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Impacts upon cultural techniques on root system development and consequences on durum yields. Proposal of mathematical models for yield assessment

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ABSTRACT/RESUME

Abstract: *This work is the main part of a research program entitled: issue of simplified cultural techniques introduction in Algeria. The purpose was to analyse effects of tillage and direct sowing on evolution of soil structure and consequences on root development and on durum yield. And establish a mathematical model which allows quantifying yield in relationship with physical and mechanical parameters of the soil and to different factors linked to cultivation. Results of different tests showed clearly that the used technique has a certain effect on moisture development, porosity and soil penetrometer resistance. Water content in the soil is better stored with direct seeding. Porosity is more important with direct seeding. As for soil penetrometer resistance, soil is more resistant on plot with direct seeding. The penetrometer resistance is also highly conditioned by water content. Results obtained show that the root system is more developed on worked plots with the conventional method than on those worked in direct seeding. Quality of grains is better at level of plots conventionally worked, which present the best root development, the best porosity and penetrometer resistance favourable resistance test. Therefore, the best yields are recorded at level of the conventional technique with the second dose of seeding. The yield modelling in relation with different parameters studied, gives us the following relationship which remain valid in our tests conditions.*

- Conventional technique : $\boldsymbol{YLD_{CT}}$=565,42.$Pr^{-0,42}$. $Rr^{0,12}$. $WTG^{0,48}$. $Sd^{0,82}$.$Gr^{0,42}$

-Direct seeding:
$\boldsymbol{YLD_{DS}}$ =482,47.$Pr^{-0,36}$. $Rr^{0,04}$. $WTG^{0,38}$. $Sd^{0,94}$.$Gr^{0,36}$

I. Introduction

In the world, water resources are very limited; they become more and more scarce, occurring droughts due to climate change notably in Mediterranean region. Water shortage is considered as the great environmental constraint of plant growth and their survival in Mediterranean ecosystems [1]. In Algeria, water and soil are considered as the important factors to be preserved to ensure a continuous production on the basis of a sustainable agriculture. Irregularity and aridity of the climate turn water resource increasingly rare needing a particular interest which aims technique use that allowing to preserve and to economise this resource. The soil degradation phenomenon is present in the Highlands and high plains, practice of cereals crops areas, due to factors; water deficit, unsuitable cultivating practices and over-harvesting of lands which no longer follow the soil-climate evolution of the environment. The classical tillage technique with ploughing reached its development limits in certain regions. Ploughed grounds are subject to erosion and to fertility decrease involving physical degradation sometimes irreversible.

To limit this phenomenon and resonate with concept of a sustainable agriculture, the use of simplified techniques and to direct seeding would be more advisable [2]. Some works on the subject have been carried out: Interest focussed more on yields obtained without considering physical and mechanical characteristics of the soil and of cultivation development during its vegetal cycle. Among these works, the most important are those performed by [3] ; [4] ; [5]. In Algeria, results obtained in semi-arid regions by [6], showed that simplification of the tillage reduces yield of the wheat compared to the classical method and that rootedness rate is directly linked to the soil structure and to its physical and mechanical properties, notably moisture, porosity and resistance by penetrometer which are themselves functions of cultural technique used. According to [7], tillage affects biotic and abiotic factors of the soil, either directly by changing soil structural properties such as gaps arrangements, aggregates, connectivity of pores, or indirectly by changing ventilation conditions, temperatures and penetrability of soil by roots. According to [8] roots lead a secret life in the soil. One hectare of winter wheat can hide 300.000 km of roots which bring water and nutrients substances to the culture. A root system well developed is the result of a good soil structure and is essential for a high yield [9] en 2014 have conducted a test during two campaigns where they studied effect of the direct seeding, classical tillage and techniques rotation between worked and no worked soil on root development. According to results obtained, conventional tillage reduces the bulk density of the soil and so penetration resistance in the area worked, which led according to authors, to an increase of a length, weight and root biomass from tillage stage to flowering stage, which has led to provide good yield of wheat. Therefore, tillage must offer to the cultivation a very favourable environment to its development, for this, root system must evolve in a soil presenting favourable physico-mechanical properties: or under other form, soil structure must responder to agro-techniques requirements of the culture to be made in place. In simple manner, selection in tillage matter, at level of exploitation, should be among other, considering effect which will have or not on root work, thanks to which will be made water supply and mineral elements during all the plant development cycle. Algerian experience in this subject is quite recent, results of different tests are not sufficiently popularized among farmers, it is in this context that we wanted to bring our contribution which is analysis of soil behaviour under action of the two cultural techniques (conventional work and direct seeding) for implementation of cereal (durum), and consequences on root development, and final yield. The fact that cultures yield depends also in major part of seeding rate, we propose to use different dosages of seeding to try highlighting the relationship between structural states and root development and so the related performance. We will try to establish also, mathematical models which allow quantifying yield in relation with physical and mechanical parameters of the soil and different factors linked to the cultures.

II. Material and methods

Tests took places at level of experiment station of ITGC (technical institute of field crops*)* of Oued Smar El-Harrach, located at 24 m above sea level; between isohyets 600 mm and 700 mm .It belongs to bio-climate sub-humid stage with mild winter. Soil texture is silty clay with 46,51% of clay; 25,30% of silt and 26,79% of sand.

The culture used for our tests is durum (Triticum durum) variety (Siméto), characterized by a germinative capacity of 96,60% and a weight of 1000 grains of 27,70 g, choice of the culture is part of introduction program test of direct seeding in Algeria of ITGC with rotation wheat/berseem. This variety is an important culture of Mediterranean environment which is traditionally cultivated in rainy conditions in marginal areas of semi-arid regions; it possesses a fasciculate root system to great number of ramification. Having into account geometry and topography of the plots and taking into consideration the objective of our experiment, the experimental device adopted is the factorial bloc type with two factors studied:

First factor: Tillage technique at two levels (CT, DS):

- Technique 1. CT: soil work with breaking up of the soil at 30 cm –deep, thanks to double furrow plough and a cover crop (14 disks)
- Technique 2, DS: direct seeding: a total weed killer (Roundup) has been applied, it active matter is the Glyphosate, with concentration of 1 litre by 100 litres of water.

Second factor: seeding dose at two levels (d1 and d2)

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- d1= 160 kg/ha;
- d2= 180 kg/ha.

The seeding operation is made thanks to a seed driller coupled to a tractor for conventional technique and a combined drill for direct sowing. A nitrogenous fertilizer (urea) has been made by a sprayer at dose of 2q/ha Parameters studied are determined as follows:

- The direct measure method of water content of a soil sample is simply made by weighing before and after steaming at temperature of 105°c during 24h:
- Humidity rate is calculated by the following relationship: H%={(Ph-Ps)/Ps}×100, with Ph weight of humid sample and Ps weight of dry sample (in g).
- Samples are collected in three points of each plot, every sampling has been carried out from the three horizons: from 0 to 10 cm, from 10 to 20 cm and from 20 to 30 cm. This distribution allows us following humidity evolution during the plant cycle and to understand effects of the soil working on its humidity.
- As for soil porosity determination, the same used samples for humidity determination have been resumed in taken into account the volume of the cylinder.
- Soil porosity (P %) is calculated by the following relation P%= (1- da/dr) ×100 with apparent density (in g/cm3) and (Rd) real density (g/cm3)
- The Penetrometer resistance (Pr) expressed in daN/cm2, parameter more often retained is measured thanks to a penetrometer:

- To obtain root density (Rd), we have used the core technique thanks to a metal cube with a known volume(18.75 dm^3) 25 cm width, 25cm length and 30 cm height, sharpened end has been embedded in the soil with mechanical manner in horizon (0-20 cm) ; then released by digging around. Once the samples are collected, we have extracted roots under water pressure. Once the roots are extracted, we measure their weight.
- The root density (g/dm^3) is calculated by the following relationship: De=Pr/Vc, with Wr weight of roots and Vc volume of the cube.
- The plants number survey by m^2 (Ps) is determined by counting of feet thanks a wooden frame measuring 1 m on each side.
- The yield (Yld) assessment expressed in q/ha, is determined by plants sampling thanks to a knife on samples of $1m^2$. The harvested grains will be then weighed and with a simple rule of three, on have converted yield in a hectare (ha).For further analysis of cultural techniques effect on different parameters studied, a statistical analysis has been carried out, it allows us analysing different correlations between parameters studied. The used method at this effect is the statistical method by analysis of simple correlations and by multiple regressions when interest is brought on combined effects. At the end of our study, a dimensional analysis has been made, to quantify yield of the durum culture in relation an different parameters studied

III.Results and discussion

III.1.Techniques 'effects on water content in the soil.

Results of variation in soil water content are mentioned on the following figure.

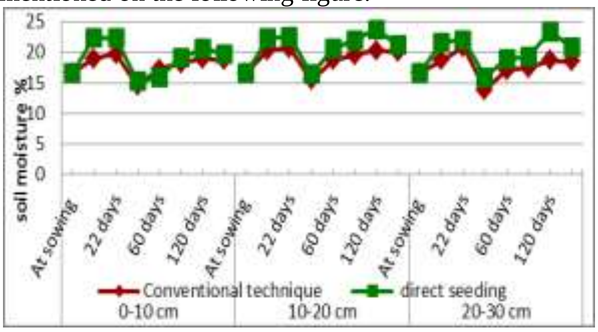


Figure 1. *Variation of water content in the soil according to the technique and the depth in %.*

According to figure below, we observe that the first horizon level (0-10 cm) humidity rate is higher in the soils led in direct seeding compared to those led in conventional work during all the vegetative cycle ; this is explained by the fact in non ploughed plots level, there is a vegetal cover of the previous cultural plots in surface. This latter contributes to evaporation decreasing (mulch effect), soil remains moist longer, which decreases its compactness.

At level of the second horizon, the report is nearly the same but with value a bit higher. Rate moisture reaches its maximum for conventional work after 22 days with rate of 20,66% and after 120 days for direct seeding with rate of 23,72%. The average gap between both techniques is of 1,74% during all cultural vegetative cycle, this gap is translated by roots effects of previous cultures which create biological porosity which allows a best deep water infiltration.

In the third horizon, superiority of humidity rate is always marked by direct seeding with an average gap of 2,12%. However, it is noted at level of direct seeding that humidity reaches its maximum after 120 day with rate of 23,32% with gap of 2,1 % compared to conventional work. This difference reflects absence of soil working and presence of microbial in this horizon.

Generally, direct seeding allows best water retention compared to conventional ploughing and whatever the depth. In fact, humidity varies from 18.98 to 20,67 % for direct seeding technique and it is only of 17.70 to 18,93 % for conventional technique.

III.2.Techniques effects on soil porosity

Results of soil porosity variation mentioned on the following figure

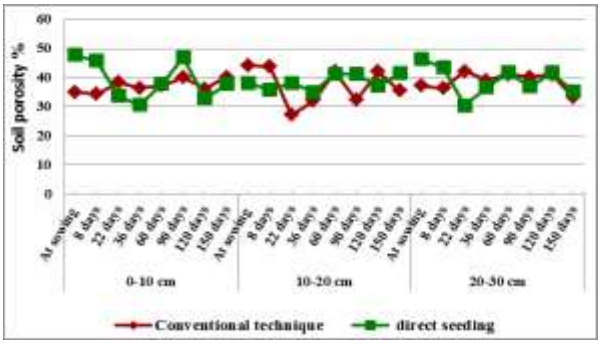


Figure 2. *Soil porosity variation according to the technique and depth in %.*

This graphic representation shows clearly that, whatever depth, porosity is more important at level of direct seeding. These values are probably justified by the fact after ploughing, there are high rainfall having effect on degradation of clods by water erosion, which

it means that the fine earth comes down and creates a compact environment at level of the conventional tillage. In contrast at level of direct seeding plots, the covered soil surface by thatch and weed roots which maintain certain moisture in the soil with structure maintaining.

In the first horizon, we observe a decrease of the porosity at level of the direct seeding technique until 36 days after, then it increases until reaching it maximum with a rate of 47%, in the opposite to worked soils where porosity rate increases with time, it passes from 34, 43% to 40,16%, the average gap between both techniques is of 1.95%

In the second horizon, porosity values are nearly stable at direct seeding level, it increases gradually

with the time, passing from 35, 82% to 41, 48%, contrary to worked tillage where values are instable during all vegetal cycle of the culture. This difference is translated by the fact that tillage provokes disturbance in soil structure, which is not the case for direct seeding which has a stable structure.

In the third horizon, we record close porosity values for both techniques after 36 days until the end of vegetative cycle, and in this horizon where we find maximum porosity values for conventional tillage with rate of 38, 82%.

III.3.Effect of techniques on soil penetrometer resistance

Variation results of soil penetrometer resistance are mentioned on the following figure:

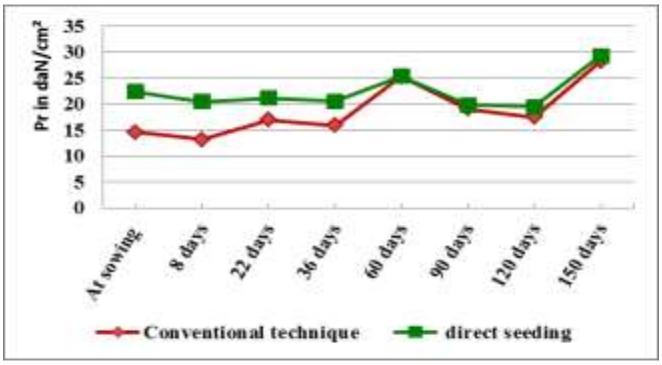


Figure 3. *Variation of soil penetrometer resistance (daN/cm^2) according to cultural technique*

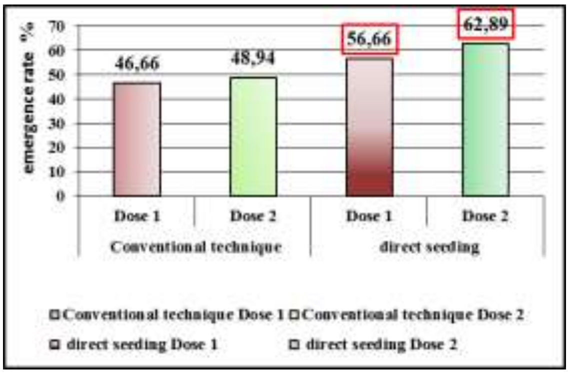
Basing on figure above, we observe that soil penetrometer resistance fluctuates in a similar fashion for both cultural technique: just it is clearly upper in the soil led in direct seeding, until 60 days of vegetative cycle, then an approach until 120 days; which it means that roots of the two cultures exert nearly the same force to penetrate more deeper. After

120 days, direct seeding technique returns to its superiority position with a gap of 2.04 daN/cm^2 compared to conventional tillage. These results allow us saying that roots develop more easily on worked plots with plough (CT). Roots at level of direct seeding should encounter an obstacle well before of those conventional technique.

III.4.Effect of techniques on emergence rate

Results of durum crop emergence rate are mentioned on the following figure:

Figure 4. *Rate of durum emergence according to the*



technique and the seeding dosage in %.

According to results presented above, the first remark which we can do is that the populating emergence remains depending to the seeding dosage and of the cultural technique. Whatever seeding dose, direct sowing presents a higher emergence rate than this of

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conventional technique with an equal rate of 56,66 % and 62,89 % for dose 1 and 2 respectively, which difference is traduced by the good location of seed in direct seeding (3 to 4 cm depth) by contrast, in conventional tillage, seed can enter in cracks produced during tillage, therefore it moves away from light and do not germ. The second remark which we can underline is that seeding with high dose d2=180 kg/ha allows the best emergence populating whatever the applied technique with an average gap of 35 plants/m2 compared to seeding with dose of 160 kg/ha.

III.5.Techniques' effect on root development

Results of rate roots are mentioned in the following figure:

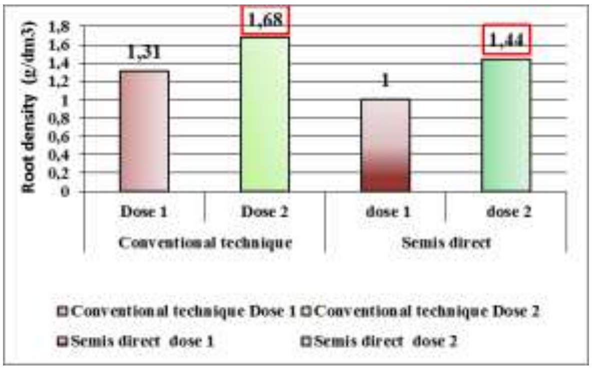

Figure 5. *Root density (g/dm3) according to seeding dose and of technique at the heading stage.*

corresponds to a number of 204 plants by m2 and 239 plants by m2 for dose 1 and 2 respectively. This

The results regarding to root development show clearly that root system is very developed on ploughed plots (CT) where root density is of 1,31 g/dm3 and 1,68 g/dm^3 for dose 1 and 2 respectively, in the opposite, at level of direct seeding plots (DS), we have the lowest value of root rate which is 1g /dm^3 and 1,44 g/dm^3 for dose of 1 and 2 respectively. This would be explained by existence of favourable conditions to root development at level of conventional tillage, quoting important soil moisture and favourable penetrometer resistance, contrary to direct seeding, roots limit their development by finding water at their disposal particularly in surface.
Generally, we can say that root growth is favoured by a good structure; in the conventional technique, the soil structure is mainly created by tillage operating while in direct seeding, the structure is mostly created by climate action and by biological processes.

III.6.Techniques' effect on yields

Results on yields and their components are mentioned in the following table:

Table 1. *Summary of yield components and yield according to technique and seeding dosage*

Techniques	Number of ears /m^2	Number of grains /ear	TGW	theoretical yield (q/ha)
CT d 1	245	57	46	56,13
CT d 2	264	57	47	69,23
DS d 1	222	56	40	47,24
DS d 2	237	55	46	58,35

According results obtained in the above table, we remark that:
The ears populating by surface unit do not only depend of tillage power, of germination rate, and of seed rate, but also of cultural technique practised The best ears populating has been obtained at level of worked plots and sowed to the dose of 180 kg/ha with an average of 264 ears/m^{2}.

The TGW of durum is better on ploughed plots and sowed to the second dose, it is of 47 gr, which gives therefore, the best wheat quality.
This is transferred on the culture yields. The latter is therefore better on ploughed plots sowed with dose 2, it is of 69,23 q/h. These results are of the same order than those obtained on other sites with the same soil texture by [10] who has obtained on the ploughed plots, a yield of 50,03 q/ha, while on direct seeding plots, it was only 36,19 q/ha. Difference of these yields between both techniques is highly significant; it is of 14 q/ha.

IV. Results statistical analysis

In order to confirm and modelling observations made previously, a statistical analysis by linear polynomial regressions method has been made. This analysis allowed establishing relationship between soil parameters illustrated by penetrometer resistance, moisture and porosity, and parameters linked to the culture (Nbr ear/m²: Gr, Nbr plants/m², Nbr grains/ear: Ge, TGW, Dr).
Analysis by linear regression allowed establishing the following relationships: HDS = f (HCT), PDS = f (PCT) and Rp DS = f (Rp CT) and they remain valid in the conditions of our tests

Pr CT - 0,789+0,790* Pr DS with r = 0,902 and R^2= 0,813

H CT = - 4,334+0,670* H DS with r = 0,947 and R^2= 0,847

P CT = - 13,639+0,671* P DS with r = 0,806 and R^2=0,650

The statistical analysis showed that values of p (probability) are below 0.05 and determination coefficients R^2 are above 0.65 which that means these relationships are statistically significant at the confidence level of 95%. These relationships confirm well effect of the cultural technique on water conservation in the soil, on porosity value and on soil penetrometer resistance. Analysis by multiple regressions, putting in relation Pr with H (%) and P (%), gives the following relationships:

Pr (CT) = 46,51 - 1,75* (H CT) - 1,11* (P CT) with R^2=0,956

Pr (DS) = 14,85 - 0,45* (H DS) - 0,41* (P DS) with R^2=0,792

These relationships highlight effect on water content and soil porosity on roots evolution in the soil. Taking into account coefficients of these equations and comparatively to porosity, soil moisture is more influent on value of penetrometer resistance and this at level of plots led in conventional tillage. By contrast, at direct seeding level, moisture and porosity have practically the same effect on penetrometer resistance. That means that on plots worked in direct sowing, roots development will be practically the same to the field capacity but to low moisture, roots will enter more easily on ploughed plots than those on direct seeding. Selection of cultural techniques has therefore a certain effect on the root development. Correlation between Rr (CT) and Rr (DS), YLD (CT) and YLD (DS), gave the following relationships:

R_d CT D1 = 0,827+0,835* R_d DS D1 with r = 0,839 and R^2=0,703

R_d CT D2 = 0,990+0,850* R_d DS D2 with r = 0,840 and R^2=0,705

YLD CT D1 = 97,077+0,866* YLD DS D1 with r = 0,994 and R^2=0,989

YLD CT D2 = 95,407+0,262* YLD DS D2 with r = 0,900 and R^2=0,810

According these correlation results, it appears clearly that cultural technique has certain effect on root development and on durum yield. Therefore, it is important to select correctly the technique to be implemented and the different forms of working parts. Analysis by multiple regression; putting in relationship the yield with variations (Pr, H, P, aerial part, underground part,) gave the following relations:

YLD_{CTD1}=111,07-1,11*H_{CT}+0,05*P_{CT} - 4,17* Pr_{CT}+6,77*Rd_{CTD1}+1,02*Ps_{CTD1}+10,18*Ea_{CTD1}+12,19*Ge_{CTD1} +18,45*TGW_{CTD1} with R^2= 0,986

YLD_{CTD2}=55,59 - 4,14*H_{CT}+0,18*P_{CT} -6,18* Pr_{CT}+9,20*Rd_{CTD2}+2,01* Ps_{CTD2} +13,01*Ea_{CTD2} + 14,15 *Ge_{CTD2} +20,51*TGW_{CTD2} with R^2= 0,900

YLD_{DSD1}=127,69+1,95*H_{DS} - 3,44*P_{DS} +4,20* Pr_{DS} - 9,32*Rd_{DSD1}+2,01* Ps_{DSD1} +10,55*Ea_{DSD1} +10,35*Ge_{DSD1} +11,77*TGW_{DSD1} with R^2= 0,999

YLD_{DSD2}=48,00+1,49*H_{DS} - 4,02*P_{DS} +6,68* Pr_{DS} - 10,63*Rd_{DSD2}+ 2,04 * Ps_{DSD2} +11,22*Ea_{DSD2} +11,15*Ge_{DSD2} +15,82*TGW_{DSD2} with R^2= 0,980

For a confidence interval of 95%, the whole of the models are highly significant. Determination coefficients are near of 1, show that yield is highly influenced by all parameters studied. Except yield components, comparison between parameters shows that effect of root rate is more important than this of penetrometer resistance which is itself more important that other parameters effect (Porosity and soil moisture / Plants Nbr/m^2). Also it must be noted that effect of these parameters on yield appears more clearly at level of sowed plots with the second seeding dose. Therefore, choice of seeding rate has a certain effect on culture yield.

V. Modelling of results

In this part, this concerns a proposal of mathematical models for each of the cultural techniques applied in order to quantify yield of durum culture in relationship with different parameters studied. The mathematical

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models will be presented as follows: **Yd = f (Pr; TGW; Gr; Rd; Sd).**

V.1. Characteristics of the models

Different used parameters to establish models are illustrated in the following table:

Table 2. *Different parameters used to establish models*

Paramters	Notations	Unit (SI)	Dimension
Yield	**Yld**	Kg/m²	**ML^{-2}**
penetrometerresistance	**Pr**	N/m²	**$ML^{-1}T^{-2}$**
Rootdensity	**R_d**	kg/m³	**ML^{-3}**
thousand grains Weight	**TGW**	Kg	**M**
Number of grains/m²	**G_r**	m^{-2}	**L^{-2}**
Seeding dose	**S_d**	Kg/m²	**ML^{-2}**
Gravitationalacceleration	**g**	m/s²	**LT^{-2}**

V.2. Number of p terms (theorem of Buckingham)

Fundamental principle of modelling is based on the law of **Kuszewski** which is: All parameter (dependant variable) can be quantified by the product of parameters powers (independent variables) which influences, which gives number of Pi Term : i=n-m

With:

- n: number of physical quantity (n=6)
- m: number of fundamental dimensions (m=3)
- i: number of necessary dimensional group (n-m=3)

Therefore, the three Pi terms π_1 ;π_2 ;π_3 are : $\pi_1 = \frac{YLD}{Sd}$; $\pi_2 = \frac{Pr}{Gr.TGW.g}$;$\pi_3 = \frac{TGW.Rd^2}{Sd^3}$

Use of theorem of Buckingham illustrated by the above relation allows determining the yield models:

$$\pi_1 = (\pi_2)^a \times (\pi_3)^b$$

Thus : $\frac{YLD}{Sd} = \left[\frac{Pr}{Gr.TGW.g}\right]^a \times \left[\frac{TGW.Rd^2}{Sd^3}\right]^b$

Values of exponents (power) a, **b** and**Cste** are:

a_{CT} = -0,42 ; b_{CT} =0,06 and regression constant $Cste_{CT}$ = 5,37 for conventional technique.

a_{DS} = -0,36 ; b_{DS} =0,02 and regression constant $Cste_{DS}$ = 5,35 for direct seeding. Therefore, we can write that durum yield of each technique is determined by models below and which remain valid in our tests conditions.

$$YLD_{CT} = 565{,}42.\ Rd^{0,12}.\ TGW^{0,48}.\ Sd^{0,82}.\ Gr^{0,42}$$
$$YLD_{DS} = 482{,}47.\ Rd^{0,04}.\ TGW^{0,38}.\ Sd^{0,94}.\ Gr^{0,36}$$

V.3. Models verification:

To verify models validity established, we carry out a comparison of values obtained from equation found and values obtained par experiment. Results are presented in table below:

Table 3. *Comparative table between yield measured and yield calculated according to cultural technique*

Conventional technique			Direct seeding		
Measured yield (kg/m²)	Calculated yield (kg/m²)	Measured yield / calculated yld	Measured yield (kg/m²)	Calculated yield (kg/m²)	Measured yield/ Calculated yld
0,475	0,487	0,98	0,547	0,456	1,20
0,534	0,543	0,98	0,530	0,459	1,15

0,516	0,514	1,00	0,525	0,449	1,17
0,609	0,540	1,13	0,512	0,469	1,09
0,579	0,529	1,09	0,422	0,442	0,96
0,565	0,531	1,06	0,420	0,443	0,95
0,588	0,547	1,07	0,402	0,454	0,88
0,547	0,534	1,03	0,466	0,491	0,95
0,620	0,584	1,06	0,463	0,478	0,97
0,529	0,525	1,01	0,443	0,467	0,95
0,556	0,546	1,02	0,467	0,491	0,95
0,617	0,570	1,08	0,472	0,528	0,89

In the conditions of our tests, values obtained by experiment and values calculated are close, and correction coefficients are ≤ 1 that means models established for both cultural techniques are exact.

VI. Conclusion

All results show that cultural technique for implementation of wheat culture has certain effect on the main soil's physico-mechanical parameters and consequently on culture development. Our works have demonstrated that:

- The technique "called" direct seeding allows having water content and porosity more important than the conventional technique.
- Penetrometer resistance is more important on direct seeding plots than on ploughed ones. Penetrometer resistance is a good indicator for assessment of root development, shows that this latter develops better at level of the plots conventionally worked:

In matter of populating emergence and independently of seeding dosage, rates of emergence obtained are directly linked to the technique used: direct seeding seems to offer the best rate of emergence compared to the conventional work. The best yields have been obtained on ploughed plots and sowed at the dose of 180kg/ha, it is of 69.53 quintals at hectare.

According to correlation results, it clearly appears that yield is highly influenced by penetrometer resistance and root density and so the seeding density. Modelling of the yield in relation with penetrometer resistance (Pr): root density (Rd): Seeding dose (Sd): WTG and grains number/m^2 (Gr) give us the following models which remain valid in the conditions of our tests:

$$\mathbf{YLD_{CT}=565{,}42..\,Rd^{0{,}12}.\ TGW^{0{,}48}.\ Ds^{0{,}82}.Gr^{0{,}42}}$$
$$\mathbf{YLD_{DS}=482{,}47.\,Rd^{0{,}04}.\ TGW^{0{,}38}.\ Ds^{0{,}94}.Gr^{0{,}36}}$$

Thus, yield is closely linked to climate conditions, to soil structure state, to seeding density and to the applied cultural techniques, which have a deep influence and certain on physical and mechanical properties of the soil, consequently, on the form and development of the roots. As perspective, we propose to undertake other tests on different types of soil and in other working conditions in order to generalize those models. So, it is indispensable to achieve it by a suitable technical and economic study.

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