A few structural and growth parameters describing corn root system
Marie Odile M. O. Jordan, D. Picard, Philippe P. Girardin

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HAL Id: hal-02854795
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Submitted on 8 Jun 2020

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A few Structural and Growth Parameters describing Corn
(Zea mays L.) Root System. M-O. JORDAN and D. PICARD
and PH. GIRARDIN, INRA of COLMAR.

Nodal roots of corn plant (cv. f.m. DEA) originate form the
first eight internodes. There is a relationship between num-
ber of visible leaves and level of nodal root emergence. The
emergence of nodal roots doesn't affect growth rate of lower
roots. In the first five "shoot units", number of primary
roots is 2 to 5 and remains almost stable within hybrid for
a given year and location. Above the fifth internode, number
of nodal roots increases towards upper "shoot units". Basal
diameter of nodal roots and number of ramifications on prima-
ry roots increase with successive internodes. Upper is the
"shoot unit", more vertical is the growth direction of nodal
roots. The first emerged roots grow sub-horizontally and co-
lonize preferably the top-soil layers.

Mailing Address of Corresponding Author:
Marie-Odile JORDAN
INRA - STATION D'AGRONOMIE
28, rue de Herrlisheim
P-68021 COLMAR - CEDEX

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(over)
I. INTRODUCTION

FRANQUIN (1974) define the structure as the arrangement of the different parts of the system. It is an abstract component of the plant's architecture which is obvious through the number of organs and her spatial relations. The evolution during time of this structure introduced the notion of dynamics.

For a plant, the position of an organ is under the influence of its exchanges with the others components of the vegetable, on one side, and with the environment, on the other side. So, for example, transpiration and photosynthesis rate of a leaf is dependent on the position along the axis, and the nutrient absorption level of one root is dependent on the resources of the soil which it is in direct contact with.

So, the knowledge of a plant's structure is a necessary preview of the study of her functioning.


In return, our knowledge concerning root is far limited.

At a given moment, rooting depends on a double interaction between growth and development of the system and, growth and development of the shoots, on one side, and climate and soil environment on the other side.

If the existence of close correlations between growth and development of shoots and roots is longest known (BROUWER, DE WITT, 1969), the deficiency in precise information on this subject, often not allows to overstep the statement of allometric relations between weight of the shoots and the one of the roots (THROUGHTON, 1969); However, some recent works show a strong correlation between the number of visible leaves and those of primary roots by maize (PICARD et al., 1982), wheat (KLEPPER, 1984), rice (YAMAZAKI, 1982; PICARD, 1984) and dactylis (GOUNOT, 1980).
The influence of the physical, biological and chemical soil characteristics, have been studied on a more fragmentary way. The authors tried usually, to express the evolution on only one rooting parameter in terms of only one environmental factor. Growth rates, for example, have been expressed in terms of temperature (ONDERDONK and KETCHESON, 1973) or matric potential (MIRREH et al., 1973). The model, built by WANG (1984) is one of the few works which synthesize the informations concerning the surrounding factors in an explanatory model. It seems important to extend this kind of work to the all developmental stages of the plant.

The subject of this study is double: first, the aim of the study is to built an architectural model on the root system of maize. Such a model allows to know, why and when the root system develops in the most frequent architectural conditions. During this first step, it is important to draw out the unvarying, facts dependent on the species and the hybrid, and therefore stable whatever the soil and climate conditions. Thatfore, we need a standard time scale for the whole plant, which can be the phyllochrone (GOUNOT, 1980) expressed in number of visible leaves.

This model can be used as a reference and compared with really observed field conditions. The structural variability induced by surrounding factors can be inferred from that comparison. After that, the action of each of this factors can be described more precisely in an explicative model, which recovered the whole cultural cycle.

II. MATERIAL AND METHODS

1- Model building

At first, we clearly definite the descriptive parameters of the root structure and kinetics, as well as the relations binding them together.
The characterisation in space and time of the maize root system is possible by recording, for each of the rooting orders, the four following variables:

- emission, ramification and necrosis rhythms.
- growing speed
- root diameter
- root angle with the vertical.

The structural model of graminaceous root systems built by LUNGLEY (1973) has been a guide for this study. This work, completed by the results of our own observations, allowed to build the chart of a root kinetic descriptive model for maize plants. At each day, squares a phyllochronic time, taken as stable time unit. This time, induced, or not, the emission of a primary root level. The subsequent growth of this roots is under casting influence of the environmental factors, but her growing direction will be dependent on her insertion level. This primary roots will branching out, as soon as her lenght will be higher then the sum of the distances between the basis and first ramification and between the apex and last ramification. Both the distances as well as the ramification potential can be expressed in terms of insertion level of the bearing roots. This secondary roots will grow and branch out in accordance with surrounding conditions, such as the necrosis level. Our model will stop with the emission of the tertiary roots because we rarely observe lengthennings more than few centimeters.

This model established a three dimensional matrix which gives the position in space of every rooting order.

2. Experimentation

The used parameters will be given by an experimentation on 7 plots established on loam soils. The number samples is important enough, to include the intra specific variability of the measured variables. For some of them, such as growth rate, which was estimated with difficulty in the open fields, rhizotrons or containers with a glass face have been used.
The evaluation of the parameters is recorded, either with direct measurements on plants, either after excavation on soil monoliths which didn't disturb the arrangement of the root system, or with the rhizotrons. As often as possible, several methods have been used to evaluate one parameter.

III. RESULTS

Here, we limited our presentation to only one parameter: the emission of the primary roots.

1. Structure of a maize plant

KISSELBACH (1949) displayed the structure of elementary superposed structural units called phytomers. Each of them, include a node, an internode, a leaf, and an axillary bud. A row of buds at the basis of the internode generate, or not, primary roots. For ONDERDONK and KETCHESON (1973) only one seminal root shall exist. The mesocotyle (or first internode) supports 2 or 3 nodal roots. (Observation, maken on french hybrid Dea; PICARD et al., 1985). By a few plants, we see 5 or 6 other roots along the mesocotyle. This shows a bad condition of the plant as exposed by MONGELDORF (1929) and MASS and ZUBER (1971).

The number of primary roots boreed by the upper internodes depends on her level. Five types can be seen.

- Internode 1 represented the first class

- The second type is constituted by internodes 2 to 4. By french hybrid DEA the mean number of roots supported on these internodes is respectively 3,8 ; 2,9 and 2,3. These numbers remain almost constant within plant and years. In addition, the work of Professor MILLET showed that all the initiated roots were emitted. All this gives way to think the great influence of genotype.
Internodes 5, 6 and 7 are in the third class. The number of roots issued from this internodes increase. Here are 3 roots on internode 5; 4,2 on internode 6 and 9,2 on internode 7. The observed variability inside the same sample, which is unfortunately not beared on the graph, increase obviously, as like the differences between the two years. In this case, there are more initiated, thanm effectively emitted roots. The root emission, will be, here, more sensible to the environmental factor.

Internode 8 has a particular behaviour. As a matter of fact, this roots emitted at soil level, can either strech and ramificate, or stop their growth at 5-6 cm length. The choice between the one or the other behaviour is still unexplained.

At least, the roots issued from the upper internodes will stay in rough sketch conditions, and therfore not layed out on this graphic.

This data can be completed by the study of spatial variability. These recordings have been made on 7 sites. The panel give the results of the mean comparisons for internode 2 and 6 belonging on two different classes. The great stability presented by internode 2, and the variability observed on internode 6 confirm the hypothesis expressed previously: it remains the dependance of the internode 2 towards genotype and the influence of the sourrounding factors on internode 6.

A least, four different hybrids, brought up on the same place have been compared. The dispersion is greater for internode 2 than for internode 6, where similar soil and climate conditions favoured an homogeneous distribution. The effect of genotype is more marked on internode 2. In this case too, the emited hypothesis are confirmed.
2. Root emission kinetics

For each of the 9 first internodes, the upper regression line bind dates of beginning of the emission, the lower line those of end of emission. For a given internode, $x$ the emission ended when the leaf $2x$ emerge out of the world (See, for example, internode 4). For each level the emission spread out for a duration of about 2 phyllochrons, as it is shown by the calculation of the differences between the "abscissas" at the origin of the lines. At least, we can see that the emission of a given level begin when all the roots of the lower level are emited.

IV. DISCUSSION - CONCLUSION

Concerning the emission of primary roots, some unvarying characters, bounded to the genotype have been clearly displayed.

So, in spite of the presence of some variability, which could be partly explained by the period of 3 or 4 days separating two sample series, the number of visible leaves, used at time scale, permitted the explanation of the emission of primary roots of maize. This has already been shown for rice, dactylis and wheat. As well, the number of roots bearing by the 4 lower internodes, is constant and dependent on genotype.

If we have shown the influence of external factors for the emission on the upper internodes, the effect of each of this factors could not be explained for the moment. The search of explicative variables form the subsequent step of this work.

It remains yet to extend this kind of reflexion to the whole rooting descriptive parameters, previously stated : growth and senescence rate, and, ramification. This work is already done for root diameter.
ROOT KINETICS

- Emission rhythm
- Necrosis rhythm
- Ramification rhythm

- Growing speed

- Instantaneous orientation

ROOT STRUCTURE

- Number of first order root
- Second order root
- Third order root

- Length of each root

- Root diameter

- General orientation

- Length of the root system

- Diometric surface

- Total volume and total weight

- Colonization and rooting density for each soil level
Earlier evolution of the root system

(Growth and development)

Growth and development of the shoots

Soil and climate conditions

- physical
- chemical
- biological
STRUCTURE OF A CORN PLANT IN STRUCTURAL UNITS (PHYTOMERS)

KIESSELBACH, 1949
ONDENBAN et KETCHESON, 1972

L18
L17
L16
L15
L14
L13
L12

Auxiliary bud
Coleoptile
First internode
Scutellar node
Seminal root

First leaf
Coleoptilar node
internode 2 to 6
### E2

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**Variety Effect. Mean Number of Roots Per Internode**

**Results of the Mean Comparisons**
YEAR EFFECT: MEAN NUMBER OF ROOTS PER INTERNODE
**Location effect**: Mean number of roots per internode.

**Results of the mean comparisons (5% level)**

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<td>Colmar 1</td>
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<td>Altkirch 1</td>
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<td>Mons-en-Chaussée</td>
<td>7.08</td>
<td>e</td>
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</table>
DATES OF THE BEGINNING AND OF THE END OF NODE PRIMARY ROOTS EMISSION EXPRESSED IN PHYLLOCHRONIC TIME, PER INTERNODE.

\[
\begin{align*}
\text{beginning of emission : } & y_1 = 0.50 x_1 + 0.05 \quad r = 0.98 \\
\text{end of emission : } & y_2 = 0.45 x_2 - 0.16 \quad r = 0.99 \\
\end{align*}
\]

\[
y_1 = y_2 = 0 \quad x_2 - x_1 = \frac{0.15 + 0.30}{0.45 - 0.50} = 1.95
\]