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THE RESPONSE OF FLUE CURED TOBACCO TO FERTILIZER NITROGEN AS A FUNCTION OF NITRATE NITROGEN IN THE SOIL PROFILE

LA REPONSE DU TABAC VIRGINIE A LA FERTILISATION AZOTEE EN FONCTION DE L'AZOTE NITRIQUE DANS LE PROFIL DU SOL

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Abstract

The response of flue-cured tobacco to nitrogen fertilization was studied on a coarse grained loamy sand brown forest soil in 1985, 1986 and 1988. The experiment was set up in a split-plot design with nitrogen fertilizer rates from 0 through 120 kg N ha^{-1} by 20 kg increments as whole plots and cultivars as sub-plots.

While the main soil characteristics and nutrient levels were unchanged, the soil nitrate - N content in spring showed a substantial increase in the course of the years: 1985 (0-50 cm): 6,2 kg N ha^{-1}, 1986 (0-60 cm): 17,4 kg N ha^{-1}, 1988 (0-60 cm): 53,9 kg N ha^{-1}.

The results can be summarized as follows:

The response of flue-cured tobacco to fertilizer N was a function of soil nitrate - N in spring. The economically optimum rate of nitrogen fertilizer application decreased with increasing amounts of soil nitrate - N.

Under the conditions of this experiment, the soil nitrate - N to a depth of 60 cm could be considered equivalent in its effect to fertilizer N. These data indicate that it may be possible to predict N fertilizer need of flue-cured tobacco, by subtracting the soil nitrate - N measured prior to transplanting, from the total mineral nitrogen uptake by the crop. This method appears to be a simple tool to avoid excessive rates of N fertilizer application.

Résumé

La réponse du tabac virginie à la fertilisation azotée a été étudiée sur un sol brun forestier, sable limoneux, pendant trois années (1985, 1986, 1988).

L'essai a été établi selon un dispositif factoriel en blocs-complets à quatre répétition, avec les doses d'azote de 0 à 120 kg ha^{-1} par des échelles de 20 kg ha^{-1} comme parcelles principales, subdivisées en deux d'après les variétées.

Alors que les caractéristiques principales du sol et la fourniture d'éléments nutritifs, sauf celle de l'azote, ont été quasi constantes, la teneur en azote nitrique du sol, mesurée au printemps, a augmenté considérablement au cours des années: 1985 (0-50 cm): 6,2 kg N ha^{-1}, 1986 (0-60 cm): 17,4 kg N ha^{-1}, 1988 (0-60 cm): 53,9 kg N ha^{-1}.

Les études ont conduit aux résultats suivants:

- La réponse du tabac virginie à la fertilisation azotée a varié de l'année à l'autre en fonction de l'azote nitrique dans le profil du sol.
- L'optimum économique de la dose d'azote a baissé avec l'augmentation de la teneur en azote nitrique du sol.
- Dans les conditions de cet essai, l'azote nitrique du sol sur 60 cm a pu être considéré, en ce qui concerne son influence sur le tabac, comme équivalent à l'azote de l'engrais.

- Les données obtenues permettent de prévoir l'engrais azoté pour le tabac virginie de facon à soustraire la quantité d'azote nitrique mesurée dans le sol avant la plantation de la quantité d'azote absorbée par le plante pour un rendement fixé.
- Cette méthode parait être un outil simple pour éviter l'application excessive de l'engrais azoté.

Introduction

Methods to predict optimum rates of N fertilizer for flue-cured tobacco show great diversity. Until recently, N fertilizer recommendations in Hungary have been based on the organic matter content of the soil, accepting the concept that soil mineral nitrogen is not a good index of nitrogen available to the crop. This concept does not take into account that mineral N can accumulate in the root zone, most frequently as residual nitrogen from the previous crop, thus substantially modifying the amount of nitrogen supplied by the soil.

Current N fertilizer recommendations for arable crops are generally based on measurements of soil mineral nitrogen (usually referred to as N_{min}) in early spring. The basic principle of the N_{min} method is an inverse relationship between the mineral nitrogen content of the soil in spring and the optimum rate of N fertilizer application. This relationship has been demonstrated to exist for several crops, including barley (Soper and Huang 1963), sugarbeet (Reuss and Rao 1971) and winter-wheat (Wehrman and Scharpf 1979).

High quality flue-cured tobacco requires a precisely controlled nitrogen fertility regime with supplies of N being controlled within narrow limits. To obtain well matured tobacco, the available nitrogen in the soil must be nearly depleted by the time maximum growth is attained (Elliot 1975).

Although the tobacco plant will absorb both ammonium and nitrate N, the nitrate form has been shown to be utilized more effective-

ly from an acid medium (McCants and Woltz 1967). The measured amount of this form of nitrogen is the best expression of the N - supplying power of the soil, where serious leaching is not a problem (Peterson et al. 1960).
Little information is available on the nitrogen fertilization of tobacco, based on the mineral N content of the soil. Most recently it was demonstrated that for flue-cured tobacco in Germany 60 kg N ha^{-1} has to be present in available form at the beginning of the season in the 0-60 cm depth, as the sum of soil mineral N and fertilizer N (Hechler 1988).

The present study was conducted to determine (i) whether varying amounts of nitrate N in the soil would result in substantial differences in the response of flue-cured tobacco to fertilizer N, and (ii) whether soil nitrate nitrogen levels can be used as an index of N fertilizer needs of Hungarian flue-cured tobacco.

Experimental procedure

The experiment was conducted on a coarse-grained , loamy sand, brown forest soil in the north of Hungary, at the Kápolna Experiment Station of the Tobacco Research Institute, in 1985, 1986 and 1988.
The weather data for each growing season are shown in Table 1. The main soil characteristics are shown in Table 2. The soil samples were taken for analysis in March each year, to a depth of 50 cm in 1985, and 60 cm in 1986 and 1988. Ten cores were composited for the whole experimental area (2000 m^2) by 25 cm depth increments in 1985, and by 20 cm increments in 1986 and 1988. Nitrate nitrogen was determined on a 1 M KCl ectract, by colorimetric procedure. A 2 year rotation was used with tobacco preceeded by winter-wheat.
The experiment was established in different sites of the same field each year. The main soil characteristics as well as nut-

rient levels, except for N, show little variation for different years.

It is important to note that soil NO_3 - N increased substantially from 1985 through 1988 (Table 3). Calculations converting soil nitrogen analysis to kg N ha^{-1} were made assuming bulk density of soil as 1,3 g cm^{-3}.

The main factors that contributed to the accumulation of the residual N in the soil are as follows:

Owing to the dry weather in 1986 and 1987, the yield of the preceeding crop was lower than expected. Since N fertilizer application had been based on the yield potential and related crop N uptake, part of the fertilizer N was not used up, but carried over from one year to the next.

The leaching from the root zone of mineral nitrogen was not considerable, due to the dry weather.

There was no influence of subsoil water on the annual movement of NO_3 - N in the upper 0-60 cm layer, as water table could be found at a depth of more than four meter.

The experiment was set up in a split plot design with N fertilizer rates from 0 through 120 kg N ha^{-1} by 20 kg increments as whole plots and cultivars (Hevesi 5 and Hevesi 6, F_1 hybrid both) as sub plots. Treatments were replicated four times. Row width was 1.00 m with plants spaced 0.40 m apart. Each sub plot was comprised of 50 plants.

The phosphorus and potassium fertilizer was applied uniformly over nitrogen rates, using 30-50 kg P_2O_5 ha^{-1} and 100-120 kg K_2O ha^{-1} depending on the soil analysis each year.

The tobacco was transplanted in early May. Cultural practices and harvesting were in accordance with those recommended for flue-cured tobacco in Hungary. The plants were irrigated when it was necessary. Topping was made in the button stage and followed immediately by the application of a contact suckercide.

The cured leaves, by plot and primings, were weighed for yield, and leaf samples were composited by grades and primings for chemical analysis. Total nitrogen and total alcaloids were determined by the Kjeldahl and UV spectrophotometric method, respectively.

Data for yield, quality, crop value and rate of ripening were analysed by analysis of variance and regression analysis. The rate of ripening was the percentage of total yield harvested by September 4.

For each characteristic the data were pooled by cultivars before the analysis.

Results and discussion

The data of agronomic characteristics are presented in Table 4, and regression curves are shown in Figures 1-5. Yields tend to increase rapidly as nitrogen fertilizer rates increase and reach a peak at around 90 kg N ha^{-1} in 1985, with low soil nitrate nitrogen content (Figure 1). The points shown are treatments means averaged over four replications. As soil nitrate-N becomes higher in 1986 and 1988, the shape of the curve becomes more level and the coefficients of correlation between yield and fertilizer N rates are decreasing. The yields from the 0 kg N ha^{-1} treatments are a reflection of differences in nitrate - N content of the soil for different years.

Average price of the cured leaf decreases with increasing rates of nitrogen fertilizer, and this relationship was found to be linear (Figure 2). The slope of the curve is the slightest, and the correlation coefficient is the lowest in 1985, indicating that higher rates of nitrogen fertilizer can be used without adverse effect on visual quality, when soil nitrate - N content is low. In years with high soil nitrate - N content in spring, tobacco responds to increasing rates of N fertilizer with sharply decreasing average price and highly significant (r) values. The same is true for the percentage of the top two grades of cured leaves (Figure 3), with the distinction that a quadratic equation fitted better the relationship than a linear type one.

A pronounced effect of cropyear on the absolute level of visual quality is demonstrated in Figures 2 and 3, inasmuch as high temperature in 1986 resulted in better quality than that obtained in the two other years.

Changes in nitrate - N content of the soil for different years, are best reflected by crop value (Figure 4). The economically optimum rate of nitrogen fertilizer application decreased with increasing amounts of soil nitrate - N in spring: 70-90 kg ha^{-1} in 1985, 40-60 kg ha^{-1} in 1986, and 0 kg ha^{-1} in 1988.

The rate of ripening, expressed as percentage of yield harvested by September 4, showed a linear decrease with increasing rates of nitrogen fertilizer (Figure 5). The slope of the curve was again the slightest in 1985, with values of cured leaf percentage harvested by September 4 around 90 %. Increasing amounts of soil nitrate - N in spring resulted in a lower percentage of harvested leaves by the above date, together with a more pronounced response to fertiliter nitrogen.

Regression curves of total N and total alcaloids in the cured leaves are shown in Figures 6 and 7. The total N content in leaves increases both with higher rates of fertilizer N, and with increasing amounts of soil nitrate - N, the response to fertilizer being somewhat less pronounced in 1988 than in the two other years.

While showing no response in 1985, the curve of total alcaloids is sharply responding to fertilizer N in 1986 and 1988.

The data discussed to this point indicate that varying amounts of nitrate - N in the soil result in substantial differences in the response of flue-cured tobacco to fertilizer N, as far as agronomic characteristics and chemical components are concerned.

The question arises whether the N_{min} method is applicable to the fertilization of flue-cured tobacco, in other words, whether it is possible to estimate the optimum nitrogen application by measuring the amount of soil nitrate - N prior to transplanting.

Based on earlier investigations into yield potential and related crop N uptake of Hungarian flue-cured tobaccos, a balance sheet can be drawn up with N requirements of the crop on one side and contribution of fertilizer N and soil mineral N on the other. In more refined methods, the amount of N mineralized during the growing season is also taken into account (Rémy 1981). Predicting nitrogen supplied from organic sources is, however, quite difficult. Moreover, for light soils with less than 1,5 % organic matter in the top 20 cm, the nitrogen supplied form this source is of limited practical importance, partly because of the restricted amount and partly because of losses that may, to a certain extent, compensate the gains.

Research on whole-crop N uptake per unit of yield has demonstrated that Hungarian flue-cured tobaccos require around 33 kg N ha^{-1} to produce one ton of cured leaf (Gondola 1989). For a yield goal of 2 t ha^{-1} the expected crop N uptake is around 66 kg ha^{-1}. Subtracting the soil nitrate - N content in spring from the total mineral N required to produce a yield of 2 t ha^{-1} and neglecting the amount of N mineralized from different sources during the growth period, fertilizer N need can be estimated as 60 kg ha^{-1} in 1985, 49 kg ha^{-1} in 1986 and 12 kg ha^{-1} in 1988 (Table 5).

Conclusions

The response of flue-cured tobacco to fertilizer N was a function of soil nitrate - N content in spring. The high responsiveness of flue-cured tobacco to varying amounts of soil nitrate - N is accounted for by the modest amount of mineral N required to produce 1 ton of cured leaf. With crop nitrogen uptake of 33 kg ha^{-1} t^{-1} cured leaf, even a small variation in soil nitrate - N will substantially modify the N supply to this crop.

Under the conditions of this experiment, the soil nitrate - N to a depth of 60 cm could be considered equivalent in its effect to fertilizer N. These data indicate that it may be possible to predict N fertilizer need for flue-cured tobacco, by subtracting the soil nitrate - N measured prior to transplanting, from the total mineral nitrogen uptake by the crop. This method appears to be a simple tool to avoid excessive rates of N fertilizer application.

Since flue-cured tobacco absorbs most of the total nitrogen within 50 to 60 days after transplanting, and since soil samples can be taken as late as April, the time interval between soil sampling and maximum N uptake is relatively short as compared to other crops. Thus, the dependability of the N_{min} method will accordingly be higher.

Sampling the soil to a depth of 60 cm in three layers is a laborious job for the tobacco grower. A great majority of the tobacco root system by weight occurs within the 0-30 cm layer, as shown for air-cured tobacco by Chouteau (1959). Studies are in progress to determine the most suitable sampling depth for Hungarian flue-cured tobacco.

LITERATURE CITED

1. Chouteau, J.: 1959. Répartition pondérale au système radiculaire du tabac Paraguay dans une terre d'alluvions profondes
Annales de l'Institut Expérimental du Tabac de Bergerac, 3: N° 2.

2. Elliot, J.: 1975. Production factors affecting chemical properties of the flue-cured leaf. III. Nutrition
Tob. Int., 177 (4): 22-35.

3. Gondola, I.: 1989. Investigations on the specific N, P and K requirements of flue-cured tobacco Agrochemistry and Soil Sci., 38: 357-368.

4. Hechler, G.: 1988. Extraction-orientated nitrogenous fertilization of virginia tobacco
Tobacco Journal Intl., 6/1988. 380-382.

5. McCants, C.B. - Woltz, W.G.: 1967. Growth and mineral nutrition of tobacco
Adv. in Agronomy, 19: 211-265.

6. Peterson, L.A. - Attoe, O.J. - Ogden, W.B.: 1960. Correlation of nitrogen soil test with nitrogen uptake by the tobacco plant
Soil Sci. Soc. Am. Proc., 24: 205-209.

7. Remy, J.C.: 1981. Etat actuel et perspectives de la mise en oeuvre des techniques de prévision de la fumure azotée
C.R.Ac.Agr.France 67: 859-874.

8. Reuss, J.O. - Rao, P.S.C.: 1971. Soil nitrate nitrogen levels as an index of nitrogen fertilizer needs of sugarbeets
J.Am.Soc.Sugar Beet Technol., 16: 461-470.

9. Soper, R.J. - Huang, P.M.: 1963. The effect of nitrate nitrogen in the soil profile on the response of barley to fertilizer nitrogen
Can.J.Soil Sci., 43: 350-358

10. Wehrmann, J. - Scharpf, H.C.: 1979. Der Mineralstickstoffgehalt des Bodens als Maßstab für den Stickstoffdüngerbedarf (N_{min}-Methode)
Plant and Soil, 52: 109-126.

Table 1. Meteorological data at the experimental site

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Characteristic	months						total mm	average °C
	April	May	June	July	August	September		
Rainfall (mm)								
1985	32	143	82	40	76	33	406	
1986	19	38	88	33	42	0	220	
1988	19	37	53	30	121	54	314	
50 years average	42	60	67	56	57	46	328	
Mean temperature (°C)								
1985	-	16,0	15,9	20,1	20,3	15,1		17,5
1986	-	17,8	18,6	19,6	20,8	15,8		18,5
1988	-	16,0	17,8	21,9	20,3	15,6		18,3
50 years average	-	15,8	19,2	21,1	20,5	16,4		18,6

Table 2. Characteristics of the soil used

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Characteristic / year and depth (cm)	1985		1986			1988		
	0-25	25-50	0-20	20-40	40-60	0-20	20-40	40-60
pH (KCl)	4,78	4,75	5,47	4,79	5,25	4,64	4,77	5,09
clay %	lo	12	11	15	16	11	13	15
organic matter %	0,97	0,72	0,59	0,31	0,23	1,12	1,01	0,86
NO_3+NO_2-N mg kg^{-1}	0,8	1,1	2,9	1,7	2,1	7,1	7,6	6,0
P_2O_5 mg kg^{-1} (AL)*	182	94	212	92	75	210	214	119
K_2O mg kg^{-1} (AL)*	205	185	222	127	69	299	290	179
Mg mg kg^{-1} (KCl)	118	132	83	97	130	61	93	105

* The readily soluble P_2O_5 and K_2O content of the soil were determined using ammonium - lactate as solvent

The above values indicate medium to high supply in the 0-20 cm layer

Table 3. The amount of soil NO_3+NO_2 - N in the experimental plots in spring

N kg ha^{-1}

year	1985		1986			1988		
sampling depth (cm)	0-25	25-50	0-20	20-40	40-60	0-20	20-40	40-60
NO_3+NO_2 - N by sampling layers	2,6	3,6	7,5	4,4	5,5	18,5	19,8	15,6
NO_3+NO_2 - N in the whole of the sampled layer	0-50:	6,2	0-60:	17,4		0-60:	53,9	

Table 4. Effect of N fertilization on agronomic characteristics of flue-cured tobacco

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characteristic / year; rate of fertilizer N kg ha^{-1}	yield t ha^{-1}			average price* 1000 Ft t^{-1}			% of the top two grades			crop value* 1000 Ft ha^{-1}			% of yield harvested by September 4		
	1985	1986	1988	1985	1986	1988	1985	1986	1988	1985	1986	1988	1985	1986	1988
0	1,54	1,80	2,17	81,7	101,7	82,3	53,2	79,2	57,7	121	182	178	88,1	95,8	74,4
20	1,82	1,80	2,12	79,1	100,9	76,1	47,9	78,4	48,4	141	183	161	91,3	76,8	50,6
40	1,87	2,03	2,20	85,8	93,1	71,1	63,6	69,0	41,6	158	187	156	91,3	77,5	56,3
60	1,85	1,96	2,23	83,0	98,0	73,0	56,6	78,5	42,9	153	192	163	91,2	71,8	58,5
80	2,20	2,11	2,19	75,8	92,7	71,2	48,8	69,4	41,1	166	193	155	89,5	57,6	49,9
100	2,21	1,99	2,31	81,1	84,3	69,7	54,3	50,1	37,9	177	166	161	90,0	71,2	51,5
120	1,94	2,05	2,14	77,5	82,1	65,9	48,0	54,6	29,9	150	169	141	86,3	69,0	55,7
L.S.D. 5 %	0,51	0,36	0,13	11,4	7,9	7,6	14,9	12,6	11,2	31	36	19	5,8	15,0	8,8
L.S.D. 1 %	0,68	0,49	0,18	15,4	10,6	10,3	20,4	17,3	15,3	41	48	25	7,9	20,6	12,0

* average price and crop value are expressed in Hungarian monetary unit (1 USD ≈ 63 Ft)

Table 5. <u>Estimated and economically optimum rate of nitrogen fertilizer application</u>

$N\ kg\ ha^{-1}$

year	1985	1986	1988
crop nitrogen uptake for a yield goal of 2t ha^{-1}	66	66	66
soil nitrate - N in spring	6	17	54
estimated rate by the N_{min} method	60	49	12
economically optimum rate	70-90	40-60	0

Figure 1. Effect of nitrogen fertilization on yield

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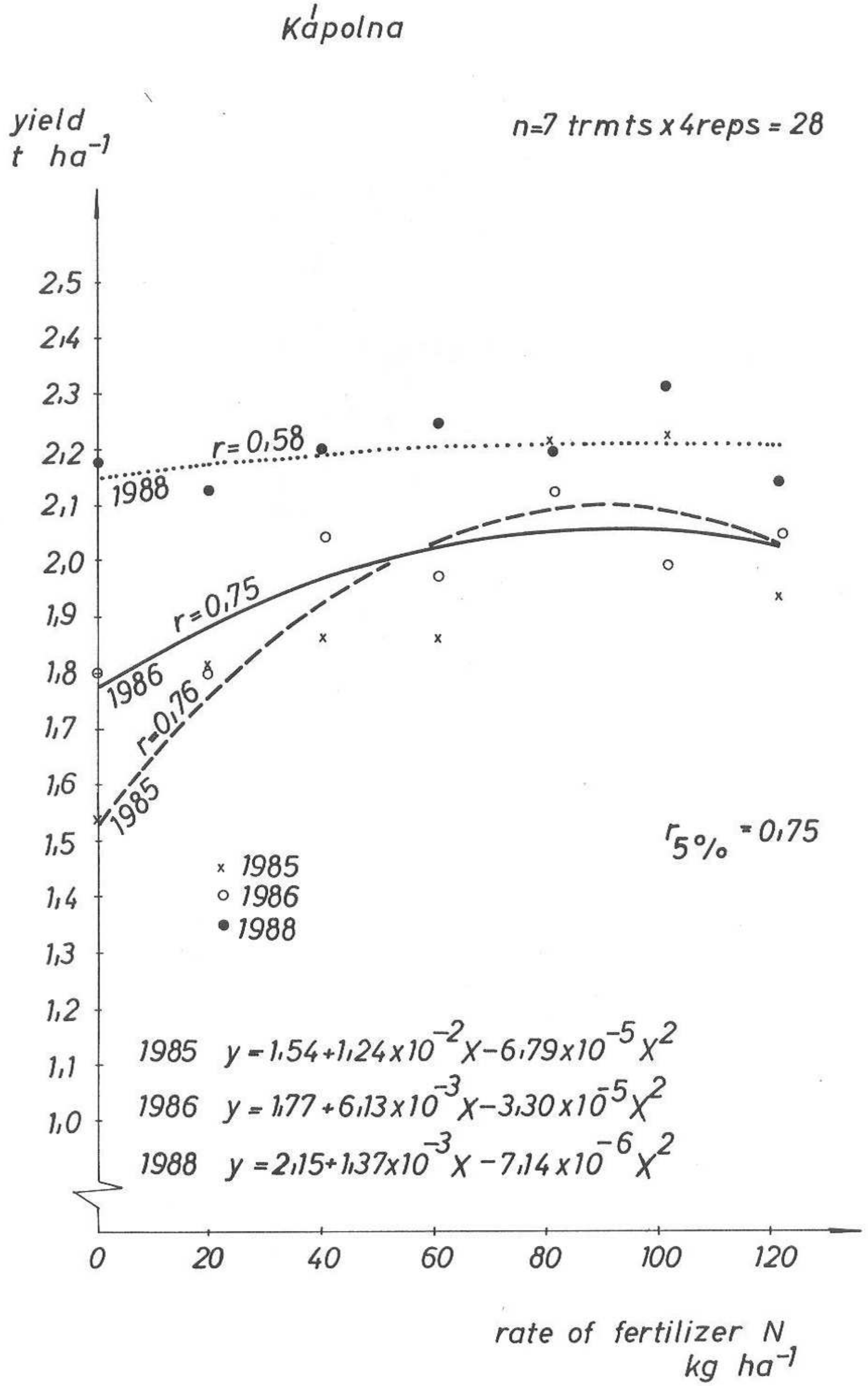

Figure 2. Effect of nitrogen fertilization on average price

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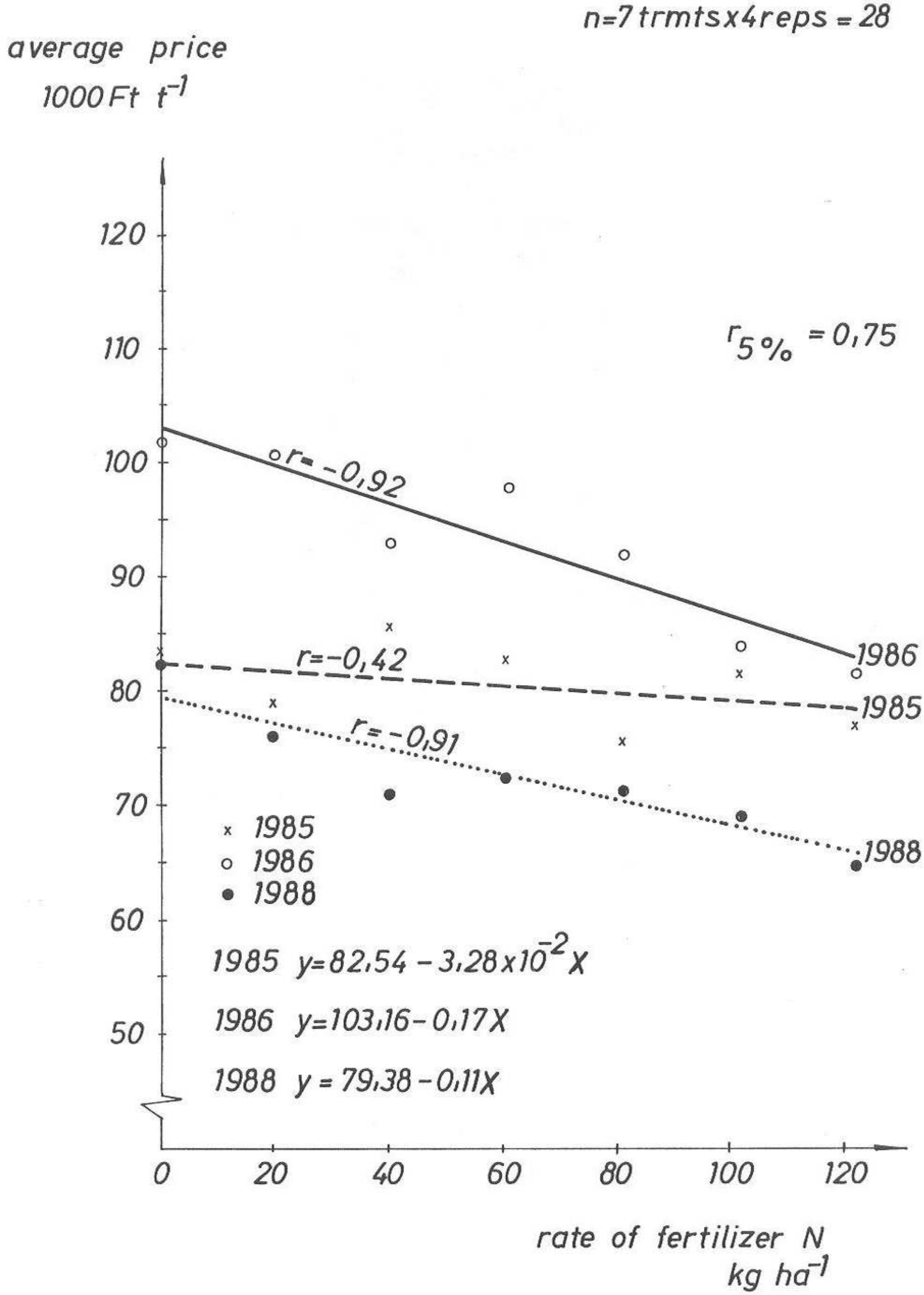

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Figure 3. Effect of nitrogen fertilization on the percentage of the top two grades

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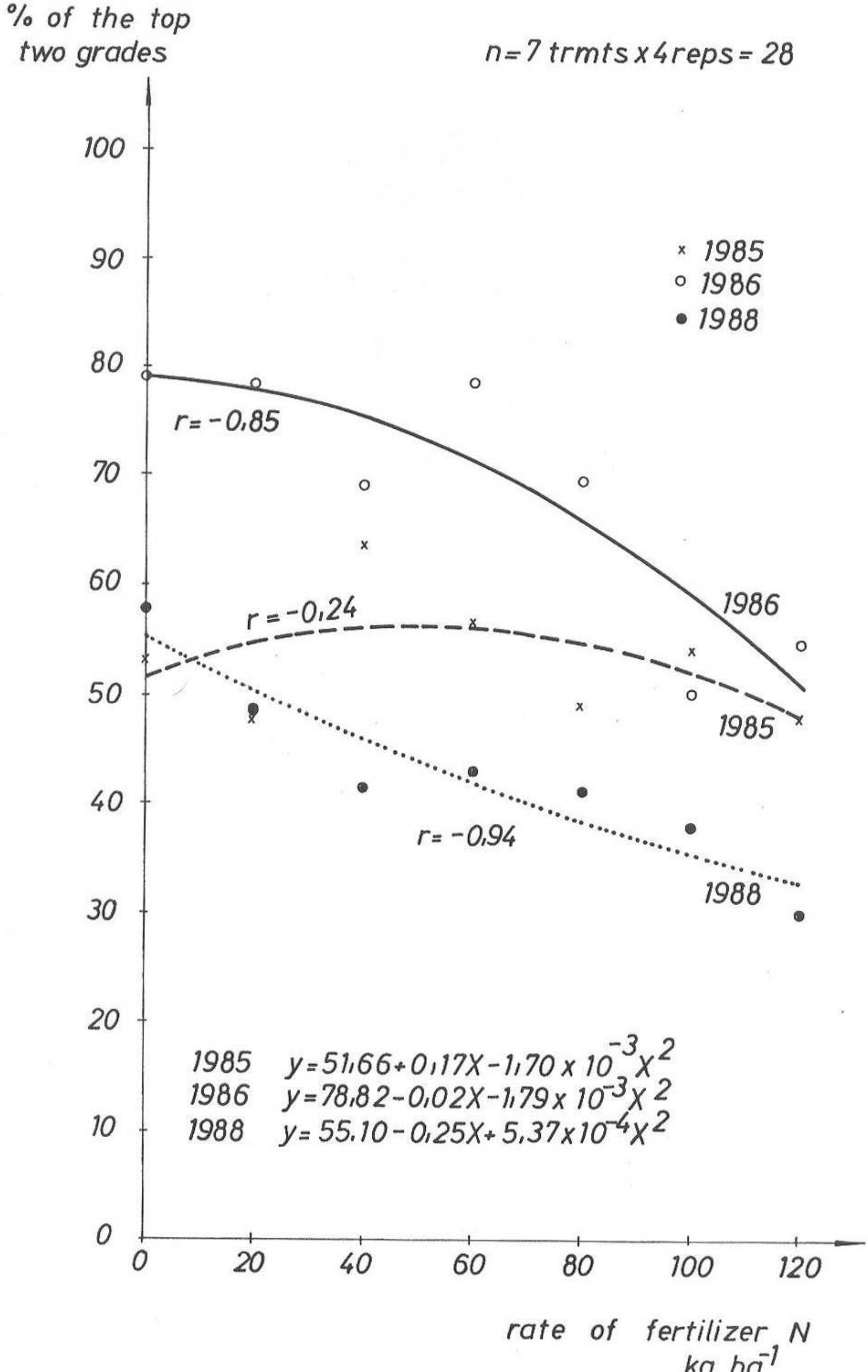

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Figure 4. Effect of nitrogen fertilization on crop value

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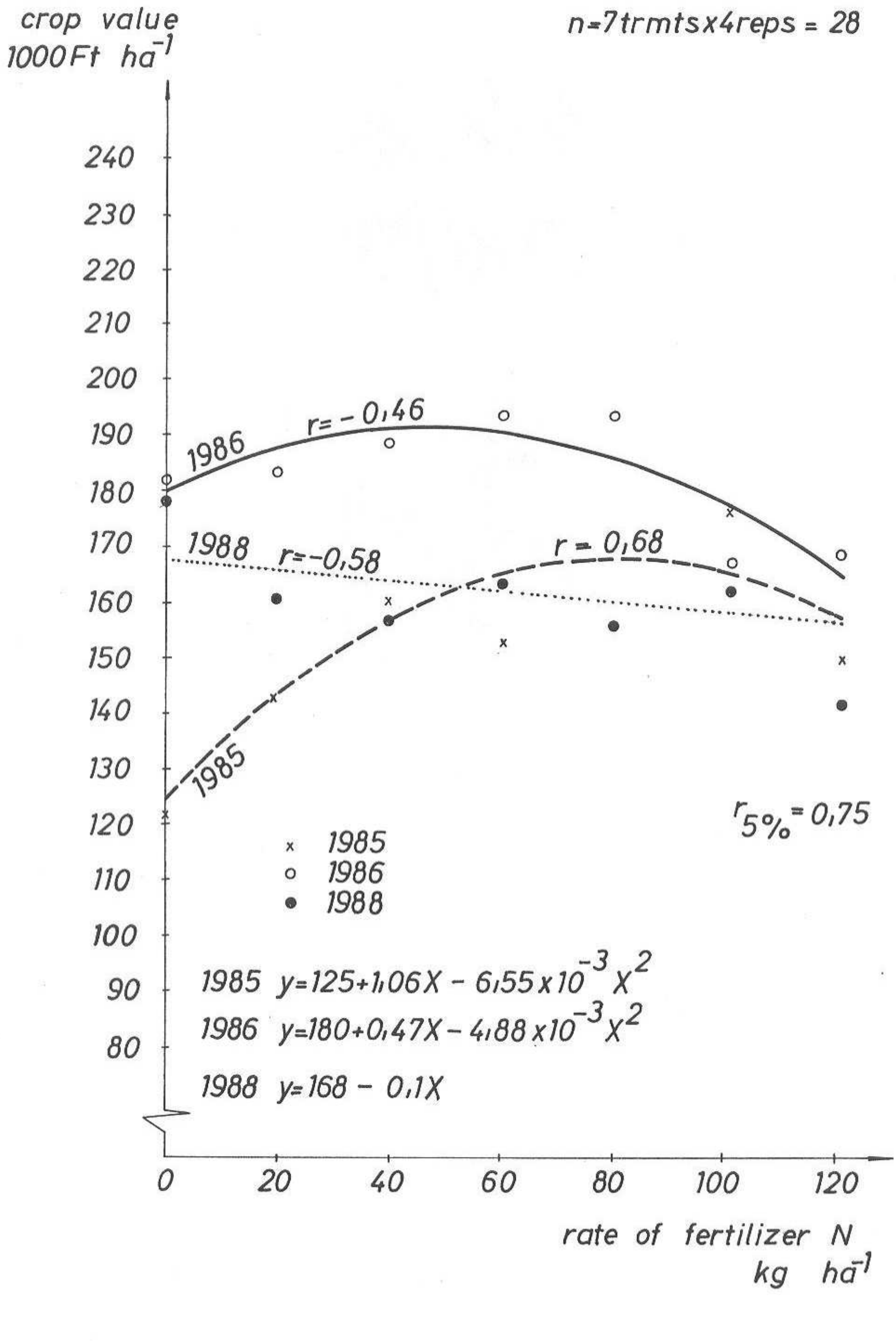

Figure 5. Effect of nitrogen fertilization on the rate of ripening

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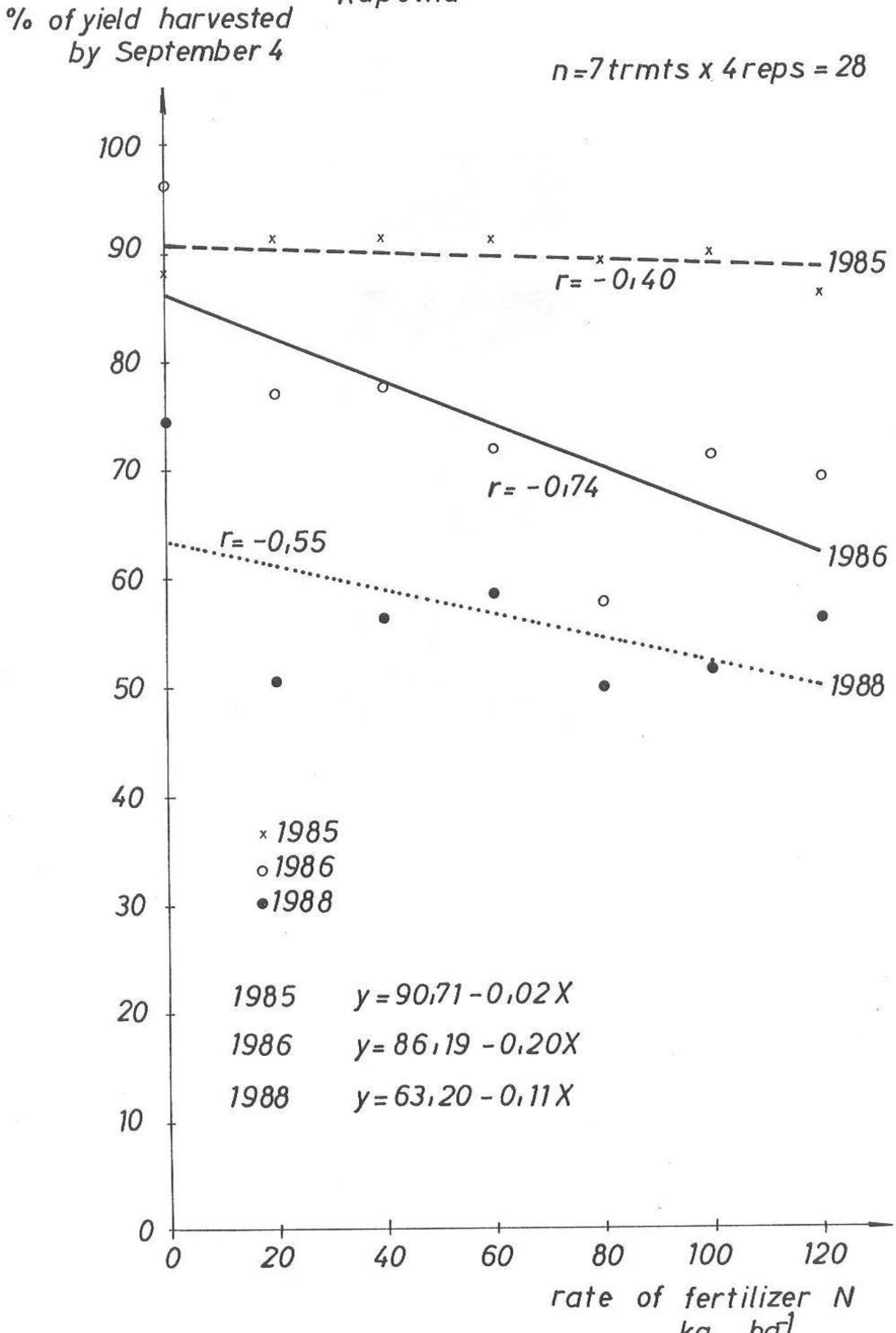

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Figure 6. Effect of nitrogen fertilization on total N content of the leaves

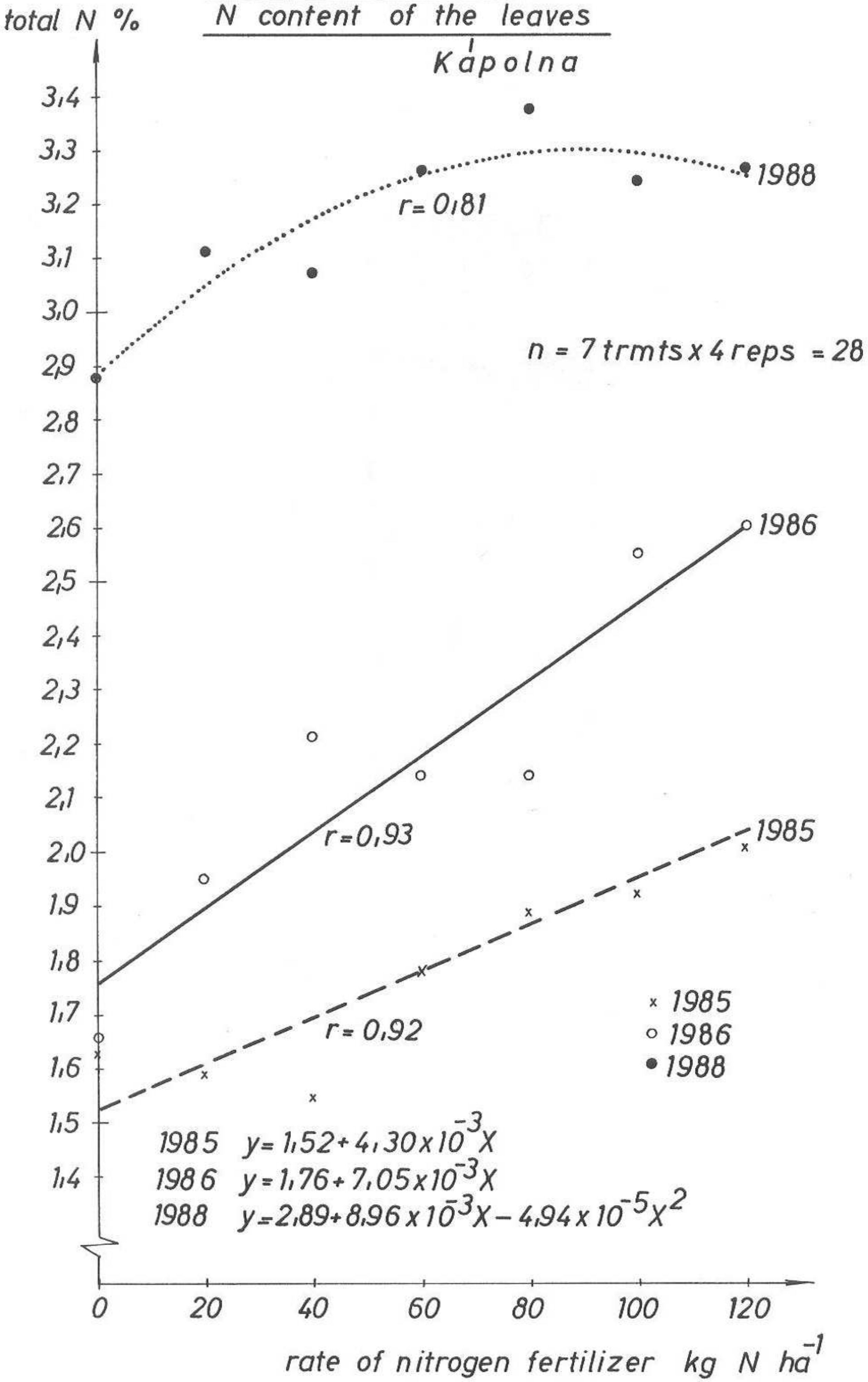

Figure 7. Effect of nitrogen fertilization on total alcaloid content of the leaves