SOIL COMPACTION IN AGROFORESTRY SYSTEMS CAN AFFECT THE EARLY STAGE GROWTH OF FARM TREES LIKE *VACHELLIA NILOTICA* (L.) P.J.H. HURTER & MABB

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خلاصہ

بھاری مشینری کا متواتر استعمال کر کے فصلوں کی زیادہ سے زیادہ پیداوار حاصل کی جاتی ہے جس کی وجہ سے زمین کی بالائی اور اندرونی سطح سخت ہو رہی ہے جس کو سوائل کمپیکشن (Soil Compaction) کا نام دیا گیا ہے۔ سخت زمین میں مٹی کے ذرات کے درمیان فاصلہ انتہائی کم ہو جاتا ہے۔ جس کی وجہ سے زمین کی کثافت بڑھ جاتی ہے۔ زمین کا سخت پن دنیا کے بہت سارے ممالک کی زرعی اور جنگلات کی زمینوں میں بھی پایا گیا ہے۔ جسکی بنیادی وجہ بھاری مشینری کا استعمال ہے۔ تاہم اس کے فارمی درخت کی ابتدائی نشوونما پر اس کے اثرات واضح نہیں۔ اس مطالعہ کا بنیادی مقصد کیکر کی نشوونما کو سخت زمینوں کے مختلف درجات پر دیکھنا ہے جن کو (T0, T1, T2, T3, T4) پانچ درجات میں تقسیم کیا گیا اس سارے تجربے میں پودے کے مختلف حصوں کا مطالعہ کیا گیا جیسا کہ تنے کی لمبائی، جڑ کی لمبائی، جڑ کا وزن، تنے کا وزن اور پودے میں نمی کی مقدار وغیرہ۔ تحقیق کی روشنی میں کیکر کے پودے میں سب سے زیادہ تنے کی موٹائی جو کہ 0.18 ملی میٹر 1.50 میگا گرام کثافت پر اور سب سے کم 0.064 ملی میٹر 1.75 میگا گرام کثافت پر ریکارڈ کی گئی۔ اس طرح 1.05 میگا گرام کثافت پر سخت زمین کے بغیر تنے کی لمبائی 35 سینٹی میٹر ریکارڈ کی گئی اور سب سے کم تنے کی لمبائی 1.76 میگا گرامکثافتپر ریکارڈ کیگئی۔ جب کہ اس تجربے سے یہ نتیجہ اخذ کیا گیا ہے کہ جو سخت زمینیں ہیں وہ کیکر کی ابتدائی نشوونما اور ظاہری خدوخال پر منفی اثرات مرتب کرتی ہیں۔

Abstract

Use of heavy machinery in agroforestry systems for intensive cropping is resulting in soil and subsoil compaction. The soil compaction is a process that results in the reduction of pore spaces between soil particles and increase in the soil bulk density. Soil compaction owing to mechanization is a serious problem in agriculture and forestry that is widely reported worldwide, however, its impacts on early stage growth of farm friendly tree seedlings have not been reported yet. So, the objective of this study was to evaluate the growth response of *Vachellia nilotica* against various levels of induced soil compaction. Five compaction levels were developed (T_0 T_1 T_2 T_3 T_4) artificially. The major eco-physiological parameters like collar diameter, shoot length, root length, root fresh weight, shoot fresh weight, biomass, root dry weight, shoot dry weight, moisture contents availability, and root shoot ratio were analyzed for this study. The diameter of *Vachellia nilotica* was recorded the maximum (0.183 mm) in controlled having bulk density 1.50 Mg m^{-3} and minimum diameter was (0.064 mm) at bulk density 1.76 Mg m^{-3}. The shoot length was recorded the maximum (35 cm) without compaction having bulk density 1.50 Mg m^{-3} and the minimum (16.33 cm) at 1.76 Mg m^{-3}. Similarly, root length was recorded the minimum (8 cm) at 1.76 Mg m^{-3}. From the results it was concluded that the soil compaction negatively affected the growth of *Vachellia nilotica*. The results showed that soil compaction can affect all the eco-physiological parameters of trees at early stage of growth.
Keywords: Agroforestry, Mechanization, Soil Degradation, Soil Structure, Plant Growth

Introduction

Soil compaction is defined as a process in which soil particles come close to each other that results in reduction of soil pore spaces and increase in soil bulk density (SSSA, 1996). The deterioration of the soil is as old as agriculture and this type of land degradation is hindering us to achieve our goals of food safety and environmental amelioration. Soil undergoes a number of destructive processes or threats in severe soil compaction (EU, 2006). The affected area from soil compaction is distributed in the whole world and is reported about 68 million hectares. Approximately half of the reported area (about 33 million hectares) is present in Europe (Akker and Canarache, 2001) and about 4 million ha is present in wheat cultivated areas in Western Australia (Carder and Grasby, 1986). Soil compaction is similarly reported in many other countries (Hamza and Anderson, 2003; Nawaz *et al*., 2013). It is considered as major soil degradation problem in Azerbaijan, Japan, Russia, France and New Zealand (Russell *et al*., 2001). Soil compaction is arising as a serious global problem of

21st century due to reduced yields in agronomic crops and negative impact on the environment and quality of life (Eswaran and Lal, 2001).

The use of heavy weight machines during intensive crop cultivation is causing more severe compaction problems than traditional agricultural practices. The soil compactness is comparatively uniform in cultivated lands than forests because of the presence of intense tree root systems in soils under tree cover. In earlier studies, the scientist focused only the physical characteristic of soil compaction (Horn *et al*., 1995) but later on, it was described that it affects the absorption, transport and mineralization of nutrients in soils as well (Nawaz *et al.*, 2016). It changes the aeration in the soil (Gliriski and Stepniewski, 1985) and water absorption properties in humid climates (Hansen, 1996). Soil compaction usually affects the soil structure, bulk density, vigour, hydrology, water flow and soil erosion. It breaks up the soil structure, while reducing the pore spaces and penetration capacity (Nawaz *et al*., 2013). Soil compaction disturbs various physical, chemical and biological processes and mechanisms of soil that ultimately, boost the agricultural problems such as soil erosion and passage of water, chemical and hazardous compounds into groundwater, that ultimately may reduce the plant yield and overall production capability of plants (Nawaz *et al*., 2013).

Soil compaction is created either due to vehicular traffic, foot traffic in cultivated areas or recreational activities which has detrimental effects on growth and mortality rates of plants (Kozlowski, 1999; Alameda and Villar, 2009). Moderate soil compaction is good for plant development, but use of heavy weight equipment during commercial logistics may cause huge damage to soil and plant (Imai *et al*., 2012). Mechanized operation in tropical rain forests are the major cause of reduction in timber yield and biodiversity (Jusoff, 1991). Modern heavy weight machinery such as excavators and midstory reduction cause serious compaction in the soil (Whitman *et al*., 1997) when they are used in different forest operations such as planting, pruning and harvesting (Talbot *et al*., 2003). Keeping in view the above mentioned scenario, it was necessary to quantify the impact of soil compaction on the perennial vegetation to devise the policies for future afforestation of compacted sites. *Vachellia nilotica* is very common agroforestry tree species in subcontinent (Pakistan and India) and is very famous for its multipurpose uses (Nawaz *et al*., 2018). The present study is designed to determine the effects of soil compaction on the growth of *Vachellia nilotica*.

Materials and Methods

The current study is designed to find out the early stage growth response of *Vachellia nilotica* when grown in different compacted soils.

Study area:
The study was conducted in the post graduate research area of Forestry and Range Management University of Agriculture Faisalabad (UAF) during spring season, 2016. The geographical location of Faisalabad district is 72.08 to 73^{o}E longitude, 30.35 to 31.47^{o}N Latitude and 150 m height from sea level. The site faces the extreme conditions because of arid to semi-arid climate. In this study, the average maximum and minimum temperature was 42 $^{\circ}$C and 27 °C during the month of April to September is respectively. The average maximum and minimum temperature was recorded 29 °C and 6 °C during the winter.

Preparation of site:
The whole experiment was carried out in small earthen plots. A suitable levelled area was selected in the nursery of Department of Forestry and Range Management and then it was divided into five plots with three replicates. Soil compaction was artificially created by using the metallic compactor having the weight of 8 kg and throwing it from 0.33 m (1ft) height repeatedly in whole plot. First earthen plot was untreated and set as controlled plot (T_0) without compaction. Second plot was uniformly beaten 10 times (T_1) and similarly third, fourth and fifth earthen plots were beaten 20 times (T_2), 30 times (T_3) and 40 times (T_4), respectively. Dry bulk densities (oven dried soil mass over unit volume) of all the plots were determined using iron ring of measured volume and are given in Table 1.

Table 1. Bulk Densities established in experimental plots

Beds	T_0	T_1	T_2	T_3	T_4
Bulk Densities (Mg m^{-3})	1.50 ± 0.03	1.64 ± 0.05	1.70 ± 0.06	1.72 ± 0.04	1.76 ± 0.08

Statistical Analysis:
The experiment was laid out in (RCBD) randomize complete block design. The analysis of collected data was determine by using Minitab 2017 statistical software through analysis of variance techniques (ANOVA) and comparison of mean was calculated along with their standard error. All tests and correlations were taken as significant at P< 0.05 (Steel and James, 1999).

Results

The results of all morphological traits as affected by soil compaction are given in Figure1 and Figure 2. All the traits were significantly affected by severe soil compaction. The diameter of *Vachellia nilotica* was recorded the maximum (0.183 mm) in controlled treatment where no soil compaction levels was developed and having bulk density (1.50 Mg m^{-3}). The response of diameter was recorded the minimum (0.064 mm) at compaction level of T_4 where bulk density was about 1.76 Mg m^{-3} (Fig.1a). The shoot length of *Vachellia nilotica* was recorded the maximum (35 cm) in T_0 and it was recorded the minimum (16.33 cm) in T_4 (Fig.1b). The root of *Vachellia nilotica* showed luxurious root growth (18 cm) in uncompacted soil, however, it reduced dramatically in severely compacted site (T_4) where the minimum root length was observed (8.0 cm) in T_4 (Fig.1c). Similarly, root fresh weight of *Vachellia nilotica* was recorded the maximum (0.006667 kg) at control T_0 and it was recorded minimum (0.002333 kg) at compaction level T_4. (Fig.2c)

The shoot fresh weight of *Vachellia nilotica* was recorded the maximum (0.03700 kg) at T_0 and shoot weight was decreases (0.01200 kg) in highest compaction level T_4 (Fig.2a). The biomass of *Vachellia nilotica* was luxurious (0.04067 kg) at controlled without compaction levels having bulk density 1.50 Mg m^{-3} and it was recorded the minimum (0.014000 kg) at maximum compaction level T_4 at bulk density 1.76 Mg m^{-3} (Fig.2e). The shoot dry weight was recorded maximum (0.030667 kg) at T_0 and it was recorded the minimum (0.009100 kg) at compaction level T_4 (Fig.2b). The root dry weight was recorded the maximum (0.005663 kg) at T_0 having bulk density 1.50 Mg m^{-3} and it was recorded the minimum (0.002113 kg) at T_4 compaction level 1.76 Mg m^{-3} (Fig.2d) The moisture contents availability was recorded highest (36.6667 %) at T_0 and it was recorded the minimum (13.111 %) at T_4 compaction level. The root shoot ratio recorded maximum (39.156 %) at controlled T_0 without soil compaction at bulk density 1.50 Mg m^{-3} and it was recorded the minimum (18.22 %) at T_4 compaction level having bulk density 1.76 Mg m^{-3} (Fig.2f)

Discussion

The results shows that the growth response of *Vachellia nilotica* against different compaction levels. The results shows that plant diameter was affected due to compaction levels. The plant diameter was decreased with the increase of soil compaction levels. Punyawardena and Yapa (1991) also reported that by increasing soil compaction levels the plant height and diameter were decreased. Similarly, Kayambo *et al.,* (1986) also found that plant diameter decreases with the increase of soil compaction levels (Fig.1a). The results of this study are in agreement with previous studies. The shoot length of *Vachellia nilotica* was also reduced with the increase of compaction levels (Fig.1b). Ankeny *et al*., (1990) reported that plant root and shoot were affected due to soil compaction because increase in the soil bulk density and decrease in the hydraulic conductivity. The pore space among the soil particles reduced that limit the soil water and oxygen and produce anaerobic conditions. The study specified that soil compaction affected the plant root system.

Tree growth is affected due to soil compaction but it depends on the availability of nutrients present in the soil. It is reported that the soil nutrients in the compacted soils are the major factor that affect on the plant growth. The ions movements are disturbed that reduce the root penetration ability, root growth and shoot growth of the plant. So, it results in the reduced plant height and yield of agronomic crops (Nawaz *et al.,* 2012). Panayiotopoulos *et al*., (1994) found that soil compaction and mechanical independence negatively affected roots as compared to controlled condition. In another study, the root length and root weight were significantly correlated with mechanical impedance in the earlier stage of plant development (Kristoffersen and Riley, 2005)

The plant root length was also affected due to soil compaction in our study (Fig.1c). The root length was decreases due to decreased root penetration and root depth of plant. It is estimated that calcareous loamy soil having 5% organic matter restricted the root penetration at 14.5 Mg load (Botta *et al*., 2006). Root penetration was restricted in deeper soil >20 cm. The root penetration decreased due to increase in soil strength and decrease in macro pores (Nawaz *et al.,* 2013). Ankeny *et al*., (1990) determine that soil compaction stunted the plant root and shoot because of high soil strength and saturated hydraulic conductivity. In the current study, the biomass of *Vachellia nilotica* was also affected with the increase of soil compaction levels. This is in agreement with the findings of Greacen and Sands (1980), in which they found that severe soil compaction decreased the plant growth. Plant growth rate and biomass is defined as unit biomass increase and time to biomass increase. Mechanized forest operations cause severe soil compaction and reduce the water availability (O'Sullivan *et al*., 1999). Therefore it is suggested that similar types of studies should be conducted on other indigenous tree species to screen out the tree species, which can resist this form of land degradation and can be efficiently used in future national afforestation programs on compacted sites. In conclusion, *Vachellia nilotica* is moderately fast growing tree that is negatively affected by soil compaction but survived well on compacted soils.

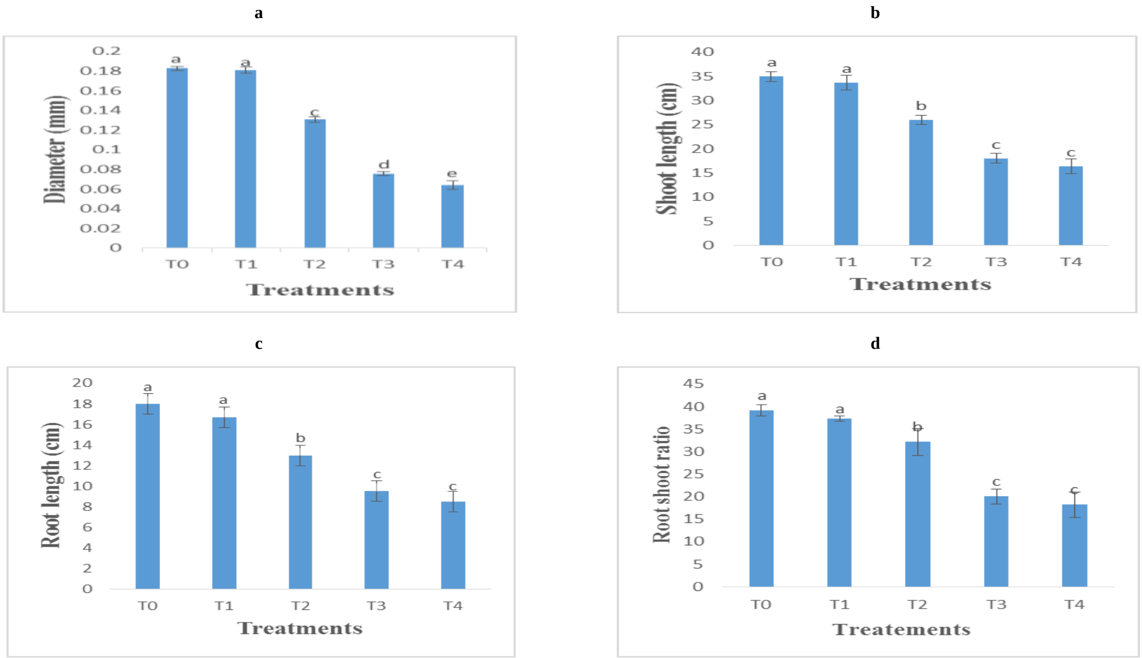

Fig-1. Effects of soil compaction on the morphological characteristics of *Vachellia nilotica*. a) diameter; b) shoot length; c) root length; d) root shoot ratio.

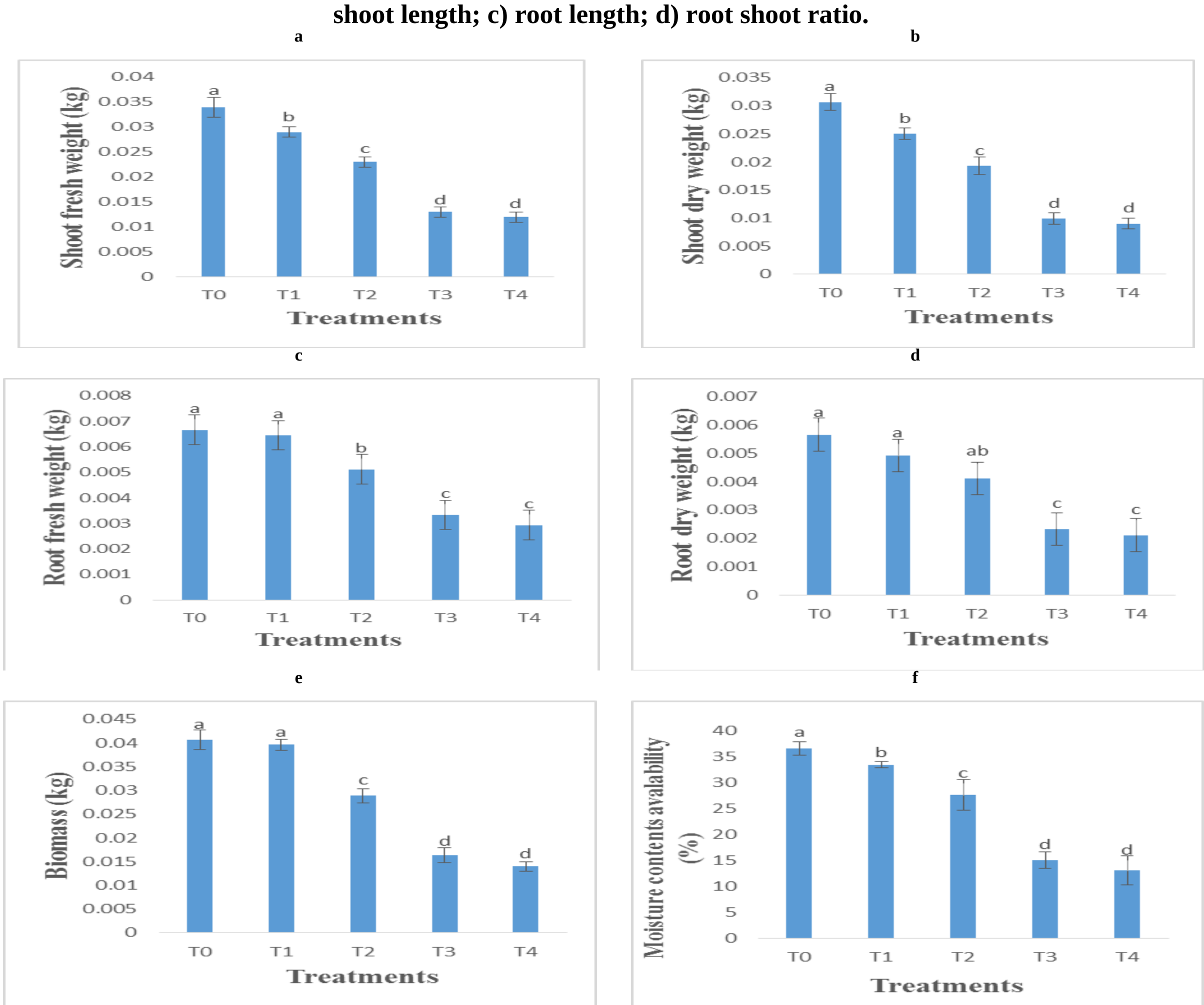

Fig-2. Effects of soil compaction on morphological characteristics of *Vachellia nilotica*. a) Shoot fresh weight; b) shoot dry weight; c) root fresh weight; d) root dry weight; e) biomass; f) moisture contents availability

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