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FERTILIZATION WITH NPK AND HUMATE NPK: PLANT YIELD AND NUTRIENT DYNAMICS

A. Benedetti, A. Figliolia, C. Izza, R. Indiati and S. Canali

Experimental Institute for Plant Nutrition
Agriculture and Forests Ministry. Rome, Italy

RESUMEN

FERTILIZACION CON NPK Y NPK HUMATOS: DINAMICA DE LOS ELEMENTOS NUTRITIVOS Y PRODUCCION VEGETAL

Se han realizado investigaciones dirigidas a evaluar la validez agronómica de productos formados por fertilizantes minerales mezclados con ácidos húmicos extraidos de turba. En dos suelos con diferente fertilidad abonados con un complejo ternario (8-24-24), al de ácidos húmicos, en proporciones del 1.12 y 3.22% se cultivaron tres especies vegetales en tiestos Mitscherlich: ***Zea Mays, Lolium perenne,*** y ***Lactuca sativa.***

Los resultados obtenidos en el cultivo del maiz han permitido poner en evidencia, de acuerdo al tratamiento efectuado, diferencias significativas con relación a algunos parámetros biométricos. En lo que concierne a la producción, el NPK con el 3.22% de substancias húmicas determina un aumento altamente significativo respecto al control. En cuanto al ***Lolium*** las diferencias de producción han resultado menos marcadas mientras que con el tratamiento de ácidos húmicos solos se observó una disminución del rendimiento. Este fenómeno se ha verificado también en el caso de la ***Lactuca*** para la cual el abono ternario, solo o asociado a los ácidos húmicos, determina un aumento progresivo de la biomasa vegetal con valores altamente significativos. Se ha observado la misma tendencia de la producción en la concentración de los aminoácidos libres de las hojas.

Las curvas respirómetricas del suelo después del cultivo del maiz evidencian un incremento de la acitividad microbiológica en las muestras tratadas con NPK humato ya sea respecto al NPK y al control.

Se han realizado pruebas de lavado del suelo en columna, que demostraron una mayor disponibilidad de P_2O_5 y de nitrógeno asimilable para el cultivo por efecto de los ácidos húmicos asociados al NPK.

Palabras claves: Acidos húmicos. Efectos fisiológicos. Fertilización. NPK.

SUMMARY

Surveys have been carried out to estimate the agronomic validity of products consisting of NPK mineral fertilizer formulated with low concentrations of humic acids extraeted from peat. Three plant species: ***Zea mais, Lolium perenne*** and ***Lactuca sativa*** were grown in Mitscherlich pots on two soils of different fertility treated with a ternary complex 8-24-24 as such and with 1.12% and 3.22% of humic acids.

Results obtained for maize showed significant differences relative to some biometric parameters, according to the treatment given. As regards yield, NPK with 3.22% of humic acids produces an extremely significant increase as compared to the check. For rye-grass, differences in yield were less marked, while there was a decrease in yield when humic acids alone were applied. This phenomenon also occurred with lettuce, where the ternary fertilizer, both on its own and with the humates, causes a progressive increase in plant biomass, with extremely significant values. The same yield pattern was noted in the concentration of leaves free aminoacids.

The respirometric tests of soil after maize showed an increase in microbial activity in samples treated with humate NPK, with regard both to NPK and the check.

Lastly, column leaching tests were carried out, which showed that P_2O_5 and available nitrogen were assimilated to a greater extent by the crop as a result of NPK combined with humic acids.

Key words: Humic acids. Physiological effects. Fertilization. NPK.

INTRODUCTION

During the time, as everyone knows, soils in the countries of the Mediterranean area become progressively poorer in organic matter, with a humus destruction rate in italian soils around 1-2% $year^{-1}$. The causes of this process are many, including "aggressive" crop techniques such as deep and frequent tillage, single-cropping, etc., as well as a decrease in the contribution of plant and animal residues.

All this has meant an increasing and sometimes indiscriminate use both of mineral, organic and mineral-organic fertilizers, often of low quality.

In the light of these problems, researches were begun in 1988 to make an exhaustive study of the mechanisms by which humic acids added to the soil, both as such and formulated with mineral fertilizers, affect microbial turnover and plant metabolism.

The functions of humus as a regulator of physical, chemical and biological properties of the soil are well known and have been the subject of extensive research by many scientists, particularly in the last 40 years. Less known, however, because more difficult to quantify, is the complex of "physiological actions" exercised by the humic fractions on plant growth, which are due to different levels of intervention on the plant mechanism (Aso and Sakai, 1963; Linehan, 1976; Vaughan and Malcolm, 1979; Mylonas and McCants 1980; Fortun and Polo, 1982; Cacco and Dell'Angnola, 1984), for example, an increase in the absorption and efficient use of nitrogen. Moreover, humic substances improve plant resistance to wilting by increasing osmotic pressure (Saalbach, 1956; Flaig *et al.*, 1957); they affect plant respiration by influencing the redox process between dehydrogenase and oxidase (Flaig and Otto, 1951).

The literature reports that these studies have often only been carried out on hydroponic crops or in germination trials (Tattini and Bertani, 1989; Sequi, 1989). Therefore it is indispensable to check this activity in agronomic reality, first in pots and then in the field, both with regard to energy saving and environmental impact.

The aim of this research was to estimate the agronomic validity of mineral fertilizers with low levels of humic acids.

MATERIALS AND METHODS

Two soils of different fertility were used, a sandy-loam soil derived from the Experimental Institute for Plant Nutrition fields (T1) and the other a pozzuolan, a typical Central Italy soil (T2) whose chemical and physical characteristics are shown in Table 1 (Tombesi *et al.*, 1982). The fertilizer used was one of the most common ternary complexes 8-24-24 (N, P_2O_5 and K_2O) (NPK0) and a new fertilizer 8-24-24 formulated with industrially prepared humic acids, extracted from peat, at two levels: 1.12% (NPK1) and 3.22% (NPK2). The composition of NPK and humate NPK together with humic acids are decribed in Table 2 and 3.

Three plant species were grown in Mitscherlich pots holding 32 Kg of soil (diameter 50 cm) *Zea mays* Dekalb XL 72, *Lolium perenne* Dekalb cv. Belinda and *Lactuca sativa* cv. Colosseo, with different fertilizer treatments as shown in the Table 4.

Preliminary experiments were carried out growing maize on the T1 soil fertilized with and without NPK and humate NPK. The effect of humic acids alone on the same T1 soil has been studied. The treatments NPK, humate NPK and humic acids alone, were extended on the pozzuolanic soil (T2) with lettuce, a crop with a short life cycle.

Maize density was five plants/pot, while rye-grass and lettuce were broadcasted distributing the same quantity of seeds/pot. Amounts of both NPK and humic acids were given at different times (sowing and plant cover).

Each sample was replicated seven times, distributed in a fully randomized sequence and irrigated to capillary retention capacity.

The above-ground plant biomass was collected at the end of maize stem extention and after 90 days from sowing for lettuce while six cuts were made at monthly intervals for rye-grass.

Trials with maize to be considered preliminary, allowed dry matter yield to be measured and certain biometric parameters to be noted (leaf surface height, total numbers of leaves, height of the third leaf, stem thickness). In order to show the effects of humic acids on crop metabolism of rye-grass and lettuce, samples were set up using only humic acids (HA1 and HA2) applying them both in the same dose as in the trial with NPK1 and NPK2 and in a further dose corresponding to 100 ppm (HA3) of humic acids. The spectrum of free amino-acids by HPLC (Cale *et al.*, 1985) was monitored on these two crops, as well as the dry matter yield.

After maize, once the roots had

TABLE 1

Chemical and physical properties of soils (values referred to dry matter at 105 °C).

Parameters	Soils	
	T1	T2
Sand, %	75.00	90.00
Silt, %	20.00	7.00
Clay, %	5.00	3.00
Texture	Sandy-loam	Sandy
Field capacity, %	20.00	8.90
pH (H_2O 1:2.5)	7.20	7.40
Available P_2O_5, kg ha^{-1} (Olsen)	443	29
Exchangeable K_2O, kg ha^{-1} (C. E. C.)	36.0	18373
Na^+, cmol$_C$ kg^{-1}	2.22	1.91
K^+, cmol$_C$ kg^{-1}	7.67	7.56
Ca^{++}, cmol$_C$ kg^{-1}	7.06	7.30
Mg^{++}, cmol$_C$ kg^{-1}	3.25	2.20
H^+, cmol$_C$ kg^{-1}		
C. E. C., cmol$_C$ kg^{-1}	20.20	19.00
N-NH_4, kg ha^{-1} (Bremner)	8.00	n. d.
N-NO_3, kg ha^{-1} (Bremner)	13.00	n. d.
N-NO_3 + NH_4 kg ha^{-1}	21.00	n. d.
Total N % (Kjeldhal)	0.11	n. d.
Organic C % (Springer - Klee)	1.34	n. d.
Humus, % (C %. 1.724)	2.31	n. d.
C/N	12.18	
Total $CaCO_3$, %	n. d.	n. d.

n. d. = not detectable.

TABLE 2

Analysis of commercial product with humic acids.

Density, g cm^{-3}	0.75
pH	10
Water solubility at room temperature %	100
C.E.C., cmol$_c$ kg^{-1}	950
Moisture, %	5
HA + FA on such % (active)	38

been removed, biological fertility trials were carried out on the soil by respirometric measurements, using a technique standardized by Nigro *et al.* (1978) in order to estimate the effect of humic acids on microbial turnover.

Column leaching tests, again of a preliminary nature, were also carried out (h = 80 cm, diameter = 4 cm) to show the affects of humic acids on the dynamics of nitrogen and phosphorus. Specifically 100 g of T1 soil mixed with quartz sand (ratio 1:1) were treated, in the top 5 cm, with NPK and humate NPK to the amount of 250 mg kg^{-1} and 750 mg kg^{-1} of P_2O_5. The columns were brought to capillary retention capacity and incubated at 30 °C for 15 days, than leached for a week with 100 ml of distilled water/day and re-incubated for a further seven days. Following a cyclic pattern, three series of leachings were carried out overall for a total experiment time of 45 days. At the same time other columns kept at room temperature (20 ± 2 °C) were set up using the same procedure and leached at the same intervals pre-set for incubation. All the sample trials were repeated twice. Nitrogen (nitric and ammonium forms) and P_2O_5 determinations were made on the eluates by colorimetry with an Autoanalyzer Technicon II.

TABLE 3

Composition of the fertilizers NPK 8-24-24 formulated with two different levels of humic acids.

	8 - 24-24 (NPKO)	8-24-24 + HA 1.12 % (NPK1)	8-24-24 + HA 3.22 % (NPK2)
Potassium chloride, %	40.4	39.0	36.8
Monoammonium phosphate, %	43.6	42.5	40.3
Ammonium sulphate, %	16.0	15.6	14.7
Commercial product with humic acids, %		2.9	8.2

TABLE 4

Treatments with NPK, humic acids and humate NPK.

Treatments	Humic acids, NPK and humate-NPK kg ha^{-1}
Check	0
Humic acids HA1	5.7 (active) 14.6 (commercial product)
Humic acids HA2	17.0 (active) 44.8 (commercial product)
Humic acids HA3	400 (active) 1052 (commercial product)
8-24-24 NPK0	500
8-24-24 + HA 1.12 NPK1	514.6
8-24-24 + HA 3.22 NPK2	544.8

STATISTICAL - MATHEMATICAL PROCESSING

Values of biometric parameters and of dry matter yield were subjected to variance analysis. The range test was then applied, which is based on the same criterion as Duncan's test.

RESULTS AND DISCUSSION

The results obtained with maize (Table 5) in regard to biometric parameters show significative differences on total height, height of the third leaf and leaf surface, in the treatments NPK1 and NPK2 compared with NPK0 and check, while not significative differences are showed on number of leaves and on stem bases diameter.

With regard to dry matter yield (Table 6), only NPK2 produces significant differences compared to the check. Yields of rye-grass follow the same pattern of maize (decrease for samples with humic acids alone) although with less marked, not significant differences. Also for lettuce, applications of ternary fertilizers both combined with and without humate, causes a progressive increase in yield, while for samples with humic acids alone this yield is greatly reduced, with highly significant

TABLE 5

Biometric parameters of the maize crop at the end of tasseling (average values).

Treatments	N. leaves	Tot. height cm	Steam basis diam. cm	Leaf surface cm^2	Height 3rd leaf cm
Check	9 a	131 a	2.2 a	3148 a	50 a
NPK0	9 a	135 a	2.2 a	3300 ab	51 a
NPK1	9 a	144 ab	2.1 a	3496 b	65 b
NPK2	10 a	146 b	2.2 a	3413 ab	63 b

(p = 0.05). Same letter in each column indicates no significative difference.

TABLE 6

Dry matter yield of Zea Mays, Lolium Perenne and Lactuca Sativa.

Plant specie	Treatments	D. M. g pot^{-1}	NPK0 = 100 %	Check = 100 %
Zea Mays	Check	200.0 a	93.0	100.0
	NPK0	215.0 a	100.0	107.5
	NPK1	235.0 ab	109.3	117.5
	NPK2	250.0 b	116.3	125.0
Lolium Perenne. . . .	Check	177.0 a	98.3	100.0
	HA1	166.2 a	92.3	93.9
	HA2	164.2 a	91.2	92.8
	HA3	170.0 a	94.4	96.0
	NPK0	180.1 a	100.0	101.8
	NPK1	192.4 a	106.8	108.7
	NPK2	196.0 ab	108.8	110.7
Lactuca Sativa	Check	18.9 b	48.8	100.0
	HA1	11.6 a	30.0	61.4
	HA2	15.2 b	39.3	80.5
	HA3	10.4 a	26.8	54.8
	NPK0	38.7 c	100.0	204.9
	NPK1	42.4 cd	109.5	224.3
	NPK2	48.5 d	125.2	256.6

(p = 0.05). Same letter in each column indicates no significative differences.

differences between the treatments. This decrease in yield can be explained bearing in mind that the known activation of the plant respiratory processes produced by humic acids (Fortun *et al.*, 1986) causes an inbalance in metabolism because uncreased nutritive requirements are not satisfied. Possible competition between microbial biomass and crop for nutrients should be considered, with consequent temporary immobilization.

From the sum of these results it appears that lettuce best reflected the influence of fertilization with humate NPK, also shown in the increased concentration of leaves free aminoacids (Fig. 1). It is interesting to note that in the amino-

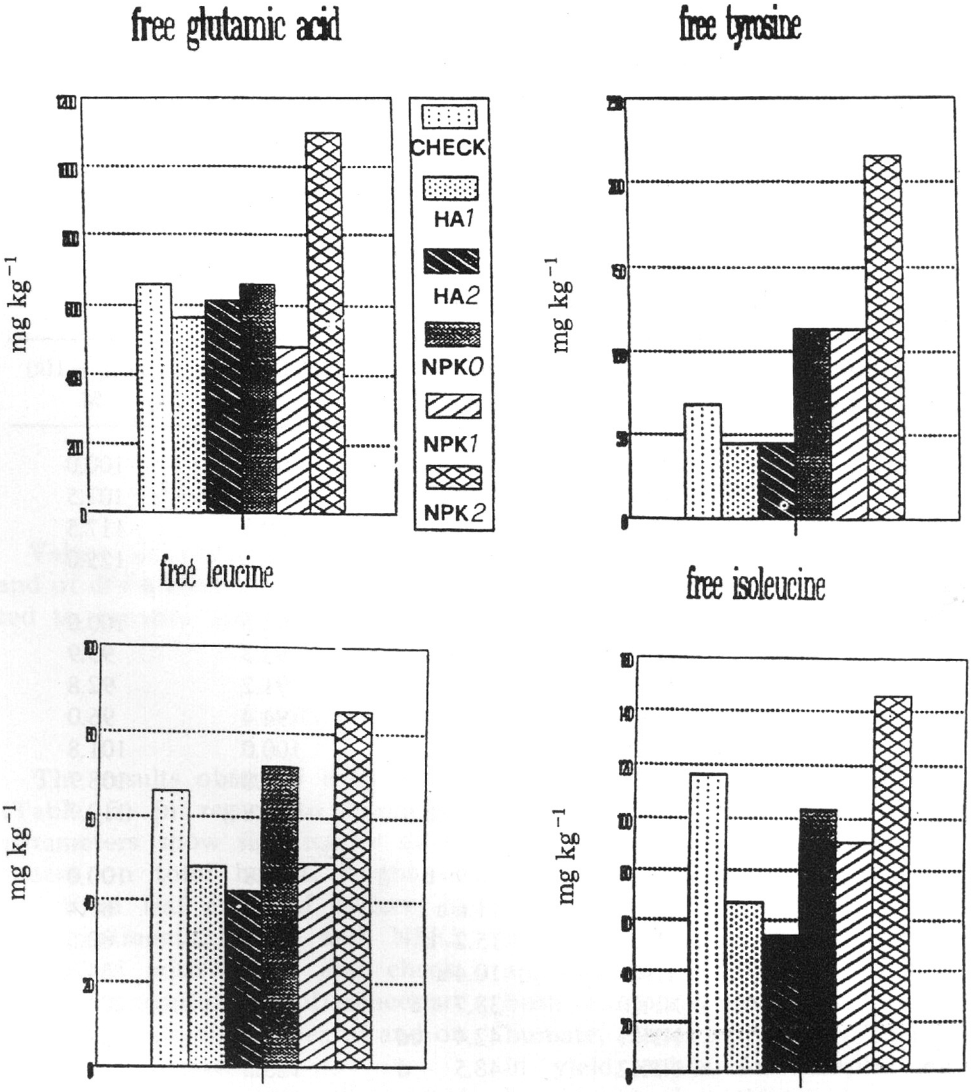

FIG. 1.–*Lactuca sativa leaves.*

acids spectrum, particular sensitivity to mineral fertilizer applied with the largest amount of humic acid is shown by glutamic acid, tyrosine, isoleucine and leucine which increase 66, 92, 42 and 18% compared to the NPK0 treatment. As a consequence, the indirect effect of humic acids on the principal metabolic activities of plants, such as protein synthesis, respiration, etc. may be hypothesized. Treatment with humic acids alone, on the other hand, particularl in HA2, causes a decrease in the concentration of all the free aminoacids (Fig. 1). In rye-grass, as already noted for yield, these phenomena are less evident.

Various hypotheses can be formulated to explain the increase in yield caused by humate NPK:

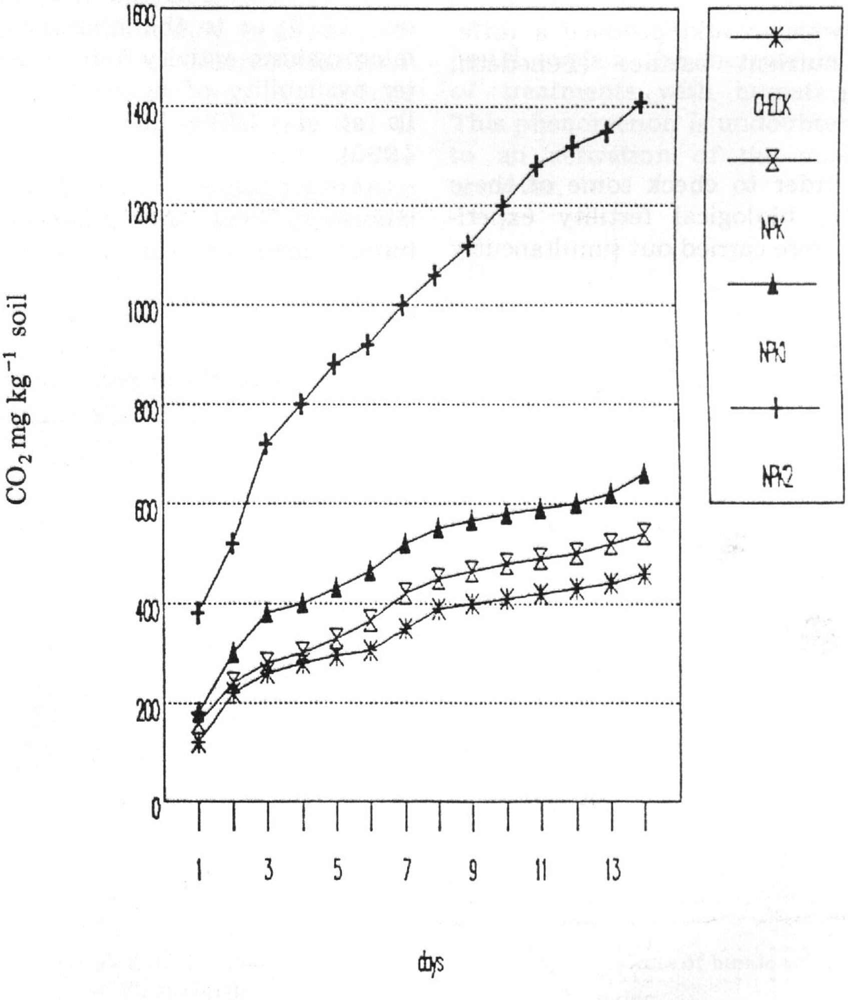

FIG. 2.–*CO_2 evolution from T1 soil after maize cultivation.*

1) greater availability of nutrients for plants, following the solubilizing effect of humic acids (Sequi, 1989);

2) modification of the permeability of the cellular membrane at the level of the root system, with a consequent increase in absorption (Dell' Agnola and Ferrari, 1968);

3) greater development of the root biomass (Linehan, 1976; Fortun and Polo, 1982);

4) activation of the soil microflora which could produce a different nutrient balance (Benedetti, 1983).

In order to check some of these aspects, biological fertility experiments were carried out simultaneusly with the agronomic tests, using T1 soil after maize (Fig. 2). The respirometric curves seem to confirm microbial activation in the samples treated with humate NPK compared to NPK and to the check, showing that in this case the best formulation of NPK is with 1.12% humate (NPK1). This increase in soil respiration could mean both an increase in microbial biomass due to the presence of auxinic and indolacetic types substances in the HA (O'Donnel, 1973) or to the stimulation of microrganism activity following greater availability of nutrients (Figliolia *et al.*, 1990; Benedetti *et al.*, 1990).

Another aspect checked in the laboratory was the influence of humic acids on the dynamics of

TABLE 7

Leaching experiments on soil columns.

	P_2O_5 (mg kg^{-1} of soil)		Fixed P_2O_5 (%)	
	Incubated 30 °C	Room temperature	Incubated 30 °C	Room temperature
Check	162.3	190.3		
NPK0	256.8	594.5	87	46
NPK1	382.4	634.2	71	41
NPK2	389.8	542.8	70	53

	N (mg kg^{-1} of soil)	
	Incubated 30 °C	Room temperature
Check	146.6	99.4
NPK0	272.4	88.6
NPK1	329.0	97.1
NPK2	358.6	151.0

nutrients in column leaching tests. The results (Table 7), relative both to P_2O_5 and nitrogen, show a distinct influence of humic acids on soil chemical dynamics. Particularly with regard to P_2O_5 a decrease in insolubilization takes place (Izza and Indiati, 1982) of about 25% only in incubated samples while those kept at room temperature have no significant differences between them. It appears, however, that this insolubilization following incubation increases by about 50% in all samples. There is also a considerable difference in nitrogen between the leaching values obtained when the soil is incubated or not. In fact, in the former case, 85.3 and 50% of the added nitrogen is leached respectively from NPK2 and NPK1, while in not incubated soil these quantities are 29.7 and 4%. However, only by using N^{15} it is possible to clarify whenever the different quantities leached come from the nitrification of added N rather than from mineralization of the soil organic matter. From these results it can be seen that humic acids combined with NPK cause a greater availability of P_2O_5 and nitrogen for the crop at high temperatures, comparable with the incubation values, which could explain the increase in yield of treatments with humate NPK. This phenomenon is undoubtely due to an activation of the microbial turnover.

CONCLUSIONS

The increase in yield of the maize, rye-grass and lettuce crops obtained after fertilization with NPK formulated with 1.12 and 3.22% of humic acids extracted from peat could be explained by the "physiological effect" of the humic acids both on the plant and on the soil microorganisms. The results obtained by adding humic acids alone to the soil show a decrease in yield probably due to a greater unsatisfied need of nutrients. This phenomenon can also occur as a result of the temporary immobilization of macro-nutrients due to the growth of the microbial biomass that competes with the crop.

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