Characteristics of soil physical properties in different soil management of oxisols, and inceptisols

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ABSTRACT

Oil palm (Elaeis guineensis Jacq.) is a plantation crop that has a bright future. Soil management such as land clearing, burning, use of heavy equipment and fertilisation in oil palm plantations will affect changes in soil physical properties. This study aims to assess the physical properties of soil in various treatments (planting circle, dead interplant spacings and live interplant spacings) on Oxisol and Inceptisol soil types. This research was conducted in Rancabungur and Malingping Banbten in October 2021 - May 2022. The method used in this study was multistage random sampling. Soil samples were taken from the Malingping area of Banten for the Oxisol soil type (2005 and 2009 planting years), and the Rancabungur area for the 2005 Inceptisol soil type. Comparison of soil physical properties of Oxisol of 2005 planting year with Oxisol of 2009 planting year and the ratio of Oxisol soil type of 2005 planting year and Inceptisol of 2005 planting year in various treatments did not show significant differences in soil physical properties (organic matter, content weight, field capacity moisture content, permanent wilting point, and particle density) between planting circle, dead interplant spacings and live interplant spacings. However, there were significant differences in the physical properties of soil texture between each management and permeability.

Keywords: *1; Inceptisol 2; Oil palm 3; Oxisol 4; Physical properties 5; Soil properties*

INTRODUCTION

Oil palm (Elaeis guineensis Jacq.) has bright prospects in the plantation industry. Initially, oil palm plantations were developed in North Sumatra and Aceh. However, it has now spread to various regions such as Riau, Jambi, West Sumatra, South Sumatra, Bengkulu, Lampung, West Java, West Kalimantan, East Kalimantan, Central Kalimantan, Sulawesi, Maluku, and Papua. The demand for palm oil tends to increase every year, which encourages the expansion of oil palm planting areas. In 2021, the estimated area of oil palm plantations reached 14.62 million hectares, although crude palm oil (CPO) production experienced a slight decline of 5.01 per cent from 45.74 million tonnes to 45.12 million tonnes (Badan Pusat Statistik, 2021).

The success of oil palm cultivation is determined by environmental factors, namely soil factors and climatic factors. One of the most influential soil factors is soil physical properties, which include texture, particle specific gravity, organic matter, content weight, pore size distribution, moisture content, and soil permeability. Soil physical properties are dynamic and tend to influence soil chemical and biological properties. Soil physical properties play an important role in the movement of water and solutes, air, heat, root penetration, specific surface area, compressibility, and others. This will greatly affect plant growth and development (Hilel et al. 1980, Cit Utomo 2016). According to Sarief (1989), the value of soil permeability which shows the rate of water movement in the soil affects the water content and plant growth.

As for what affects the physical properties of soil is from land clearing, fertilization, and harvesting using heavy equipment is also one of the problems because it causes soil compaction due to the trajectory of heavy equipment. Soil damage due to heavy equipment tracks can damage the top soil layer which will later be used in oil palm planting activities. The impact of heavy equipment tracks from the land area passed can reduce soil porosity, root penetration, soil moisture content and can increase soil density (Putri, 2019).

Differences in land use affect the physical characteristics of soil; especially texture, porosity, and permeability (Sudarmanto et al. 2014). Meanwhile, organic matter (C-organic) and initial moisture content are not influenced by different types of land use. According to Sumarno (2009), soil with organic matter gives a dark or blackish colour as an indication of fertile soil. According to Njurumana (2008) the higher the organic matter content, the darker the soil colour.

Very important crop production factors are soil type and soil physical properties. Soil type greatly influences the physical properties of the soil, one of which is Oxisol and Inceptisol. Soils rich in minerals of iron and aluminium oxidation, having undergone further weathering in the area around the equator (intertropical region) are called Oxisols, while for Inceptisols are immature soils with weaker profile development compared to mature soils and still have properties similar to the parent material (Hardjowigeno, 1993).

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Oil palm plantations have several areas with different intensities of disturbance, viz: planting circle, live interplant spacings, and dead interplant spacings. Each type of management has different treatments. The planting circle are usually used for fertilisation and harvesting activities, the dead interplant spacings are used for the preparation of oil palm fronds, and the live interplant spacings are used as traffic roads for fruit transport. According to Murtilaksono et al. (2007) oil palm requires at least 150 mm/month or 5-6 mm/day of water. The low ability of the soil to hold water will cause a decrease in soil moisture content. A decrease in soil moisture content will be followed by an increase in soil penetration resistance so that it will inhibit root growth (Wahyuni et al. 2012).

In oil palm plantations, vegetation and plant age also affect differences in soil physical and soil quality, age and type of plant have different abilities to protect the soil (Yasin et al. 2006). Based on this background, it is necessary to conduct a comparative study of the characteristics of Oxisol and Inceptisol soil physical properties against various disc management, dead swards, and live swards in Rancabungur and Malingping Banten. Specific objectives to be achieved: (1) to assess the characteristics of soil physical properties of Oxisol in 2005 planting year with Oxisol in 2009 planting year under various management, (2) to assess the characteristics of soil physical properties of Oxisol in 2005 planting year with Inceptisol in 2005 planting year under various management.

MATERIALS AND METHODS

Research Time and Place

The research was conducted from October to July 2022 in the Malingping and Rancabungur regions. The Malingping area is located between the south latitude of 6°37'09.7" to 6°62'00" and east longitude of 105°59'39.2", while Rancabungur is located between the south latitude of 6°37'40" to 6°32'00" and east longitude of 106°42'20" to 6°45'20". Soil samples were collected in Banten and West Java provinces. Soil sample analysis was conducted at the Soil Physics Laboratory located at the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.

Research Design

conducted in oil palm plantations in several locations, namely Banten and Rancabungur. Variables observed included the same soil type with different crop ages (Oxisol 2005 and Oxisol 2009) and different soil types with the same crop age (Oxisol 2005 and Inceptisol 2005). In Malingping, Banten, the soil type observed was Oxisol, while in Rancabungur it was Inceptisol. Soil samples were taken from areas of dead interplant spacing, live interplant spacing, and oil palm planting circle at depths of 0-30 cm and 30-60 cm, with three replicates for each condition. The total number of samples taken was 54, consisting of 3 blocks (Oxisol 2005 and 2009, and Inceptisol 2005) x 3 observation points (disc, live interplant spacing, and dead interplant spacing) x 3 replicates x 2 depths (0-30 cm and 30-60 cm).

Soil Sample Analysis

Comparisons were made of soil physical properties, including texture, organic matter, soil specific gravity, bulk density, field capacity moisture content, permanent wilting point, and permeability, of different types of management applied to the same soil type with different cropping years (Oxisol in 2005 and Oxisol in 2009). Furthermore, a comparison was made of soil physical properties, including texture, organic matter, specific gravity, bulk density, field capacity moisture content, permanent wilting point, and permeability, of different types of management applied to different soil types with the same cropping year (Oxisol in 2005 cropping year and Inceptisol in 2005 cropping year). This comparison was done using the mean difference test method.

RESULTS AND DISCUSSION

Comparison of soil properties under various management at different planting ages.

Soil Texture of Oxisol 2005 and Oxisol 2009

Based on the analysis of soil physical properties, Table 2 shows that in the Oxisol soil type in the 2005 planting year, the sand fraction in the management type of live interplant spacing and dead interplant spacing did not show significant differences, but both were significantly different with a disc of 20%. The sand fraction in the dead spacing interplant management type in Oxisol in the 2005 planting year had the highest percentage at 28%, while the live spacing interplant had the lowest percentage at 13%. In addition, soil texture also affects soil drainage ability.

Table 1. Methods of analyzing soil properties in the laboratory

No.	Parameters	Analysis Method
1	Texture	Pipette
2	Bulk density	Gravimetry (sample ring)
3	Particle density	Gravimetry (pycnometer)
4	Pore size distribution	Formula calculation (BI, BSW, pF curve)
5	Moisture content pF	Gravimetry (pressure plate apparatus)
6	Permeability	Constant water level (Klute and Dirksen)
7	Organic matter	Walkley and Black

Tabel 2. Sand soil texture fraction (%) on Oxisol 2005

Texture parameters	Management Type			
	Planting circle	Interplant spacing Dead	Live Interplant spacing	Average
Sand	22,04±7,07 ab	28,54±7,07 b	13,01±2,82 a	21,19±8,19
Silt	34,12±1,41	35,08±4,24	36,17±4,24	35,71±2,89
Clay	44,23±5,65	37,41±2,82	51,01±7,07	44,08±7,53
Texture class	Liat	Liat	Liat	

Notes: Numbers followed by different letters in the same row indicate significantly different based on Duncan's Test at 20% level.

Table 3. Sand soil texture fraction (%) on Oxisol 2009

Texture Parameters	Management Type			
	Planting circle	Interplant spacing Dead	Live Interplant spacing	Average
Sand	9,00±5,65	11,04±0,00	10,09±2,75	10,52±2,75
Silt	41,52±9,19	41,58±6,36	44,58±5,31	42,33±5,31
Clay	49,57±14,84	47,53±6,36	46,44±4,24	47,67±7,63
Texture class	Liat	Liat	Liat	

Soils that have a coarse structure with sand or gravel content tend to have good drainage, allowing excess water to easily flow out of the plant roots. On the other hand, soils with fine textures such as clay have poor drainage, so in wet growing years excessive waterlogging can occur which can damage the roots and cause plant diseases. Table 3 shows the soil texture of Oxisol in the 2009 planting year, the sand fraction has an average value of 10%, but does not have a significant difference between the types of management, this is different from the sand fraction of Oxisol in the 2005 planting year, but for the silt fraction, and clay the same as Oxisol in the 2005 planting year, Oxisol in the 2009 planting year does not have a significant difference between the types of management. The soil texture class for Oxisol in 2005 and 2009 is clay, because the soil type and the research area are the same. Soil texture can also affect effective tillage methods. Soils with clay texture tend to be more difficult to work and can clump when wet. Physical and chemical properties of soil such as texture, BO, moisture content, and soil permeability are very supportive in infiltrating water into the soil, and the ability of soil to infiltrate water is measured by the infiltration capacity value (Dewi, 2007).

Table 4. Comprises a comparison of organic matter, content weight, field capacity moisture content, permanent wilting point capacity moisture content, particle specific gravity, and permeability for each management type (disc, dead interplant spacing, and live interplant spacing) and a comparison of soil physical properties between Oxisol 2005 and Oxisol 2009.

Organic matter content

Table 4 shows that the organic matter content of Oxisol in the 2005 planting year did not have a significant difference in organic matter levels between discs and dead spacing interplants, and did not have a significant difference in organic matter levels between dead spacing interplants and live spacing interplants (ranging from 1.34-1.57%). Likewise, the organic matter content of Oxisol soil type in the 2009 planting year did not have a significant difference in organic matter levels between the disc and dead spacing interplant, and did not have a significant difference in organic matter levels between dead spacing interplant and live spacing interplant (1.36-1.42%). Based on these results, it can be seen that the organic matter content of Oxisol soil in the 2005 planting year has no significant difference from Oxisol in the 2009 planting year. According to Endriyani (2011), one of the things that affects the process of soil aggregation is organic matter, the more organic matter content, the more adhesive content in the soil so that it solidifies soil aggregates..

Content weight

Table 4 shows that the content weight of Oxisol in the 2005 planting year did not differ significantly between discs, dead interplant spacing, and live interplant spacing (ranging from 1.29-1.36 gr/cm3). Likewise, the content weight of Oxisol in the 2009 planting year had no significant difference between dead interplant spacing discs, and live interplant spacing (1.21-1.28 gr/cm3). According to Baskoro and Tarigan (2007), soils with high levels of organic matter tend to have good and stable soil physical properties. An increase in soil content weight can occur when there is an increase in water content in the soil. Under live interplant spacing conditions, a good soil structure allows for good air circulation and drainage, so that the soil can hold water without excess or drying out. The use of organic matter, such as compost or manure, can help improve soil structure, increase water retention, and improve overall fertility..

Moisture content Field Capacity (McFC).

Table 4 shows that McFC Oxisol in the 2005 planting year had no significant difference in discs with dead spacing interplants, and had no significant difference in McFC between dead spacing interplants and live spacing interplants (32.32-34.05%). Likewise, the McFC of Oxisol in the 2009 planting year did not have a significant difference between the disc with dead interplant spacing, and did not have a significant difference in McFC between dead interplant spacing and live interplant spacing (29.17-31.17%). Based on these results, it can be seen that the McFC of Oxisol soil in 2005 planting year has no significant difference with Oxisol in 2009 planting year. Field capacity moisture content refers to the maximum amount of water that can be stored in the soil after gravity water flows out, so that only water is absorbed by the soil and available to plants. It is related to the physical properties of the soil, such as texture, structure and composition.

Moisture content Permanent Wilt Point (McPWP)

Table 4 shows that the McPWP of Oxisol in the 2005 planting year did not have a significant difference in discs with dead spacing interplants, and did not have a significant difference in McPWP between dead spacing interplants and live spacing interplants (18.97-20.19%). Likewise, the McPWP of Oxisol in the 2009 planting year did not have a significant difference between the disc and dead interplant spacing, and did not have a significant difference in McPWP between dead interplant spacing and live interplant spacing (18.0-21.91%). Based on these results, it appears that the McPWP of the Oxisol soil in the 2005 planting year has no significant difference from the Oxisol in the 2009 planting year. Permanent wilting point moisture content is highly dependent on soil type. Sandy soils tend to have lower permanent wilting point moisture content, while loamy or sandy loam soils tend to have higher permanent wilting point moisture content. Permanent wilting point moisture content refers to the soil moisture level at which the plant can no longer take up enough water to maintain its normal growth and function. At this point, the plant experiences prolonged drought and may suffer damage or die. Permanent wilting point moisture content helps growers in determining the right time for irrigation and ensures that plants get sufficient water supply for healthy growth.

Permeability

Table 4 shows that the permeability of Oxisol in the 2005 planting year had no significant difference between the disc and the dead spacing interplant, and had no significant difference in permeability between the dead spacing interplant and the live spacing interplant. The permeability of Oxisol in the 2009 planting year did not have a significant difference with dead spacing interplants, but had a significant difference in permeability between dead spacing interplants and live spacing interplants. Based on these results, it can be seen that the permeability of Oxisol soil in the 2005 planting year has no significant difference from Oxisol in the 2009 planting year. This is in accordance with the research of Mauli (2008) which states that permeability is closely related to the total soil pore space, where the smaller the total soil pore space, the smaller the soil permeability, and vice versa. Soil permeability plays an important role in the growth and production of oil palm plants. Here are some of the effects of soil permeability on oil palm plants.

Soil properties under different soil management on different soils

Soil Texture of Oxisol 2005 and Inceptisol 2005

Based on the results of the analysis of soil physical properties, Table 5 shows that the soil texture of Oxisol in the 2005 cropping year sand fraction in the management type of live spacing interplant with dead spacing interplant, but both are not significantly different from the disc at the level of 20%. The fraction of sand in the management type of dead spacing interplant Oxisol in 2005 planting year was the highest (28%) while the live spacing interplant was the lowest (13%). Soil texture can affect the soil's ability to provide water and nutrients needed for good oil palm growth. In addition, soil texture can also affect drainage, water retention and soil aeration.

Table 4. Comparison of soil physical properties based on different crop ages on the same soil type (Oxisol 2005 and Oxisol 2009) with management types.

Parameters	Soil Type	Management Type			Average
		Planting circle	Interplant spacing Dead	Live Interplant spacing	
Organic Matter	Oxisol 2005	1,34	1,57	1,51	1,52
	Oxisol 2009	1,36	1,42	1,41	1,40
Bulk density	Oxisol 2005	1,36	1,33	1,29	1,32
	Oxisol 2009	1,21	1,28	1,25	1,25
McFC	Oxisol 2005	33,90	34,05	32,32	33,43
	Oxisol 2009	29,90	29,17	31,17	30,26
McPWP	Oxisol 2005	20,02	20,19	18,97	19,72
	Oxisol 2009	19,73	18,60	21,91	20,08
Particle Specific gravity	Oxisol 2005	2,46	2,63	2,43	2,50
	Oxisol 2009	2,42	2,36	2,67	2,48
Permeability	Oxisol 2005	10,58	7,53	1,59	6,57
	Oxisol 2009	8,43 a	4,26 a	8,66 b	7,12

Therefore, understanding soil texture in oil palm fields is important to manage optimal irrigation, fertiliser and water management to support optimal oil palm growth and productivity.

Table 6 shows that the soil texture of Inceptisol in the 2005 planting year, the sand fraction does not have a significant difference between the types of management, this is different from the sand fraction of Oxisol in the 2005 planting year, but for the silt fraction, and clay is the same as Oxisol in the 2005 planting year, Inceptisol in the 2005 planting year also does not have a significant difference between the types of management. The soil texture class of Oxisol in the 2005 and 2009 cropping years is sandy clay, because the soil type and the research location area are different. This soil has a good water retaining ability because clay particles can hold and store water well. Loamy soils also tend to have aggregated physical properties, which allow for good infiltration and water retention in the oil palm root zone.

Table 7. Comprises a comparison of organic matter, content weight, field capacity moisture content, permanent wilting point capacity moisture content, particle specific gravity, and permeability for each management type (disc, dead interplant spacing, and live interplant spacing) and a comparison of soil physical properties between Oxisol 2005 and Inceptisol 2005. Sandy soils have high sand content and low clay content. Sandy soils tend to be well-drained, allowing water to quickly infiltrate into the soil and drain out of the oil palm root zone.

Organic matter content

Table 7 shows that Oxisol organic matter levels in the 2005 planting year did not have a significant difference in organic matter levels between the disc and dead spacing interplants, and did not have a significant difference in organic matter levels between dead spacing interplants and live spacing interplants. Likewise, the organic matter content of Inceptisol in the 2005 planting year did not have a significant difference in organic matter levels between the discs with dead spacing interplants, and did not have a significant difference in organic matter levels between dead spacing interplants and live spacing interplants. Based on these results, it appears that the soil organic matter content of Oxisol in the 2005 planting year did not have a significant difference from Inceptisol in the 2005 planting year. Soil organic matter content and solum depth are derived from soil moisture content, the higher the moisture content obtained, the higher the organic matter content, and the higher the moisture content, the deeper the solum depth (Hanafiah, 2010). The addition of oil palm empty fruit bunches as compost on oil palm plantation land can improve soil physical properties, one of which is organic matter. This is in line with the research of Widodo (2018) who said that the addition of compost increases the number of microbes in the soil that act as soil adhesive agents that make soil aggregates stable.

Content Weight

Table 7. Shows that the content weight of Oxisol in the 2005 planting year did not differ significantly between discs, dead interplant spacing, and live interplant spacing. Likewise, the content weight of Inceptisol in the 2005 planting year had no significant difference between the dead interplant spacing discs, and the live interplant spacing. Soil bulk density affects root aeration, which is the availability of oxygen in the plant root zone. Oxisol soil of 2005 planting year with a high bulk density tends to be dense and less porous than Inceptisol of 2005 planting year, which may limit air movement into the soil. Oil palm roots need good aeration for efficient respiration and metabolism. If the soil has a high bulk density and is less porous, oil palm roots may experience a lack of oxygen, which can lead to reduced growth and productivity. High bulk density will affect the permeability of the soil to be lamba. According to Natalia's research (2018) to increase soil productivity, it is necessary to seek management that can reduce the content weight and/or penetration resistance of the soil.

Table 5. Sand soil texture fraction (%) on Oxisol 2005

Texture parameters	Management Type			
	Planting circle	Interplant spacing Dead	Live Interplant spacing	Average
Sand	22,00±7,07 ab	28,00±7,07 b	13,00±2,82 a	21,00±8,19
Silt	34,00±1,41	35,00±4,24	36,00±4,24	35,00±2,89
Clay	44,00±5,65	37,00±2,82	51,00±7,07	44,00±7,53
Texture class	Liat	Liat	Liat	

Note: numbers followed by different letters in the same row

Table 6. Sand soil texture fraction (%) on Inceptisol 2005

Texture parameters	Management Type			
	Planting circle	Interplant spacing Dead	Live Interplant spacing	Average
Sand	7,00±0,12	11,00±4,24	6,54±0,71	8,16±2,92
Silt	50,00±12,72	54,50±0,71	58,22±7,07	54,16±7,44
Clay	43,00±12,71	34,51±3,53	35,56±7,77	37,67±8,01
Texture class	Sandy clay	Sandy clay	Sandy clay	

Table 7. Comparison of soil physical properties based on the same crop age on different soil types (Oxisol 2005 and Inceptisol 2005) with management type

Parameters	Soil type	Management Type			
		Planting circle	Interplant spacing Dead	Live Interplant spacing	Average
Organic Matter	Oxisol 2005	1,47	1,57	1,51	1,52
	Inceptisol 2005	1,11	1,04	1,22	1,12
Bulk density	Oxisol 2005	1,33	1,32	1,29	1,32
	Inceptisol 2005	1,13	1,07	1,08	1,10
McFC	Oxisol 2005	33,90	34,05	32,32	33,43
	Inceptisol 2005	50,79	49,85	49,56	50,07
McPWP	Oxisol 2005	20,02	20,19	18,98	19,72
	Inceptisol 2005	26,49	26,33	26,66	26,49
Particle Specific gravity	Oxisol 2005	2,46	2,63	2,43	2,50
	Inceptisol 2005	2,48	2,49	2,55	2,48
Permeability	Oxisol 2005	10,58	7,52	1,59	6,57
	Inceptisol 2005	2,77 b	4,46 a	5,22 a	4,15

Note: numbers followed by different letters in the same row indicate significantly different based on Duncan's test at the 5% level.

Moisture content Field Capacity (McFC)

Table 7 shows that McFC Oxisol in the 2005 planting year had no significant difference in discs with dead spacing interplants, and had no significant difference in McFC between dead spacing interplants and live spacing interplants. Likewise, McFC Inceptisol in 2005 planting year did not have a real difference between the disc with dead interplant spacing, and did not have a real McFC difference between dead interplant spacing and live interplant spacing. Based on this result, it can be seen that the McFC of Oxisol soil in 2005 planting year did not have a significant difference to Inceptisol in 2005 planting year. This research is not in accordance with (Harjowigeno, 2007) which says that soil moisture content depends on the amount of rainfall, the amount of evapotranspiration, the ability of soil to hold water, and the content of organic matter. This was due to the absence of cover crops in the disc management, and dead interplant spacing.

Moisture content Permanent Wilt Point (McPWP)

Table 7 shows that the McPWP of Oxisol in the 2005 planting year did not have a significant difference between discs and dead spacing interplants, and did not have a significant difference in McPWP between dead spacing interplants and live spacing interplants. Likewise, the McPWP of Inceptisol in the 2005 planting year did not have a significant difference between the disc and dead interplant spacing, and did not have a significant difference in McPWP between dead interplant spacing and live interplant spacing. Based on these results, it can be seen that the McPWP of Oxisol soil in the 2005 planting year did not have a significant difference from Inceptisol in the 2005 planting year.

Particle Density (PD)

Table 7 shows that the BSW of Oxisol in the 2005 planting year did not have a significant difference between the disc and the dead spacing interplant, and did not have a significant difference in BSW between the dead spacing interplant and the live spacing interplant. Likewise, the BSW of Inceptisol soil type in the 2005 planting year did not have a significant difference in discs with dead interplant spacing, and did not have a significant difference in BSW between dead interplant spacing and live interplant spacing. Based on these results, it can be seen that the BSW of Oxisol soil in the 2005 planting year did not have a significant difference from Inceptisol in the 2005 planting year..

Permeability

Table 7 shows that the permeability of Oxisol in the 2005 cropping year had no significant difference between the discs and the dead spacing, and had no significant difference in permeability between the dead spacing and the live spacing. In Inceptisol, permeability in the 2005 cropping year had a significant difference between the discs and the dead spacing, but had no significant difference in permeability between the dead spacing and the live spacing. Based on these results, it can be seen that the permeability of Oxisol soil in the 2005 planting year did not have a significant difference with Inceptisol soil in the 2005 planting year. This is in line with the research of Evarnaz (2014) who said that the cause of high permeability comes from the sandy loam texture class and soil texture that contains more sand fraction.

CONCLUSION

The study concluded that the comparison of soil physical properties between Oxisol of 2005 planting year and Oxisol of 2009 planting year, as well as the comparison between Oxisol of 2005 planting year and Inceptisol of 2005 planting year, under different management showed that there were no significant differences in soil physical properties such as organic matter, content weight, field capacity moisture content, permanent wilting point, and particle density between disc, dead interplant spacing, and live interplant spacing. However, there were significant differences in soil physical properties such as texture between each management, as well as in permeability.

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CONFLICT OF INTEREST

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