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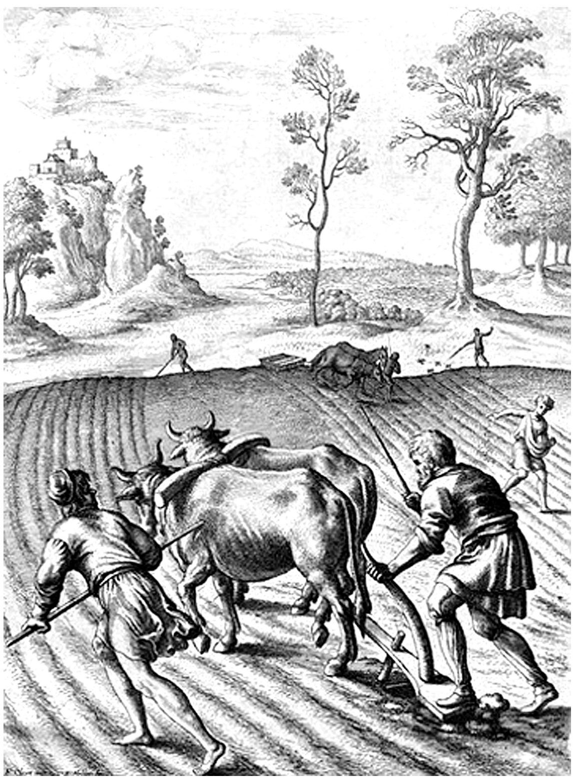

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Effects of Soil Texture on Vegetative Growth of the Tropical Legume Marama Bean (*Tylosema esculentum*)

[1]I.S. Travlos and [1]A.J. Karamanos
[1]Laboratory of Agronomy, Department of Crop Production, Agricultural University of Athens, 75, Iera Odos st., 11855 Athens, Greece

Abstract: Marama bean (*Tylosema esculentum* (Burch.) A. Schreib) is an under-utilized perennial tropical grain legume of southern Africa, which produces protein-and oil-rich seed and tubers of relatively high protein and carbohydrate content. Glasshouse-grown marama plants were grown in four different soils and measurements of several growth parameters were taken during all the experimental period. Vegetative and tuber growth and production of the plants grown in the clay and the clay loam soil were significantly restricted and therefore they have to be avoided. On the contrary, well drained light sandy soils seem ideal for marama growth and establishment. This study revealed the beneficial effect of good aeration and drainage on growth and dry matter production of marama. The careful selection of such a soil texture is crucial for a sufficient tuber growth and further establishment of *T. esculentum*, in order to ensure plant survival under extensive drought conditions, as long as the tubers clearly act as water reservoirs (tuber water content about 85-90%).

Key words: *Tylosema esculentum*, marama, soil texture, tuber, vegetative growth

INTRODUCTION

Marama bean (*Tylosema esculentum* (*Burch.*) *A. Schreib*) is a wild perennial tuberous legume, indigenous to the arid and semi-arid grasslands of southern Africa (Bousquet, 1981-1982). The bean is highly nutritious when cooked, with protein and oil content comparable to soybean (*Glycine max*) and groundnut (*Arachis hypogaea*), respectively (Bower *et al*., 1988), while the tuber (it can grow up to 200 kg after several years) is also edible and contains large amounts of water, carbohydrates and proteins (Ketshajwang *et al*., 1998). The presence of the tuber is crucial not only for the survival of the plant but also for the survival of the people of Kalahari, especially during the periods of extensive drought (Ross, 1982). Because of its great ability to survive under unfavourable conditions and its several desirable features, the plant can be considered suitable for cultivation, especially under preventive conditions for other crops (National Academy of Sciences, 1979; Keegan and Van Staden, 1981).

Likewise *T. esculentum*, many others tropical tuberous plants, such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and yam (*Dioscorea rotundata*), are already an important source of carbohydrates in the developing countries and they are also identified to be potentially the major source of carbohydrates for the populations of the world in the next decades (Scott *et al*., 2000). Their importance lies mainly upon their ability to produce harvestable materials in marginal soils and under adverse environmental conditions, while the effective management of some of the crucial soil factors could be beneficial for the optimization of their productivity and further establishment. Soil texture is one of these factors and refers to the relative proportions of sand, silt and clay particles present in the soil. Although the tuber growth in response to several soil texture types has been extensively studied, little information exists on *T. esculentum* particular responses.

Therefore, the objective of this research was to evaluate the effects of different soils on marama growth parameters, i.e., to study the impacts of soil texture on vegetative growth and especially tuber growth of marama and to examine whether a particular soil type is really prerequisite for a satisfactory growth of marama, by means of glasshouse pot experiments.

MATERIALS AND METHODS

Two pot experiments were conducted in a glasshouse of the Agricultural University of Athens (AUA) during the summers of 2004 and 2005. Minimum/maximum

Corresponding Author: Dr. I.S. Travlos, Department of Crop Production, Agricultural University of Athens, 75, Iera Odos st., 11855 Athens, Greece Tel: +3 210 5294482 Fax: +3 210 5294482

air temperature and relative humidity were: 20/40°C and 40/60% , respectively and the plants were subjected to a natural day length ranging between 13-15 h during the experiments.

The *T. esculentum* seeds were collected directly from the wild in Letlhakane, Botswana (Latitude-21°34′S; Longitude-25°42 `E) and stored at 4°C and 50% RH until their use. All selected seeds were about two years old and their fresh weight was ranged between 2 and 3 g. They were presoaked in distilled water at 20°C for 24 h and then allowed to germinate in petri dishes on two layers of filter paper (Whatman No.1) saturated with water at 28°C in the dark.

The experiments were arranged in a randomized complete blocks design (RCBD) with fifteen replicates and four treatments (different soils). One pregerminated seed (without pretreatment) reaching a radicle of 3 cm was sown in each plastic pot, at a depth of 3 cm. The pots were 15 cm in diameter and filled with 2.4 l of soil having one of the following soil textures: (1) clay (C), (2) clay loam (CL), (3) sandy clay loam (SCL) and (4) sandy (S). Minimum/maximum air temperature and relative humidity were: 20/40°C and 40/60%, respectively and the plants were subjected to a natural day length ranging between 13-15 h during the experiment. Irrigation was carried out with 200 mL of distilled water in each pot every two days, in order to promote plant emergence.

Measurements of the length of main stems, number of leaves and number of secondary stems were taken on all plants starting from 30 days after sowing. In total, there were taken 10 measurements of each vegetative feature. Plants remained in the vegetative phase throughout the experiments. Besides, the length, maximum diameter and fresh weight of the tubers were measured at 110 days after sowing (day of harvest). The dry matter contents of the tubers were also determined after oven drying at 100°C for 48 h and consequently tuber water content was also estimated.

Data from both experiments were analysed together and treatment values for all features were expressed as means between the two years. Statistical analysis of the results was performed using ÌANOVA and Fisher' s least significant difference ($p<0.05$) by means of Statistica 6.0 software package (Statsoft., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Table 1 shows the physical and chemical properties of the four slightly alkaline soils used in our two experiments. The SCL was the soil with the most desirable chemical properties compared with the others, as long as there were the highest concentrations of potassium, nitrogen, phosphorus and organic matter. The C and the CL soil had generally intermediate values for the above mentioned properties, while their cation exchange capacity (CEC) was very high. On the contrary, in S soil (containing 88.8% sand) total nitrogen, phosphorus, potassium and organic matter contents were very low.

Table 1: The physical and chemical properties of the soils used

Parameter	C	CL	SCL	S
Sand (%)	28.6c	29.8c	50.2b	88.8a
Clay (%)	41.3a	38.2a	15.8b	2.66c
Silt (%)	30.1a	32a	34a	8.95b
pH(in H_2O)	7.4a	7.6a	7.4a	7.8a
Total $CaCO_3$ (%)	6.6b	10.8b	20.4a	9.2b
Organic matter (%)	3.74a	1.98b	3.96a	0.2c
Nitrogen (g kg^{-1})	0.19b	0.12b	0.32a	0.02c
Phosphorus (g kg^{-1})	0.05b	0.02b	101.34a	0.03b
Potassium (g kg^{-1})	0.44b	0.5b	1.5a	0.14c
Sodium (g kg^{-1})	0.16ab	0.13b	0.19a	0.15ab
CEC (meq $100g^{-1}$)	26a	11.3b	8.7bc	7.5c

Means followed by the same letter(s) within a row are not significantly different at p = 0.05 Fisher's least significant difference test. C = Clay, CL = Clay Loam, SCL = Sandy Clay Loam, S = Sandy

There were no significant differences between the plants of the two experiments (2004 and 2005) for any measured vegetative parameter. Number of leaves was consistently highest in the plants growing in the SCL and S soil, reaching values of 18.25 and 17.5, respectively, at the end of the experimental period (Table 2). Plants grown in the C and the CL soil had significantly lowest number of leaves. Soil texture was similarly affective at length of main stem and number of secondary stems, as long as *T. esculentum* plants grown in the C and the CL soil had the significantly lowest vegetative growth without secondary stems at all. This significantly negative effect of inadequately drained soils (such as C and CL) on branching or tillering has already widely mentioned (Houlbrooke *et al.*, 1997), while the beneficial effect of well drained sandy soils on vegetative growth is common among several tuberous species (Howeler *et al.*, 1993; Asadu *et al.*, 2002).

Concerning the tuber growth, there is a clear superiority of plants grown in the S and secondly in the SCL soil (Table 3). The plants grown in the S soil produced tubers with the significantly highest fresh and dry matter and the highest length and diameter among all soil types. This behavior is well known in many tuberous plants. Potatoes production is high in porous, non-compacted soils that ensure optimum water, nutrient and oxygen supply, while cassava and other tuberous plants of the tropics (e.g., yam) need a friable soil texture providing good aeration for the high development of the tubers. The significantly negative effect of the C and the CL soil on marama growth was true for tuber, too, while the SCL soil resulted to intermediate values of tuber growth parameters. Various factors may limit root and

Table 2: Effects of soil texture on leaf number, length of main stem and number of secondary stems of *T. esculentum* plants grown in Greece

Parameter	C	CL	SCL	S
Number of leaves	12.9b	13.5b	18.25a	17.5a
Length of the main stem (cm)	72.3b	76.75b	86.75a	84.25a
Number of secondary stems	0b	0b	1.25a	1.5a

Means followed by the same letter(s) within a row are not significantly different at p = 0.05 Fisher's least significant difference test. C = Clay, CL = Clay Loam, SCL = Sandy Clay Loam, S = Sandy

Table 3: Effects of soil texture on size (length and maximum diameter), fresh and dry weight and water content of the tubers of *T. esculentum* plants grown in Greece

Parameter	C	CL	SCL	S
Tuber length (cm)	7.24b	7.83b	10.5ab	13.5a
Tuber maximum diameter (cm)	1.96c	2.07c	2.32b	2.82a
Tuber fresh weight (g)	14.14b	14.58b	21.48ab	25.12a
Tuber dry weight (g)	1.64b	1.94b	2.55a	2.71a
Tuber water content (%)	86.2a	86.7a	88.13a	89.21a

Means followed by the same letter(s) within a row are not significantly different at p = 0.05 Fisher's least significant difference test. CL = Clay Loam, SCL = Sandy Clay Loam, S = Sandy

tuber growth, especially those parameters that correlate closely with the availability of oxygen and any kind of mechanical impedance that roots and tubers face during the main growth period (Ehlers *et al*., 1983; Passioura, 1991). Tuber growth and yield of potatoes, cassava, yam and other similar crops is significantly reduced on heavy clay soils, perhaps due to the bad drainage, the low total porosity (high bulk density) and high penetration resistance of these soils (Howeler *et al*., 1993). It is also noticeable that the tuber water content was ranged at relatively high values (> 85%) for all the plants, while there were no significant differences between the four soil types (Table 3), confirming the significant role of marama tuber for the water storage in this species (Mitchell *et al*., 2005).

CONCLUSIONS

Soils differ in physical and chemical properties that affect plant productivity. Even if management of soil chemical properties is relatively attainable, changing the physical characteristics of the field, however, can be more difficult and sometimes impossible. This is why field selection (matching the physical characteristics of the field with plant requirements) is so important, especially for tuberous plants, even if they usually can grow on a wide range of soil types. Well drained light sandy soils seem ideal for seedling emergence (preliminary tests, data not shown), vegetative growth and tuber production of marama, while heavy clay or clay loam soils are clearly unsuitable and have to be avoided (they have a tendency to compact and crust, thus presenting a higher risk of drainage impedance). The high tuber growth of *T. esculentum* is crucial for water economy, survival of the species and then rapid growth under favourable conditions, as long as tubers act like water reservoirs (Mitchell *et al*., 2005). A lack of adequate tuber growth restricts the plant's ability to obtain and store needed nutrients and to withstand periods of water stress, thereby increasing the risk of drought damage. These results-clearly indicating the significant role of soil texture and good drainage on vegetative growth and tuber yield of *T. esculentum* plants-need to be validated by further field experiments, which are already conducted. The low seed set of this species (Hartley *et al*., 2002) combined with the high risk of its over-exploitation and its potential establishment as a crop, confirm the significant role of similar studies, which must be continued in order to optimize marama establishment, growth and productivity.

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