Alleviating the negative effect of salinity on soil respiration by plant residue addition – effect of residue properties, mixing and amendment frequency

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Grateful to God, the Almighty

Dedicated to my little family

My wife Zatin
And my daughters Syadza and Adella

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ABSTRACT

Salinity is a major constraint to crop production and also contributes to land degradation, particularly in arid and semiarid regions. Salinity has negative effects on soil microorganisms, reducing soil respiration, microbial biomass and microbial diversity. One of the main reasons for the negative impact of salinity is the low osmotic potential induced by high salt concentrations in the soil solution which reduces water uptake into cells and can cause water loss from cells. Some microorganisms can adapt to salinity by accumulation of osmolytes which is a significant metabolic burden. Rapidly decomposable plant residues contain high concentrations of easily available compounds which can be utilised by many soil microbes. Slowly decomposable residues on the other hand contain complex compounds which can only be utilised by few microbes, those capable of releasing specialised enzymes to break down these compounds. If salinity inhibits or kills some microbes, the decomposition of rapidly decomposable residues may be less affected than that of slowly decomposable residues because the loss of sensitive microbes can be compensated by a larger number of microbes with the former compared to the latter. If this is true, microbial activity after addition of slowly decomposable residues (high in lignin content and C/N ratio and low in water soluble carbon) should decrease more strongly with increasing salinity than after addition of rapidly decomposable residues. However, most previous studies on respiration in saline soils only used one or two types of plant residues (e.g. cereal or legume shoots). A further factor that may influence the impact of salinity on soil respiration is the frequency of residue addition. Frequent residue addition may provide soil microbes with a continuous supply of nutrients and therefore improve

salinity tolerance compared to a single addition where easily available compounds are rapidly depleted. These two assumptions have not been systematically investigated. The aim of this project was to investigate the effect of the chemical composition of added residues, mixing of residues and addition frequency on soil respiration and microbial biomass in soils with different salinity. Three studies were carried out to address the aims in non-saline soil and naturally saline soils with different salinity levels.

The aim of the first study was to investigate the impact of salinity on respiration in soil amended with residues differing in chemical composition (lignin concentration, water soluble organic carbon and C/N ratio). Three incubation experiments were conducted in this study. In the first experiment various residue types (shoots of wheat, canola, saltbush and kikuyu, saw dust, eucalyptus leaves) differing in C/N ratio, lignin and water extractable organic carbon concentration, were applied at 2% w/w to a non-saline soil ($EC_{1:5}$, 0.1 dS m^{-1}) and three naturally saline soils with $EC_{1:5}$ 1, 2.5 and 3.3 dS m^{-1}. Cumulative respiration decreased with increasing salinity but the negative effect of salinity was different among residues. Compared to non-saline soil, respiration was decreased by 20% at $EC_{1:5}$ 0.3 dS m^{-1} when slowly decomposable residues (saw dust or canola shoots) were added, but at $EC_{1:5}$ 4 dS m^{-1} when amended with a rapidly decomposable residue (saltbush). In the second experiment, the influence of residue C/N ratio and lignin content on soil respiration in saline soils was investigated. Two residues (canola and saw dust) with high C/N ratios but different lignin content were used. The C/N ratio was adjusted to between 20 and 80 by adding ammonium sulfate. Increasing salinity had smaller impact on cumulative respiration after addition of residues with C/N ratio 20 or 40 compared to residues with higher C/N ratio. In the third experiment, the effect of the concentration of water-soluble organic C (WEOC) of the residues was determined. WEOC was partially removed by leaching from two residues with high WEOC content (eucalypt leaves and saltbush shoots). Partial WEOC removal decreased cumulative respiration in saline soil compared to the original residues, but increased the negative effect of salinity on respiration only with saltbush shoots.

The second study was conducted using the four soils from the first study ($EC_{1:5}$, 0.1, 1, 2.5 and 3.3 dS m^{-1}) to compare the impact of single and multiple additions of residues that differ in decomposability on the response of soil respiration to increasing salinity. Two residues with distinct decomposability were used; kikuyu with 19 C/N ratio (rapidly decomposable) and canola with 82 C/N ratio (slowly decomposable). Both residues were added once or 2-4 times (on days 0, 14, 28 and 42) with a total addition of 10 g C kg^{-1} soil and incubated for 56 days. Compared to a single addition, repeated addition of the rapidly decomposable residue reduced the negative effect of salinity on cumulative respiration, but this was not the case with slowly decomposable residues.

The third study was carried out to investigate the effect of the proportion of rapidly and slowly decomposable residues in a mixture on the impact of salinity on soil respiration. This study included two experiments with two residues differing in decomposability (slowly decomposable saw dust and rapidly decomposable kikuyu grass). In the first experiment, both residues were added alone and in mixtures with different ratios into four soils having $EC_{1:5}$ 0.1, 1.0, 2.5 and 3.3 dS m^{-1}. The addition of 25% of rapidly decomposable residues in mixture with slowly decomposable residues was sufficient to decrease the negative impact of salinity on cumulative respiration

compared to the slowly decomposable residue alone. In the second experiment, three soils were used ($EC_{1:5}$ 0.1, 1.0 and 2.5 dS m^{-1}), residues were added once or 3 times (on days 0, 14 and 28) to achieve a total of 10 g C kg^{-1} soil either with sawdust alone, kikuyu alone or both where final proportion of kikuyu was 25%, but the order in which the residues were applied differed The negative effect of salinity on cumulative respiration was smaller when the rapidly decomposable residue was added early, that is when the soil contained small amounts of slowly decomposable residues. Salinity reduced soil respiration to a greater extent in treatments where rapidly decomposable residue was added to soil containing larger amounts of slowly decomposable residues.

It is concluded that rapidly decomposable residues can alleviate salinity stress to soil microbes even if they make up only a small proportion of the residues added. By promoting greater microbial activity in saline soils and providing nutrients, rapidly decomposable residues could also improve plant growth through increased nutrient availability.

DECLARATION

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