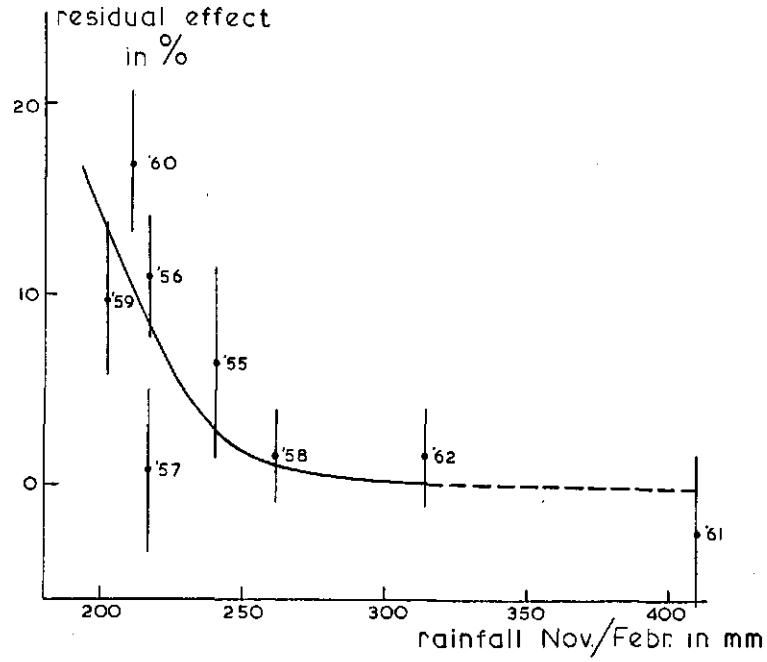

Fig. 2. Relation between amount of rainfall in November-February and average residual effect of nitrogen in different years. Vertical lines through dots indicate the standard errors. Result 1962 has been added after the manuscript had been prepared.

found in these experiments may occur after extremely dry winters. The number of data obtained in 1949—1954 is too scanty to allow for an accurate determination of the residual effects.

The present results are not contradictory to those in drier regions where higher values have been found.

DISCUSSION

The average residual effect of nitrogen in the Netherlands marine climate is small. The average annual effects varied between zero after very wet and 17 per cent after relatively dry winters. Effects may be higher in extremely dry winters and equal those found in Iowa where the winters are dry.

Fertilization with nitrogen contributes considerably to a rise of soil fertility when the winters are dry. If rainfall remains below normal for some years (van der Paauw [10 11]), the fertility level increases cumulatively due to an increase in residual fertilizer

nitrogen. On the other hand in long periods with high rainfall there will be a continual loss of nitrogen.

The nature of the preceding crop is especially important after dry winters. The high value attributed to root crops in the rotation may partly be due to the large amounts of nitrogen applied to those crops.

The uncertainty of residual effects of nitrogen in a variable climate necessitates an adaptation of fertilizing practice to the pattern of the preceding weather as claimed by the author [9]. Lodging of cereals resulting from excessive fertilization can be avoided by reducing nitrogen dressing after dry winters. Considerable increases of yields can be obtained by increasing this dressing after wet winters. The amount of nitrogen in an available form in the early spring after a dry winter averages 40 kg per ha higher than after a wet one (van der Paauw [12]).

SUMMARY

In the moderate marine climate of the Netherlands the annual residual effect of fertilizer nitrogen applied in the preceding year on nine experimental fields (1948–1961 and especially 1955–1961) varied between zero and 17 per cent of the effect of the same amount of freshly applied nitrogen. The average effect in 162 experiments was 5.6 per cent. In relation to the amount of fertilizer nitrogen left by the preceding crop the residual effect amounts to 13.5 per cent.

The effect was found for all crops and all soils investigated although it was not always statistically significant.

The residual effect depends on the amount of rainfall in the months November to February (Fig. 2). It tends to zero in very wet winters. After very dry winters almost as high results may be obtained as has been found in climates with pronounced dry winters.

After dry winters, and especially during dry periods of longer duration, fertilizer nitrogen will contribute considerably to a rise of soil fertility [10 11].

Received February 13, 1963

LITERATURE

1 Baumann, H., Die Abhängigkeit der Düngewirkung von der Witterung im Dikopshofer Dauerdüngungsversuch 1906–1957. Z. Pflanzenernähr. Düng. Bodenk. **95**, 1–9 (1961).

2 Crowther, F., Multiple-factor experiments on the manuring of cotton in Egypt. Empire J. Exptl. Agr. **5** 169–179 (1937).

3 Dumenil, L., Residual effect of nitrogen fertilizer applied to corn on the yields of the succeeding corn or oats crops. Agron. Abstr. **1954**, 28–29 (1954).
4 Fisher, R. A., The influence of rainfall on the yield of wheat at Rothamsted. Phil. Trans. Roy. Soc. London Sci. B **213**, 89–124 (1924).
5 Harmsen, G. W., Einfluss von Witterung, Düngung und Vegetation auf den Stickstoffgehalt des Bodens. Landw. Forsch. Sonderheft **15**, 61–73 (1961).
6 Hunter, A. S., and Yungen, J. A., The influence of variations in fertility levels upon the yield and protein content of field corn in eastern Oregon. Soil. Sci. Soc. Am. Proc. **19**, 214–218 (1955).
7 Jacquot, H. D., Annual cropping with nitrogen in the intermediate rainfall areas of eastern Washington. Washington Agr. Exp. Sta. Circular **124** (1953).
8 Lehr, J. J. and Veen, B., Nitrogen economy of the soil in relation to seasonal and periodical climatic variations. Intern. Soc. Soil Sci. Trans. Dublin 1952 **II**, 61–67 (1952).
9 Paauw, F. van der, Effect of winter rainfall on the amount of nitrogen available to crops. Plant and Soil **16**, 361–380 (1962).
10 Paauw, F. van der, Cyclical variations of crop yields induced by weather through the intermediary of the soil. 7th Intern. Congr. Soil Sci., Madison, Wisc., U.S.A. **IV**, 481–487 (1960).
11 Paauw, F. van der, Periodic fluctuations of soil fertility, crop yields and of responses to fertilization effected by alternating periods of low or high rainfall. Plant and Soil **17**, 155–182 (1962).
12 Paauw, F, van der, Invloed van de regenval in de winter op de behoefte aan stikstof op verschillende grondsoorten. Landbouwvoorl. **20**, 102—107 (1963)
13 Pearson, R. W., Jordan, H. V., Bennett, O. L., Scarsbrook, C. E., Adams, W. E., and White, A. W., Residual effects of fall- and springapplied nitrogen fertilizers on crop yields in the Southeastern United States. Agr. Research Service U.S. Dept. Agr. Techn. Bull. **1254** (1961).
14 White, W. C., and Pesek, J., Nature of residual nitrogen in Iowa soils. Agron. Abstr. **1957**, 30 (1957).
15 White, W. C., Dumenil, L., and Pesek, J., Evaluation of residual nitrogen in soils. Agron. J. **50**, 255–259 (1958).