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ROOT ARCHITECTURE OF THE PROMISING BIO-DIESEL PLANT *JATROPHA*

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INTRODUCTION

Jatropha curcas L. (Euphorbiaceae) receives a lot of attention as a source of renewable energy. The drought resistant, oil bearing small tree is well adapted to tropical semi-arid regions and marginal sites. As a pioneer species, originating from Central America, but now growing pantropic, *J. curcas* is easily propagated and can establish quickly in a wide variety of soils, although the plant suffers immediately from frost and waterlogging (Heller, 1996). The *J. curcas* seeds contain 30-35% inedible oil which can be easily converted to bio-diesel that meets the American and European standards (Azam *et al.*, 2005). The bio-diesel production chain also results in some valuable by-products (e.g. seedcake, fruit husks, glycerin) (fig. 1). Next to the bio-diesel the plant is also useful as living fence. Since *J. curcas* is not browsed, the fences can be used to protect food crop production (Gubitz *et al.*, 1999). Further the fences are used for ecological restoration of degraded areas (Zahawi, 2005). *J. curcas* cultivation is also reported to prevent and control erosion (Gubitz *et al.*, 1999), although not based on scientific data. The protective role of vegetation has been proven in many studies and especially plant roots could play an important role in slope stabilization and erosion control (Abe & Ziemer, 1999; Coutts, 1983). Although still a hypothesis, *J. curcas* probably could be used simultaneously for bio-diesel production as well as erosion control in tropical areas. In this context there is a need for scientific research to better understand the effects of this species and its roots on geomorphologic processes. In general, as is the case with many plant species, belowground structural and functional development of *J. curcas* has received very little attention so far, mainly as a consequence of methodological difficulties (Gyssels & Poesen, 2003; Waisel *et al.*, 2002). Nevertheless, in order to sustainably guide the booming use of this promising species, it is important to also fully understand its belowground as much as its aboveground functional and structural development. Besides the stabilising role mentioned before, another primary role of roots is off course the uptake and storage of water and nutrients (Gregory, 2006). Summarised, the main reasons for studying roots are ecological significance, resource capture and allocation, carbon flow, plant interactions, effect on soil structure, anchorage, use of root products, as well as simply basic biological information on a part of the plant which is of physiological and developmental interest in its own right (Smit *et al.*, 2000).

In this communication an ongoing study is highlighted in which attention is primarily paid to the root structural development of *J. curcas* seedlings, and the link of architectural characteristics with erosion control potential. During the last decades, this relationship received more attention (Reubens *et al.*, 2007). At the moment of writing only preliminary results are available. The main aim of the research is to assess the erosion control potential of this plant, although the results might also be useful for other applications, such as determining the optimal agroforestry and plantation layout.

MATERIAL AND METHODS

Plant material and growth conditions

The research is organised in the faculty greenhouse complex of the faculty of bio-science engineering, K.U.Leuven, campus Arenberg. Day temperature is kept between 22°C and 25°C. At night the temperature is allowed to drop till 15°C. The relative humidity is kept on 70%. The CO_2 concentration in this artificial environment varies around 600 ppm. In order to measure root architecture at different ages (i.c. 10 days after germination, 1 month after germination and 2 months after germination), pots with different dimensions are used. The plant which are allowed to grow 10 days are sown in pots with a diameter of 24cm and depth of 21cm, while the other plants are sown in pots with a diameter of 41cm and depth of 28cm. The pots were filled with a 2:1 river sand (300µm) – peat mixture. Ethiopian *J. curcas* seeds, obtained from FACT-fuels, Eindhoven (the Netherlands), were sown after nicking and cold water treatment. Soil was kept moist and two seeds were sown in each pot. After germination solar radiation depending drip irrigation was installed. Fertigation was applied after the sprouting of the second leaf.

Measurement and analysis

Before destructive measurement of the root system structure, a limited set of aboveground characteristics is measured. These include measurement of shoot length using a measuring tape (accuracy 1mm), diameter at the base with a digital calliper (accuracy 0.01mm), number of leaves and individual leaf dimensions, using a digital calliper.

After removal of the aerial part, roots are exposed by carefully removing the soil around them with a spatula, taking care to maintain original root position. Root architectural measurements are performed by recording the diameter with a digital calliper (accuracy 0.01mm) and the XYZ coordinates (accuracy 0.5mm) of every individual root segment with a frame consisting of moveable rulers in X, Y and Z direction. By shifting these rulers to the right position, coordinates of each root segment can be determined Henderson, *et al.*, 1983; Khuder *et al.*, 2006; Danjon & Reubens, unpublished). A root segment ends when a root branches or changes orientation or diameter. All root segments up to a limit of 0.5mm at the beginning of a new root axis are measured. Additional information, such as the presence of fine roots, growth along the pot border or breakage of a root, is carefully recorded.

Finally both above- and belowground plant material is weighed fresh as well as after 24 hours of oven-drying at 70°C.

The root system structure is ultimately represented as a multi-scale tree graph (MTG) (Godin *et al.*, 1999) and analysed in the AMAPmod freeware (Godin *et al.*, 1999) and R open statistical package (Ihaka and Gentleman, 1996). AMAPmod includes an utility to control the structure of the input file, numerous built-in functions which can be assembled in user-made functions to compute parameters, a program to display 3D graphics of various elements of the root system and functions required for a detailed architectural exploration, analysis or modelling of root systems (Danjon *et al.*, 1999a; Danjon *et al.*, 1999b; Danjon & Reubens, unpublished).

RESULTS AND DISCUSSION

As this research project has only very recently been set up, results represented in this communication are still preliminary, and based on a very limited dataset. In the next months, detailed measurements will continue and full analysis of the extended dataset will take place.

Nevertheless, some interesting first observations have been made. A first step in analysis is the visualization of the root system structure, as represented in figure 1. Most remarkable observation is the development of a predictable root structure consisting of one central taproot and four laterals (figure 1 and figure 2). Heller (1996) assumed this consistent root formation from seedlings, but the root formation and structure has never systematically been described. All of these laterals originate at one and the same position of the taproot, and grow in four perpendicular directions. A high number of fine roots is also observed, and root biomass increases at high speed.

A large set of qualitative root system characteristics can be obtained through further analysis in AMAPmod and R. A subset of important above- and belowground characteristics is represented below in Table 1. Again, some remarkable first conclusions can be taken, such as e.g. the low Root Partitioning Coefficient (RPC) and Root-Shoot ratio (R:S). Another interesting observation is the very high moisture content both in root and shoot, as can be derived from the difference in fresh and dry weight.

Although more research still has to be undertaken, including different stages of development, varieties and growing substrates, the observed 3D structure reveals a potential for control of different types of erosion and slope stability. It has been hypothesized that in general woody species with a large, deep and strong central part of the root system having some rigid vertical roots penetrating deeply into the soil and anchoring into firm strata, as well as a large number of finer roots numerously branching from the main lateral roots, would be most effective to increase shallow slope stability (Reubens *et al.*, 2007).

Table 1: Set of above and belowground characteristics of 10-days-old *J. curcas* seedlings.

Variable (unit)	Average ± s.d.
Height (cm)	22.18 ± 4.70
N° leaves	2.00 ± 0.00
Dbase[1] (mm)	6.32 ± 0.35
Fresh weight Stem (g)	6.93 ± 1.13
Fresh weight Root (g)	1.33 ± 0.20
Dry weight Stem (g)	0.62 ± 0.09
Dry weight Root (g)	0.12 ± 0.01
Stem density (g/cm^3)	0.16 ± 0.03
Root density (g/cm^3)	0.08 ± 0.00
R:S[2]	0.20 ± 0.02
CSD_2nd [3] (cm)	0.08 ± 0.00
RPC[4]	16.48 ± 1.40
Total root length (cm)	104.97 ± 10.34
Individual root length (cm)	21.03 ± 2.05
Total root volume (cm^3)	1.46 ± 0.11
Total stem volume (cm^3)	3.98 ± 1.10
Individual root volume (cm^3)	0.29 ± 0.02
Individual root volume (no tap[5]) (cm^3)	O.10 ± 0.02
SRL[6] (cm cm^{-3})	71.13 ± 5.09

[1] Dbase = diameter at the base of the stem
[2] R:S = (M_{root} / M_{shoot}) with M = mass
[3] CSD_2nd = Cross-Sectional Diameter of 2nd order roots
[4] RPC = (V_{root} / (V_{root} + V_{stump} + V_{stem})) with V = volume (Danjon *et al.*, 2005)
[5] no tap=without taking tap root into account
[6] SRL= Specific Root Length = (total length/total volume).

For soil erosion processes by water operating in the topsoil, species colonizing the upper soil horizons with a fast-growing and highly branching rooting system would have the highest capacity to hold soil particles together (Reubens *et al.*, 2007). At first sight, *J. curcas* seems to be promising for both situations. Its fast growth is another important favorable fact. However, some other characteristics, such as the low density, R:S ratio and RPC, seem to have a rather adverse effect on erosion control potential. At least at seedling stage *J.curcas* roots are very fragile. This reminds us of the fact that not only structural but also mechanical aspects should be taken into account.

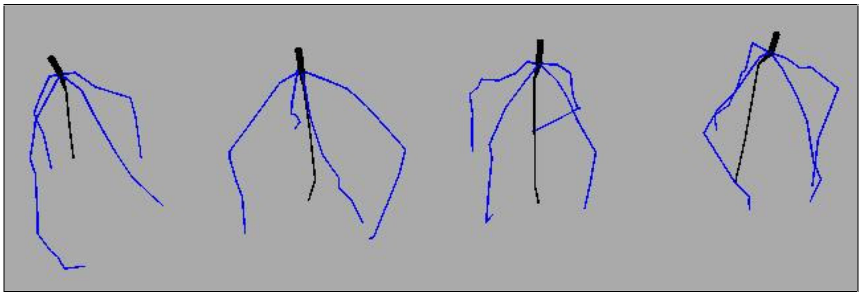

Figure 1: Visualisation of root structure of four 10-days-old *J. curcas* seedlings grown in greenhouse conditions. The root configuration of a single taproot (black) and four perpendicular laterals (bleu) is consistent between different seedlings.

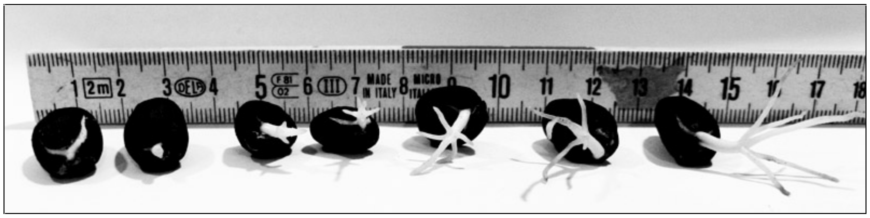

Figure 2: Root formation during germination of *J. curcas*.

CONCLUSION

Although it is too early to draw conclusions, the root structure of the young *J. curcas* shows to be very interesting. The root system, consisting of one taproot and four perpendicular oriented laterals, is remarkably predictable and is thought to have promising erosion control potential. Other characteristics however seem to be less favourable. In order to take the right conclusions more research is necessary. On-field investigation of the root structure of mature individuals as well as measuring root tensile or bending strength is needed. Detailed information on the rooting system will elaborate the optimization of agroforestry and plantation systems.

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