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Influence of Cone Index on Mean Relative Growth Rate, Leaf Area Index and Yield of Soybean in Sandy Clay Soil

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ABSTRACT

Mean Relative Growth Rate (MRGR), Leaf Area Index (LAI) and yield of soybean (varTGX-1448-2E) as affected by cone index in sandy clay soil was tested. Soil tests were carried out before and during the experiment. Penetrometer and moisture meter were used in measuring cone index and soil moisture content before and after treatments. The area was cleared and harrowed. Four treatments including a control were imposed on the land. A Mersey Fergusson – MF 275 Xtra2WD/4WD tractor with 75 Hp and 2,360 kg weight was used. The treatments were ***PLH*** *= Ploughed and Harrowed-zero passes of tractor wheels (control),* $\boldsymbol{PLC_{10}}$ *= Ploughed, harrowed and compacted to10 passes of tractor wheels,* $\boldsymbol{PLC_{20}}$ *= Ploughed, harrowed and compacted to 20 passes of tractor wheels,* $\boldsymbol{PLC_{30}}$ *= Ploughed, harrowed and compacted to 30 passes of tractor wheels, These were replicated three times making a total of twelve subplots. The treatments and replications were laid in a Randomized Complete Block Design (RCBD). A soybean variety TGX-1448-2E was planted and parameters were measured at 2, 4, 6, 8, 10, 12, and 14 weeks after planting (WAP). Among the variables measured were plant height, width, number of leaves, leaf area, dry matter weight, and weight of threshed soybean. Analysis of the data revealed that the Leaf Area Index (LAI) of 42.83 was realised at cone index of 0.081 MPa. Thus the LAI reduced to 10.20 at cone index of 1.21 MPa. On the other hand Mean Relative Growth Rate (MRGR) of 79.66 was observed at cone index of 0.081 MPa. Whereas at 1.21 MPa, a MRGR of 59.29 was observed. While a MRGR of 52.36 was realised at cone index of 1.82 MPa. A yield of 2.50 t/ha was realised from soybean planted on* ***PLH*** *plots with an average cone index value of 0.081 MPa. Whereas at higher cone index value of 1.21 MPa, only 1.15 t/ha of soybean yield was realised. A strong negative correlation exists between cone index and growth, and yield variables. Thus correlation values of -0.906, -0.999, -0.983 exist for plant height, leaf area and yield of soybean respectively. It can be concluded that increase cone index of soil leads to reduction in MRGR, LAI and yield parameters of crops.*

Key words: Influence, Cone Index, Growth Rate, Yield, Soybean, Soil

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INTRODUCTION

This technique is used because of some reasons viz (a) in order to eliminate any size related growth differences, (b) to determine which seedlings are inherently more viable, (c) combined performance of various parts of plants is integrated, species and treatment differences can be compared and (d) calculation of MRGR of sub-components (root and shoot) are directly analogous to MRGR. This technique is mostly base on the theory that crop growth occurs as constant percentage of initial size, that is, the compound interest law. Agricultural Engineers and Scientists apply this process even when the percentage increase changes with increasing size, that is, the variable interest law. Analysing the mean relative growth rate (MRGR) of crops is one of the methods used in comparing growth differences that arise from experimental treatments [20]; [41]; [19]; [45]; [33].

The MRGR has been used to examine crop growth as affected by different levels of fertilizers, weed control, tillage methods, soil moistures, bulk densities, porosity, soil strength, erosion, flooding, and chemical properties of the soil [18]; [17]; [27]; [32]; [37].

According to [33], the MRGR is given by the following expression:

$$MRGR = \frac{1}{W}\frac{dw}{dt} = \frac{lnW2 - lnW1}{t2 - t1} \quad (1)$$

Where,

w	=	dry weight of plant
dw	=	change in dry weight of plant
dt	=	time interval
ln	=	Natural logarithm
w1	=	initial dry mass of seedlings at time, t_1
w2	=	final dry mass of seedlings at time t_2, and
t2 – t1	=	the growth period (t1 = starting time and t2 = finishing time in days)

Using this technique, [4] reported a 41% significant increase of relative growth rate when seedlings of 17 woody plant species were grown under moderate compacted soil (0.1 – 1.0 MPa) in a green house.

Cone index (CI) refers to the applied force required to press a cone penetrometer into the soil to measure the extent of compaction; and it is an index of the shear resistance of the soil to penetration. Thus, CI gives the specifications of the actual probe and the force required to press the probe into the soil.

[29] reported that the ability of plant roots to penetrate soil is restricted as soil strength increases and ceases entirely at 2.5 MPa. [1] reported that as cone index approaches 2. 0 MPa and moves above this value, root growth has been shown to be restricted to varying degrees. Hence 2.0 MPa has been considered as a measure in the determination of soil hard pan layer [44]. [34] and [35] further revealed that critical limit of penetration resistance restraining root distribution is within 40-50cm soil depth and that subsoiling can reduce and provide increased rooting depth. [42], [30], [29], and [28] explained that hydrostatic pressure (turgor) within the elongating region of the root provides the force necessary to push the root cap and meristematic region through the resisting soil. If the hydrostatic pressure is not sufficient to overcome wall resistance and soil impedance, elongation of that particular root tip ceases. This explains why at high cone index, crops yields are greatly reduced. [21] reported a below average corn yield of 89 percent at cone index of above 1.4 MPa.

Leaf Area Index (LAI) [m2/m2] represents the amount of leaf material in an ecosystem and is geometrically defined as the total one-sided area of photosynthetic tissue per unit ground surface area. Ground-based measurements have no standards as several methods, like harvesting methods, hemispherical photography or light transmission through canopies, can be used. Leaf area index (LAI) calculation is another method used in estimating growth relationship among crops grown using different treatments. It is normally estimated using the relationship as proposed by [38] and used by [3]:

$$LAI = Y \times N \times A_L \times (A_P)^{-1} \quad (2)$$

where,

Y = Population of plants per plot

N = Average number of leaves per plant

A_L = Average area per leaf

A_P = Area of plot

Soybean (*Glycine max L.*) is considered as one very important grain grown commercially in more than 35 countries of the world and USA the leading producer (41%), followed by Brazil (23%), Argentina (16%) and China (9%), [16]. Soybean contains 40% protein, 35% total carbohydrate and 20% cholesterol-free oil[14]. Mineral content of whole soybean is about 1.7% for potassium, 0.3% for Magnesium, 110 ppm iron, 50 ppm zinc and 20 ppm copper [39].Soybean provides the world leading vegetable oil and accounts for about 20 to 24% of all fats and oil in the world. Soybean is becoming increasingly important in agriculture because it is a food source in human and animal nutrition. So many varieties of soybean have been developed around the world that it is a major task to know all of them [6], [15]; and [26]. Moreover, [23] reported that soybean is increasingly becoming important as a source of oil for bio-diesel production. This trend is likely to continue, at an even faster rate, considering the volatility in crude oil prices and/or the environmental concerns related to use of crude oil.

In general, the uses of soybean throughout the world can be classified according to Soybean vegetable oil; Soybean Meal with 40% soy protein content; Soybean Flour; Soybean Infant formula; Soybean Meat and dairy substitutes and extenders; Soybean Cattle feed; Soybean Health benefits (Omega-3 fatty acids); and Soybean Natural phenols. [15] further stressed that the rapid growth in the poultry sector in the past five years has also increased demand for soybean meal in Nigeria. It is believed that soybean production will increase as more farmers become aware of the potentials of the crop, not only for cash/food but also for soil fertility improvement and Striga control.

There are hundreds of varieties of soybean cultivated throughout the whole world [26]. In Nigeria many varieties abound [15] and [31]. Some of the varieties commonly cultivated are: TGX 1448-2E, TGX 1835-10E, TGX 1485-1D, TGX1740-2F, TGx1987-10F, and TGx1987-62F. According to the authors, the varieties have the following characteristics viz high yielding with 2248 kg/ha on the average, produce more pods per plant up to the top of the plant, early maturing with reduced cost of weeding, smoother with golden colour at maturity and perform well under poor and erratic rainfall, and have better lodging resistance, smother with reduced cost of weeding and especially for their golden color at maturity, and high in nutritive value, and offer a cheap source of protein.

The objective of this research therefore was to use cone index values of soil to explain growth and yield variation in soybean crop.

MATERIALS AND METHODS

Experimental Site and Land Preparation

The experiment was carried out in 2012 planting season at the Science and Technology Education Post-Basic (STEP-B) Research Farm of Federal University of Technology (FUTA), Akure, Ondo State with geographical coordinates of 7^o15^I N and 5^o15^I E.

The assessment of the effects of compaction on the growth and yield of soybean was carried out by first locating a plot at the experimental site. Soil Compaction and moisture content were randomly taken on the selected site. Soil samples were taken using soil cores for analysis. The vegetation was removed and the site was ploughed and harrowed on 9th July 2012. The specifications of the tractor used for this operation are shown on table 1 below.

Table -1 Specifications of the Tractor Used in the Study

Tractor Unit	Specification
Country of origin	India
Make	Mersey Fergusson – MF 275 Xtra2WD/4WD
Engine HP	75 HP (55 Kw) @ 2200 Erpm
Bore	3.94 inch (100 mm)
Stroke	5 inch (127 mm)
Hydraulic system control	Position and draft control on right-hand side of drive seat
Pump capacity	4.75 gpm (18 lpm) @ 2000 Erpm (basic)
Lift capacity (max.)	2050 kgf (4730 lbf) – horizontal range
PTO speed	540 rpm @ 1790 Erpm
Shaft diameter	34.8 mm
Tires (2WD) – Front Tire Rear Tire	7.5 x 16.00 – 8 PR 16.9 x 30 – 14 PR
Tractor weight	5676 lb (2360 kgs) – approx.

Source: Mersey Fergusson – MF 275 Xtra2WD/4WD manufacturer's manual

Treatments

An agricultural machinery, tractor was used to induce compaction (creation of artificial hard pans) on the experimental plot. Four treatments including the control were imposed on the plot. The treatments were:

PLH= Ploughed and Harrowed - zero passes of tractor wheels (control)
$\mathbf{PLC_{10}}$ = Ploughed, harrowed and compacted to 10 passes of tractor wheels
$\mathbf{PLC_{20}}$ = Ploughed, harrowed and compacted to 20 passes of tractor wheels
$\mathbf{PLC_{30}}$ = Ploughed, harrowed and compacted to 30 passes of tractor wheels

These were replicated three times making a total of twelve subplots. The treatments and replications were laid in a Randomized Complete Block Design (RCBD). The total plot area used for the experiment was 945 m^2. Each subplot had an area of 25 m^2 separated from each other by 3 m for manoeuvring of the tractor. This design was similar to that of [24] and [12] where the effect of soil compaction on crop growth and yield was tested. This also agreed with the work carried out by [26], where soil compaction induced by repeated passes of rubber tracked Excavator in sandy clay soil was evaluated.

Planting and Weeding Operations

The variety of soybean (Glycine max) used was TGX-1448-2E. The quantity planted was 1.5 kg. One quarter (¼) of sachet of fungicides (Captan) was applied before planting to reduce the incidence of insects on the grains. Planting of 3 to 4 seeds/hole at a spacing of 70 cm between rows and 10 cm between stands, at a depth of 2-5 cm was carried out. Manual weeding was carried out at two weeks, six weeks and twelve Weeks after Planting (WAP).

Soil Properties

Penetration resistance (cone index) and moisture content were taken using penetrometer and moisture meter at three levels of depth viz 0 – 15cm, 15 – 30cm and 30 – 45cm, on all the plots before and after the treatments. Soil cores were used in taking soil samples for analysis. Three samples each were taken at depths of 0 – 15cm, 15 – 30cm and 30 – 45cm, making a total of 36 samples. These samples were analysed for physical and chemical properties of the soil.

Data Collection

The growth and yield response of soybean to soil compaction was measured by collecting data on regular (Weeks After Planting (WAP)) basis, deduced from [36], [11], [13], [2], [25], [5], [9],[43], [40], [10], [22] and [7] and [8]. Among the parameters measured were: Plant height (cm); Stem diameter (cm); Number of branches; Number of leaves; Leaf area; Dry matter (biomass) weight and weight of threshed soybean.

Measurement of Growth Characteristics
At two weeks after planting (2 WAP) 10 plants were randomly selected from each plot and tagged for the measurement of growth characteristics. The growth parameters were measured at 2, 4, 6, 8, 10, 12 and 14 weeks after planting (WAP) as scheduled below:

Plant Height and Stem Diameter
A tape rule was used in measuring the height of the 10 selected plants on each plot from the base to the top in centimetres. The mean height from the 10 randomly selected plants was taken as the height for each plot.
A Vanier calliper was used to measure the stem width of each of the 10 randomly selected plants in each plot. The mean diameter was calculated for each of the plots.

Number of Branches and Leaves
The number of branches for each of the 10 randomly selected plants in each plot were counted. Mean values were calculated for each of the 12 plots and recorded.
Number of leaves of each of the 10 randomly selected plants in each plot were counted. The mean values for the 10 randomly selected plants in each plot were recorded as the number of leaves for each plant in each plot.

Leaf Area and Leaf Area Index
In order to get an estimate value of the Leaf Area Index (LAI) for each of the 10 randomly selected plants in each plot, leaf area of each of the selected plants were measured using leaf area meter (AT Delta T Scan). Leaf area index (LAI) was estimated using the relationship in equation (2) above.

Dry Matter (Biomass) Yield per plant
Dry matter weight (g) was determined at 4 and 7 WAP. This was carried out by uprooting 5 randomly selected plants from each plot and oven dried at 100 ^{0}C for three days. The values of the mean weight (g) of the oven-dried 5 randomly selected samples in each plot were recorded.

Analysis of Growth Rate
In order to compare growth differences that may have arose from experimental treatments, the mean relative growth rate (MRGR) on a biomass basis was determined following the classical approach [20]; [41]; [19]; [45] and [33] as recorded in equation (1) above.

Root Development and Structure
At maturity (16 WAP), 2 plants were uprooted from each plot and their roots were carefully observed and measured using the tape rule (cm). The mean values were taken as the length (cm) of each of the plants in the plots.

Measurement of Yield Traits
The soybean was harvested at maturity (16 WAP) according to the plots, sun dried, threshed, and winnowed. The weight of 100 seeds and grain yield per plot were taken. This was replicated 5 times and the mean weight was determined for each plot.Grain yield for each of the 12 plots was measured using weighing balance. These were converted from grams per 25 m^2 to tons per hectare (t/ha) using simple arithmetic.

Statistical Analysis
Statistical analysis was carried out on the data using Statistical Package for Social Sciences (SPSS) version 17, Genstat Discovery Edition 4 and Microsoft Excel 2010. Analysis of variance (ANOVA) procedure for randomized Complete Block Design (RCBD) was used to separate means. Correlation and Regression analysis were also carried out on the appropriate data, and figures were generated.

RESULTS AND DISCUSSIONS

Soil Properties

Table -2 Soil Properties of Science and Technology Education Post –Basic (STEP-B) Research site of FUTA

Soil Properties	**Values**
Sand	49 %
Silt	14 %
Clay	37 %
Organic matter	2.58 %
Organic carbon	1.5 g/kg
C/N ratio	7.86
Total nitrogen	0.19 g/kg

Soil pH	6.54
Mg^{2+}	2.24 $cmolkg^{-1}$
Ca^{2+}	3.10 $cmolkg^{-1}$
K^{+}	0.23 $cmolkg^{-1}$
Na^{+}	0.16 $cmolkg^{-1}$
P	16.44 $mgkg^{-1}$

Source: Field data, 2012

Effects of Soil Compaction on LAI and MRGR

Figure 1shows the effect of soil compaction on leave area index (LAI) of soybean crops. In 2012 cropping season, LAI of 42.83 was realised at cone index of 0.081 MPa. Thus the LAI reduced to 10.20 at cone index of 1.21 MPa. This further reduced at higher cone index.

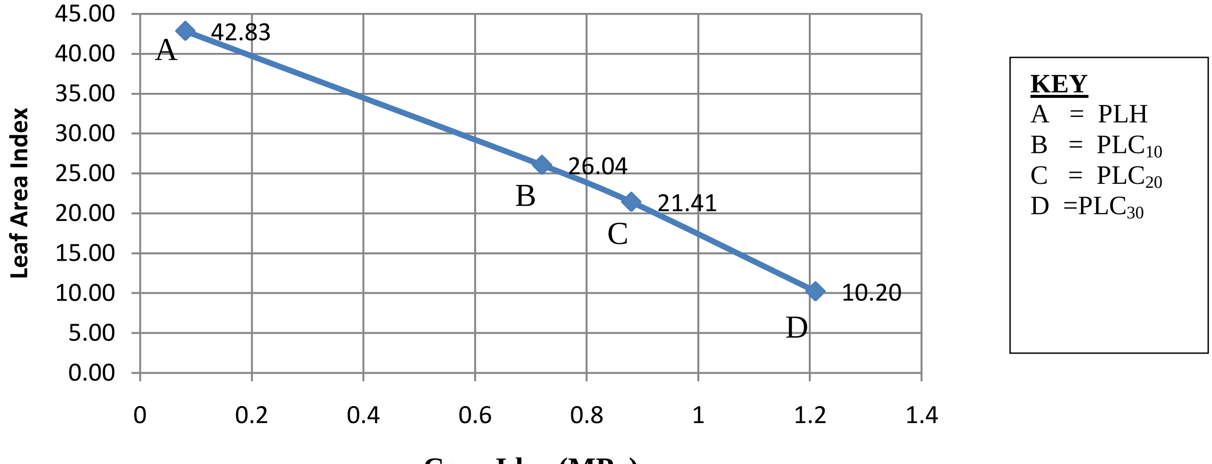

Fig. 1 Leaf Area Index of Soybean as affected by Soil Compaction, During the 2012 Cropping Season

In figure 2 the MRGR at different cone indexes for 2012 planting season were shown. In 2012 cropping season, MRGR of 79.66 was observed at cone index of 0.081 MPa. Whereas at 1.21 MPa in 2012 season, a MRGR of 59.29 was observed. While a MRGR of 52.36 was realised at cone index of 1.82 MPa. In general, at higher cone index, MRGR is lower.These results are in line with the work of [4] where the effect of soil compaction on biomass, relative growth rate and total leaf area was tested, and found to be significance.

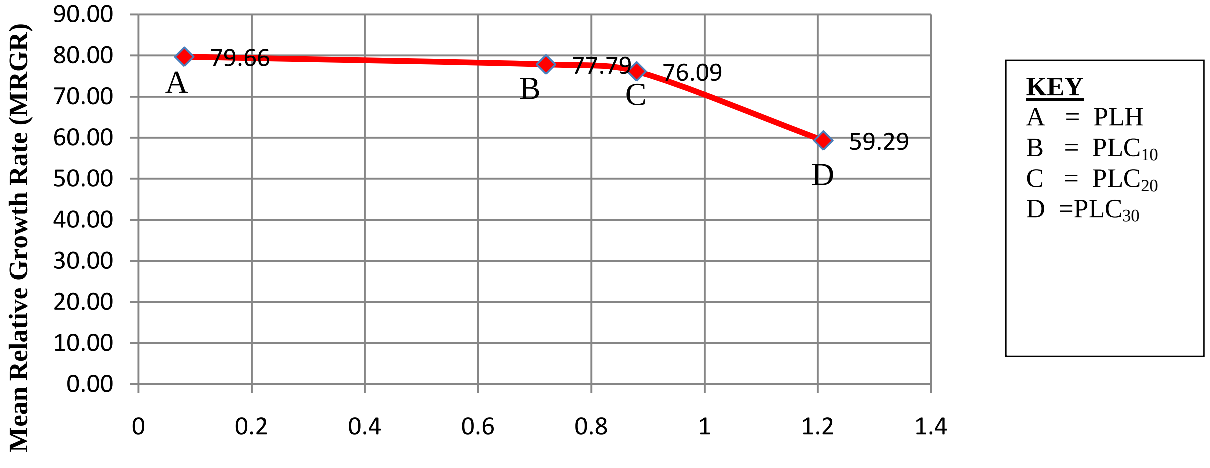

Fig. 2 Effect of Cone Index on MRGR of Soybean for the Four Treatments, During the 2012 Cropping Season

Effect of Soil Compaction on Yield of Soybean

Figure 3shows the effect of compaction on yield of soybean. In 2012 cropping season, a normal yield of 2.50 t/ha was realised from soybean planted on ploughed and harrowed plots with an average cone index of 0.081 MPa. At higher cone index such 1.21 in 2012 cropping season, only 1.15 t/ha of soybean yield was realised.These results agree with the findings of [9] where the effect of subsoiling on soil bulk density, penetration resistance, and cotton yield in Northwest Iran was carried out. Thus as cone index increases towards 2.0 MPa, root growth has been shown to be restricted at varying degrees leading to a reduction in yield [1].

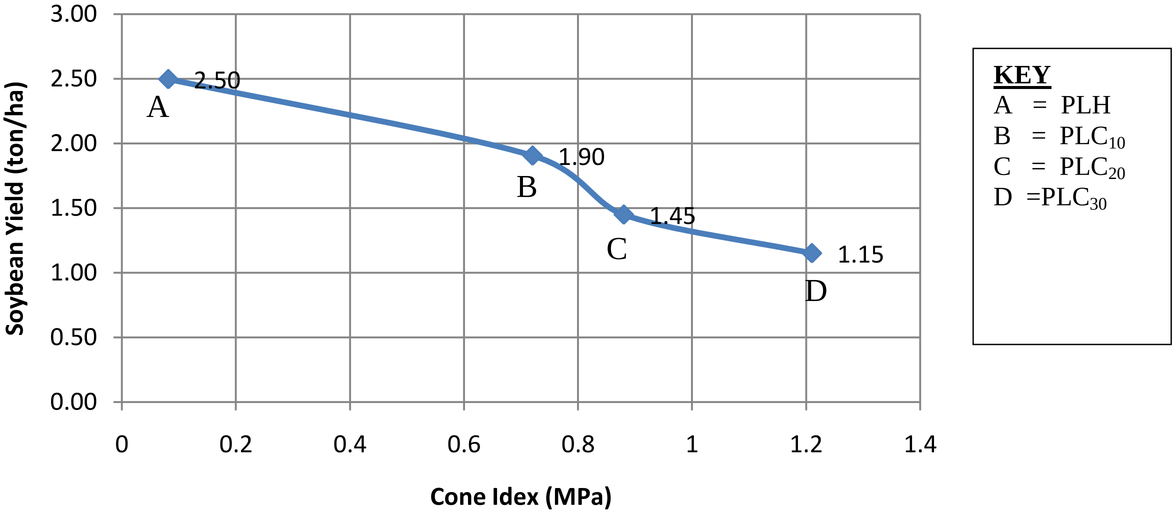

Fig. 3 Soybean Yield (ton/ha) as Affected by Cone Index of Soil for the Four Treatments During the 2012 Cropping Season

Correlation coefficients of Cone Indexes of Soil on growth and yield parameters

As shown on table 3 below, a strong negative correlation exist between cone index (MPa), growth parameters and yield. the correlation values for plant height, number of branches, number of leaves, diameter of plant, leaf area index, MRGR and yield of soybean were -0.906, -0.962, -0.999, -0.738, -0.998, -0.785 and -0.983 respectively. This is in line with the work of [21] where cone index were correlated with yield and was found to be strongly and negatively correlated, in their work 'Using cone index data to explain yield variation within a field. Thus a below average yield of crop was observed at high cone index.

Table -3 Correlation coefficients of Cone Indexes of Soil on growth and yield parameters during the 2012 Cropping Season

	Cone Index (MPa)	**Plant Height (cm)**	**Number of Branches**	**Number of Leaves**	**Diameter of Shoot**	**Rooting Depth (cm)**	**Leaf Area Index**	**MRGR**	**Yield (ton/ha)**
Cone Index (MPa)	1.000	-0.906	-0.962*	-0.999**	-0.738	-0.984*	-0.998**	-0.785	-0.983*
Plant Height (cm)		1.000	0.896	0.926	0.924	0.932	0.931	0.945	0.934
No. of Branches			1.000	0.959*	0.664	0.992**	0.957*	0.713	0.992**
No. of Leaves				1.000	0.772	0.985*	1.000**	0.816	0.984*
Diameter of Shoot					1.000	0.739	0.783	0.997**	0.742
Rooting Depth (cm)						1.000	0.984*	0.783	1.000**
Leaf Area Index							1.000	0.826	0.984*
MRGR								1.000	0.786
Yield (ton/ha)									1.000
*. Correlation is significant at the 0.05 level									
**. Correlation is significant at the 0.01 level									

CONCLUSIONS

There has been a general reduction in growth parameters and yield of soybean due to increase in cone index values of soil as a result of soil compaction caused by agricultural machinery (tractor) traffic. The MRGR and LAI of soybean were found to reduce appreciably due to increase in cone index values of soil. It is hereby recommended that farmers should avoid having many wheel traffic of agricultural machinery on soil to induce un-necessary compaction. Also compacted soils should be identified and alleviated before cropping.

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