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KOALESEN AGREGAT TANAH DALAM HUBUNGANNYA DENGAN LAJU PEMBASAHAN DAN POLIVINIL ALKOHOL

Soil Aggregate Coalescence in Relation to Wetting Rate and Polyvinyl Alcohol (PVA)

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ABSTRAK

Laju pembasahan dan tingkat pembasahan disamping bahan organik dipercaya mempengaruhi proses awal terjadinya koalesen agregat tanah yang dapat meningkatkan kekuatan tanah. Penelitian ini dirancang untuk memisahkan kedua pengaruh itu sehingga dapat dilakukan perbaikan pengelolaan yang dapat dievaluasi dalam rangka meningkatkan efisiensinya yaitu apakah pengelolaan harus berfokus pada perbaikan teknik irigasi atau meningkatkan bahan organik, atau keduanya. Polivinil alkohol (PVA) yang merupakan salah satu senyawa kimia yang dapat meningkatkan stabilitas agregat diberikan secara terkontrol dengan menggunakan sprayer terhadap agregat tanah berdiameter 0,5-2 mm. Sampel tanah bertekstur kasar dan halus ditempatkan dalam ring dan laju pembasahan air (1, 10 dan 100 mm/jam) menggunakan sistem tetesan yang dikontrol oleh pompa peristaltik. Sampel tanah kemudian dibasahi hingga mendekati jenuh atau hisapan 10 kPa selama 24 jam, kemudian didrainase dengan menggunakan plat tekanan pada hisapan 100 kPa. Pengukuran tahanan penetrometer diukur dengan menggunakan penetrometer kerucut berdiameter 2 mm, sedangkan kekuatan tarik diukur dengan alat uji tidak langsung *Brazilian*. Tahanan penetrometer lebih rendah pada sampel tanah yang mendapat perlakuan PVA sebelum pembasahan dan pada sampel tanah yang yang mendapat hisapan lebih tinggi (10 kPa) setelah pembasahan awal. Pengaruh tersebut semakin menonjol pada tanah bertekstur kasar. Pada kedua jenis tekstur tanah, kekuatan tarik meningkat dengan semakin tingginya laju pembasahan dan tingkat pembasahan (lebih besar pada kondisi hampir jenuh). Laju pembasahan cenderung lebih penting dalam mendorong proses terjadinya koalesen agregat dari pada tingkat pembasahan.

Kata kunci : Bahan organik, koalesen, laju pembasahan, penetrometer dan tingkat pembasahan,

INTRODUCTION

Cultivation that leaves soil loose with random aggregate orientation and large pores between aggregates is prone to structural breakdown once the soil is wetted. Wetting rate is known to be one external factor that affects the degree of aggregate breakdown. Keller (1970) investigated the effect of wetting rate on loosely packed columns of unstable and relatively stable aggregates. It was found that in both unstable and stable soils, increased bulk density was the result of increasing wetting rate. Wetting causes the aggregates to be weakened and allows forces such as gravity and surface tension to actively thrust the aggregates into more intimate contact forming a new structure (Kemper *et al*., 1975). Soil conditioners such as polyvinyl alcohol (PVA) have long been used to stabilise aggregates. Many studies have shown increased aggregate stability along with improved shear strength, permeability, infiltration rate, aeration and resistance to crust formation (Allison and Moore, 1956; Stefanson, 1974; Oades, 1976; Barry *et al*., 1991). However, little is known about the effect of wetting rate and soil conditioner, particularly PVA, on the coalescence of relatively stable aggregates. Results from previous experiments in this work showed that rapid wetting of relatively stable aggregates increases soil resistance.

The purpose of this experiment was to determine the relative effect of wetting rate, wetting extent and PVA on the coalescence of relatively water stable aggregates.

MATERIALS AND METHODS

Aggregate fractions (0.5–4 mm) of two cultivated soils, Shepparton and Cornella were used in this experiment. The aggregates were divided into two samples; one sample was treated by spraying the aggregates with PVA (molecular weight = 22,000; diluted into the amount of R.O. water equal to water content at field capacity at a rate of 1.5 g/kg soil). The other sample was sprayed with R.O. water (untreated). In this way both untreated and treated soils were slowly wetted to field capacity (10 kPa suction) and then left overnight to allow the PVA to be uniformly distributed into the aggregates. The aggregates were then air dried and sieved again prior to use to obtain the same aggregate size fractions for both treatments.

The soil aggregates were packed into cylindrical rings (5 cm high and 4.77 cm i.d.) and wetted from the soil surface at different rates using a peristaltic pump. Three wetting rates were used: (i) 1 mm h^{-1} (slow), (ii) 10 mm h^{-1} (medium), and (iii) 100 mm h^{-1} (fast). All wetting events were conducted until a volume of water equivalent to field capacity (10 kPa suction) had been applied. At the end of the wetting process one group of the soil cores was left overnight at saturation and the other at field capacity by placing them on a ceramic pressure plate with a 100 cm hanging water column. The cores were then drained to 100 kPa suction for one week. The methods used for measuring penetrometer resistance, bulk density, water content and tensile strength are in accordance with Hasanah (2008).

For each soil, a factorial design was used with PVA and wetting rate as factors and three replicates were used. Data was analysed using a Genstat 5 program (Genstat 5 Committee, 1987). If there was a significant effect at $P<0.05$, the analysis was continued with Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Shepparton Soil

Penetration resistance. Slow application of water tended to reduce soil resistance but the effects were not statistically significant at $P<0.05$ (Figure 1).

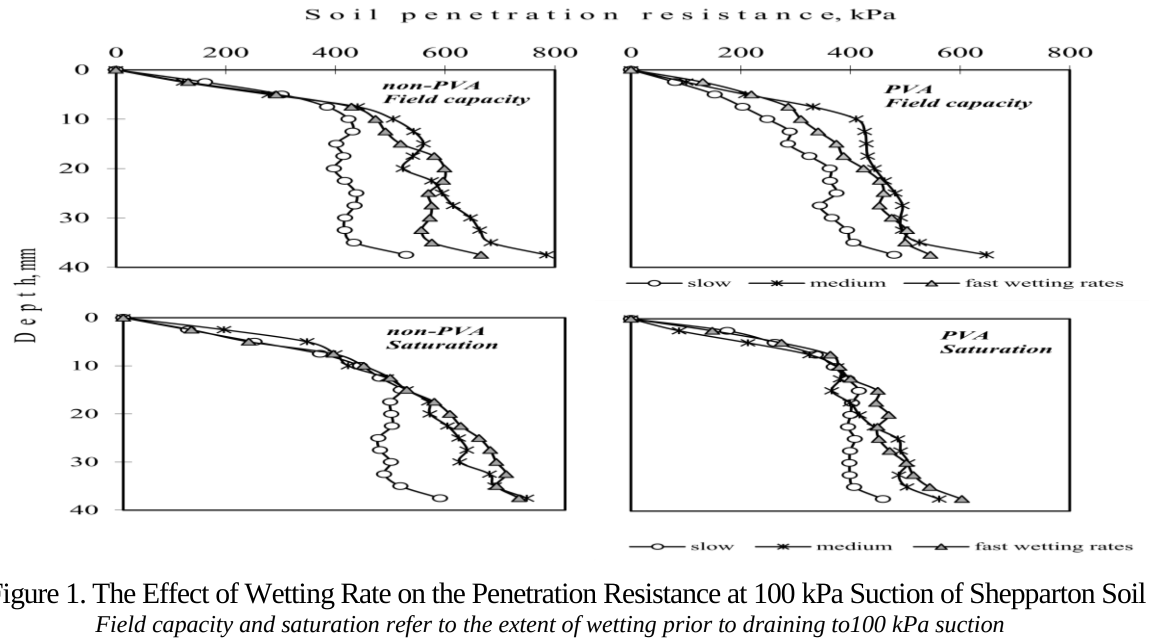

Figure 1. The Effect of Wetting Rate on the Penetration Resistance at 100 kPa Suction of Shepparton Soil

Field capacity and saturation refer to the extent of wetting prior to draining to100 kPa suction

Figure 2 presents the soil resistance as a function of depth as affected by PVA. The application of PVA resulted in lower penetrometer resistance for all wetting rates and extents although it was not statistically significant at P<0.05. The reduction in penetrometer resistance varied from 9 to 41 % at 20 mm depth.

Bulk density. Figure 3 shows the bulk densities of Shepparton soil as affected by wetting rate, and PVA. There was no significant effect of different wetting rates or wetting extents but the effect was significant for PVA application. For the soil that had been kept at field capacity after either slow or fast wetting, PVA decreased the bulk densities significantly, whereas for the soil that had been kept at saturation the only significant difference was found in medium wetting.

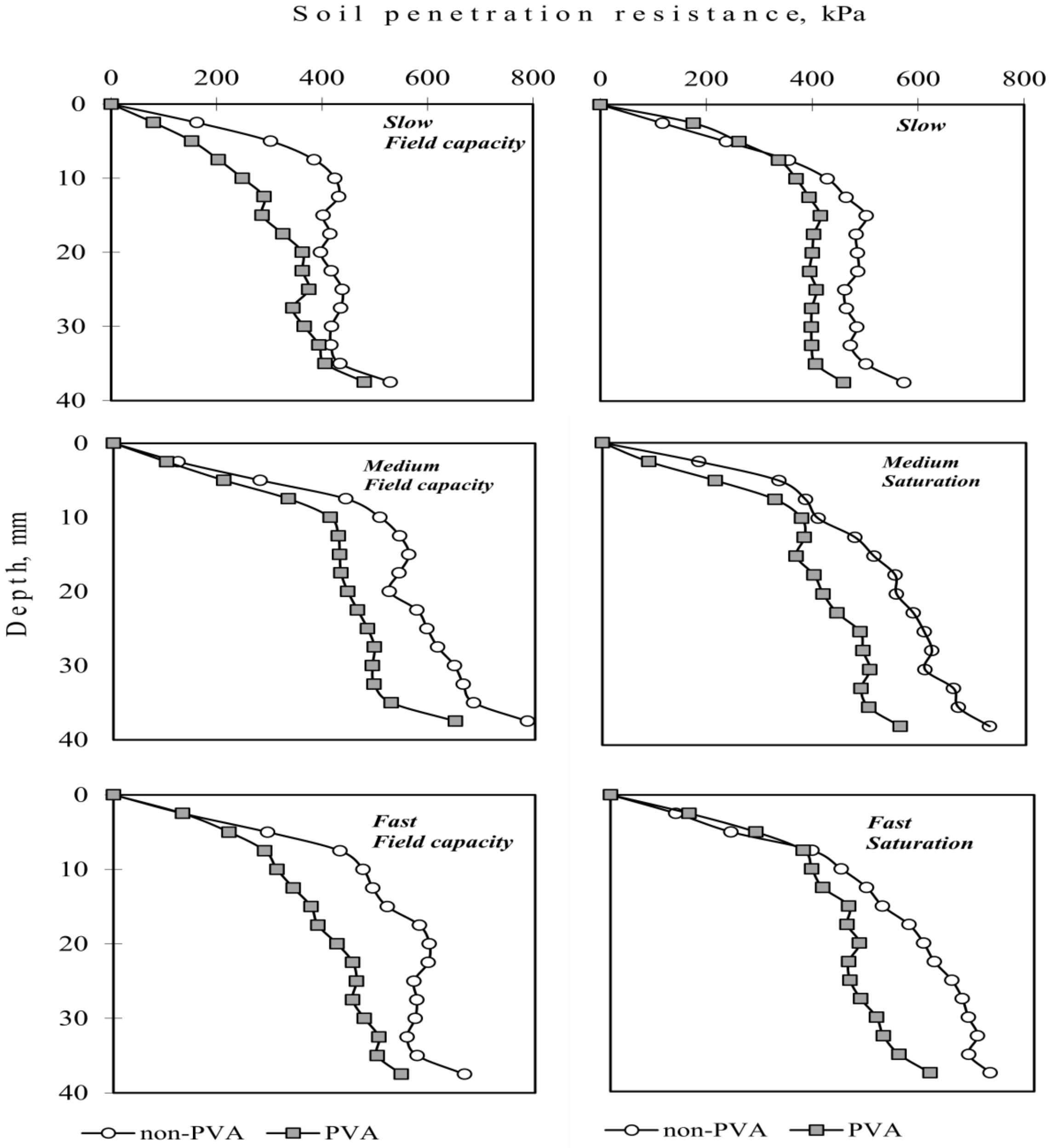

Figure 2. The Effect of PVA on the Penetration Resistance at 100 kPa Suction of Shepparton Soil

Slow, medium and fast refer to wetting rates

Field capacity and saturation refer to the extent of wetting prior to draining to 100 kPa suction

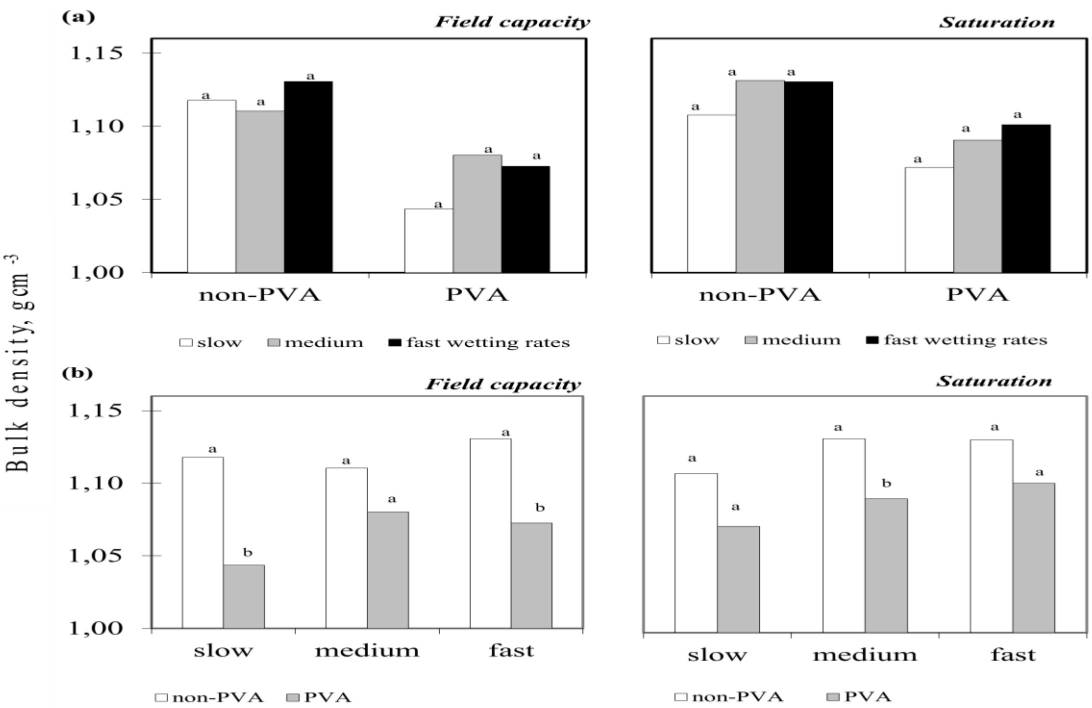

Figure 3. The Effect of (a) Wetting Rate and (b) PVA on Bulk Density at 100 kPa Suction of Shepparton Soil

Different letters above the bars indicate significant differences at P<0.05

Field capacity and saturation refer to the extent of wetting prior to draining to 100 kPa suction

Water Content. Table 1 shows the gravimetric water contents of the Shepparton soil as affected by wetting rate, wetting extent and PVA. There were no significant effects of the treatments.

Tensile Strength. Different wetting rates and wetting extents had significant effects on the tensile strength of Shepparton soil while the effect of PVA was not significant. Figure 4 shows the tensile strength of Shepparton soil as affected by wetting rate, wetting extent and PVA.

As the wetting rate increased from slow to fast, the tensile strength of untreated PVA soil increased from zero to 1.7 kPa and from 0.55 to 3.4 kPa when the soil had been kept at field capacity and saturation, respectively (Figure 4a). The effects of wetting rates were mediated to some extent by the application of PVA. Increasing the extent of wetting from field capacity (10 kPa suction) to saturation increased tensile strength (Figure 4b), but mainly at the fast wetting rate. The application of PVA tended to reduce tensile strength but not in any significant way (Figure 4c).

Table 1. The Effect of Wetting Rate, PVA and Wetting Extent on Gravimetric Water Content ($g\ g^{-1}$) at 100 kPa suction of Shepparton soil

Wetting Rate	Non-PVA		PVA	
	Field capacity	Saturation	Field capacity	Saturation
Slow	0.125	0.126	0.128	0.125
Medium	0.117	0.122	0.122	0.122
Fast	0.117	0.118	0.124	0.124

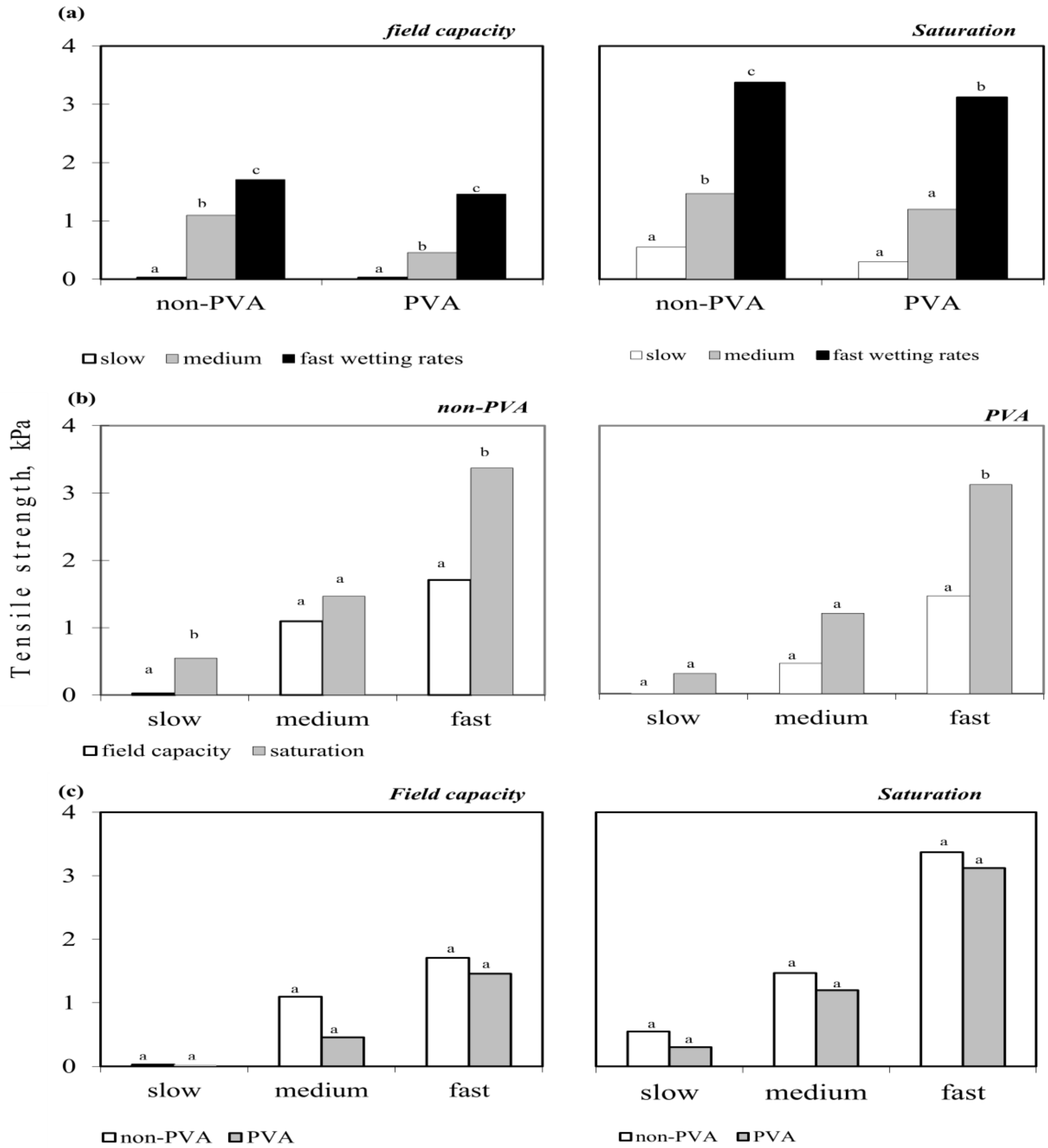

Figure 4. The Effect of (a) Wetting Rate, (b) Wetting Extent and (c) PVA on Tensile Strength of The Air-Dried Shepparton Soil

Different letters above the bars indicate significant differences at P<0.05

Field capacity and saturation refer to the extent of wetting prior to draining to 100 kPa suction

Cornella Soil

Penetration Resistance. Again, for the Cornella soil, there was no significant effect of different wetting rates, wetting extents or PVA on penetration resistance. For this soil, only the effect of wetting rate (Figure 5) is presented as this is the only treatment that showed a relatively clear trend in the penetration resistance.

The soil resistance increased slightly with increasing wetting rate from slow to fast. This result was more pronounced when the soil was not treated with PVA and the wetting extent was at field capacity.

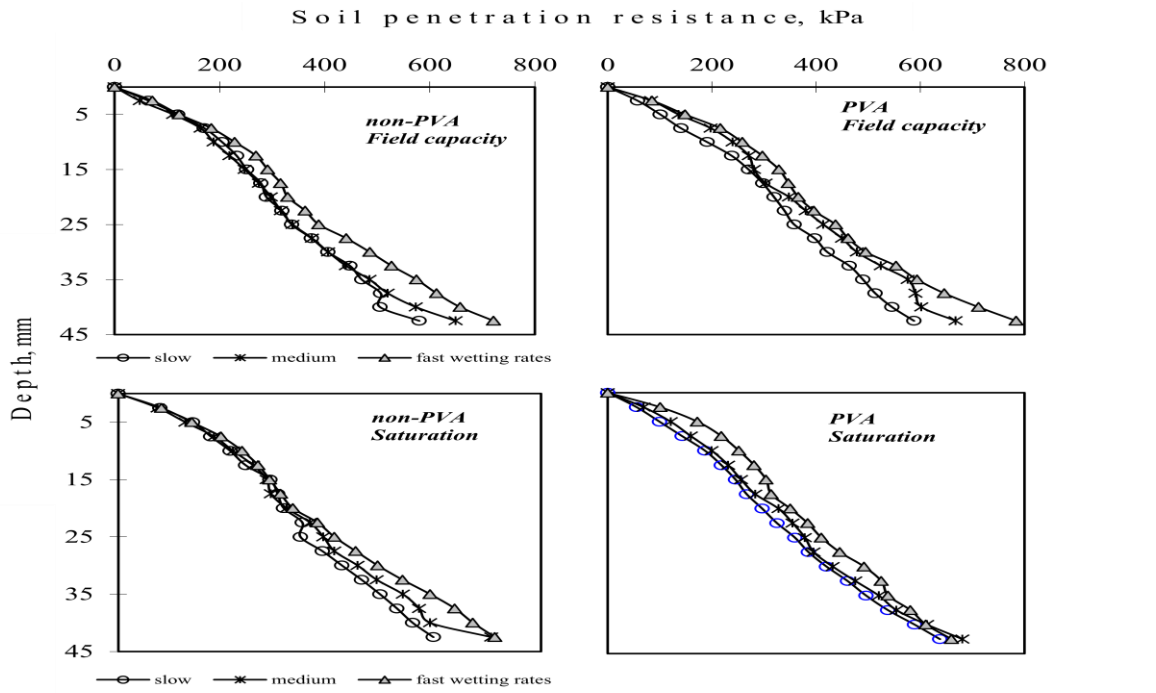

Figure 5. The Effect Of Wetting Rate On Penetration Resistance at 100 kPa Suction of Cornella Soil
Field capacity and saturation refer to the extent of wetting prior to draining to 100 kPa suction

Bulk Density. Figure 6 shows the bulk densities of Cornella soil as affected by wetting rate, and PVA. Although the effects were not generally statistically significant at P<0.05, increased wetting rates tended to increase bulk density slightly while soil treated with PVA appeared to have higher bulk density than untreated soil at all wetting rates and extents.

Water content. Table 2 shows the gravimetric water content of the Cornella soil as affected by wetting rate, wetting extent and PVA.

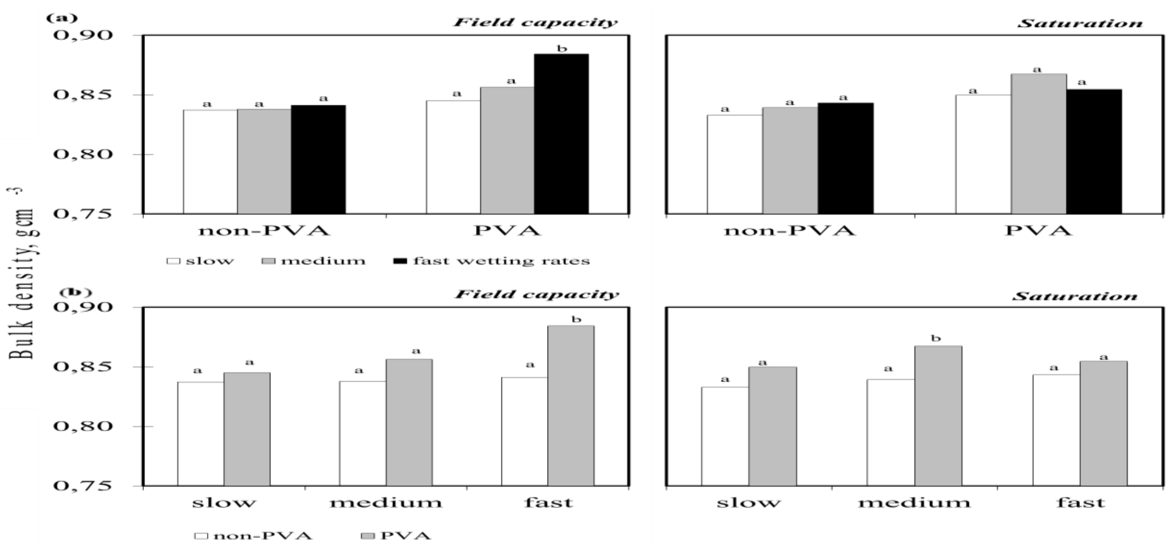

Figure 6. The Effect of (a) Wetting Rate and (b) PVA on Bulk Density at 100 kPa Suction of Cornella Soil
Different letter above the bars indicate significant differences at P<0.05
Field capacity and saturation refer to the extent of wetting prior to draining to 100 kPa suction

significant, soil treated with PVA generally had lower water contents.

Although the effects were not significant, soil treated with PVA generally had lower water contents.

Tensile Strength. Figure 7 shows the effect of wetting rate, wetting extent and PVA on tensile strength of Cornella soil. Increasing wetting rate increased the tensile strength significantly in either untreated or treated PVA soil. Soil treated with PVA tended to have significantly lower tensile strength than untreated soil.

Table 2. The Effect of Wetting Rate, Wetting Extent and PVA on Gravimetric Water Content ($g\ g^{-1}$) at 100 kPa Suction, for Cornella Soil.

Wetting rate	Non-PVA		PVA	
	Field capacity	Saturation	Field capacity	Saturation
Slow	0.320	0.309	0.300	0.310
Medium	0.326	0.320	0.308	0.312
Fast	0.317	0.319	0.298	0.318

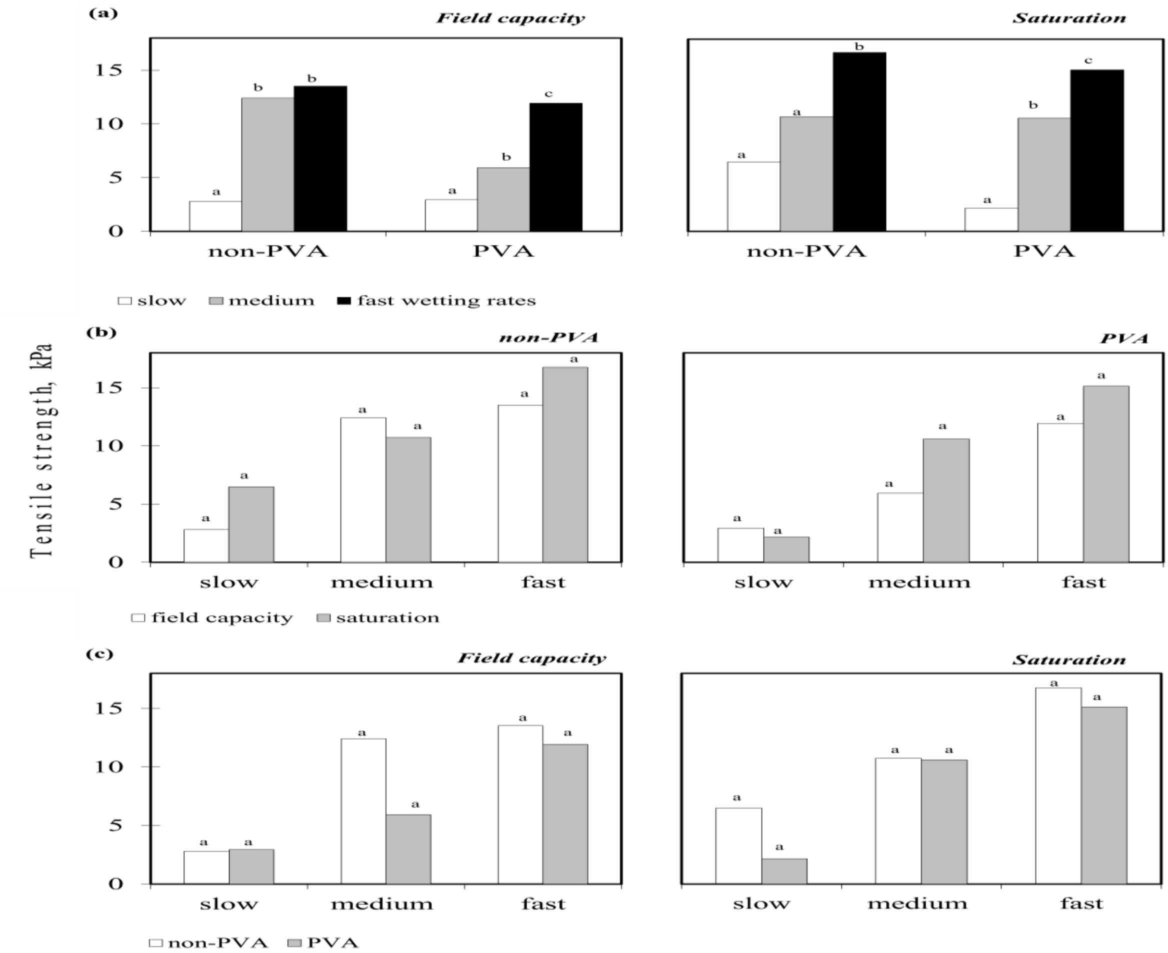

Figure 7. The Effect of (a) Wetting Rate , (b) Wetting Extent and (c) PVA on Tensile Strength of Air- Dried Cornella Soil

Different letters above the bars indicate significant differences at P<0.05

Field capacity and saturation refer to the extent of wetting prior to draining to100 kPa suction

Slow, medium and fast refer to wetting rates

The effect of wetting rate, extent of wetting and PVA was more pronounced in the Shepparton than the Cornella soil in terms of soil resistance and bulk density. According to Kemper *et al*. (1975) the degree to which aggregates break down is determined by the bonding strength within the aggregates and the rate of soil wetting. The increase in penetrometer resistance in Shepparton soil as a result of increased wetting rate was often accompanied by a small increase in bulk density indicating that rapid wetting may have caused some disintegration of the aggregates due to incipient failure (Quirk and Panabokke, 1962). This phenomenon in the Cornella soil was not as obvious as in the Shepparton soil as the penetration resistances were very similar between wetting rates.

Application of PVA always reduced the soil resistance in the Shepparton soil but produced little change in the Cornella soil. It appeared that the use of PVA is more effective in coarse-textured soil (Shepparton) than clay soil (Cornella). However, PVA may only affect the soil resistance in the Shepparton soil indirectly as the bulk densities also decreased accordingly. When PVA solution is added to a soil, the PVA molecules will diffuse into the pores according to the suction under which it is applied. Quirk and Williams (1974) showed that the application of PVA to the soil will stabilise the pores occupied by the PVA upon drying; in their experiment the stabilised pores were of 30 m diameter or less as the PVA was added at field capacity (10 kPa suction). This in turn might reduce the effect of incipient failure (Quirk and Panabokke, 1962) of the aggregates when they are wetted rapidly.

Both the Cornella and Shepparton soils showed similar results in terms of tensile strength, although the magnitude was lower in the Shepparton soil due to its lower clay content. The tensile strength increased with increasing wetting rate and wetting extent but decreased with the addition of PVA. The increase in tensile strength indicated that aggregate coalescence had progressively developed as a result of increased wetting rate and extent of wetting while PVA retarded this development.

CONCLUSIONS

The effect of PVA and wetting rate on soil penetrometer resistance was more pronounced in coarse-textured soil (cultivated Shepparton fine sandy loam) than in a clay soil (cultivated Cornella clay). PVA may have affected the penetration resistance of the Shepparton soil indirectly by reducing its bulk density. Both Shepparton and Cornella soils showed similar trends in tensile strength in which it increased with increasing wetting rate and wetting extent but decreased with the addition of PVA. Increasing rate of wetting might increase the rate and amount of soil materials exchange between aggregate at their point of contacts while PVA might coat the exterior part of aggregates minimising the development of aggregate coalescence by limiting materials exchanged between the aggregates

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