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Relationships between soil biological and other soil properties in saline and alkaline arable soils from the Pakistani Punjab

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Abstract

In six regions of the Punjab forming a gradient in precipitation, soils differing in texture, salinity and sodicity were taken at 29 representative sites. The aim was to assess the effects of these interacting differences on microbial biomass C, biomass N, and biomass P in relation to their element-specific storage compartment, i.e. soil organic C, total N and total P. The soils formed three groups: five sites were non-saline, 16 sites were saline and nine sites were saline and sodic. The salt content of the soils showed a strong negative correlation with the sand content. Textural effects on salinity and sodicity clearly override direct precipitation effects. All soils were in the alkaline range, with a median soil pH of 9.2 ranging from 8.1 to 10.4. The soil pH had significant negative effects on soil organic C ($r = -0.62$, $P < 0.0001$), but not on the microbial indices. Microbial biomass C and biomass N were closely correlated with $r = 0.69$ ($P < 0.0001$), but showed a strong variability between the four sampling subplots. The group-specific averages of microbial biomass C and biomass P varied without clear salinity and sodicity effects. In contrast, microbial biomass N, ergosterol and basal respiration declined by 20%, 31%, and 33%, respectively, comparing the group-specific maximum averages of the non-saline soils with the minimum values of the saline-sodic soils. The ratios microbial biomass C-to-soil organic C and microbial biomass N-to-total N declined by 19% and 35%, respectively, from maximum values of 2.6% and 3.1%. In contrast, the microbial biomass P-to-total P ratio remained unaffected by the salt content. A decrease in salinity and sodicity would improve the accessibility of soil organic matter to the soil microbial community. This implies a threat of further reduction in soil organic matter levels if the C input is not improved at the same time.

Keywords: Basal respiration; Microbial biomass; Salinity; Sodicity; Soil organic C

1. Introduction

The Punjab is the second largest province of Pakistan on an area basis, but the largest on a population basis with a strong demand for intensive cropping. Most areas in the Punjab comprise plain land formed by the

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river Indus. The soils are generally low in organic matter (Khan and Joergensen, 2006) and deficient in plant available nutrients, especially P (Muhammad et al., 2006). If not irrigated, the soils also suffer from water stress during most parts of the year, as roughly two-thirds of the total annual rainfall is received in only 2 months (July and August) during the monsoon season. The high temperatures during wet periods lead to fast turnover rates of soil organic matter, which are considerably slowed down during dry periods. High evapotranspiration and shallow water tables in the Punjab result in salinity (electrical conductivity $>4\,\mathrm{mS\,cm^{-1}}$) and sodicity (sodium absorption ratio (SAR) >14), affecting roughly 30% of the arable land (Sandhu and Qureshi, 1986). Salinity and sodicity are important threats to soil fertility. Accumulation of excess Na^+ in soil causes numerous adverse phenomena on soil physical and chemical properties, such as destabilization of soil structure, deterioration of soil hydraulic properties, increased susceptibility to crusting and specific ion effects on plants (Qadir and Schubert, 2002; Shainberg and Levy, 1992).

The effects of salinity on soil microorganisms and microbially mediated processes have been increasingly investigated in the past decade (Rietz and Haynes, 2003; Tripathi et al., 2006; Zahran, 1997). However, the dimension and the direction of the effects observed on microbial activity, biomass and community structure are not uniform and seem to depend on the environmental conditions, such as soil pH, anion composition, texture, and soil organic matter level (Li et al., 2006). At present, information regarding the function of the microbial biomass as sink and source of plant nutrients in sub-tropical soils is still not sufficient, considering the large variety of environmental conditions and management practices. In six regions of the Punjab forming a gradient in precipitation, soils differing in texture, salinity, and sodicity were taken at 29 representative sites. The aim was to assess the effects of these interacting differences on microbial biomass C, biomass N, and biomass P in relation to their element-specific storage compartment, i.e. soil organic C, total N and total P. The quotient microbial biomass C-to-soil organic C indicates the availability of organic substrates to soil microorganisms (Anderson and Domsch, 1989). Similarly, the quotients microbial biomass N-to-total N and microbial biomass P-to-total P indicate the availability of organic N and P components to soil microorganisms (Dilly et al., 2003; Khan and Joergensen, 2006). Information on these relationships might be useful for improving the land-use management systems of saline and saline-sodic soils of the Punjab.

2. Material and methods

2.1. Soil sampling and specification

Soils included in the present study were collected from 29 arable sites of the province Punjab (33.36°N and 73.07°E), central Pakistan, in the regions of Faisalabad (370 mm), Lahore (540 mm), Sargodha (610 mm), Gujranwala (720 mm), Gujrat (750 mm), and Rawalpindi (1180 mm), forming a gradient in mean annual precipitation (in brackets). The local climate is characterised by two distinct seasons, a very hot summer from June to August with maximum mean monthly temperatures up to 49°C and a cool period from October to February with minimum mean monthly temperatures down to 2.6°C. The mean annual precipitation is unevenly distributed over the year, i.e. approximately 50% comes in July. The cropping pattern is dominated by wheat, maize, and sorghum at Faisalabad, by rice, wheat, maize, and fodder legumes at Lahore and Gujranwala, by sugarcane, wheat, tobacco, maize, and sorghum at Sargodha, and by barley, maize, wheat, and sorghum at Gujrat and Rawalpindi. All sites are under low-input arable management. Consequently, the yield of all regions varies generally at a low range from 700 to 1300 $\mathrm{kg\,ha^{-1}}$ (Muhammad, 2005). Independent samples were taken from four sub-plots per site in July 2002 at 0–15 cm depth with a soil corer (4×15 cm), sieved under field moist conditions (<2 mm) and transported to Witzenhausen, Germany.

2.2. Soil physical and chemical properties

Soil textural analysis was carried out after pre-treatment with H_2O_2, HCl, and suspension in sodium polyphosphate using a combined sieving and pipette method (Schlichting et al., 1995). Soil pH was measured using a soil-to-water ratio of 1-to-2.5. Electrical conductivity (EC) was estimated using a soil-to-water suspension of 1-to-5, which was converted to EC values in a saturation extract (EC_e). Sub-samples of dried soil material were homogenised in a ball mill. Total C and N were determined using a Vario Max CN analyser