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THE EFFECT OF SOIL COMPACTION UNDER DIFFERENT RATES OF BIOCHAR ON SOME PHYSICALAND HYDRODYNAMICAL SOIL CHARACTERISTICS AND IN SOYBEAN (*GLYCINE MAX. L*) PRODUCTIVITY

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Abstract: *Biochar is proven to enhance soil fertility and increase crop productivity. Given that the influence of biochar on soil compaction remains unclear, selected physico-hydrodynamical properties of soil amended with wood-derived biochar will be assessed. Thus, agricultural land application of organic wastes, such as biochar, could alter soil properties to offset the degradation effects. This research would shed some light on the effect of the use of heavy agricultural machinery on compaction of the soil-biochar matrix which has yet to be studied in detail. A field experiment will be carried out over two consecutive seasons on a Sandy-loam soil in a completely randomized block design, which includes three rates of biochar (0,5,10%) and three levels of compaction (0, 199.04, 330 Kpa) and each treatment has three replicates. Biochar will be produced by pyrolysis from woody residues at 450°C and added to soil with mineral fertilizers before 40 days of cultivation. The compaction procedure will be performed at the plastic limit with a tractor and a water trailer hanging on it. The weight can be controlled on the axle of the rear wheels of the trailer, where three different loads of the trailer will be used, and the weight of the trailer will be calculated. Trial plots will be prepared with an area of 5 m^2 per plot (2.5 m length* 2 m width) after that soybean seeds will manually be implanted on lines so that the distance between the lines is 50 cm, and 18cm between plants..*

Keywords: *Biochar; bulk density; soil compaction; soybean; soil shear stress; Unsaturated hydraulic conductivity*

INTRODUCTION

The proliferation of agricultural mechanization and excessive agricultural activities results in applying more pressure on the soils. Increased pressure application is detrimental to the soil quality, thereby adversely affecting fertility and sustainable use of soils. The increase of soil bulk density, penetration resistance (PR) and decrease of water and air permeability by depending on the applied pressure and soil properties weaken the plant root development, and subsequently this is accompanying with chemical, physical and biological degradation within the soil [1]. Soil compaction is defined as the densification and distortion of soil by which total and air-filled porosity are reduced, causing a deterioration or loss of one or more soil functions [2]. Biochar is viewed as a potential long-term amendment improving soil chemical and physical conditions while sequestering carbon [3].
It is produced by pyrolysis, a process whereby biomass material is decomposed in the absence of oxygen at temperatures ranging from 250 to 700°C [4]. The organic starting material can be drawn from a variety of types of biomasses, including wood chips, crop residues, manure, and animal waste.
Pyrolysis conditions and feedstock material are responsible for biochar characteristics such as chemical composition, surface chemistry, nutrient composition, adsorption capacity, cation exchange

capacity (CEC), pH, and physical structure [5].

The application of rice husk biochar by (6%) could increase soil pore structure parameters by 20 % and shear strength, as well as decrease soil swelling by 11.1% [6] expansive clayey soil (vertisol). Its application decreased the tensile strength of soil cores to 353.6 kPa from the initial 936.8 kPa at 6% addition rate [6] this reduction offers greater potential for root growth because the roots can bypass the zones of high mechanical impedance. Soil strength is affected by a number of factors including the properties of the particle surfaces, indicating that the use of biochar can reduce the risk of soil compaction [6].

n addition, biochar application at 100 t ha^{-1} rate could ameliorate compaction by over 10% [7] decrease bulk density from 1.47 to 1.44 mg m^{-3}, and increase porosity from 0.43 to 0.44 m^3 m^{-3} at 20 tha^{-1} application rate of woody biochar on sandy loamy soil [8]. However, 5% biochar treatment on clayey silty soil could increase base saturation percentage from 6.4 to 26 % and saturated hydraulic conductivity from 16.7 to 33.1 cm h^{-1}, decrease soil erosion rate from 1458 to 532 g m^{-2} h^{-1} [9].

Barus et al. [10] stated that adding 1 ton/acre of biochar increases the number of plant pods to 43.77 pods/plant compared to the control (34.77 pods/plant), and the number of empty pods decreased from (5.03 pods/plant) to (3.18 pods/plant), and the grain yield increased by 31% for L13 soybean cultivar and 51% when biochar was added at a rate of 5% and 10%, respectively, which is due to the increase in plant biomass and phosphorous uptake [11]. An increase in the weight of seeds/plant and the weight of seeds/hectare (18.6 g/plant) compared to the control (13.6 g/plant) without adding biochar and (5.4 ton/ha) compared to the control (3,922.50 ton/ha), respectively for the treatment 3 tons/dunum of biochar 12]. This research would shed some light on the effect of the use of heavy agricultural machinery on compaction of the soil-biochar matrix which has yet to be studied in detail.

GOALS

1. Studying the effect of soil compaction under different levels of biochar on some physical and hydrodynamical characteristics of soil.
2. Determination the threshold values of pressure at different levels of biochar for the soybean plant.
3. Identification the effect of pressure on underlying soil layers and the contribution of biochar in reducing this pressure.
4. the effect of pressure on soybean growth and productivity.

MATERIALS AND METHODS

1. **Plant material:** Soybean plant.
2. **Biochar:** it will be manufactured by pyrolysis with the two-barrel charcoal retort design.
3. **pyrolysis used residues** are from woody basis
4. **Used soil:** Sandy-loam

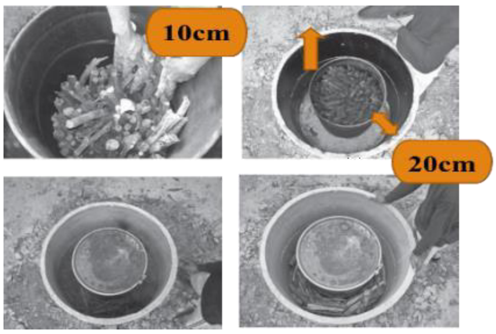

Figure 1

Soil preparation for cultivation

Biochar will be added at three rates before 40 days of cultivation:

C0: no amendment
C1: 5%
C2: 10%
Then, the soil will be plowed to the depth of 30 cm. Thus, fertilizers could be mixed with soil according to the fertilizer equation N-P-K:
Nitrogen fertilizer: three doses of urea 46%. First, 30 kg/ha during soil preparation. Second, 100 kg/ha after plant singularity. Third, 100 kg/ha at the beginning of flowering.
Phosphorous fertilizer: 160 kg/ha $P_2O5\%$ as TSP 46% before cultivation.
potassium fertilizer: 120 kg/ha as potassium sulfate $\%K_2O$ 50% before cultivation.
After plowing, the compaction will take place at three rates:
B0=0 kpa
B1=199.04 kpa
B2=330 kpa
However, the rotary hoe will be used to smooth the surface layer of the soil (0-5 cm). Next, trial plots will be prepared with an area of 5 m^2 per plot (2.5 m length* 2 m width) after that soybean seeds will manually be implanted on lines so that the distance between the lines is 50 cm, and 18cm between plants. As a result, each trial piece includes 3 lines.
Soybeans will be planted manually in a hollow on 20/6/2022 as an intensified grove, at a rate of 3 seeds in each hollow, subsequently the seeds will be covered well, after which the soil will be irrigated until the field capacity.

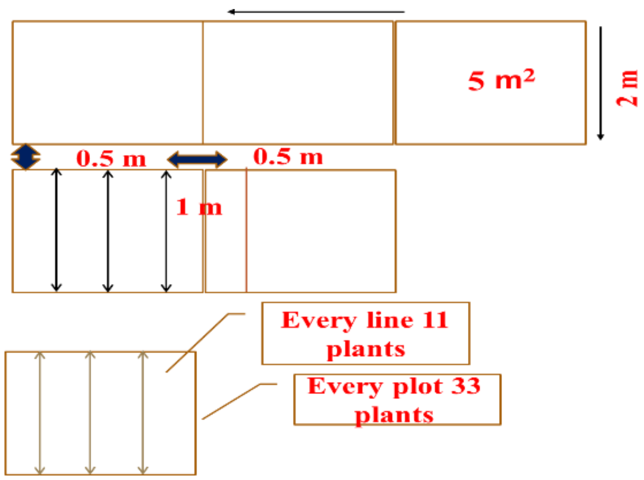

Figure 2

Compaction procedure

This procedure will be performed at the plastic limit (the appropriate moisture for conducting agricultural operations) with three replicates for each compaction level. We will prepare a tractor (Forat) and a water trailer hanging on it)the pressure system is composed of three axes). The weight can be controlled on the axle of the rear wheels of the trailer, where three different loads of the trailer will be used, and the weight of the trailer will be calculated. The tractor with the trailer, then the weight of the tractor front axle, the middle axle, and the rear axle (trailer axle) will be calculated by electronic weighing. The weight on the rear axle is the largest. As a result, it will be adopted, becauseit is the largest compressive force, as the weight on the rear wheels is relative to the required pressure levels, as shown in the Table (1)

Table 1. the pressures that the soil will be subjected

Treatment	Rear axle weight (kg)	Wheel load(kg)	Wheel contact surface with soil (cm)	Pressure (kpa)	Wheel load (KN)
B1	0	0	0	0	0
B2	1400	700	351.68	199.04	6.86
B3	2730	1365	414	330	13.39

After determining the load of the wheels (axles), the load of the single wheel will be calculated in kilo newton (KN), as it follows:

$$\text{wheel load (KN)} = \frac{\textbf{wheel load(kg)} * \textbf{9.81}}{\textbf{1000}}$$

The maximum wheel load of the tractor-trailed wheels during traffic will be as follows:
B1=0KN
B2=6.86KN
B3=13.39KN
After setting the wheel load in both KN and Kg: The contact surface area of the wheel with the largest load will be determined on solid soil surface where we will put a piece of cardboard and on top of it a piece of carbon paper. After passing the rear wheel on this piece at the required loads, the wheel location will be printed on the cardboard sheet. Afterward, the width of the wheel contact with the soil and the length of the contact in the case of standing will be determined, in effect it is in the form of ellipse, so that the area of the contact surface will be as follows:

$$A = \frac{a * b * 3.14}{4}$$

a: The length of the ellipse (cm)
b: The width of the ellipse (cm)
A: Contact surface area (cm^2)
Where the wheel's contact surface area with the largest load (rear axle) according to the treatment is as follows:
A=0 (cm2) in B1
A=351.68 (cm2) in B2
A= 414 (cm2) in B3
Thereafter, the applied pressure will be calculated in kilopascals on the treatments as follows:

$$pa = \frac{P}{A} * 100$$

A= Contact surface area (cm2)
P=Wheel load (Kg)
The applied pressure levels corresponding to the rear wheel load of the trailer were as follows:
B0=0 kpa
B1=199.04 kpa
B2=330 kpa
Moving on, the soil compaction process will take place on the moistened soil via tractor and the trailer linked to it for the studied treatments. So that each treatment will be compacted with its duplicates for the entire treatment area, Since the wheel trajectory is adjacent to the subsequent wheel trajectory, firstly, B1 will be compacted. Secondly, we will move to the treatments with lesser compaction levels by emptying a quantity of the tank water, estimated by liters. To reach the lowest weight equivalent to the aforementioned studied loads, then weight it by electronic weight once again, so that the load of the rear axle always remains greater than the load of the middle and front axle. However, the tire pressure on the rear axle is greater than the pressure of the other wheels on the soil will be taken into account.

Experiment design

The experiment will be carried out over two consecutive seasons in a completely randomized block design, which includes three rates of biochar (0,5,10%) and three levels of compaction (0, 199.04, 330 Kpa) so there are 9 treatments, and each treatment has three replicates.

Table 2.

C0B0	C1B0	C2B0
C0B1	C1B1	C2B1
C0B2	C1B2	C2B2
C1B0	C2B0	C0B0
C1B1	C2B1	C0B1
C1B2	C2B2	C0B2
C2B0	C0B0	C1B0
C2B1	C0B1	C1B1
C2B2	C0B2	C1B2

C: biochar
C0: mineral fertilizer with no biochar
C1: 5%
C2: 10%
B: compaction level
B0: mineral fertilizer with no compaction
B1:199.04 kpa
B2: 330 kpa

Harvest procedures

1. Harvest will be done when the seed moisture becomes 15%.
2. The plant will be placed in paper bags for drying in an oven at 70 °C for at least 24 hours, towards taking the dry weight.

READINGS AND MEASUREMENTS

Soil physical properties

Non-destructive structure samples will be taken from versatile depths (20-40-60cm) after harvesting using metal cylinders from all treatments with three replicates from each treatment to determine:
Bulk density at different rates of biochar and compaction.
The distribution of the porous system at different rates of biochar and compaction.
And it will be defined in the pressure plate device according to this law:
$P_W=4\sigma W/d$
P_W: pressure (pascal),
d: pore diameter
σw: Surface tension of water N/m
After that, the size of the porous groups will be determined as follows:
PV %> 50µW=PV%-Wvol.pF1.8
PV %> 10µW=PV%-Wvol.pF2.5
PV % (10-50) µW=Wvol.pF1.8-Wvol.pF2.5
PV % (0.2-10) µW=Wvol.pF2.5-Wvol.pF4.2
PV %< 0.2 µW=Wvol.pF4.2
As WvolPF1.8 is the volumetric moisture at the end of the equivalent pressure to pF1.8
Soil's total porosity will be determined as follows:

$$PV\ \% = (1 - \varrho d/\varrho s) * 100$$

dϱ: bulk density g/cm^3
Sϱ: true soil density g/cm^3

Figure 3.

Soil moisture characteristic curves by pressure plate device at pF = 1.8-2.5-3-3.5-4-4.2

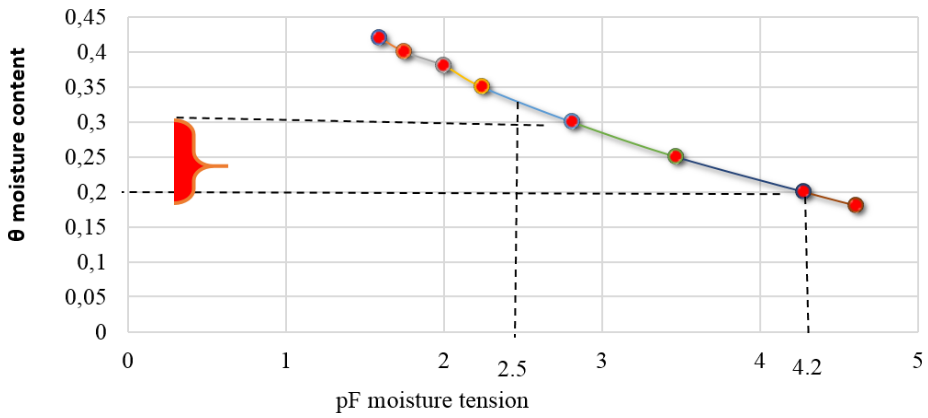

Figure 4.

Soil moisture characteristic curves will be determined using the pressure plate device by applying increasing pressures starting from pF1.8, pF2, pF2.5, pF3, pF3.5 and pF4.2 using soil cylinders with a height of 4 cm. Next, the moisture content will be calculated at different moisture tension levels, and the corresponding averages of moisture will be determined. At the end these values will be processed by computer, so the relationship between ψ and θ was from the form: $\psi = a\ \theta^{b}$.
The former equation represents the most used form by many researchers, including (Gardner et al.,1970) [13], and after determining the moisture content at different levels of pressure, the experimental equations and constants (a and b) will be reached at all rates of biochar and compaction.

Using these curves, we could determine:

1. available water
2. Specific capacity= $\partial\theta/\partial\varphi$ (1/cm)
3. Hydrodynamic constants

Saturated hydraulic conductivity Coefficient

Determining this parameter is very difficult due to the manifold of the pore system in the soil, in addition to the variations in the shape and length of the tubes. Based on Darcy's law [14] determined the conductivity coefficient in the laboratory:

$$Kf=q/Grad\ \varphi H$$

q: the amount of water flowing through the soil profile (m/day),
Grad Φh: hydraulic gradient, Where measurements will be carried out for all samples at one hydraulic

gradient, and in the case of continuous flow

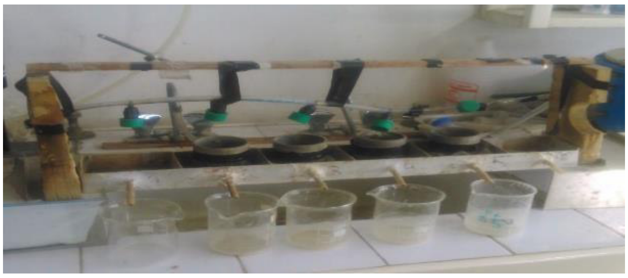

Figure 5

Unsaturated hydraulic conductivity coefficient based on hydraulic diffusivity which will be determined by hot air method [15]:

Figure 6.

After exposing the sample of 10cm height to hot air 220 C° until the upper layer dryness with saturation moisture at the bottom, which led to the creation of hydraulic gradients that allow water to move upward and within a short time. according to the following relationships:
After exposing the sample of 10cm height to hot air 220 C° until the upper layer dryness with saturation moisture at the bottom, which led to the creation of hydraulic gradients that allow water to move upward and within a short time. according to the following relationships:

Starting with Darcy's law $q = -K\frac{\varphi\partial}{\partial Y}$

It is a continuation equation $\frac{\partial\theta}{\partial J} = -\frac{\partial q}{\partial Y}$

We will have Richard relation $\Rightarrow \frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}[K(\varphi).\frac{\varphi\partial}{\partial Y}]$

$$\mathcal{D}_{(\theta)} = \frac{K(\varphi)}{\frac{\partial\theta}{\partial\varphi}}$$

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}[\mathcal{D}_{(\theta)}.\frac{\partial\theta}{\partial\varphi}.\frac{\partial\theta}{\partial x}]$$

$$\Rightarrow \frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}[\mathcal{D}_{(\theta)}.\frac{\partial\theta}{\partial x}]$$

$Y.t^{-\frac{1}{2}} = \lambda = \frac{x}{\sqrt{t}}$ using a Boltzmann number

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}[\mathcal{D}_{(\theta)}.\frac{d\theta}{\partial x}]$$

After summarizing, we get: $\frac{-x d\theta}{2t} = d.\mathcal{D}_{(\theta)}.\frac{d\theta}{\partial x}$

By integrating the previous relationship, we get:

$$\mathcal{D}_{(\theta)} = \frac{1}{2t} . (\frac{dx}{d\theta}) . \int_{\theta x}^{\theta i} x \; . d\theta$$

It is the specialized basic equation for calculating hydraulic diffusivity at different levels of moisture tension
D: hydraulic diffusivity
K: unsaturated hydraulic conductivity
Ψ: moisture tension
t: time
θx: moisture at depth x
θi: initial moisture
After cutting the soil samples into slices with a thickness of 3 mm and determining their moisture, the relationship between volumetric moisture and sample height will be found.

Figure 7.

Then, the volumetric moisture numbers (Θ) and their corresponding values (x) will be given to the computer using the Q basic program to determine the hydraulic diffusivity at different levels of moisture tension after determining the hydraulic diffusivity value. And determining the values of dΘ/dφ from moisture characteristic curves, the hydraulic conductivity coefficient of unsaturated soils at different levels of moisture will be determined using the following relationship:

$$K = \mathcal{D}_{(\theta)} . (\frac{d\theta}{d\varphi})_{(\theta)}$$

Ku values will be converted to m/day by converting the hydraulic diffusivity values (D) from mm^2/day to cm ^{2}/day by dividing on 100, then we will multiply the result of D cm^2/s with dθ/dφ estimated by 1cm, as a result, we will get Ku estimated by cm/s, then we multiply the result by 864 to convert from cm/sec to m/day.
After determining the unsaturated hydraulic conductivity coefficient at different levels of moisture tension, the relationship between moisture tension and the corresponding values of the unsaturated hydraulic conductivity coefficient for soil according to first-order correlations will be determined to find the hydrodynamic constants for this soil c and d Ku=c Ψd
These hydrodynamic constants are among the most substantial physical indicators of the ease of water absorption by the plant within the soil-plant-atmosphere system:
Compaction curves under different rates of biochar and compaction.
The ρ max and θ *opt* will be determined through the standard Proctor compaction test, following the procedure of ASTM (2007). Soil consistency limits will be determined according to (ASTM 2010)
Soil penetration resistance.
The PR of the compacted soil in the standard Proctor mold will be determined by a penetrometer

(FieldScout, SC900 Soil Compaction Meter) according to ASAE (2013) with a penetrometer cone diameter of12.83 mm and a cone angle of 30°

Soil shear stress.

Torvane (Humboldt, H4221 Geovane Soil Shear Strength Tester) will be used to determine the SS of the compacted soil in the compaction mold according to ASAE (2016).

Aggregate stability

Using immersion method of artge and Horn [16].

Figure 8.

We take soil samples using a set of sieves with diameters 1-2-3-5-8 mm

Sift the soil and calculate the weight of the soil on each sieve. Then we collect the soil and moisten it carefully over a short distance and leave for the next day.

On the next day, they are placed on the upper sieve, then the sieves are submerged in water for five minutes, with a movement stroke distance of 4 cm, and the number of immersion times is 35 times per minute. After that, we calculate the remainder on each sieve.

The average change in the diameter of the secondary particles before and after immersion in water is determined according to the following equation:

$$\Delta GM = \frac{\sum ni.di - \sum na.di}{\sum ni}$$

ni: weight of completely dry grains of diameter di before wet sieving

na: the weight of completely dry grains of diameter di after wet sieving

∑ni: weight of completely dry soil before sieving

>1.2 mm high stability

1.2-4.5 mm medium stability

>4.5 Poor stability

Then the percentage of secondary grains for dry and wet sieving will be calculated as a cumulative sum curve and the graphs are plotted:

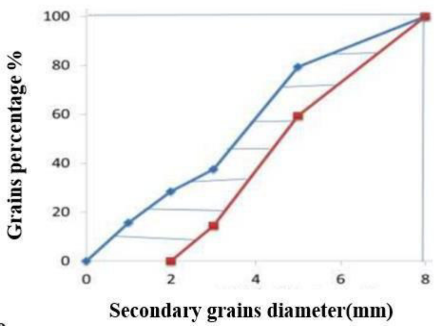

Figure 9.

Thus, the mutual area between the two lines gives an idea of the structure stability, as the greater this area, the less the stability of the building and vice versa.

CHEMICAL ANALYZES

Table (3): The most important chemical analyzes that will be conducted for the sandy-loam soil

The used method	analysis
wet digestion Ryan and others (2003) [17]	Organic matter
Ryan and others (2003) calibration	Calcium carbonate
Ryan and others (2003) Dorino	Effective lime
(2003) Ryan and others Sodium acetate	Cation exchange capacity
Ryan and others (2003) Kjeldahl	Mineral nitrogen
Ryan and others (2003) Olsen	Available phosphor
Ryan and others (2003) ammonium acetate	Available potassium
PH- METER	pH
EC-METER	(EC) Electrical conductivity

PLANT'S CHARACTERISTICS

Morphological traits:

- Average leg length (cm):

2- The number of main branches
3- first horn height (cm)
4-leaves numbers on the plant

Productive traits:

1- The number of seeds per pod
2- of one seed Weight (g)
3- Weight of seeds per pod (g)
4- Weight of one horn (g)
5- The number of pods in the plant
6- The weight of the pods in the plant
7- 100 seeds weight (g)
8- Number of seeds per plant (g)
9- Weight of seeds per plant (g)
10- Seed yield kg/ha

Physiological traits:

1- Area of one leaf: leaf length x leaf width x correction factor for beans (0.583)
Paper area: leaf area x number of leaves in the leaf according to jonkheree et al. [18]
2- The area of leaves per plant/cm^2: the area of one leaf x the number of leaves on the plant (Jonkheree et al., 2004)
3- Leaf area index = the area of the leaf surface of the plant / the area of land it occupies
4- Average dry weight of the plant (g)
5-Total chlorophyll (mg/g/leaves): The total chlorophyll in leaves will be estimated according to Machinney [19] method.

Qualitative traits:

1- Oil percentage %:
2-Protein content %: according to the Kjeldahl method
Protein percentage = nitrogen content x protein coefficient (6.25).
3-Estimation of the amount of oil and protein per unit area kg/h

STATISTICAL ANALYSIS

Experimental data will be subjected to the analysis of general variance (ANOVA) according to

sources of variance and replicates.
Calculating the averages and determining the value of the least significant difference (LSD) at the 5% level of significance, using the SAS statistical program (SAS Institute, 1999)

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