Tropentag 2009
University of Hamburg, October 6-8, 2009

Conference on International Research on Food Security, Natural
Resource Management and Rural Development

Early Tomato Growth Under Soil Aggregate Coalescence

U. Hasanah[a*], C.D. Grant[b] and R.S. Murray[b]

[a] Tadulako University, Soil Science Department, Kampus Bumi Tadulako Tondo, Palu 94118, Indonesia.
[b] The University of Adelaide, School of Earth and Environmental Sciences, SA 5005, Australia.

Introduction

High soil resistance is a major problem in agricultural soil as a result of intensive tillage. However, it can also occur in soils that have no history of tillage and which have previously experienced no compaction, slaking or dispersion and yet plant roots appear to experience high resistance (Cannel, 1985). Aggregate coalescence might have occurred in these soils (Cockcroft and Olsson, 2000). A microscopic examination of a coalesced orchard soil showed that the soil had 100% of its aggregate coalesced with a penetration resistance of 2.3 MPa compared to only 20% in a nearby uncoalesced soil with a penetration resistance of only 0.8 MPa soil (Cockcroft and Olsson, 2000). It appeared that in the coalesced soil the orchard roots prefer to grow in previously existed biopores rather than through the bulk soil. This leads to questions on how annual crops respond to soil coalescence where their roots system need to establish themselves, rather than simply explore biopores previously created by perennial plant roots. Therefore, this experiment was designed to study the effect of an early stage of aggregate coalescence on the early growth of tomato. The objective of the study was to answer the question: Does an early stage of aggregate coalescence affect the germination, emergence and early growth of tomato?

Materials and methods

Two cultivated soils were used: Shepparton fine sandy loam (15% clay; 1.5% C) and Cornella clay (60% clay; 1.5% C) from Rochester in south-eastern Australia. Aggregate fractions of 0.5 – 5 mm were packed into cylindrical rings of 4.77 cm i.d. and 5 cm height. Tomato (Lycopersicum esculentum, Mill), cv. Gross Lisse was used as a test plant. Ten seeds per core were planted for germination and emergence experiments while three seeds were used in separate cores for the early growth experiment. The seeds were planted at 5 mm depth in the dry aggregates before imposing the initial wetting treatments.

Soils were initially wetted according to the following procedures aimed at simulating different field conditions: (i) *Uncoalesced* with slow irrigation (NC): the air-dried soil cores were wetted at a rate of 1 mm h^{-1}, controlled by a peristaltic pump, to achieve water contents at field capacity (10 kPa suction). The cores were then left at this suction for 24 h before being transferred to a pressure plate at 100 kPa suction. During plant growth, irrigation was conducted at a rate of 1 mm h^{-1}. This treatment was aimed at minimizing slaking and coalescence. (ii) *Coalesced* with slow irrigation (Csl): The wetting process was the same as the uncoalesced treatment except that, after achieving water content at 10 kPa suction, the soil cores were brought to saturation for 24 h. Irrigation was the same as for the uncoalesced treatment. It was intended that the saturation period in this treatment would encourage the soil aggregates to coalesce, yet minimize slaking (and dispersion). (iii) *Coalesced* with rapid irrigation (Cfs): The wetting process was the same as the treatment 2 but with irrigation carried out by adding the amount of water needed at once.

---

[*] Corresponding author. Email: uswahmughni@yahoo.co.id

During plant growth, soil water contents for each soil were allowed to decline each day until they reached values (by weight) corresponding to a suction of 125 kPa. Water was then added (by weight) to reduce the suction to 75 kPa; this procedure was monitored and repeated throughout the plant-growth experiment.

Both the germination and emergence experiments were arranged in a completely randomized design with 4 replicates. Two treatments, uncoalesced and coalesced, were imposed for each soil. Observations on germination and emergence were conducted before irrigation commenced, by removing the soil cores from the pressure plate extractor so for the germination experiment, the rate of germination and the length of radicles of the seeds that had germinated were obtained after 4 and 6 days using a digital caliper. For the emergence experiment, only the time of emergence was observed.

The early growth experiments were arranged in a completely randomized design with 7 replicates. Three treatments were imposed on each soil. After 7 days, the extent of seedling emergence was evaluated by opening the pressure plates daily until there was sufficient emergence to proceed. After emergence, the soil cores were removed to a growth cabinet with a constant temperature of 20^{0}C and 14 h of light/d. Each soil core was covered with plastic beads to minimize evaporation losses. Plants were harvested at 6 and 10 d after emergence. Plant measurements conducted included: Number of lateral roots, and lateral root length. The length of individual roots and was determined using a Videopro 32 Color Image Analysis system version 5 (Leading Edge Pty. Ltd., Australia).

Penetrometer resistance and bulk density were measured after the shoots were removed and water was added to achieve 100 kPa suction. The resistance measurements were conducted at three positions in every core using a cone penetrometer of 2 mm diameter with a total cone angle of 60^0 moving at 0.3 mm/minute as it entered the soil core resting on a digital top-loading balance. At each position the load (g) was recorded at 10 second increments. Balance readings were converted to force (N) and then penetration resistance was calculated as the force divided by the area of the cone-base (Zhang *et al*., 2001).

Analysis of variance was carried out using the Genstat 5 programme (Genstat, 1987). The least significant difference was calculated wherever the F-test was significant at P<0.05.

Results and Discussion

There was a marked increase in the percentage of seed germination and the length of radicles as a result of different treatments (Figure 1).

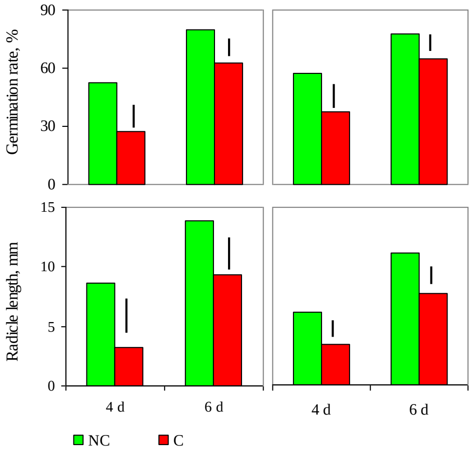


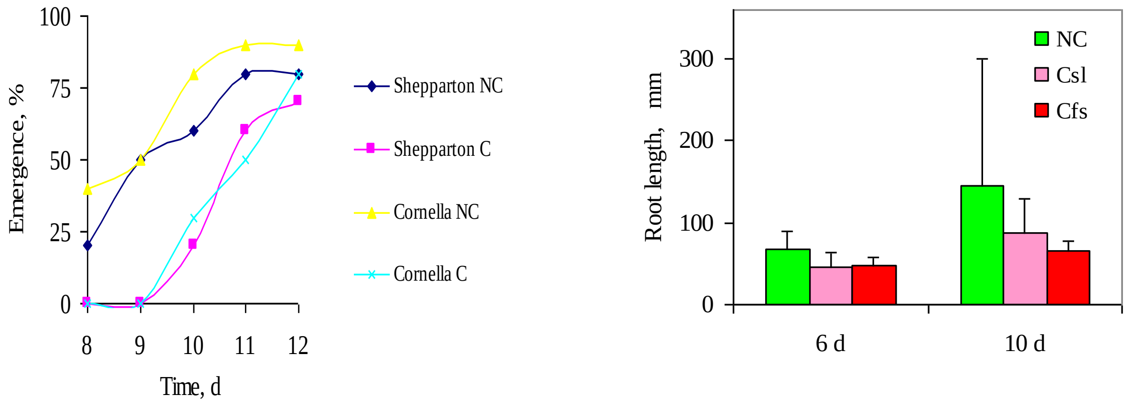
Figure 1. The effect of aggregate coalescence on germination rate and radicle length of tomato seeds at 4 and 6 d after sowing in Shepparton and Cornella soils

Vertical bars indicate least significant differences at P<0.05

The uncoalesced treatment have a significantly higher percentage of germination, with an accompanying increase in radicle length. However, it seems unlikely that the soil treatment was the major factor that affected both the percentage of seed germination and the length of radicles as penetration resistance values between the treatments were similar up to 15 mm depth whereas the seeds were sowed at 5 mm depth. Therefore soil resistance appeared not to be a constraint for the seeds to germinate.

It is possible that the wetting process might have been a key factor. In the uncoalesced treatment, the soil was never saturated so that lack of oxygen was not a problem in this treatment. While in the coalesced treatment, the soil was left saturated for 24 h; this may have led the soil to be anaerobic for a certain period delaying seed germination and emergence. The porosity of the Shepparton soil was 0.61 with volumetric water content of 0.44 at near saturation whereas the Cornella soil had porosity of 0.65 with volumetric water content of 0.52 at near saturation.

The rate of tomato seedling emergence is presented in Figure 2a. Emergence in the coalesced treatments for both soils was delayed for up to 2 d. This delay may be attributed to the delay of seed-germination due to lack of oxygen in the coalesced soil.



a

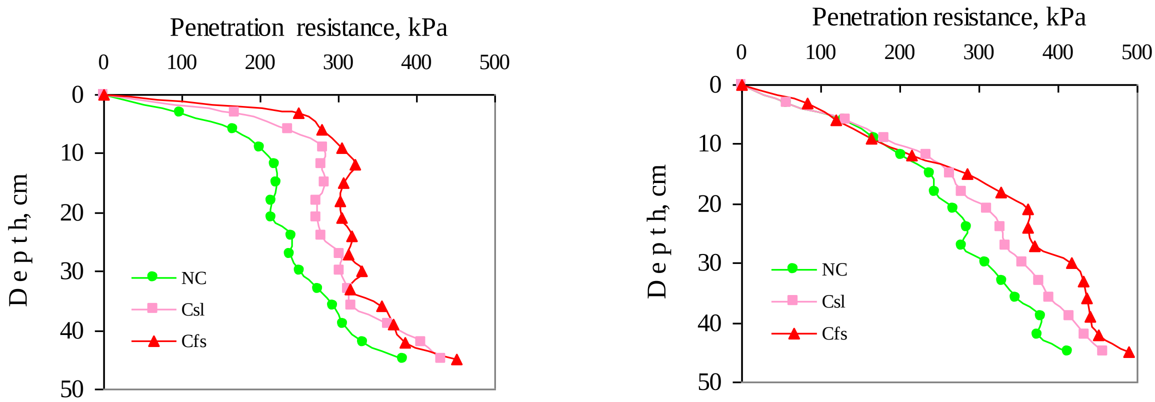
b

Figure 2. (a) The rate of tomato seed emergence with different treatments at various times after sowing; (b) The effect of aggregate coalescence on the total length of tomato root at 6 and 10 days in Shepparton soil.

There were no statistically significant differences ($P<0.05$) between treatments of the cultivated Shepparton soil for all plant parameters measured. However, the results of total root length were consistent in both harvests (6 d and 10 d) in that the uncoalesced treatment tended to have higher values than the coalesced treatments (Figure. 2b).

In general, the magnitude of the soil resistance, measured as a function of soil depth 10 d after plant emergence, appears to be below the critical point of 0.5 MPa (Figure 3a) where roots begin to encounter difficulties and the bulk densities of the coalesced and uncoalesced soils were very similar at 1.10 and 1.12 g cm^{-3}, respectively. However, the coalesced soil tended to have higher soil resistance than the uncoalesced soil, this may have presented some problems for root growth of very young seedlings, especially for root attempting to explore the base of the soil cores. In this experiment, the soil was exposed to only one cycle of wetting and draining and so any development of aggregate coalescence was at an early stage. The effects of aggregate coalescence on the early growth of tomato were apparent even though the results were not statistically significant at $P<0.05$. A more advanced stage of aggregate coalescence after repeated wetting and draining may restrict plant root development more severely as the soil resistance rises beyond 0.5 MPa (Grant *et.al.*, 2001; Hasanah, 2007).

In the cultivated Cornella soil, the plant growth appeared to be normal until 7 days after emergence when the leaves started to change colour beginning at the tips. The plants eventually could not survive for the second harvest (i.e. 10 d after emergence).



a

b

Figure 3. The effect of aggregate coalescence on penetration resistance at 100 kPa suction of (a) Shepparton soil; (b) Cornella soil

Visual observation of the plant leaves was consistent with the symptoms of plant death due to salinity. Later examination showed that the electrical conductivity of the soil (1:5) was found to be >0.4 dS/m which may be sufficient to cause problems particularly for a sensitive plant such as tomato. Due to this problem, observations were conducted only on the first harvest (6 days after emergence). The effect of aggregate coalescence on penetration resistance was not statistically significant ($P<0.05$). It also appeared that aggregate coalescence in this soil had no significant effect on the plant and root parameters measured. Although the coalesced soil showed higher values of penetration resistance, there is no significant difference at $P<0.05$ and all soil penetrometer resistances (Figure 3b) were below 0.5 MPa. At the same time the bulk densities ranged from only 0.906 to 0.926 g cm^{-3}.

Conclusions

The differences in the rate of seed germination and seedlings emergence may have been affected by the lack of oxygen in the coalesced soils as a result of the initial soil wetting processes rather than the intended constraints. In the cultivated Shepparton soil, total root length was consistently higher in the uncoalesced treatment than in the coalesced treatment. Soil penetration resistances in the Shepparton and Cornella soils appeared not to be major constraints for plant growth, however, the fact that soil resistances approaches 0.5 MPa in soils of such low bulk density is an indication that plant responses would likely to be greater as the soil aggregate coalescence become more advance.

References

CANNEL, R. Q. (1985). Reduced tillage in north-west Europe: A review. Soil Till. Res. 5: 129-177.

COCKROFT, B and OLSSON, K.A. (2000). Degradation of soil structure due to coalescence of aggregates in no-till, no-traffic beds in irrigated crops. Australian Journal of Soil Research 38: 61-70

GRANT, C.D., ANGERS, D.A., MURRAY, R.S., CHANTIGNY, M.H. and HASANAH, U., (2001). On the nature of soil aggregate coalescence in an irrigated swelling clay. Australian Journal of Soil Research 39: 565-575

HASANAH, U. (2007). Soil Aggregate Coalescence and Factor Affecting It. Ph.D. thesis, The University of Adelaide

ZHANG, B., HORN, R. and BAUMGARTL, T. (2001). Changes in penetration resistance of Ultisol from southern China as affected by shearing. Soil Till. Res. 57: 193-202.