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Interrelation of nitrogen, organic matter, soil structure and yield

Summary

This paper is intended as a scientific introduction to the excursion to the experimental farms of the Institute for Soil Fertility in the Northeast Polder (a comparison between the use of artifical fertilizers only, green-manuring with supplementary artificial fertilizers, and ley-farming on a silty clay soil). Some preliminary results with potatoes concerning the influence of organic manuring on the nitrogen conditions of the soil, on the soil structure dependent on the weather circumstances, and on the yield of tubers are mentioned. Furthermore the relation between the maximum yield of tubers and between the nitrogen uptake by the tubers on the 0 N-plots of the object 'artificial fertilizers only', and the mean temperature during the growing period have been studied. The yield differences between the objects 'ley-farming' and 'artificial fertilizers only' have been related with the length of the growing season. The nitrogen-yield curve has proved itself useful to study the interrelations of nitrogen, organic matter, soil structure, and yield.

The experimental scheme of well chosen series of nitrogen-amount field trials for the study of the interrelations of nitrogen, organic matter, soil structure, and yield has been introduced in our Institute for the first time in 1947. The nitrogen yield curve is used here for the characterization of the nitrogen conditions of the soil. The mobility of the soil nitrogen makes it practically impossible to define this 'nitrogen status' by a single value as in case of phosphate and potassium. The parameters of the nitrogen-yield curve, the yield without nitrogen dressing, the maximum yield, and the optimum nitrogen amount, may be plotted against soil factors as structure, humus content, clay content, water level, and also against meteorological factors. It will be clear that for this purpose the field trials ought to be chosen in such a way as to cover quite a stretch of the variance of the factors mentioned.

Fig. 1 and 2 show some results from these experiments in 1947 taken from Ferrari [1]. These results concern the relation between soil structure and the optimum nitrogen dressing for potatoes in a region of marine clay. It has been proved that this relation for both old arable land and broken pastures (shown separately in the figure) is strongly dependent on the weather conditions in each year.

This experimental scheme has been applied afterwards many times in our Institute, also to the problem: 'How may the productivity of a silty clay soil[1] be maintained in the course of the years?'. This is the main research project studied on our four experimental farms in the Northeast Polder. Three farms with exactly the same history and behaviour, lying close together, gave the opportunity for a study about the influence of the intensity of organic manuring on the workability and productivity of the soil under cir-

[1] pH 7.4; $CaCO_3$ 10.5%; humus 2.3%, particles $< 16\ \mu$ 33%.

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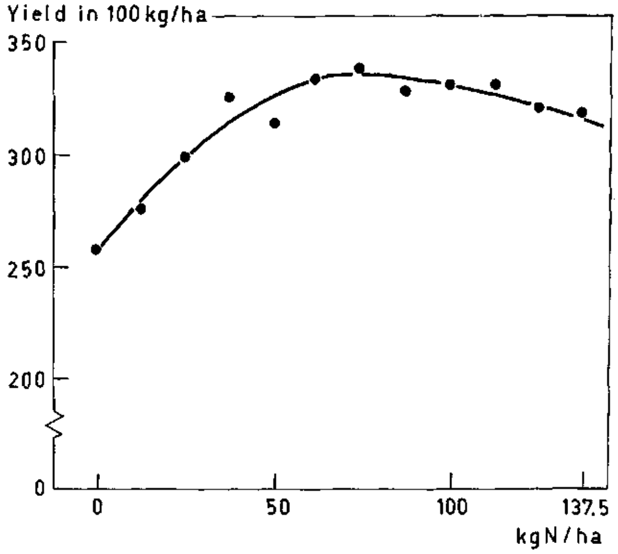

Fig. 1. Influence of nitrogen dressing on yield of potatoes on a special field (marine clay soil).

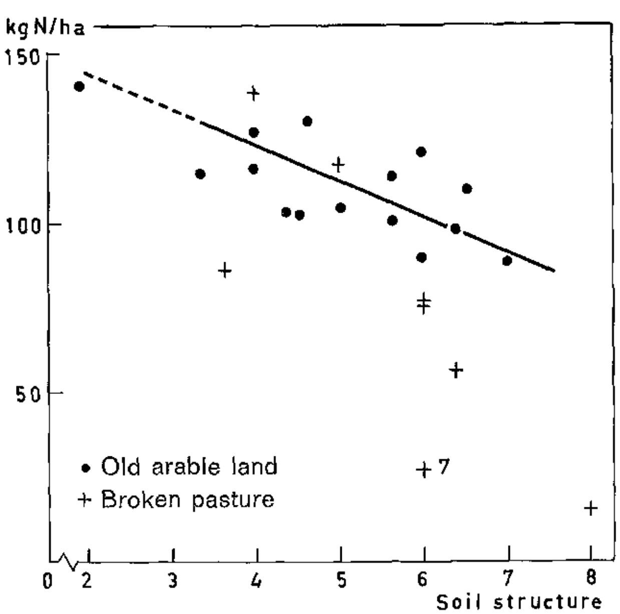

Fig. 2. Relation between soil structure and quantity of nitrogen dressing necessary to obtain maximum yield.

cumstances of practical farming with a heavy mechanization. On these farms are used: only artificial fertilizers *(Kunstmestakker)*, clovers and Italian ryegrass in the crop rotation supplemented by artifical nitrogen fertilizer *(Klaverland)* and ley-farming *(Wisselweide)* respectively. The fourth farm is the experimental farm *Dr. H. J. Lovink-hoeve*. Many experiments about fertilization and soil cultivation have been accommodated on this farm. One of these experiments is the so-called 'Miniature organic-matter farms', an experimental field with the same scheme as the farms mentioned before. In this paper the three objects are indicated by A, B, and C. Nitrogen-amounts field trials have been laid out on these 'three small farms'. Many measurements are performed on soil and plant under varying weather conditions. The results provide insight into the problem and are furthering the transferability to other conditions. The miniature farms form the scientific background of the practical problem, while on the large farms we are getting much experience about difficulties met under practical conditions when applying different intensities of organic manuring. We aim to give an impression of our scientific approach, although the amount of experimental years is too small for exact conclusions. We have to restrict ourselves mentioning only some results of the experimental field 'small farms' about the influence of organic manure on the soil and on the growth of potatoes.
The experiment started in 1954. The crop rotation, that had to be changed in the course of the years, is at present: flax, seed potatoes, sugar beets, spring barley, consumption potatoes, and winter wheat. Consequently 50% of the land is under beets and potatoes. The organic-matter supply of the soil on experimental object A is restricted to the roots and the stubbles of the crops, about one ton of dry organic material per ha per year. Since 1965 on object B this supply is more than three times that of A, viz. about 3.4 ton, using green manure in four of the six years of the rotation. On object C the organic-matter supply is about the same as on object B, but of a different character. Here not only roots and stubbles of the crops are concerned, but also twice a turned ley, once green manuring, and twice stable dung during the rotation. All organic matter, except the normal straw and grain yield remains on object C.

It will be clear that the nitrogen and organic-matter conditions changed in the course of years in a different way on the three objects. The optimum nitrogen dressing of consumption potatoes is on an average for the last three years 140, 128 and 70 kg N/ha.
Fig. 3 and 4 show the changes of the nitrogen and the organic-carbon content of the soil brought about in the course of years up to 1965. The organic-matter

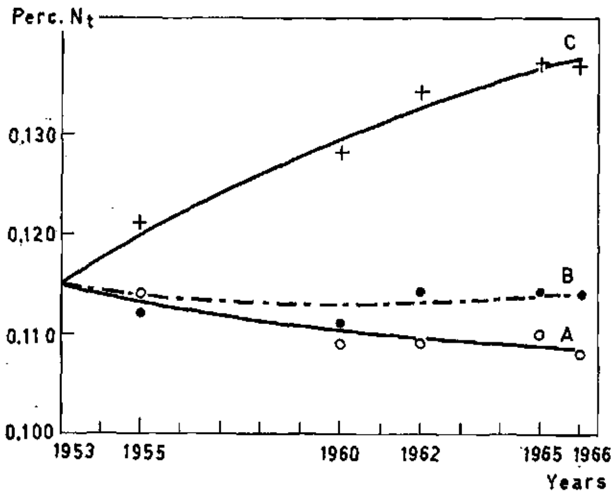

Fig. 3. The change of the total nitrogen content of the soil in the course of years.
A - artificial fertilizers only, B - green-manuring, C - ley farming.

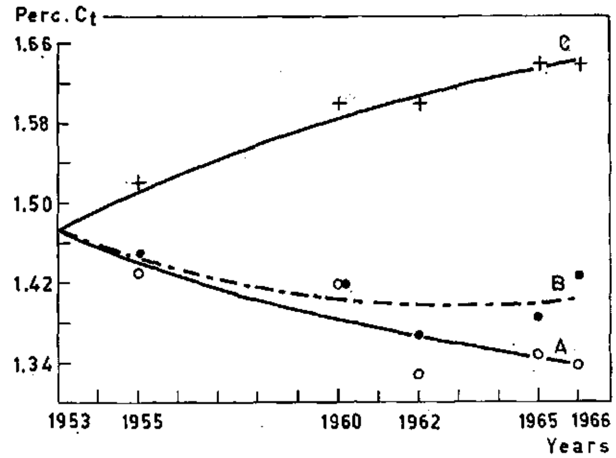

Fig. 4. The change of the total carbon content of the soil in the course of years.
A - artificial fertilizers only, B - green-manuring, C - ley farming.

Table I. **The nitrogen effect of different green-manure crops on potatoes during the first year following application, on marine silty clay.**

Green-manure crop	Organic matter (kg/ha)	Total N in the green manure (kg/ha in topsoil)	C/N ratio of the manure	Nitrogen effect compared with that of $Ca(NO_3)_2$ *	'Nitrogen effect' relative to N_t of the green manure
White clover after flax as cover-crop	3000	110	10	100	91
Vetch as second crop after peas	3000	100	10	80	80
Berzeem as second crop after peas	2500	80	12	60	75
Black medick after flax as cover crop	5000	150	14	80	53
The stubble of one year old red clover	2500	80	18	35	44
Black medick after winter wheat as cover crop	4000	120	19	40	33
Stubble of two years old lucerne	5000	145	19	50	34
Italian ryegrass after peas	4000	100	19	40	40
Ley (2½ years old)	10,000	170	21	50	29

* This effect has been deduced from the nitrogen-yield curve.

supply to the soil was at the time 1, 2.5, and 4.3 tons, respectively. As for object A this amount proves to be not sufficient to maintain the original nitrogen and carbon contents. This was hardly the case for object B (since 1965 the organic-matter supply has been increased), whereas there is a steady increase of N- and C-contents on object C.
The maintenance of the organic-matter conditions of the soil is an important problem in The Netherlands, especially for loam and clay soils. These often are marginal in this respect. Kortleven [3] determined under our climatic conditions the coefficients for the break-down of the humus (2% per year relatively) and the humification of the supplied organic matter (40%). These are average figures. These parameters of the equation given by Kortleven have, however, still to be studied more in detail, particularly as for various kinds of organic matter. Experiments like these in the Northeast Polder may provide us with important results in this respect.
The C/N-quotients of the humus are decreasing as follows:

Year	A	C
1953	12.8	12.8
1960	12.5	12.3
1965	12.2	12.4

It is a well known fact that the C/N-quotient may be an important measure for the 'quality' of not only the soil organic matter but also of the organic manure.
Table I shows the relation between the C/N-quotient of the green manures and the availability of the nitrogen for the potatoes in the first year after application: the lower the C/N-quotient, the faster the availability. In the second year the after-effect of the manures with a low C/N-quotient (approx. 10) is much lower than that of the organic manure with a high C/N-quotient (approx. 20). It has been proved in our experiments that the nitrogen availability of the ploughed-in leys may have a significant influence on the nitrogen content of the soil in late summer and consequently on the length of the growth period. It is a pity that the Phytophthora often partly spoils this profit. We mostly are obliged to kill the potato haulm before its dying off. For instance the results of the year 1963 are unusable due to this drawback.

Ley farming has always favourably influenced the structure of the soil. Green manure has less influence; its effect depends on the weather conditions and the moisture of the soil at the moment of turning under the manure. Green manuring specially suppresses the danger of slaking.
Only the influence of rainfall on the soil structure in the course of years will be mentioned. On the soil of the miniature organic-matter farms it proved that during the growing season the total pore space may increase or decrease under influence of the rainfall; the limit between increase and decraese lies at a rainfall of about 240 mm in the months June, July and August. Fig. 5 shows the results.

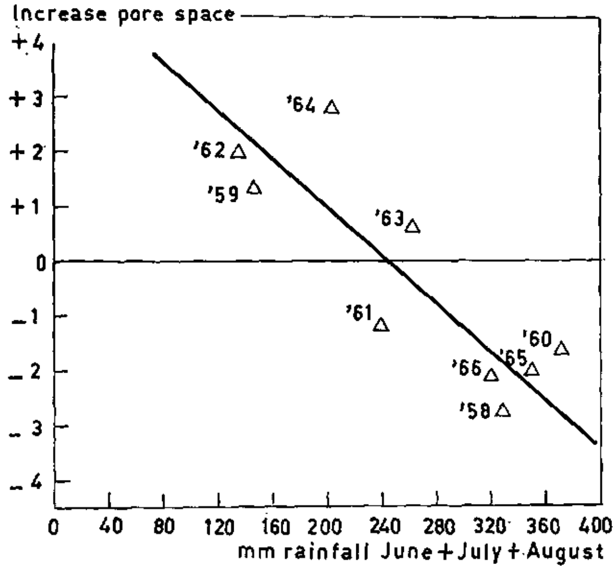

Fig. 5. The change of the total pore space during the growing season in relation to the rainfall for the different years.

As a matter of fact the following winter influences the soil structure also. In general the soil structure in late spring of the following year appears to be the result of the rainfall in the preceding year (Fig. 6).
Couples of years with a low and a high rainfall can be clearly distinguished. The difference is 0.6 points in the visually determined soil structure (this value is correlated with the pore space). The slope of the curves shows the influence of the humus content (differences caused by ley farming) on the soil structure.

At last we have to consider the yearly yield variations and the differences of the yield between the three experimental objects. The experiments were continued during 13 years. It is a drawback that after 5 years the variety had to be changed from Eigenheimer to Bintje; only 8 experimental years with Bintje are consequently available, one of which (1963) was spoiled by Phytophthora. It is clear that 7 points may only provide us with indications whether we are on the

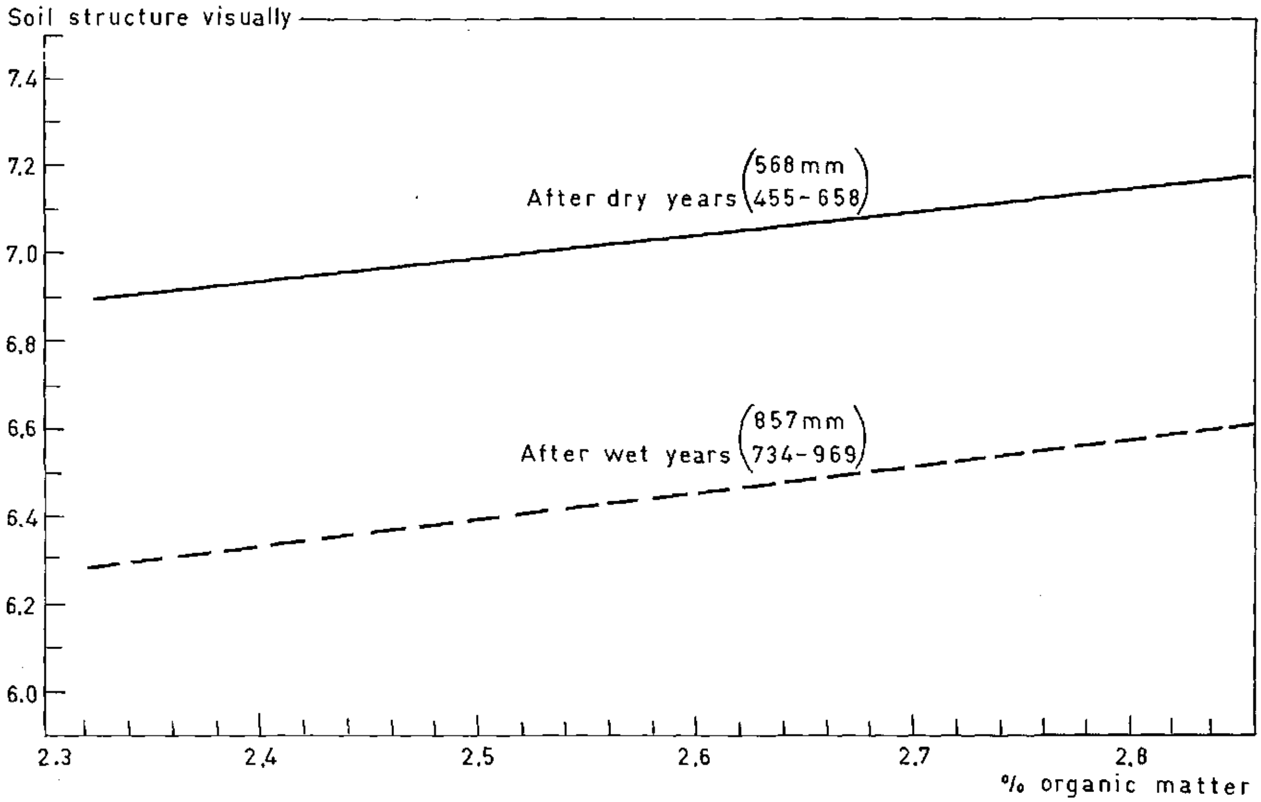

Fig. 6. The mean difference in soil structure after relatively dry and wet years in relation to the organic-matter content.

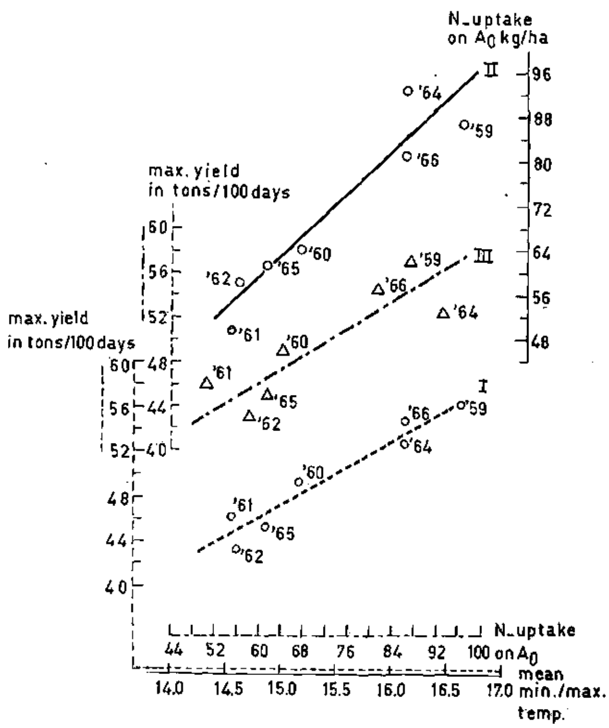

Fig. 7. Line I — The relation between the mean min./max. temperature during the growing season of potatoes and the maximum yield of tubers reduced on 100 growing days in the course of years.
Line II — The relation between the mean min./max. temperature and the nitrogen uptake of the tubers on the undressed plot of the A-object (artifical fertilizers only) reduced on 100 growing days in the course of years.
Line III — The relation between the N-uptake of the tubers on A_o and the maximum yield reduced on 100 days in the course of years.

right path with regard to our experimental set and to the various measurements needed for the interpretation of the results.
Fig. 7 shows some relations between the mean temperature (average of maximum and minimum temperature) during the growing season, the nitrogen uptake of the potatoes on the undressed plots of the object A (N-A_o) and the average maximum yield of the three objects reduced to 100 growing days. The 'mean' temperature has been used as a measure for the type of weather in the different years. N-A_o is to a certain extent a measure for the mineralization.
We aim with the three relations shown in Fig. 7 to get some information how far the maximum tuber yield and N-A_o have been influenced by the mean temperature and if there may be any indication that N-A_o as a measure for the mineralization process has a characteristic influence on the maximum yield. The lines I and II show the relation between the mean temperature as an independent factor and the dependent factors max. yield and N-A_o. Line III is a relation between the two dependent factors mentioned.
It follows from line I that a mean temperature increase of 2°C (from 14.6° to 16.6°) attends a tuber yield increase of 27% (from 44 to 56 tons). Line II shows a N-A_o increase of 67% (from 54 to 90 kg N/ha).
The increase of N-A_o has been caused not only by the influence of the temperature on the mineralization process, but may be influenced also by a direct increase of growth with which a nitrogen uptake is going parallel (a vaster and deeper root development). The steeper slope of line II in relation to line I supports this supposition.
Line III (relation between N-A_o and the maximum yield) shows a yield increase of 20% (from 44.5 to 53.5 tons). The larger scattering of the points around this line is already an indication that the mean temperature (a measure for the type of weather) is prevailing over N-A_o (a measure for the mineralization) as an explaining factor for the maximum yield differences. Tentative calculations that have to be omitted in this paper, are leading to the preliminary conclusion that the introduction of N-A_o as a concomitant factor for the explanation of the yearly maximum yield differences does not have an advantage above the use of the factor mean temperature alone.

The preliminary conclusion mentioned above does not say anything about any influence of the mineralization of green manure or a ploughed-in ley on the yield differences between the experimental objects A, B, and C. We mentioned already that the nitrogen availability of a turned ley has a significant influence on the nitrogen content of the soil in late summer and consequently on the length of the growth period. So

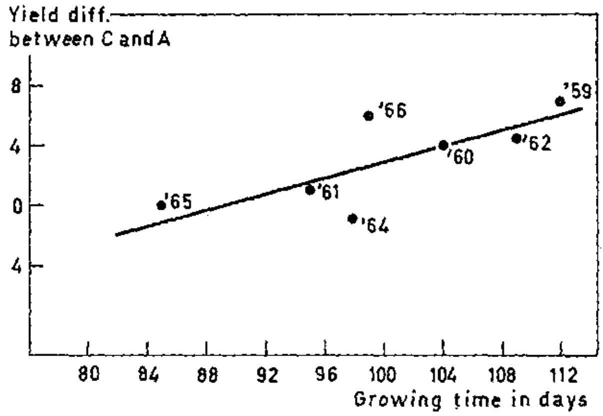

Fig. 8. The relation between the growing time of potatoes and yield difference of the tubers between the experimental objects C (turned ley) and A (artificial fertilizers only).

the speed of availability of the nitrogen comes into play here. The difference in growing period between the objects C and A has not been determined quantitatively. The Phytophthora is a drawback. Now we are arguing on the assumption that the longer the growing season is, the more the yield profits by ley-farming.
Fig. 8 demonstrating the relation between the length of the growing season (from the coming up of the potatoes till the necesary killing of the potato haulm) supports our supposition.

Surveying our results, that only partly have been communicated in this paper, we are getting the impression that our experimental plan may give ultimately useful results as to our agricultural study about the interrelations of nitrogen, organic matter, soil structure and yield.

Summary and conclusions

The nitrogen yield curve has proved itself useful studying the interrelation of nitrogen, organic matter, soil structure and yield (Fig. 1 and 2). This experimental scheme has been applied to the problem how the productivity of a silty clay soil may be maintained in the course of years. Three farms and one experimental field, 'the miniature organic-matter farms', consisting of three objects, viz. the use of artificial fertilizers only (A), green-manuring supplied by artificial rtilizers (B), and ley-farming (C) with a fixed crop tation, are used for the solution of this problem.

he optimum nitrogen dressing of consumption potoes is for the three objects on an average for the ast three years of a series of 13 experimental years, 40, 128 and 70 kg N/ha. The total nitrogen and carbon contents of the soil are decreasing on object A, hardly maintained on object B and increasing on object C. The C/N-quotient is decreasing (Fig. 3 and 4).

Ley farming has always favourably influenced the soil structure, green manure has less influence. The total pore space is changing during the growing season in relation to the rainfall in the months June, July and August (Fig. 5). In general the soil structure in late spring of the following year appears to be the result of the rainfall in the preceding year (Fig. 6). The maximum yield of tubers and the nitrogen uptake by the tubers on the undressed plots of the experimental object A (artificial fertilizers only) have been influenced in the course of years by the mean temperature during the growing period (Fig. 7). The addition of N-A_0 for the explanation of the yearly maximum yield differences probably does not have an advantage above the use of the factor mean temperature alone.

The yield differences between objects C and A are showing a relation with the length of the growing season: the longer the growing season is, the more the yield profits by ley-farming (Fig. 8).

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