International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 09-12-2021, Accepted: 24-12-2021, Published: 10-01-2022
Volume 7, Issue 1, 2022, Page No. 140-144

Effect of soil compaction and soil amendments on growth and yield of *Vigna unguiculata* L

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Abstract
An experiment was conducted to study the effects of soil compaction and application of soil amendments on growth and yield of *Vigna unguiculata* L. The experiment was laid out in 2 x 3 factor factorial Randomized Complete Block Design with six treatments and each replicated with six times. The treatment combinations were; T1: compact soil with compost application, T2: compact soil with amuthakaraisal application, T3: compact soil with Department of Agriculture (DOA) recommended fertilizer application, T4: loose soil with compost application, T5: loose soil with amuthakaraisal application and T6: loose soil with DOA recommended fertilizer application. Other crop management practices were followed uniformly as recommended by DOA, Sri Lanka. Growth and yield data were collected and statistically analyzed by ANOVA and mean comparison was performed using Duncan's test at 5% significance level. The results revealed that, there were significant ($p<0.05$) interaction between the factors of soil compaction and soil amendments on all the tested parameters. *Vigna unguiculata* L. planted in loose soil with the application of amuthakaraisal showed significantly highest values in biomass of shoot, root, length of lateral roots, no. of nodules, effective nodules and yield. Comparatively lower values were observed in compact soil with the application of all tested soil amendments. Therefore, it could be concluded that in loose soil application of amuthakaraisal as a soil amendment can be used to increase the growth and yield of *Vigna unguiculata* L.

Keywords: amuthakaraisal, compost, soil amendment, soil compaction, *Vigna unguiculata* l

Introduction

Sri Lanka is a developing country and its one of the indicatable economical source is agriculture. There is a very long history in Sri Lanka's agriculture which is above 2500 years. Farmers in ancient time used their traditional knowledge and techniques in their cultivation. The rapid increase in country's population and green revolution caused a huge pressure on agricultural production. Introduction of synthetic fertilizers and agro-chemicals leads to the shifting of agricultural practice from traditional to modern (Darmarathna *et al*., 2019) [4].
Cowpea present in tropical and sub-tropical areas is a leguminous, annual, herbaceous crop and a source of protein, (Ewansiha, 2006) [5]. Cowpea crops are growing well on different soil conditions and the performance was good on well drained sandy loams/sandy soils where the pH of soil is in the range 5.5 to 6.5 (Sharma, *et al*., 2002) [22]. Cowpea is a crop grows at temperatures between 20^0C to 30^0C. Hence with sufficient moisture, cowpea can be cultivated year around in most area, although most farmers prefer it to grow during Yala (irrigated) and Maha (Rain fed) season. The major cultivated areas in Sri Lanka are, Hambantota, Ratnapura, Badulla, Monaragala, Anuradhapura, Kurunagala, Puttlam, Batticaloa, Ampara, Polonnaruwa (Crop recommendation, DOA, 2018).
The soil is considered as loose, if the soil bulk density is low. That soil has high porosity when compared to other soil. It has low strength and is easily compressible in nature. Loose soil was formed from decay of organic materials and mineral particles. Compaction of soils regarded as the formation of highly aggregated soil, on the bellow of the cultivated soil layer (Horn, *et al*., 2004) [9]. As mentioned by Chen and Weil (2011) [3], compaction of soil is a worldwide problem in modern agriculture associated with overuse of heavy machines and intensification of cropping systems. Further, McGarry (2003) [15] indicated that compaction was considered like the more harmful environmental problem was caused from modern agriculture (conventional agriculture).
Several researches were conducted to study the effects of compact soil on the crops growth and yield, rather experiments on interaction effects of soil amendments and compact soil has not been extensively studied. Further as mentioned by Bawa *et al*., (2019) [31], soil amendments are used to alleviate the unfavourable effects on compacted soil on crop growth received comparatively fewer attention on experimental studies in most crops.
Hence considering this an experiment was conducted with the objective of to investigate the effects of soil compaction and soil amendments on growth and yield of *Vigna unguiculata* L.

Methodology

Experimental location

An experiment was conducted at the University of Colombo Institute for agro-technology and rural sciences, Hambantota, Sri Lanka during the period of June to September 2020. It is located in the latitude of $6^0 15'$N and longitude of $81^0 10'$E at an elevation of 100m above mean sea level.
The area falls under the Low Country Dry Zone Agroecological region in Sri Lanka.

Planting of seeds

Pots were filled with soil according to the bulk densities as, 1.3g/cm^3 (loose soil condition) and 1.5g/cm^3 (compact soil condition. Seeds of cowpea cultivar "Waruni" was used for the experiment and seeds were collected from the sales center of Agrarian Development Center, Anamaduwa.

Treatment structure

Two different factors (Soil compaction and soil amendments) were tested as a 2x3 factor factorial experiment. The experimental units were arranged in the RCBD manner. There were six treatment combinations and six replications. DOA recommended fertilizer application was used as a control and the treatment combinations were as follows;

T1-Compact soil with application of compost
T2-Compact soil with application of amuthakaraisal
T3-Compact soil with application of DOA recommended fertilizer
T4-Loose soil with application of compost
T5-Loose soil with application of amuthakaraisal
T6-Loose soil with application of DOA recommended fertilizer

Preparation of amuthakaraisal

Cow dung, cow urine, jiggery and water were mixed in a plastic bucket and placed under the shade condition. The mixture was thoroughly mixed twice a day to activate microorganisms. The solution was filtered using a cotton cloth after 24 hours of preparation. The filtered solution was mixed with 10 times of water and applied as a foliar spray at 2 weeks interval.

DOA recommended fertilizer

The details of fertilizer application recommended for Cowpea was obtained from website of Department of Agriculture, Sri Lanka and the recommendations were as follows;

Table 1: Fertilizer recommendation

Application time	Urea (kg/ha)	TSP (kg/ha)	MOP (kg/ha)
Basal	35	100	75
Top dressing	30	-	-

(**Source:** doa.gov.lk)

Compost application

Compost purchased from the Department of Agriculture was used at the rate of 10 tons/ha.

Data collection

Leaf area, biomass of shoot and root, length of lateral and tap root, no. of nodules and effective nodules and total yield were measured at the harvesting stage of the plant.

Statistical analysis

Collected data were analyzed using ANOVA procedure in SAS statistical software and mean comparison was done by Duncan's test at 5% significance level

Results and Discussion

Leaf area

As mentioned in table 2, there was a significant interaction between the factors soil compaction and soil amendments on leaf area. The higher leaf area was recorded where *Vigna unguiculata L.* planted in loose soil with the application of amuthakaraisal, compost and DOA recommended fertilizer. Comparatively lower values were found in compact soil with all the applied soil amendments. Leaf area can cause affect on photosynthesis. The effect of photosynthesis can cause effect on dry matter accumulation in plant parts and yield. In compact soil leaf area is small. A study by Kozlowski & Pallardy (1997) [11] indicated that, reduction in total photosyntehsis was observed in smaller leaf area by inhibted leaf growth and also incresed leaf abcission. In loose soil large leaf area increase photosynthesis. Amuthakaraisal organic soil amendment prepare by using cow dung. The availability of major plant nutrient, phosphorus and potassium as well as several vital plant nutrients including Ca, Mg, S, Zn, B, Cu, Mn, etc. (Fulhage, *et al*., 2000) [6] and the occurrence of micro and macro nutrient (Khosa, *et al*., 2011) [10] increases the leaf are per plants. Hence the the essential nutrients present in the applied soil ammendments increased the leaf area in loose soil.

Biomass of shoot and root

The results showed that changes in soil compaction and soil amendments significantly ($P<0.05$) affected the biomass of *Vigna unguiculata* L. The interaction effect of soil compaction and soil amendments was also significant as shown in Table 2. The highest biomass (dry weight) of shoots and roots were recorded where *Vigna unguiculata L.* planted in loose soil with the application of amuthakaraisal and it was followed by the plants in loose soil with the application of compost and DOA recommended fertilizer application. Comparatively lower values in biomass were observed in compact soil with the application of all the tested soil amendments. In loose soil plant growth is easy than compact soil. Timm and Flocker (1996) [26] mentioned that an increase in stem has been observed in the plant in loose soil than compact soil. Soil compaction reduces root elongation and can also cause reductions in shoot growth (Schuurman, 1965) [21]. Therefore biomass of shoot and roots were comparatively high in loose soil. Increase in leaf area can lead to increase the accumulation of dry matter content of crops (Sutharsan *et al*., (2014) [27]. Nutrient content of amuthakaraisal may increase the dry weight of shoots as amuthakaraisal contained several types of micro and macro nutrients. Application of micronutrients increased dry matter content of wheat (Asad and Rafique, 2002) [2]. Hence, there has been a adequate supply of Nitrogen to increase biomass of *Vigna unguiculata*.

A study on compact soil by Bawa *et al*., (2019) [31] mentioned the beneficial effects of soil amendments in lowering the undesirable effects of compact soil on root biomass. Soil compaction leads to limit the accessibility of essential nutrients and water for plant's optimum growth and yield (Raza *et al*., 2005) [32]. Availability of nutrients and water favour the better root growth ultimatey leads to the optimum uptake of water and nutrients from the soil via roots. Further nutrients and water translocated to the shoots and which may lead to the increase in biomass of shoot. Chen and Weil (2011) [3] also found a reduction in roots decreased with the increase in bulk density of soil. For the sustainable growth and yield of crops in compacted soils, better strategies of alleviating the negative effects of soil compactions on plant growth should be developed As mentioned by (USEPA, 2007; Mackay, 2010; Hakansson and Lipiec, 2000) [33, 34, 36], undesirable effects of soil compactions on root growth can be reduced by the application of adequate amount of soil amendments.

Table 2: Effect of soil compaction and different soil amendments on leaf area, biomass of shoot and root of *Vigna unguiculata L.*

Soil Compaction (C)	Soil Amendments (A)	Leaf area (Cm^2)	Biomass of shoot (G)	Biomass of root (G)
Compact	Compost	64.27 ± 1.16^{b}	3.78 ± 0.52^{c}	1.25 ± 0.28^{c}
	A.Karaisal	61.19 ± 1.23^{b}	4.39 ± 0.71^{c}	1.15 ± 0.27^{c}
	DOA	53.07 ± 1.51^{b}	3.55 ± 0.92^{c}	0.66 ± 0.22^{d}
Loose	Compost	83.37 ± 1.61^{a}	7.53 ± 0.45^{b}	1.73 ± 0.21^{b}
	A.Karaisal	93.23 ± 2.34^{a}	10.26 ± 1.04^{a}	2.31 ± 0.18^{a}
	DOA	79.69 ± 1.23^{a}	7.09 ± 1.00^{b}	1.50 ± 0.29^{b}
	C	*	*	*
	A	*ns*	*ns*	*ns*
	C × A	*	*	*

Values represent mean ± standard error of six replicates. According to Duncan's test, means in the same column followed by the dissimilar letter/s in superscripts indicate significant difference at p=0.05. "*": significant; "ns": not significant

Length of lateral root and tap root

The results showed that changes in soil compaction and soil amendment significantly (P<0.05) influenced the length of tap root and lateral roots of *Vigna unguiculata* L. The interaction effect of soil compaction and soil amendments was also significant on length of roots as shown in Table 3. The highest length of lateral root was obtained in loose soil with the application of amuthakaraisal and it was followed by the application of compost and DOA recommended fertilizer in loose soil. The lower length of lateral root was found in the compact soil with all soil amendment application. Crop growth can be affected by the soil mechanical resistance and prolonged water stress, leading to suppressed root growth (Moraes, *et al*., 2020) [18]. In loose soil mechanical impedance is low than compact soil. Therefore root can grow in soil particle and get nutrients to plant growth. The soil compaction increased soil strength or resistance, decreased the rate of downward extension of roots and lateral movement within the compacted pans, and reduced the potential uptake of nutrient and water (Stalham, *et al*., 2005) [26]. The anatomical responses of roots to soil compaction were related to general shape of roots as induced by shape of pores (Lipiec, *et al*., 2012) [13]. Amuthakaraisal increased number of bacteria, fungi and soil invertebrates in soil (Hickisch & Muller, 1990) [8]. Nutrient absorption of root increase by microbial activity.

Table 3: Effect of soil compaction and different soil amendments on length of lateral root and tap root of *Vigna unguiculata L.*

Soil Compaction (C)	Soil Amendments (A)	Length of lateral roots (cm)	Length of tap root (cm)
Compact	Compost	15.31 ± 1.30^{cd}	27.98 ± 1.08^{ab}
	A. Karaisal	16.19 ± 1.67^{cd}	28.62 ± 1.29^{ab}
	DOA	14.60 ± 2.20^{d}	22.92 ± 1.71^{b}
Loose	Compost	23.88 ± 1.23^{b}	30.13 ± 1.67^{a}
	A.Karaisal	29.64 ± 2.88^{a}	31.48 ± 0.35^{a}
	DOA	20.92 ± 1.41^{bc}	28.85 ± 1.41^{ab}
	C	*	*
	A	*	*
	C × A	*	*

Values represent mean ± standard error of six replicates. According to Duncan's test, means in the same column followed by the dissimilar letter/s in superscripts indicate significant difference at p=0.05. "*": significant; "ns": not significant

Total number of root nodules and number of effective nodules

The results revealed that changes in soil compaction and soil amendments significantly (P<0.05) affected the total number of root nodules and number of effective nodules of *Vigna unguiculata* L. The interaction effect of soil compaction and soil amendments was also significant as shown in Table 4. The highest number of nodules and number of effective nodules were recorded where *Vigna unguiculata L.* planted in loose soil with the application of Amuthakaraisal and it was followed by the plants on loose soil with the application of compost and DOA recommended fertilizer. The lowest number of nodules and active nodules were recorded in plants where compact soil with compost and DOA recommended fertilizer application. Excessive watering and poor aeration can reduce the nodulation and N fixation (Minchin & Pate, 1975) [17] and since poor aeration is normally found in compact soils. Pahwa, *et al*., (2000) [20] observed increased bulk density ($1.72g/m^3$) caused a significant reduction in nodulation of cowpea. In loose soil number of viable nodule is high than compact soil. In compact soil has small pore space therefor aeration is low in that soil and N fixation is decrease and nodule formation is low than loose soil. Milev, (2014) [16] found that foliar sprays which contains phosphorus and potassium have significant effect on fixation of atmospheric nitrogen. FYM treated soils had higher population of Azetobacter and Rhizobium (Tippannavar, *et al*., 1990) [30] and increased number of bacteria, fungi and soil invertebrates in soil (Hickisch & Muller, 1990) [8].

Total yield

The results showed that changes in soil compaction and soil amendments significantly (P<0.05) affected the total yield of *Vigna unguiculata* L (Table 4). The interaction effect of soil compaction and soil amendments was also significant on yield. The highest plant yield was recorded where *Vigna unguiculata L.* planted in loose soil with the application of Amuthakaraisal and the plants followed it in loose soil with the application of compost. Lower values in yield were recorded in compacted soil with the application of all tested amendments. Smittle and Williamson, (1977) [24] demonstrated that soil compaction decreased nitrate concentration in tissues by 50% can cause 25%-35% decline is yield and reduced fruit length/ diameter ratio. In loose soil root growth, shoot growth and photosynthesis increased therefore crop yield is high in loose soil. Application of amuthakaraisal is reported to have improved crop yields of almost all crops. The macro and micro nutrients promotes root development and flowering. These effects also enhanced the yield of plant.

Table 4: Effect of soil compaction and different soil amendments on no. of nodules, effective nodules and yield of *Vigna unguiculata L.*

Soil Compaction (C)	Soil Amendments (A)	No of nodules	No of effective nodules	Yield (t/ha)
Compact	Compost	23.00 ± 1.86^{cd}	6.50 ± 2.91^{cd}	0.43 ± 0.09^{c}
	A.Karaisal	40.67 ± 1.44^{bc}	9.67 ± 2.00^{bc}	0.50 ± 0.06^{bc}
	DOA	17.00 ± 1.48^{d}	2.67 ± 1.33^{d}	0.36 ± 0.07^{c}
Loose	Compost	49.17 ± 1.95^{b}	13.33 ± 1.93^{b}	0.95 ± 0.08^{b}
	A.Karaisal	73.00 ± 1.20^{a}	25.00 ± 1.10^{a}	1.41 ± 0.16^{a}
	DOA	44.17 ± 1.11^{b}	12.50 ± 1.94^{b}	0.92 ± 0.09^{b}
	C	*	*	*
	A	*	*	*
	C × A	*	*	*

Values represent mean ± standard error of six replicates. According to Duncan's test, means in the same column followed by the dissimilar letter/s in superscripts indicate significant difference at p=0.05. "*": significant; "ns": not significant

Conclusions

The present experiment revealed the effect of soil compaction and soil amendments and their interaction on the growth and yield of *Vigna unguiculata* L. plants. The application of amuthakaraisal as an organic soil amendment in loose soil caused significant effect on growth and yield of *Vigna unguiculata* L. Most of the measured variables showed better response to the application of amuthakaraisal in loose soil. Therefore, It could be concluded that applying amuthakaraisal to the *Vigna unguiculata* L. planted in loose can be used to get an optimum benefit with increased growth and yield.

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