International Journal of Agricultural Science Research Vol. 3(9), pp. 187-195, September 2014
Available online at http://academeresearchjournals.org/journal/ijasr
ISSN 2327-3321 ©2014 Academe Research Journals

Full Length Research Paper

The mineralist concept to express the soil fertility perceived by plants grown under no-tillage system

Margarete Nicolodi*, Clesio Gianello, Ibanor Anghinoni, Jacques Marrè and João Mielniczuk

Post-Graduate Program in Soil Science, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, n. 7712, Porto Alegre, Rio Grande do Sul State, Brazil.

Accepted 27 August, 2014

Soil fertility is the capacity of the soil to supply nutrients in quantity and balanced proportions in the absence of toxic elements for plant growth and productivity. This concept, derived from the mineralist theory, is widely employed around the world. With the shift from conventional tillage to no-tillage system, high crop productivity has frequently been obtained under no-tillage system, even with values of soil fertility indicators that are considered inadequate for plant growth under conventional tillage. The aim of this research is to verify the capacity of the mineralist concept and the evaluation to express the fertility perceived by corn plants grown under no-tillage system conducted for long periods with different crop rotations. Soil fertility indicators and corn grain yields were evaluated during the 2005/2006 crop season in experiments that have been carried out for 20 years in Eldorado do Sul, Brazil. The results showed that the soil chemical indicators that are commonly used to evaluate soil fertility were not always able to detect changes in the soil capacity to promote crop yields in soils under different tillage systems and crop rotations. The presented evaluation and, thus, the mineralist concept of soil fertility, were not sufficient to express the soil fertility perceived by the plants in soils cultivated under long-term no-tillage conditions.

Key words: Soil fertility indicators, grain yield, concept, mineralist theory, systemic approach, field results.

INTRODUCTION

Conceptually, soil fertility is the capacity of the soil to supply essential nutrients to plants in adequate quantities and proportions in the absence of toxic elements for their development and productivity. This concept limits the fertility to the effects of the chemical conditions of the soil. However, the term *fertility* means *to produce abundantly* (Wikipedia, 2006). This concept, based on the mineralist theory that soluble minerals (nutrients) are the food of plants, was developed by Liebig (1842); this concept has not been modified and has been widely applied throughout the world for more than one and a half centuries (Scarponi, 1949). Soil fertility evaluation, defined by the mineralist concept, is similarly performed throughout Brazil based on the interpretation of the results of some chemically analyzed indicators in soil samples (Anghinoni, 2005). According to the results of this evaluation, fertilizers (minerals and organics) and amendments (to modulate acidity or alkalinity) are recommended and applied to increase or maintain the fertility of soils and, consequently, to enhance crop productivity.

In soil science and agronomy, the concept of soil fertility has an almost infinite number of definitions, and viewpoints vary widely with regard to its meaning and importance. Some researchers have suggested abandoning the concept, while others suggest that attention should be shifted towards another concept, namely that of *'soil quality'* (Patzel et al., 2000). An extensive review regarding the terms and viewpoints involved in the concepts of *soil fertility* and *yield given capacity* in the German-language literature, which contained very interesting conceptual maps, was

---

*Corresponding author. E-mail: marganicolodi@hotmail.com reported by Patzel et al. (2000). This review suggested reevaluation of the phenomenon of soil fertility in modern terms and differentiation of the concepts of soil quality and soil fertility. In southern Brazil, the soil fertility concept is being reconsidered based on observing plant responses over time after a change in the tillage system to no-tillage.

Since the beginning of intensive agricultural practices, the soils in Brazil have been cultivated using conventional tillage (CT) (prepared with a plow and disc harrow), and the chaff (residues of crops) has been burned, following European and American traditions. The no-tillage system (NTS) began to be utilized in southern Brazil in the 1960s, and great expansion of this system began in the 1980s and has since continued. Under this type of system, the soil is disturbed only in the sowing row, while a majority of the soil surface remains covered by the previous crop's residues, and crop rotation is performed (Denardin, 1998). When the same soil is cultivated under both CT and NTS, there is, respectively, frequent destruction and preservation of the relationships built in the soil as a result of the cultivation time under these systems. This result is mainly due to differences in the degree and intensity of soil mobilization and in the management of chaff and the biological diversity of these systems, which determine soil conditions for crop growth. Under CT, the soil is totally dismantled by plowing no more than twice a year, which, together with the burning of chaff, promotes the rapid degradation of organic matter (OM) and considerable alterations in the biology of the soil. Thus, under CT, during which few modifications are made to the physical and biological conditions of the soil over time, crops respond well to the improvements in the soil's chemical conditions, which are mainly caused by the application of fertilizers and amendments. However, the relationships built in the soil over time when the NTS is used are preserved and enriched by the diversity of species used in the crop rotation. Thus, under NTS, the chemical conditions, as well as the physical and biological conditions of the soil, are modified and improved.

In soils cultivated under CT, application of the mineralist concept, through the evaluation and recommendation of fertilizers, produces satisfactory results. In general, high productivities are not achieved when the values of soil fertility indicators – pH, available phosphorus (P), available potassium (K), OM and base saturation (V) – are low or when aluminum saturation (m) and the content of exchangeable aluminum (Al^{+3}) are high. However, in recent years, several studies have shown that high productivities may be obtained in soils cultivated under an NTS at pH, m, V, Al^{+3} (Pöttker and Ben, 1998; Salet, 1998; Caires et al., 1999) and available P (Sá, 2004) values that are considered inadequate for good plant growth under CT. For example, under an NTS, productivity was not found to be limited in soil exhibiting a water pH of 4.7 and 2.3 $cmol_c\ dm^{-3}$ of Al^{+3} (Pöttker and Ben, 1998), or under an 18% m and 32% V (Caires et al., 1999). These data allow us to question whether the values or range of interpretations of chemical indicators used in the evaluation and recommendation of fertilizers in Brazil reliably represent the fertility of a soil and guarantee the expression of the productive potential of a given crop in a given environment. It is possible that the evaluation and, thus, this concept might be insufficient to express the fertility of soils cultivated for a long period of time under the NTS. This leads us to reflect on the adequacy of fertility evaluation and the mineralist concept for all cultivation systems. The aim of this study is to evaluate the capacities of the mineralist concept and the mode of evaluation to express fertility as perceived by plants in soil cultivated under NTS with different crop rotations.

MATERIALS AND METHODS

The evaluations were performed in the summer season of 2005/2006 in two irrigated experiments that have been carried out for over 20 years in Eldorado do Sul (Figure 1), at the Agronomic Experimental Station of the Federal University of Rio Grande do Sul (UFRGS) in Rio Grande do Sul State, Brazil (30°06' S; 51°40' W), in a Rhodic Paleudult (Argissolo Vermelho Distrófico by the Brazilian Soil Classification System). The area has a subtropical humid Cfa-type climate, according to Köppen classification, with an average annual temperature of 19.2°C and rainfall of 1,440 mm per year (Bergamaschi et al., 2003).

Two experiments, referred to as "Vegetal coverage as an alternative for soil conservation" (Experiment 1) and "Soil preparation systems and vegetal coverage as an alternative for soil conservation" (Experiment 2) were initiated in 1983 and 1985, respectively. The experiments were conducted under a randomized complete block design, with the treatments distributed in sub-divided plots with three replications.

In Experiment 1, soil compaction and soil de-compaction represented the main plots (16 × 50 m), crop rotations constituted the subplots (5 × 16 m) and nitrogen fertilization (0 and 180 kg ha^{-1}) constituted the sub-subplots (5 × 8 m). As de-compaction effects were not observed from the 2005/2006 season onward, the subplots (5 × 16 m) were considered the main plots, and the sub-subplots were considered subplots (5 × 8 m). These subplots were divided (5 × 4 m), and those previously cultivated under zero N received dosages of 0 or 60 kg ha^{-1}, while those cultivated under 180 kg ha^{-1} received 120 or 180 kg ha^{-1}. In Experiment 2, the cultivation system constituted the main plots (15 × 20 m), the crop rotations the subplots (5 × 20 m) and nitrogen fertilization (0 or 180 kg ha^{-1}) the sub-subplots (5 × 10 m). The area where the experiments were carried out received corrective fertilization and lime application, and the inputs were incorporated into the soil to a depth of 20 cm. In Experiment 2, lime was applied again in 1988, 1992 and 1996.

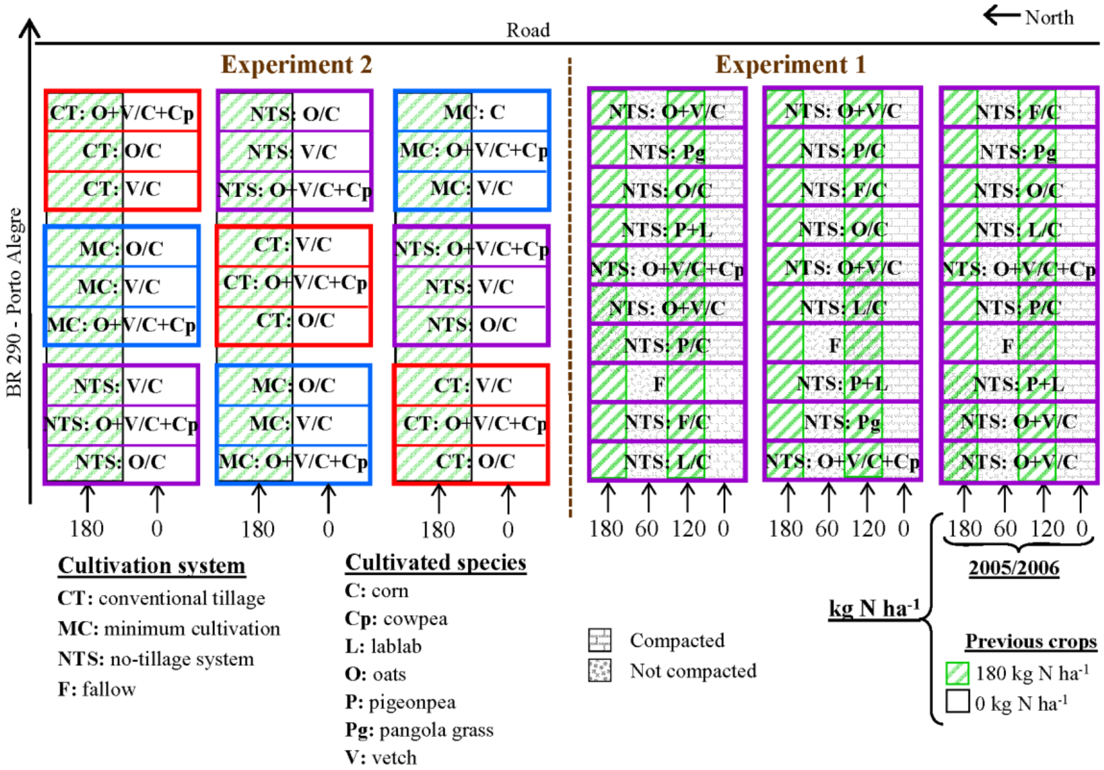

Figure 1. Schematic representation of the experiments carried out over 20 years in Eldorado do Sul, Brazil, in a Rhodic Paleudult, evaluated in this work during the 2005/2006 harvesting season: Experiment 1: "Vegetal coverage as an alternative for soil conservation" and Experiment 2: "Soil preparation systems and vegetal coverage as an alternative for soil conservation."

In all treatments in the two experiments (Figure 1), except in the plots managed under minimum cultivation in Experiment 2, soil fertility indicators and corn grain yields were evaluated. Soil samples were collected at a depth of 0-10 cm on October 13, 2005, and these samples were composed of two subsamples. The subsamples were collected with a spatula and consisted of a slice of soil 5 cm thick by 10 cm wide. For the determination of mineral N, 20 ml of soil was collected and immediately transferred to a glass flask containing 100 mL of a 1 M KCl solution, then maintained at 4°C until determination. Corn (Pioneer 32R21) was sown during the first fortnight of November 2005. In the sowing row, 250 kg ha^{-1} of fertilizer with the formula 00-20-20 ($N\text{-}P_20_5\text{-}K_20$) was applied. One-third of the nitrogen fertilization needed for each treatment was applied as coverage (urea) (Figure 1) in phenological growth stage V4 and two-thirds in stage V6. The available contents of P and K (Mehlich 1), calcium (Ca), magnesium (Mg), exchangeable Al (Al^{+3}), OM, the pH in water and the mineral N and total (TKN) were measured according to the methodology proposed by Tedesco and others (1995). V, m and effective cation exchange capacity (CEC) values were obtained through calculations. The corn grain yield was evaluated in areas of 5.4 and 7.2 m^2 per treatment in experiments 1 and 2, respectively, and grain weight was calculated as t ha^{-1}. The results of only the following crop rotations are presented: O/C: black oat (*Avena strigosa* Schreb) as the winter cover crop and corn (*Zea mays* L.) as the summer grain crop; V/C: vetch (*Vicia villosa* Roth) as the winter cover crop and corn as the summer grain crop; O+V/C+Cp: black oat plus vetch as the winter cover crops and corn as the summer grain crop, intercropped with cowpea (*Vigna unguiculata* (L.) Walp) as a cover crop; and P/C: pigeonpea (*Cajanus cajan* (L.) Millsp.) as the winter cover crop and corn as the summer grain crop.

The mineralist concept of fertility, for acidic soils, establishes a direct relationship between the quantity of nutrients in the soil and the yield of crops, when other growth factors, such as the elimination of toxicity and the water supply, are adequate. Practically, values and relationships were established for some indicators, and, based on the evaluation of these indicators, the adequate levels of these nutrients were defined for certain crops or groups of crops. Thus, for the macronutrients P, K, Ca and Mg and some micronutrients, values known as critical contents/levels or adequate or sufficient ranges have been established (Raij et al., 1997; CQFS-RS/SC, 2004; Souza and Lobato, 2004). For soil acidity, the values of pH, V, m and Al^{+3} have been established as criteria to determine whether lime should be applied to the soil. Thus, the relationships between pH and Al^{+3}, pH and V and between pH increases and effective CEC increments are well established. It is widely known that those soils showing fertility indicator values that are not defined as adequate generally produce less or are not productive, while those soils presenting adequate fertility indicators and other adequate growth factors tend to produce close to their maximum potential. In this study, the capacity of the previously described mineralist concept to express soil fertility as perceived by plants cultivated in systems different than CT is questioned through the comparison of relationships between the classical indicators and between these indicators and corn grain yields. The relationships presented are between pH and Al^{+3}; V and effective CEC; Al^{+3} and OM contents; and pH, Al^{+3}, V, OM, K and P contents and grain yields.

RESULTS AND DISCUSSION

The results of the experiments, which were carried out for the course of 20 years, show that the central tendencies of some classic relationships among fertility indicators are not altered by the shift from CT to the NTS (Figure 2). This behavior may be verified by the relationship between Al^{3+} and pH (Figure 2a): as the pH increased, the Al^{+3} content decreased, corroborating the results of many other studies such as Coelho (1973) and Kaminski (1974) among others. However, the results obtained in the CT treatments were found to be distributed more to the right in Figure 2a, while those obtained under the NTS, in addition to presenting more dispersion, form a wide range and were found to be distributed more to the left. This difference in distribution indicates that, in the same soil, under the same pH values, the Al^{3+} content may be different, depending on the cultivation system and the adopted crop rotations. In general, under the NTS, the Al^{3+} content is smaller, and its effect on the plant is less pronounced than under CT at the same pH value. This change in association with the benefits of NTS, allows the crop to grow at a lower pH value in this system than under CT.

Under CT, high productivities for most of the crops are only obtained at pH values (in water) between 5.5 and 6.5 and in the absence of Al^{+3} in the soil (Coelho, 1973; Quaggio, 2000; CQFS-RS/SC, 2004). However, in this work, under the NTS, this was not verified. The average corn grain yield did not decrease with an increase of the Al^{+3} level and a decrease of pH. In the treatments with a pH ≤ 4.6 and Al^{+3} ≥ 1.2 $cmol_c$ dm^{-3} (Figure 2a, set of points circled in orange), the average yield was 7.2 t ha^{-1}, while in those with a pH ≤ 5.1 and Al^{+3} ≥ 0.6 $cmol_c$ dm^{-3} (Figure 2a, set of points circled in black), the yield was 6.4 t ha^{-1} and in those with a pH ≤ 5.3 and Al^{+3} ≥ 0.3 $cmol_c$ dm^{-3} (Figure 2a, set of points circled in pink), the yield was 7.1 t ha^{-1}. The smaller average yields (4.7 t ha^{-1}) were obtained in the treatment with a pH ≥ 5.5 and zero Al^{+3} (Figure 2a, set of points circled in blue).

The relationship between pH and V (Figure 2b) is similar in the soil cultivated under CT and NTS. Nevertheless, it is observed that the V value is greater in the NTS than under CT for a given pH; a 65% V value corresponds to pH values of 5.5 under NTS and 5.8 under CT. These data are in agreement with those used by the CQFS-RS/SC (2004) to establish the criterion 5.5 of pH and 65% of V for the recommendation of lime application under an NTS. These differences due to the cultivation systems were not observed between Al^{+3} and m (Figure 2c).

Organic matter (OM), mainly because of its organic binders, has the capacity to complex Al^{+3}, reducing its activity in the soil and, consequently, decreasing its toxicity for plants (Salet, 1998). This indicates that under the NTS there could be an inverse relationship between OM and Al^{+3}. However, no clear tendency was observed in these experiments (Figure 2d). Most likely, there is no relationship between the total organic matter content of the soil and Al^{+3}, but there is a relationship between Al^{+3} and the labile OM components, which present a short half-life in soil but are continuously formed under the NTS, in quantity and quality variables depending on the crop rotations. Thus, soil managed under the NTS with high values of Al^{+3} and high OM contents may not restrict the development of many crops, though it may be restricted under CT. In some rotations under the NTS, the OM content doubled over a 20-year period (Figure 2d). However, it can be observed that the treatments with higher Al^{+3} content (Figure 2a, points circled in orange) presented the highest average grain yield (7.2 t ha^{-1}) in conditions where the OM content was smaller than 3%, except for one treatment (Figure 2d, points circled in orange). Thus, higher yields were not proportional to higher OM contents.

Among the classic relationships between fertility indicators, the relationships between pH and the effective CEC and between the effective CEC and OM are still highlighted (Figures 2e and 2f). In general, the effective CEC increases as the soil acidity is corrected (that is, as the pH increases) (Volkweiss, 1989). This relationship may be observed for the set of points representing the CT (Figure 2e); although in a less pronounced way, the effective CEC increased from 4.2 $cmol_c$ dm^{-3} to 4.7 $cmol_c$ dm^{-3}, with a corresponding pH increase from 4.8 to 5.8. However, in the combined visualization of the evaluated treatments, the data points are widely dispersed, which does not allow us to clearly define the relationship between pH and the effective CEC. In this situation, the crop rotation effect is greater than the effect of an increasing pH. If the points in Figure 2e are grouped into three sets (CT, NTS and circulated NTS), it is possible to state that for each separated set, there is a correlation between pH and effective CEC. However, the average pH values of 5.2, 5.0 and 5.0 obtained for the CT, NTS and circulated NTS sets correspond to effective CEC values of 4.5, 4.6 and 6.7 $cmol_c$ dm^{-3}, respectively, that is, there is no variation in the effective CEC due to the variation in soil pH. In Figure 2e, the set of points highlighted with a circle corresponds to that highlighted in Figure 2f. In Figure 2f, it can be observed that the OM content of the soil increased as the effective CEC decreased. For the relationship between OM and effective CEC (Figure 2f), on average, we found that in the CT treatments, 1.9% of the OM corresponded to 4.5 $cmol_c$ dm^{-3} of effective CEC, while for the non-circulated NTS, these values were 2.3% and 4.6 $cmol_c$ dm^{-3}, and for the circulated NTS, they were 3.6% and 6.7 $cmol_c$ dm^{-3}. This may indicate that the beneficial action of OM, in some cases, is more related to the type and quality of OM, rather than its quantity.

In Figure 3, soil fertility indicators are compared with grain yield using all of the data obtained in the experiments. In this Figure, the same set of samples is highlighted in all of the graphs shown. For clarity, some results displayed in the figures are shown again in Table 1.

The unsuitability of some soil fertility indicators used in CT for the NFS may be observed by the relationships between the traditional indicators and crop yields (Figure 3). When the conditions of the other factors that influence growth are adequate (for example, irrigation, pest control), the yield is proportional to the nutrient concentration, being determined at the minimum level, and/or the elimination of excess of acidity or alkalinity. Thus, according to the mineralist fertility concept, it would be expected, that under the described conditions, we would obtain 90% of the maximum yield when the pH and nutrient contents are interpreted as adequate (CQFS-RS/SC, 2004). In these experiments, under CT, this corresponds to the O/C rotation (Table 1; points highlighted with pink squares in Figure 3). The P content of this treatment is adequate, although low when compared with others (the adequate range for this textural class is 12-18 mg dm^{-3} according to CQFS-RS/SC, 2004). When this treatment is compared with NTS-O/C, which presented similar indicator values but was cultivated under NTS for over 20 years, it was observed that the grain yield was 50% lower in the O/C rotation (5.7 t ha^{-1}) compared with NTS-O/C (9.4 t ha^{-1}) (Table 1; points highlighted with blue squares in Figure 3). Obviously, in this case, the factor with the strongest influence was the cultivation system, which altered the productivity potential of the soil. Thus, the interpretation of the analytical results of the indicators maintains its coherence because in both cases, the soils are considered to be of adequate fertility (CQFS-RS/SC, 2004).

The comparison between tillage systems and rotations and between rotations using the same tillage system may be performed based on the results of the CT-O/C, CT-V/C and NTS-O/C and NTS-V/C treatments (Table 1). Under CT, there was a yield increase of approximately 20% between CT-O/C (5.7 t ha^{-1}) and CT-V/C (6.9 t ha^{-1}). This result could be considered normal if the fertility indicators were similar. Thus, the effect could be attributed to the rotation. However, the pH decreased from 5.4 to 4.8, while the V value decreased from 57% to 36% and Al saturation increased from 4% to 28% in the CT-V/C treatment. According to the mineralist concept (nutrient supply and the absence of toxic elements), fertility was initially adequate and became low in this treatment. As a consequence, to express its potential, the fertility of the soil should be corrected. In this case, when different rotations were employed for long periods, under CT itself, the current system for evaluating soil fertility may not be adequate.

The results obtained in treatments NTS-O+V/C+Cp (Table 1; points highlighted with blue triangles in Figure 3) and NTS-P/C, with and without nitrogen fertilization (Table 1; points highlighted with blue and orange squares, respectively, in Figure 3), indicated that it is possible to obtain high yields when soil fertility is interpreted, traditionally, as low (Raij et al., 1997; CQFS-RS/SC, 2004; Souza and Lobato, 2004). In the treatment NTS-O+V/C+Cp, the grain yield of 8.3 t ha^{-1}, the low soil pH and V and the high m and Al^{3+} contents merit attention. In treatment NTS-P/C, comparison between the treatments with and without N revealed no effect of this element on grain yield. Although the fertility in these treatments is also interpreted as low, the obtained grain yields were very high (Table 1).

The results and considerations that were shown previously reveal that the differences in grain yield were mainly due to tillage history, that is, the cultivation systems, the crop rotations, nitrogen fertilization and their interactions, rather than due to the traditionally evaluated chemical fertility indicator values. Neither the relationship between soil total N (Figure 4a) or mineral N (Figure 4b) and grain yield improved the interpretation of fertility perceived by the corn crop in the evaluated experiments.

In these long-term experiments, it is possible to observe the degree of difficulty that exists in evaluating soil fertility due several possible combinations of cultivation systems and crop rotations, in addition to the effect of the cultivation time on fertility indicators (Figure 3). In a simple system (less complex), few factors are responsible for the grain yield, and the alteration of any factor generates significant changes in the results. In more complex systems (under NTS, in addition to the chemical conditions, the physical and biological conditions also change over time; whereas under CT, only the chemical conditions change significantly over time), there is a large number of factors that influence grain yield, and the alteration of one of these factors has little or no influence on the overall yield (D̓Agostini, 2006).

The results of our experiments showed that chemical indicators do not always detect the changes in the soil productivity capacity promoted by different cultivation systems and crop rotations. These indicators demonstrated a low rate of association with the grain

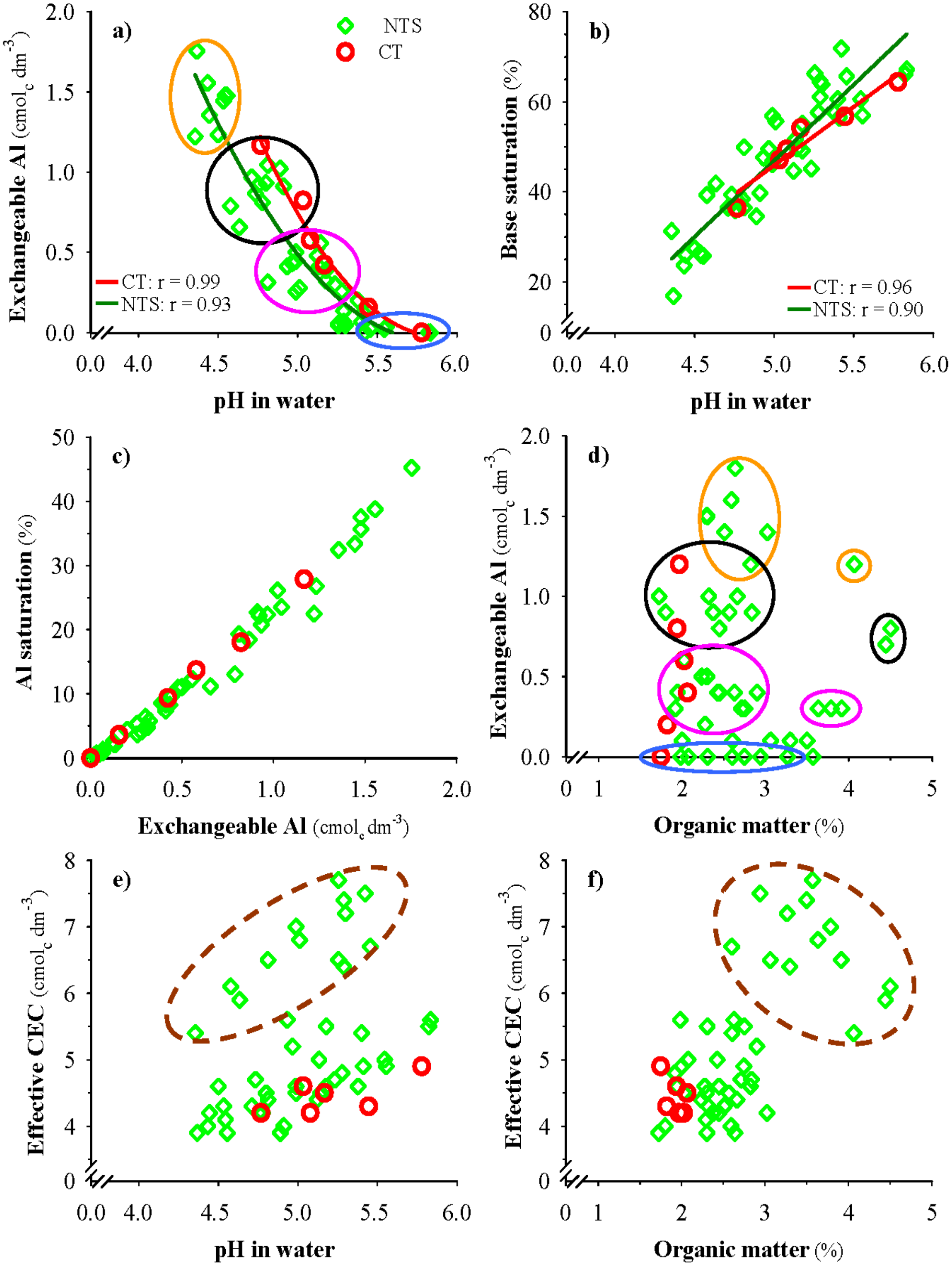

Figure 2. Classic relationships among traditional soil fertility indicators evaluated in experiments conducted under different cultivation histories for over 20 years at Eldorado do Sul, Brazil. CT = conventional tillage; NTS = no-tillage system.

yields of the plants (Figure 3). This result is largely due to the attempt to always associate yield increase with increases in nutrient content or decreases in toxic element contents. It is the mineralist soil fertility theory applied, in general, with success in CT.

According to the mineralist fertility concept, high yields

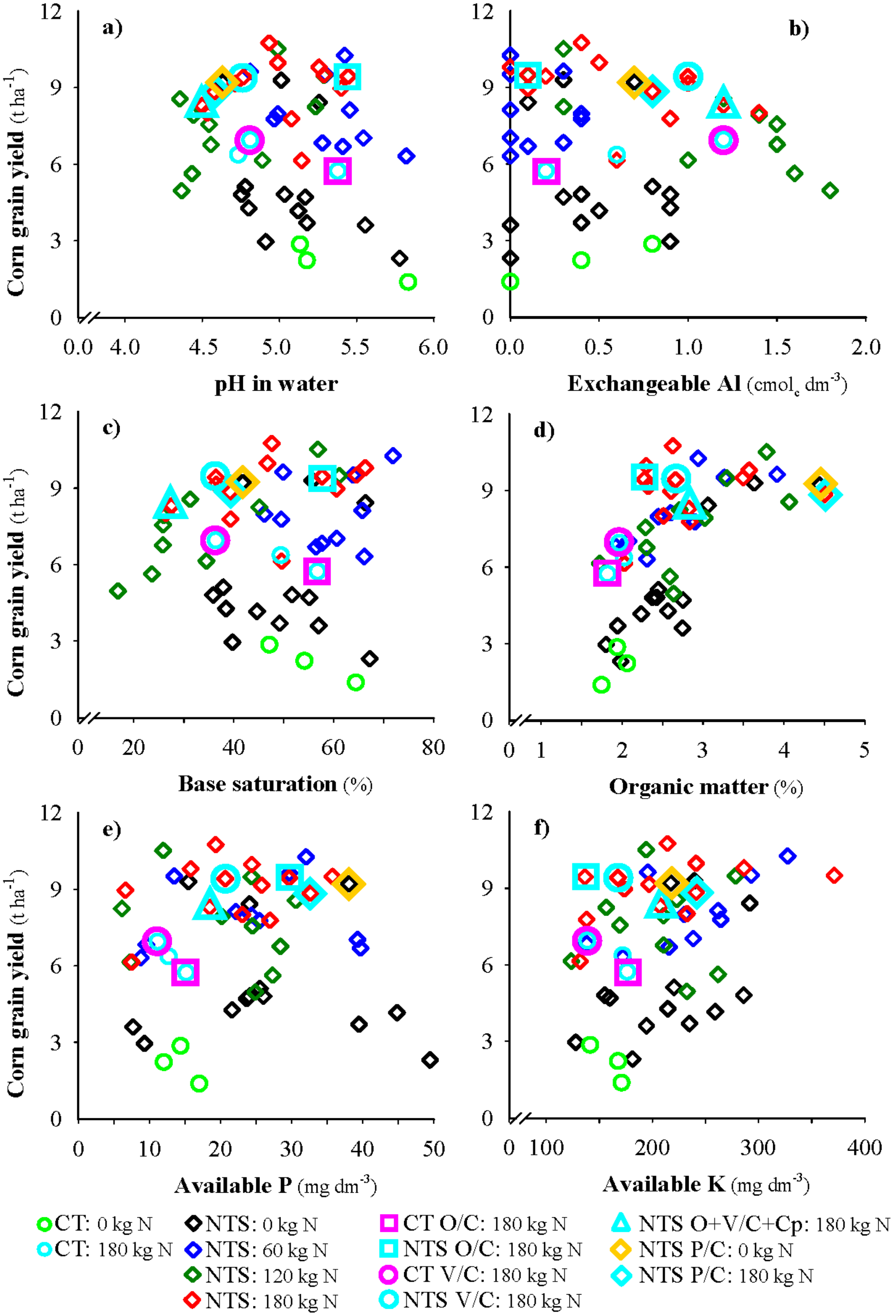

Figure 3. Relationships between corn grain yields and traditional soil fertility indicators in experiments conducted under different cultivation histories for over 20 years in Eldorado do Sul, Brazil. CT = conventional tillage; NTS = no-tillage system; C = corn; Cp = cowpea; O = black oat; P = pigeonpea; V = vetch.

Table 1. Corn grain yields and results for the main soil fertility indicators[1] in some of the treatments evaluated during the 2005/2006 crop season in experiments carried out over 20 years in Eldorado do Sul, Rio Grande do Sul State, Brazil.

Cultivation system[2]	Crop rotation[3]	Nitrogen fertilization	Grain yield	pH water	Al^{+3}	m	P Available	K Available	OM	V
		Kg of N ha^{-1}	t ha^{-1}		$cmol_c$ dm^{-3}	%	---mg dm^{-3}---		-------%------	
CT	O/C	180	5.7	5.4	0.2	4	15	176	1.8	57
NTS	O/C	180	9.4	5.4	0.2	4	30	136	2.3	58
CT	V/C	180	6.9	4.8	1.2	28	11	139	2.0	36
NTS	V/C	180	9.4	4.8	1.0	24	21	168	2.7	36
NTS	O+V/C+Cp	180	8.3	4.5	1.2	27	19	207	2.8	27
NTS	P/C	0	9.2	4.6	0.7	11	38	217	4.5	42
NTS	P/C	180	8.8	4.6	0.8	13	33	241	4.4	39

[1] Rhodic Paleudult (0-10 cm), textural class 2 (20 to 40% clay) (CQFS-RS/SC, 2004); [2] CT = conventional tillage and NTS = no-tillage system; [3] C = corn, Cp = cowpea, O = black oat, P = pigeonpea, V = vetch.

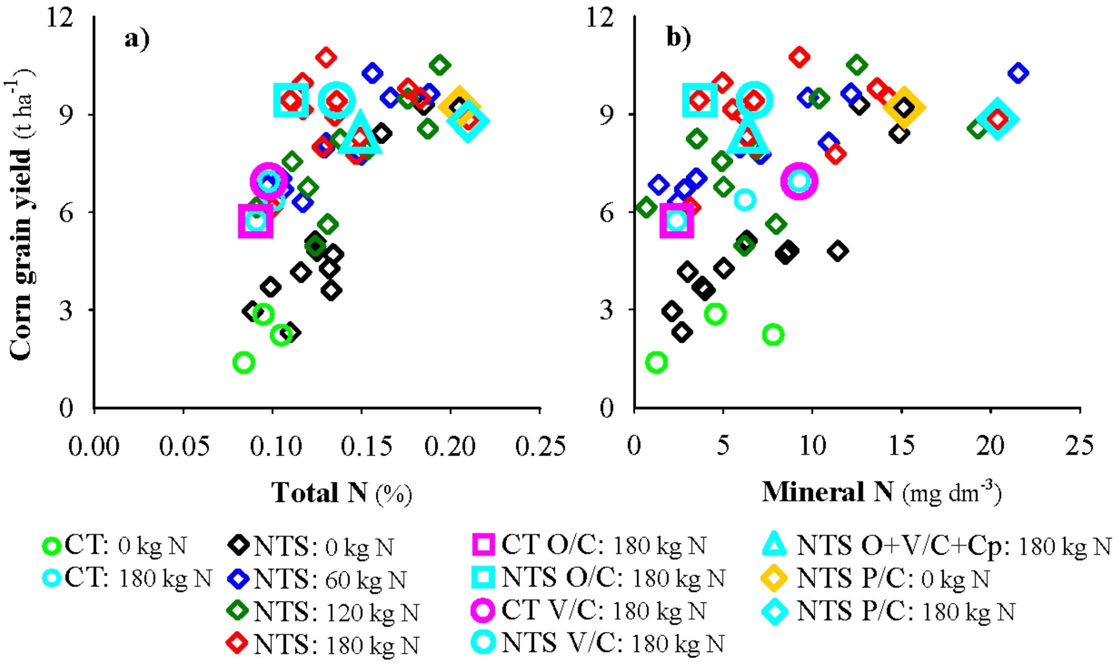

Figure 4. Relationships between corn grain yields and total nitrogen (a) and mineral nitrogen (b) in the soil, evaluated in experiments conducted under different cultivation histories for over 20 years in Eldorado do Sul, Brazil. CT = conventional tillage; NTS = no-tillage system; C = corn; Cp = cowpea; O = black oat; P = pigeonpea; V = vetch.

are not commonly obtained under low nutrient availability and/or in the presence of toxic elements in the soil. However, high yields were obtained in several treatments under low nutrient availability and/or in the presence of Al^{+3} in the soil in these long-term experiments (over 20 years). With the introduction of other tillage systems, between them the system that are widely used, the NTS, a new concept of soil fertility, and thus a new evaluation are needed. We agree with the conclusions of Patzel et al. (2000), who showed that it is important to clarify the soil fertility concept to improve communication between researchers from different regions and cultures, to reevaluate the soil fertility phenomenon in modern terms and that soil fertility and soil quality concepts have a distinctly different focus. Additionally, we desire to stimulate others to observe the responses of plants grown under NTS and to reconsider their current soil fertility concept or theory, based on comparison with what is perceived under field conditions by plants and their response in terms of grain yield. This concept must use indicators that are capable of expressing the functioning of the soil as a whole, and not only its chemical conditions (Nicolodi et al., 2004), to estimate yields given the capacity of these soils because the term *fertility* means *to produce abundantly* (Wikipedia, 2006).

CONCLUSIONS

The evaluation and, consequently, the mineralist fertility concept used to define the soil's capacity to produce abundantly, are insufficient to explain the results obtained for corn in soil cultivated under long-term NTS with different crop rotations, that is, the soil fertility perceived by plants.

The importance of the traditional soil fertility indicators is less in soils cultivated under NTS compared with CT.

High productivities may be obtained in soils cultivated for a long period under NTS in the presence of high Al^{+3} content and very low values of V and pH. The time of soil tillage under NTS and the crop rotation adopted are more important when defining crop yield than these values.

ACKNOWLEDGMENTS

The authors thank the CAPES for their financial support of the doctorate of the first author. They also thank Brazilian Professors Luiz Renato D'Agostini (UFSC) and Sandro Luiz Schlinwein (UFSC), Italian Professors Franco Zucconi (UnivPM) and Davide Neri (UnivPM) and Brazilian Researchers Otávio Antônio de Camargo (IAC) and José Eloir Denardin (EMBRAPA-Trigo) for their constructive discussions about systems, soil and fertility.

REFERENCES

Anghinoni I (2005). Fertility of soil in subtropical environment (in portuguese). Congresso Brasileiro de Ciência do Solo, 30. Recife, Brazilian Soil Science Society.

Bergamaschi H, Guadagnin MR, Cardoso LS, Silva MIG (2003). Climate of experimental station of UFRGS and region (in portuguese). Universidade Federal do Rio Grande do Sul, Porto Alegre.

Caires EF, Fonseca AFJ, Mendes WA (1999). Corn, wheat and soybean yields as a function of the changes in soil chemical charactaristics due to surfasse application of lime and gypsum under a no-tillage system. R. Bras. Ci. Solo, 23: 315-327.

Coelho FS (1973). Fertility of soil (in portuguese). Instituto Campineiro de Ensino Agrícola, Campinas.

Comissão de Química e Fertilidade do Solo (CQFS) RS/SC (2004). Manual on fertilization and liming for Rio Grande do Sul and Santa Catariana States (in portuguese) Brazilian Soil Science Society/NRS, Porto Alegre.

D'Agostini LR (2006). Notion of system: (re)emerging soil fertility, soil fertility (re)emerging systemic (in portuguese). In: Reunião Sul-Brasileira de Ciência do Solo, 6. Brazilian Soil Science Society/NRS and Embrapa Wheat, Passo Fundo.

Denardin JE (1998). Sistemic approach in no-tillage system (in portuguese). In: Nuernberg NJ (ed): Concepts and fundaments of no-tillage system. Brazilian Soil Science Society/NRS, Lages, pp. 7-14.

Kaminski J (1974). Factors of acidity and requirement of lime in soils of Rio Grande do Sul (in portuguese). Msc dissertation, Universidade Federal do Rio Grande do Sul, Santa Maria, Brazil.

Nicolodi M, Gianello C, Anghinoni I (2004). Fertility: an emerging property of the soil system (in portuguese). In: Reunião Sul-Brasileira de Ciência do Solo, 5. Brazilian Soil Science Society/NRS and UFSC, Florianópolis.

Patzel N, Sticher H, Karlen DL (2000). Soil fertility: phenomenon and concept. J. Plant. Nutr. Soil Sci., 163: 129-142.

Pöttker D, Ben JR (1998). Liming in soils under no-tillage and under native meadow of (in portuguese). In: Nuernberg NJ (ed): Concepts and fundaments of no-tillage system. Brazilian Soil Science Society/NRS, Lages, pp. 77-92.

Quaggio JA (2000). Acidity and liming in tropical soils (in portuguese). Instituto Agronômico de Campinas, Campinas.

Raij Bv, Cantarella H, Quaggio JA, Furlani AMC (1997). Recommendations of fertilization and liming for São Paulo State (in portuguese). Instituto Agronômico/Fundação IAC, Campinas.

Sá JCM (2004). Phosphorus fertilization on no-tillage system (in portuguese). In: Yamada T, Abdalla SRS: Fósforo na agricultura brasileira. Potafós, Piracicaba, pp. 201-222.

Salet RL (1998). Aluminium toxicity on no-tillage system (in portuguese). PhD dissertation, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil.

Scarponi F (1949). The concept of the fertility and its evolution in the time (in italian). Milano.

Souza DMG, Lobato E (2004). Cerrado: soil liming and fertilization (in portuguese). Embrapa Informação Tecnológica, Brasília.

Tedesco MJ, Gianello C, Bissani CA (1995). Analysis of soil, plants and other materials (in portuguese). Universidade Federal do Rio Grande do Sul, Porto Alegre.

Volkweiss SJ (1989). Chimica of acidity of soils (in portuguese). In: Kaminski J, Volkweiss SJ, Becker FC (eds). Seminário sobre corretivos da acidez do solo. Universidade Federal de Santa Maria, Santa Maria, pp. 7-38.

Wikipedia (2006). http://www.wikipedia.org/wiki/fertilidade. Acessed 20 November, 2006.