Use of Filter Cake Powder for Enhancing Soil Stability of Active Sand Dunes

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Abstract

Filter cake powder (FCP) is a residual material and the main solid waste of sugar production from sugarcane. This material contains high concentrations of polysaccharides and fats. FCP has previously been shown to act as a soil improver.

Active sand dunes (ASD) in arid and semiarid regions, cover agriculture fields, and cause significant damage to field crops and livelihood. Therefore, it is necessary to find a treatment which would improve ADS soil stability.

Biological soil crusts (biocrusts) are communities of living organisms on the soil surface in arid and semi-arid ecosystems. It was clearly shown that metabolic polysaccharides secreted by biocrust cyanobacteria, glue the soil particles to aggregates which form the crust layer, thereby stabilizing the soil surface.

The aim of this study was to investigate the effect of FCP on ASD stability.

We hypothesized that the addition of FCP to the ASD surface would enhance soil polysaccharide content, and that this would lead to soil stabilization improvement.

The degree of soil stability was determined using penetration resistance soil biocrust (PRSB) measurements.

It was found that FCP treatment increased PRSB significantly when compared with control.

These results suggest that FCP can be used as a soil stability enhancing agent in ASD.

Key Words: active sand dunes, filter cake powder, biological soil crusts, penetration resistance soil biocrust.

Introduction

The expansion of agriculture into drylands leads to significant changes in sand transport systems, resulting in an ASD problem (William & Eldridge, 2011).

It was reported that ASD cause damage to field crops and livelihood (Zaady et al., 2013), and also frequent sandstorms cause heavy damage to young lettuce, carrot, peanut and potato plants during the planting season (Genis, Vulfson and Ben-Asher, 2013).

Sugar is a broad term applied to a large number of carbohydrates present in many plants and characterized by a sweet taste (Pedro et al., 2013). Filter cake powder (FCP) is the main solid waste of sugar production from sugarcane. The chemical composition of filter cake includes both polysaccharides and fats (Pedro et al., 2010). In agriculture, filter cake is used as a fertilizer, and is applied to the sugarcane fields (Mello et al., 2013)

In arid and semiarid regions, many soil surface areas are characterized by a sparse and patchy distribution of perennial vegetation in an open matrix, colonized by biological soil crusts (biocrusts). (Zaady et al., 2017). The biocrusts are built up by soil material and by cyanobacteria, green algae, mosses, fungi and soil lichens. Soil texture, moisture content, temperature and disturbance history largely determine the composition of organisms in the crust. The biocrusts are critical factors in landscape structure and function. In dryland environments, where water is the main limiting factor, biocrusts are considered as ecosystem engineers. It was clearly shown that metabolic polysaccharides secreted by cyanobacteria and green algae glue the soil particles to aggregates, which form the crust layer allowing better water retention in the soil over time by reducing evaporation and desiccation, and helping to stabilize the soil surface. (Zaady et al., 2017). Since FCP comprises polysaccharides (Pedro et al., 2010), we hypothesized that the addition of FCP to ASD would enhance the soil stability and soil water availability.

To test our hypothesis, sand was collected from Negev area dunes, treated with FCP and sand stability was measured.

Materials and Methods

Sand was collected from the Agur sand dune area in the western Negev desert in Israel. Sand texture, wilting point, field capacity and saturation are shown in Tables 1 and 2.

Table 1

Agur Sand Dune Texture

%Sand	%Loam	%Clay
90	5	5

Table 2

Agur Sand Dune Parameters before and after adding FCP

	Before adding FCP	After adding FCP
Wilting point	5	9
Field capacity	10	19
Saturation	46	45

The sand was sieved using a 2 mm sieve (Zaady et al., 2017), and 2% w/w of FCP was added by dispersal to the sand. Then, this mixture was stored in aluminum trays (25cm x 10cm x 6cm) under controlled conditions in a greenhouse for nine weeks (Fig. 1).

The sand that was used for the experiment was not sterilized but rather used as is, and therefore probably contained biocrust fragments from the natural surrounding area.

A B

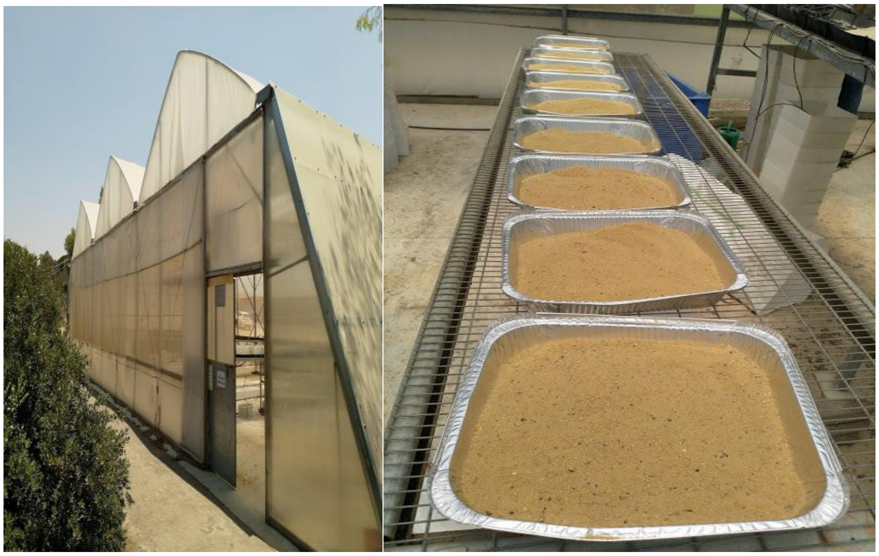

Fig. 1. The experiment setup. A-greenhouse B - Active sand dunes stored in aluminum trays.

The compaction strength was determined using a field penetrometer with a range of 0-4.5 kg/ cm^2 (Zaady et al., 2017). Soil surface resistance to breaking pressure was measured in each tray at 5 cm intervals. Protein determination was performed according to the Bradford procedure (Grintzalis et al., 2015). Soil was dissolved in 0.5 N NaOH, and was incubated at 37^{o}C for 20 minutes. The soil solution was then centrifuged at 4,000 rpm for 10 minutes. 0.1 ml of the upper liquid was collected, 3 ml of Coomassie regent was added to it and absorption at 595 nm was determined using a spectrophotometer (MRC spectro-uv-16).

Carbohydrate determination was performed spectrophotometrically using the Anthrone reagent and sulfuric acid (Disch 1955). Soil was dissolved in 3 N sulfuric acid and was incubated at 80^{o}c for 20 minutes. The soil solution was centrifuged at 4,000 rpm for 10 minutes and absorption in 595 nm was determined using a spectrophotometer (mrc spectro-uv-16).

Each experiment was performed in triplicate trays, on three separate occasions. Results are presented as mean ± standard deviation (SD). The significance of the differences between the various treatments and the control was analyzed using Student's t-test. A probability level of $P < 0.01$ was considered to be statistically significant.

As part of preliminary experiments, 3 concentrations (1%, 2% and 4%) of FCP were added to ASD and protein, carbohydrate and compaction strength ASD levels were measured. It was found that all treatments significantly increased protein, carbohydrate and compaction strength ASD levels compared to control (data not shown). The 2% FCP dose caused a half maximal increase in these parameters.

Results

Effect of FCP on ASD compaction strength. 2% FCP enhanced compaction strength by 42%, 25% and 68% after 3, 6 and 9 weeks, respectively versus control (Fig 2). These results show that 2% FCP treatment caused a change in compaction strength that was highly significant when compared with the control. The strength of the soil crust reduced significantly in week 6 and increased again in week 9.

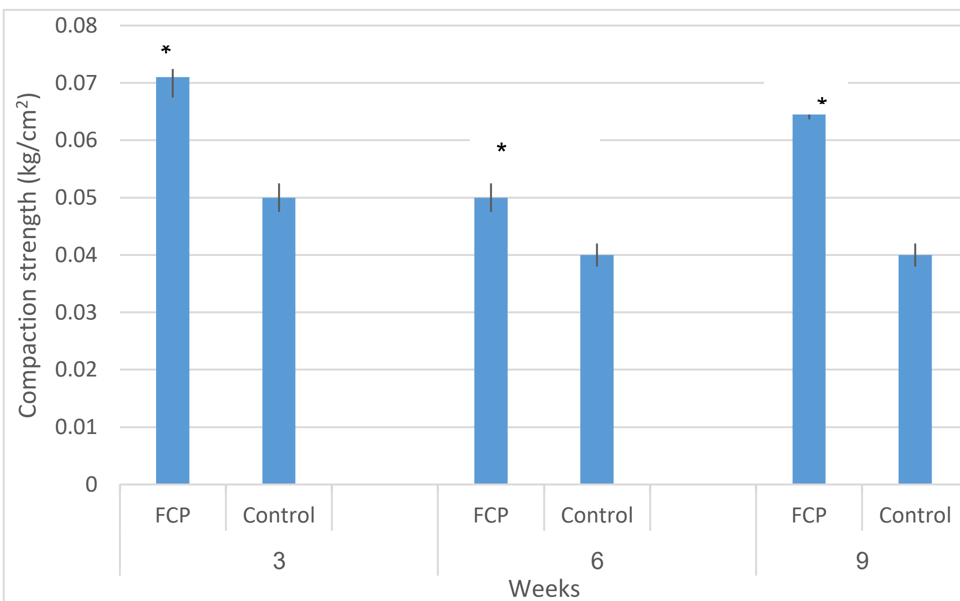

Fig 2. Effect of filter cake powder (FCP) on active dune sand (ASD) compaction strength. * $p<0.01$

Effect of FCP on active dune soil protein content

As shown in Fig 3, protein level was nearly four times greater than control after 6 weeks. It also increased by 39% after 9 weeks .With regard to the protein content in the control specimen, it may be seen that there are noticeable discrepancies in protein content between the different time frames.

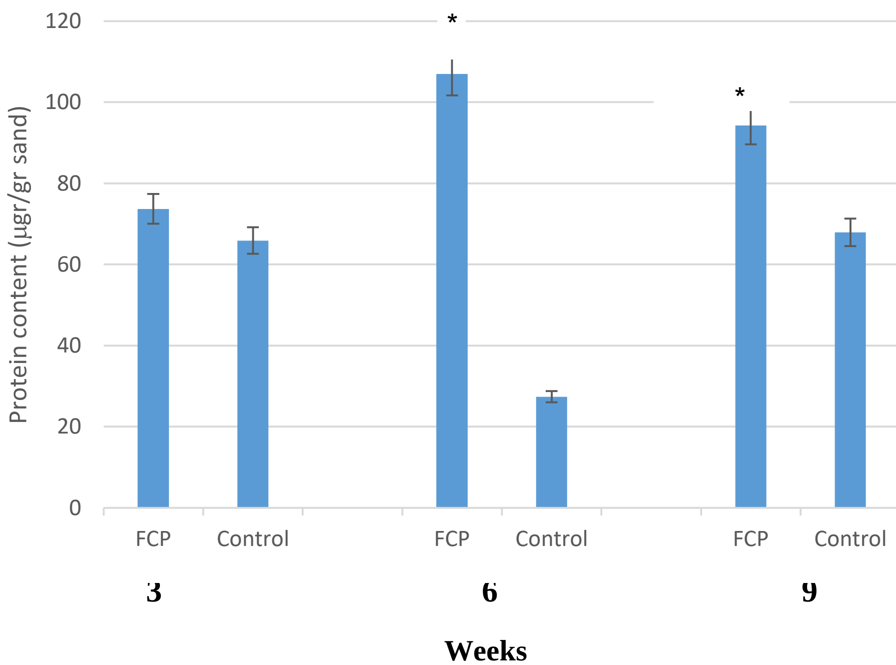

Fig 3. Effect of filter cake powder (FCP) on active dune sand (ASD) protein . *P < 0.01 compared with control

Effect of FCP on ASD carbohydrate content

As shown in Fig 4, carbohydrate content increased threefold after 3 weeks, while it increased by multiples of 13 and 4.4 at 6 and 9 weeks, respectively. These results show that 2% FCM treatment caused a change in soil carbohydrate content that was highly significant when compared with the control.

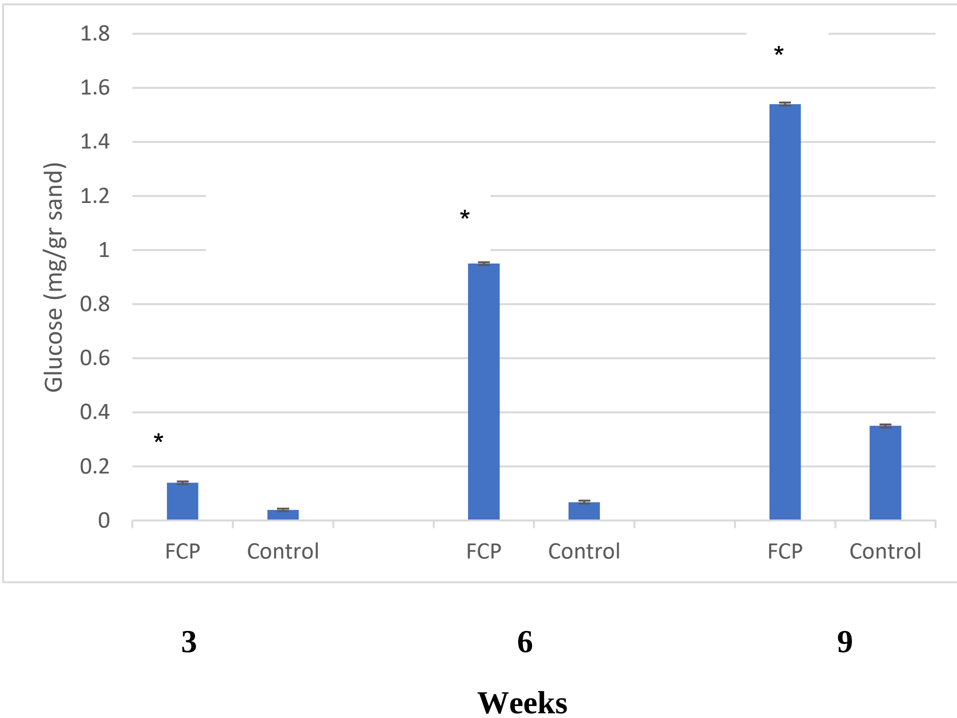

Fig 4. Effect of FCM on ASD carbohydrate content. *P < 0.01 compared with control

Discussion

Several studies suggest an important role for biological soil crusts (biocrusts) in landscape structure and function (Eldridge et al., 2010; Ayuso et al., 2016). In dryland environments, biocrusts play important roles in ecosystem processes. It was demonstrated that metabolic polysaccharides secreted by cyanobacteria glue the soil particles together to create aggregates, which form the crust layer, reducing evaporation and helping to stabilize the soil surface (Eldridge and Leys, 2003).

Therefore, biocrust recovery in active sand dunes represents an important mechanism in solving the ASD problem. As previously described (Zaady et al., 2017.), ASD cause damage to field crops and livelihood, and also sandstorms cause heavy damage to young lettuce, carrot, peanut and potato plants during the planting season (Genis, Vulfson and Ben-Asher, 2013)

In this study, we tried to improve ASD stabilization by means of adding a source of polysaccharides.

Filter cake is a residue from the industrial production of sugar from sugarcane. (Abo and Baker, 2011). This residue has been shown to act as a soil improver when applied directly to fields (Mello et al., 2013). It has also been used in the cultivation of several crops and in composting (Meunchang et al., 2005). We found that the addition of FCP to active sand dune significantly enhanced the penetration resistance of soil crust, which is known as a soil surface stabilization indicator (Zaady et al., 2017).

Protein and carbohydrate contents were also enhanced significantly after filter cake treatment, indicating that the biocrust viability was probably enhanced.

The enhancement of protein and glucose levels and penetration resistance of soil crust as a result of FCP treatment indicates a correlation between soil crust strength and the protein and glucose content of the soil.

We suggest that FCP treatment supplied a source of caloric nutrition for biocrust microorganism populations, that led to the enhancement of the protein level, as a consequence of the increasing microorganism proliferation. Since biocrusts are built up by *inter alia* cyanobacteria and green algae (Zaady et al., 2017), it is very likely that the enhancement of protein level in our model indicated the enhancement of cyanobacteria and green algae proliferation. This proliferation enhancement probably also led to an increase in polysaccharide production by cyanobacteria and green algae (Zaady et al., 2017), and resulted in high glucose level measurements. The enhancement of the soil crust strength is probably also due to the increased polysaccharide level, as previously described (Eldridge and Leys, 2003)

It should be emphasized that the control specimen showed noticeable changes in protein content. Thus, the protein level that was measured after 6 weeks was significantly lower than the levels measured after 3 and 9 weeks.

The differences could be due to the fact that control sand trays were not provided with any caloric source, a fact which may have accounted for the observed reduction in microorganism proliferation (between the 3 week and 6 week time points, which in turn resulted in the reduction of protein content seen after 6 weeks.

It is also important to note that the strength of the soil crust reduced significantly in week 6 and increased again in week 9. It might be that this phenomenon reflects changes in microbial metabolism over this time period.

In order to clarify these findings further investigation is required, and will form the subject of a future study.

In conclusion, our results demonstrate that filter cake improves the stability of active sand dunes, and probably this effect was not accompanied by any toxic effects on biocrust viability.

We therefore propose that filter cake maybe used as a soil stability agent.

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