

SUMMARY
of the doctoral thesis

**IMPACT OF TILLAGE AND HERBICIDES ON WEEDING AND YIELD IN GRAIN
MAIZE AT THE DIDACTIC STATION IN TIMIȘOARA**

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Practicing intensive agriculture can result in degradation of physical, chemical, and biological features of soil. In Romania, they have practically generalised the conventional soil work based on the annual tillage of the soil. This generalisation resulted in a decrease of the humus reserve in the soil, through the intensification of the mineralization processes of the structured aggregates hydro-stability, through the increase of soil vulnerability to degradation caused by compacting, and through erosion.

Research concerning the impact of the different land working systems on some physical, chemical, and biological features of the soil, as well as on the remnant effect of these systems were carried out by **Canarache A. (1990), Canarache A. et al. (1999), Jităreanu G. et al. (2007), Feiza V. & Cesevicius G. (2006), Mihalache M. et al. (2008), and Guș P. et al. (1998).**

In Romania, the transition from conventional agriculture through alternative systems to sustainable agriculture should take into account a series of aspects:

- rural demographics evolution and the wish to continuously increase the living standards;
- the need for a period of transition from conventional agriculture to different variants of the unconventional system of soil work;
- the existence of the necessary funds for the achievement of this transition.

Developing some unconventional ways of working the soil should rely on the conception that implementing sustainable technologies should ensure mainly the achievement of the following desiderata:

- developing an exploitation frame in agriculture and eliminating the degradation of the agricultural environment;
- re-launching and increasing agricultural production through new agricultural technologies;
- training highly-performing agricultural producers with incomes comparable with those of other economic sectors;

- developing agriculture in harmony with nature through the protection and the improvement of the basis of natural resources and, firstly, of soil resources, water, and biodiversity.

The need for diminishing as much as possible the negative impact of weeds on crops has resulted in agricultural research in the field of performing technologies meant to control weeds, technologies that are expected to undergo supplementary improvements.

The main aspect of controlling weeds is part of the weed integrated management. The target of these measures is not simply the yield or the weeds, but the maximizing of the crops.

At present, it is unanimously accepted that we cannot use a single method in the control of the weeds; we should use a complex of methods and practices together with complementary measures.

Choosing and using the methods, the means and, implicitly, the complex of measures of weed control depend on the following:

- establishing the degree of weeding, knowing and inventorying weeds, as a first step in establishing weed control methods;

- knowing the ratio between crops and weeds;

- knowing the biological features of the weeds and the weeding sources.

To all this, we should also take into account, first of all, the crop, the cultivation regime, other cultivation technologies, crop rotation, etc.

The importance and quality of soil works, scientifically motivated and practically confirmed, concern the following aspects:

- soil works have an impact on and change physical, chemical, and biological factors and develop optimal conditions for seed incorporation, seed germination, and for later plant development;

- soil works contribute to the maintenance and increase of soil fertility through periodical recovery of soil aeration and through incorporation of plant debris in the soil;

- soil works ensure the valorising of soils affected by limiting factors (excessive moisture, drought, and erosion) through the improvement of inner soil drainage, through the fragmentation of waterproof soil layers, and through the salt depletion;

- soil works control weeds as well as some diseases and pests;

- soil works favour soil de-pollution through the intensification of the activity of micro organisms, through the favouring of growth processes and root system development in young plants.

Fundamenting unconventional systems of soil works is based on the reaching of some objectives and indicators, among which the following ones deserve to be remembered:

- giving up mould board tillage totally or periodically;
- reducing the number of soil Works totally or periodically;
- preserving plant debris on the soil surface (at least 30%);
- avoiding soil erosion and preserving soil through optimal crop growth and development conditions;
- reducing production costs and increasing net benefits through the decrease of fuel, labour, and mechanical work consumption.

The experiment concerning soil work without an earth board was carried out in several countries, with literature mentioning the most significant ones: **Achenbach** (Germany, 1921), **Alfred de Pensen** (France, 1922), **Keen** (England, 1938), **Duley & Russel** (U.S.A., 1942), etc.

To note that the unconventional system appeared as an alternative to reduce soil erosion, leaving aside the second production level and neglecting, at the beginning, the advantages of reducing fuel consumption (**Guş P., 1983, Guş P. & Tianu A., 1991; Lăzureanu A., 1994; Budoï Gh. & Penescu A., 1996**).

The synthesis of data published in literature (**Guş P. et al., 2003; Jităreanu G. & Ciureanu Sorina, 1999; Lăzureanu A. et al., 1997; Budoï Gh. et al., 1997; Canarache A., 1997**, etc.) shows that the unconventional system of soil works has different variants, among which the most used are the following ones:

- a) Rationalised soil work systems, with two variants:
 - tillage – sowing system;
 - sowing – cultivation system.
- b) Minimum tillage – coverage with plant debris (15-30%).
- c) Mulch tillage – coverage with plant debris (over 30%).
- d) Cover crops or catch crops.
- e) Ridge tillage.
- f) Strip till or zone till.
- g) No-tillage or direct drill.

The main natural pest of maize is weeds.

In order to achieve yields at the biological potential of natural soil and climate conditions, maize needs to be protected from weed competition for 8 to 10 weeks, from seedling to the 8-10 leaves phase. Later weed competition can result in 5-6% potential yield (**Berca M., 1996**).

Maize plants, through their biology, totally lack weed control abilities. Because of the slow growth during the first 4 to 6 weeks (a period during which plants develop their root system) and because of the low density per m² (3-6 plants/m²), weeds enjoy from the very beginning the best conditions of vegetation.

Controlling weeds can be done through a very well organised integrated management, i.e. through the use of all the means of control: agro-technical, physical, biological, and chemical.

Chemically control weeds has known a spectacular evolution these last 50 years and it still does due to the discovery of molecules with action at enzymatic level in the plant organisms' metabolism (**Ciorlăuș At., 1996**).

The best progress in the field of herbicide production has been during the last five decades, when over 300 active substances with herbicidal effect were synthesised, substances manufactured in over 2,800 assortments (**Șarpe N., 1987**).

At present, they are synthesising a new assortment of herbicides from the group of combined herbicides, based on 2-3 active substances and on granulated substances. Using these active substances has important advantages, such as increasing efficacy through the broadening of weed control spectrum, through the diminution of the remnant effect and of the impact on the environment, reducing ratios and expenses, and easing manipulation (**Popescu Alexandrina, 1995**).

From a geo-morphological point of view, the research area is part of the Banato-Crișană Plain.

The aspect of the relief is not entirely characteristic of a piedmont plain formation, the latter representing a typical form of transition from the high to the low plain, with forms of micro relief specific to the two plain units.

Maximum altitudes here measure 93-94 m in the Northern ramification, 92-93 m in the Southern one, and 91-92 m in the erosion control.

Geologically, the studied area is part of the Eastern part of the great Pannonia Depression formed through the gradual clogging of the Pleistocene – Quaternary Lake.

Air average temperature is 10.8°C. The average winter isothermal of the coldest month, January, is between -1° and -2°C. Absolute minimal temperature oscillates between -20° and -30°C, with the lowest value -35.3°C at Timișoara, in 1963.

The multi-annual average of precipitations at the Meteorological Station in Timișoara between 1783 and 1975 was 631 mm. Between 1927 and 1996; the annual average values show the following oscillations: 407.2 mm (1983) and 908.1 mm (1970).

Soil works aim at developing optimal conditions for the crops and micro organisms to develop. Soil works also ensure on the ground the best conditions for sowing, applying pre-emergent herbicides, and even harvesting some crops mechanically.

Through judicious soil works, in perfect harmony with the other vegetation factors, we can maintain and increase soil fertility and we can also direct the process of agricultural production so that we can get favourable economic results and high-quality products.

The goal of the research on the impact of soil works and of herbicides on weeding and yield in grain maize can be synthesised as follows:

- designing a soil work system scientifically fundamented as prime necessity in the conditions of intensive agriculture;
- experimenting as many variants as possible in weed control in order to obtain an economically advantageous production;
- valorising the positive effects of soil works in order to preserve soil fertility;
- reducing soil limiting factors through the improvement of the main physical features of the soil.

The goals of the present research concern the following:

- choosing those soil work variants that can become viable alternatives in the conditions specific to the Banat Plain;
- knowing the dynamics of the physical, hydro-physical, and morphological features of the cambic chernozem, that can be changed through the working system elements;
- establishing the impact of soil works on the yielding features in grain maize;
- establishing the most efficient measures for the diminution of the weeding degree with direct impact on yield and on its quality;
- identifying the conditions in which the different soil works can be assessed and expanded in soil and climate conditions similar to the conditions in which research was carried out;
- calculating the economic efficiency of soil works and of weed control measures as final argument of the present research.

The experiments were mono-factorial, set after the randomised blocks method (Săulescu N. A. & Săulescu N. N., 1967), with 6 and 8 experimental variants, respectively, with 4 replications.

Experiment nr. 1, “The impact of soil works on weeding and yield in grain maize”, has the following technological variants:

V₁ – Tillage 20-22 cm + disc (2x)

V₂ – Tillage 28-30 cm + disc (2x)

V₃ – Chisel + rotary harrow

V₄ – Cutter

V₅ – Combinator work

V₆ – GD 6.4 (2x)

Experiment nr. 2, “Impact of herbicides and maintenance works on weeding and yield in grain maize”, shows the following technological variants:

V₁ – Not-treated with herbicides

V₂ – Dual Gold (1.5 l/ha) + Oltisan extra (1 l/ha)

V₃ – Dual Gold (1.5 l/ha) + Mistral (1.5 l/ha)

V₄ – Dual Gold (1.5 l/ha) + Equip (2 l/ha)

V₅ – Guardian extra (5 l/ha) + Oltisan extra (1 l/ha)

V₆ – Guardian extra (5 l/ha) + Mistral (1.5 l/ha)

V₇ – Guardian extra (5 l/ha) + Equip (2 l/ha)

V₈ – 2 mechanical weeding + 2 manual weeding

Normal tillage is done 18 to 20 cm deep in the soil in summer or in autumn, and always in aggregate with a harrow. Normal tillage is done as close to the time the pre-emergent plant was harvested as possible.

Deep tillage is done 21 to 30 cm deep in the soil in summer, 2 to 3 weeks after the stubble was ploughed in and, as a rule, in autumn, for tiller crops sowed in spring.

Chisel tillage. Chisel is a tool that aerates the soil up to 16-20 cm deep in the soil (maximum 40 cm for deep aeration). The work organ is a sheet of arch whose tip is a claw-shaped cutter. Chisel tillage results in soil aeration without involving the mixing up, the turning down or the reversal of soil strata. Chisel tillage is high-quality if it is done when the soil is relatively dry. It is recommended particularly in straw cereals.

Rotary harrow can be used individually to prepare the germination bed upon a single passage, after the soil was chisel-tilled or para-ploughed, or to prepare the soil for seeding, without previous processing with other equipment.

Cutter tillage is done on no-tilled medium and heavy soils where it replaces tillage and on tilled soils, to prepare the germination beds. On no-tilled soils, the work is done on the entire area for field crops (F-18) or for soil work on the space between tree or vine rows, using the de-axed cutter FD-1.3 for trees, the cutter FV-1.5 for vine, and the cutter FV-0.9 for vegetables. In truck farming, cutter tillage between vegetable rows 45-90 cm, is done with a truck farming cutter (FPL-4).

DUAL GOLD (S-metolachlorine 960 g/l)

Chemical group: Amides

This is the herbicide with the longest period of weed control compared to the other herbicides in the group of acetanilide.

GUARDIAN EXTRA (360g/l Acetochlor + 180g/l Atrazine + Antidote)

It is part of the non-volatile film herbicide category with very good tolerance to photo-decomposition and it can be applied both before and after sowing. It acts only on germinating weeds, absorption being done mainly through the hypocotyls and epicotyls when they penetrate the herbicide film.

MISTRAL (nicosulfuron 40 g/l)

It is a systemic, selective herbicide applied post-emergently in maize. It is a herbicide based on sulphonil urea, specially developed by Syngenta, for the control of annual and perennial weeds and of some broad-leaved weeds in maize crops. It has an excellent effect on problematic perennial weeds (*Sorghum halepense*) and on some annual weeds, including *Setaria* sp.

EQUIP (foramsulfuron 22.5 g/l + isoxadifen-ethyl (**safneurs**) 22.5 g/l)

Foramsulfuron has a complete systemics, being overtaken immediately by the weeds and carried throughout the entire plant: roots and rhizomes, meristems and leaves. The activity is stronger in the growth or division areas of the cells. Foramsulfuron blocks the activity of the synthetase acetolact responsible for the production of proteins in sensitive weeds. The intervention takes place in the biosynthesis of the chain of amino acids (valine, leucine, and isoleucine).

OLTISAN EXTRA is a herbicide combined from 2.4 D (as ester n-octilic) + dicamba.

Oltisan extra is manufactured as emulsionable concentrate containing 325 g/l octilic ester of the acid 2.4 D expressed as free acid and 75 g/l dicamba. It is not flammable.

Mapping weeds is a very complex work that includes several main steps: preparing data, mapping weeding areas, and establishing the complex of weed control measures (**Budoï Gh. & Penescu A., 1996**).

Mapping weeds supposes two working phases: a field phase and a data processing phase.

Data concerning weeding can be obtained through three methods:

- the *global weed assessment method* or the *visual method* consisting in crossing the plots diagonally, allows the assessment, through grades, the frequency of species and species groups: it is rapid, but not enough accurate;
- the *gravimetric quantitative method*, consisting in weighing weed species from each sample

area: it is a very accurate method, applied successfully on experimental fields;

- the *numeric quantitative method*, consisting in numbering the weed species on sample areas (0.25 m²): it is an expedient, enough accurate method.

Economic damage threshold designates the weeding degree in a crop starting from which a yield quantitative or qualitative diminution becomes obvious and that justifies economically special weed control measures (e.g., applying herbicides, tillage, weeding).

Assessing maize yield is a main concern supposing two stages: first, the monitoring of the crop vegetation during the phases characteristic to the formation of production components from sprouting to fruiting; second, direct assessment, after well established technological standards that point out the real size of production.

Soil work efficacy materialises in both weed control, and in reducing soil weeding potential. It also plays a significant role in the weed spectrum to appear.

Weeding in grain maize crops becomes obvious in the 2nd vegetation period, when herbicides are no longer efficient, and precipitations during summer-autumn favour re-invasion of the crops by the weeds.

Research carried out within the experiment “**Impact of soil works on weeding and yield in grain maize crops**” led to the following conclusions:

- the efficacy of soil works is materialised in both weed control and in the reduction of the seed reserve in the soil;

- weeding in grain maize crops is manifest during the 2nd period of vegetation, when the effect of the herbicides fades and precipitations during the summer and autumn favour the re-invasion of the crops by the weeds;

- the weeding level is between 48.79 weeds/m² in the variant tilled 28-30 cm + GD 3.2 (2X) and 101.57 weeds/m² in the variant GD 6.4 (2X);

- compared to the control variant tilled 28-30 cm + GD 3.2 (2X), in the rest of the variants the number of weeds is higher – 9.26 to 52.78 buruieni/m²;

- depending on soil works, monocots represent 22.01% in the variant tilled 20-22 cm + GD 3.2 (2X) and 44.83% in the variant GD 6.4 (2X), while dicots represent 77.99% in the variant tilled 20-22 cm + GD 3.2 (2X) and 55.17% in the variant GD 6.4 (2X);

- as a result of soil works, maize yield oscillates between 48.50 q/ha and 70.16 q/ha, respectively, with an average of the field of 58.20 q/ha;

- the tilled system 28-30 cm + GD 3.2 (2X) proves to be the most efficient, with a yield of 70.16 q/ha in which reducing tillage depth from 28-30 cm to 20-22 cm results in a decrease of the yield with 5.80 q/ha;

- the chisel + rotary harrow variant results in an yield of 60.43 q/ha, with an increase in yield of 2.23 q/ha;

- combinator work ensures an yield of 56.70 q/ha, i.e. 1.50 q/ha below the average of the field;

- working the soil with GD 6.4 (2x) and with a cutter, respectively, results in yields inferior to the other variants of 48.96 q/ha and 48.50 q/ha, respectively, because the works cause larger losses of water compared to other soil works.

Research carried out within the experiment “**Impact of herbicides and of maintenance works on weeding and on yield in grain maize**” led to the following conclusions:

- the number of weeds in the control variant is 223.17 weeds/m²;

- as for the floristic composition, annual weeds share 77.63%, while perennial weeds represent 22.37%;

- annual monocots share 31.10% and they are represented by *Echinochloa crus-galli* (16.73%) and *Setaria glauca* (14.37%), while annual dicots share 46.53% and they are represented by *Amaranthus retroflexus* (11.00%), *Chenopodium album* (9.39%), *Hibiscus trionum* (7.75%), *Poligonum convolvulus* (4.85%);

- perennial weeds are represented by *Sorghum halepense* (2.60%), *Convolvulus arvensis* (11.53%), *Cirsium arvense* (5.95%), and *Sonchus arvensis* (2.29%);

- the degree of weed control is influenced by the weed control method and ranges within 80.22% and 90.44%;

- the herbicide Dual Gold (1.5 l/ha) associated with the herbicides Equip (2 l/ha) or Mistral (1.5 l/ha) result in the most efficient weed control, the weeding degree being 90.44% and 89.83%, respectively;

- the variant 2 mechanical tillage + 2 manual weeding result in a weed control percentage of only 87.19% because of the higher amount of precipitations and of the high percentage of perennial weeds (22.37%);

- grain maize production was in direct correlation with the floristic composition of weed species, with a field average of 57.99 q/ha;

- the herbicide Guardian extra (5 l/ha) associated with the herbicides Equip (2 l/ha) and Mistral (1.5 l/ha), respectively, result in the highest yields, i.e. 68.79 q/ha and 67.46 q/ha, respectively;

- the variant with 2 mechanical weeding + 2 manual weeding result in a production of 64.65 q/ha;

- pre-emergent herbicides Guardian extra (5 l/ha) and Dual Gold (1.5 l/ha), associated with the post-emergent herbicide Oltisan extra (1 l/ha), result, compared with the average of the field, in a insignificant yield increases of 2.81 q/ha and 2.10 q/ha, respectively;

- apparent density changes depending on soil works and soil sample depth: its values differ depending on the period in which one makes the measurements – in spring they are lower and in summer and autumn they are higher at the surface and lower deep down in the soil;

- in the spring of 2002, apparent density between 0 and 10 cm oscillated between 1.19 g/cm³ in the variants tilled with the combinator and the agricultural cutter, while tillage 40-50 cm deep in the soil resulted in an apparent density of 1.42 g/cm³;

- in summer, the values of apparent density are much higher, so that in the variant tilled 20-22 cm + GD 3.2 (2x) 0-10 cm deep in the soil is 1.22 g/cm³ and reaches 1.43 g/cm³, 40-50cm deep in the soil;

- in the no-till variant, 30-40 cm deep in the soil, the values of apparent density are higher than 1.40 g/cm³: in autumn, apparent density in the variants tilled with a cutter, a combinatory and a GD 6.4 (2x), respectively, had values between 1.37 g/cm³ (0-10 cm) and 1.45 g/cm³ (40-50 cm);

- in 2003, the values of apparent density are higher compared to 2002, due to the lower amounts of precipitations in August (4.2 mm);

- 0-10 cm deep in the soil, apparent densities has values between 1.19 g/cm³ (tilled 20-22 cm + GD 3.2 -2x) and 1.27 g/cm³ (chisel + rotary harrow) in spring, between 1.25 g/cm³ (agricultural cutter) and 1.31 g/cm³ (chisel + rotary harrow) in summer, and between 1.28 g/cm³ (agricultural cutter) and 1.33 g/cm³ (tilled 28-30 cm + GD 3.2 -2x and combinator);

- apparent density had the same trend in 2004: 0-20 cm deep in the soil, apparent density had average values between 1.18 g/cm³ and 1.36 g/cm³ at the beginning of vegetation, between 1.25 g/cm³ and 1.35 g/cm³ in summer, and between 1.26 g/cm³ and 1.38 g/cm³ at the end of the vegetation period;

- the values of soil moisture and of soil water reserve are influenced by both soil works and amount of precipitations stored in the ground;

- in 2002, there were the highest values of soil moisture and of water reserve in the soil: in the tilled variant 28-30 cm + GD 3.2 (2X), between 0 and 10 cm soil moisture was 26.20%, and soil water reserve was 1,698 m³/ha, between 0 and 50 cm;

- in summer, soil moisture had much lower values between 16.84% in the agricultural cutter variant (0-40 cm): the soil water reserve was lower compared to that one in spring, reaching only 1,187 m³/ha in the agricultural cutter variant:

- upon harvesting, moisture values were between 19.20% and 23.75%, and those of soil water reserve were between 1,410 m³ and 1,535 m³/ha;

- in the spring of 2003, there were optimal values of both soil moisture and soil water reserve: the moisture values oscillated between 20.72% and 26.20%, while soil water reserve reached values between 1,440 m³/ha and 1,732 m³/ha;

- in summer, moisture values ranged between 17.59% and 22.04% while soil water reserve values were between 1,254 m³/ha and 1,429 m³/ha, respectively;

- the low amounts of precipitations in August (4.2 mm) impacted both soil moisture levels (16.45 -22.45%) and soil water reserve levels, with only 1,176 m³/ha in the variant tilled with agricultural cutters;

- in 2004, the values of soil moisture and of soil water reserve were balanced, reaching normal values;

- in spring, soil moisture oscillated between 21.05% and 26.42%, with soil water reserves between 1,448 m³/ha and 1,692 m³/ha;

- in summer, soil moisture was between 17.30% and 20.68%: soil water reserve was between 1,245 m³/ha and 1,384 m³/ha, i.e. very close values;

- upon harvesting, soil moisture was within normal limits (19-22%), while soil water reserves oscillated between 1,322 m³/ha (agricultural cutter) and 1,520 m³/ha (tilled 28-30 cm + GD 3.2 -2x);

The calculus of economic efficacy was done separately for each of the two experiments, resulting in the following conclusions:

Experiment nr. 1, “**Impact of soil works on weeding and on grain maize yield**”:

- the value of the main yield was directly impacted by the yield per ha and it varied between 1,358 lei/ha and 1,964 lei/ha;

- production expenses were closed, i.e. between 1,280 lei/ha (agricultural cutter) and 1,500 lei/ha (tilled 28-30 cm + GD 3.2 (2x): production costs were between 0.21 lei/kg and 0,27 lei/kg, with the lowest cost level in the variants tilled 28-30 cm + GD 3.2 -2x and chisel + rotary harrow, i.e. 0.21 lei/kg;

- except for the variants GD 6.4 -2x and agricultural cutter, all the other variants allow important increases in yield between 257 lei/ha (combinatory work) and 464 lei/ha (tilled 28-30 cm + GD 3.2 -2x);

- profit rate oscillated between 2.23% and 30.93%, with the variants tilled 20-22 cm + GD 3.2 -2x, chisel + rotary harrow, and tilled 28-30 cm + GD 3.2 -2x) with a profit rate above 20% allowing a new production cycle and a satisfactory income for the farmer.

Experiment nr. 2, “**Impact of herbicides and of maintenance works on weeding and grain maize yield**”:

- the value of the main yield was between 1,682 lei/ha (Dual Gold 1.5 l/ha + Oltisan Extra 1 l/ha) and 1,926 lei/ha (Guardian Extra 5 l/ha + Equip 2 l/ha);

- production expenses are directly impacted by herbicide price and they oscillated between 1,263 lei/ha (Dual Gold 1.5 l/ha + Oltisan Extra 1 l/ha) and 1,510 lei/ha (Guardian Extra 5 l/ha + Mistral 1.5 l/ha): production cost had close values between 0.2 lei/kg and 0.23 lei/kg;

- total profit was between 309 lei/ha and 497 lei/ha, respectively, materialised in a profit rate between 20.49% (Dual Gold 1.5 l/ha + Mistral 1.5 l/ha) and 34.77% (Guardian Extra 5 l/ha and Equip 2 l/ha).

In order to implement the most efficient soil work technologies and weed control technologies to get low-cost high-level yields, we recommend the following:

- cultivating maize in the Banat Plain should take into account the physical and chemical features of the soil, as well as climate conditions, i.e. temperature and precipitations;

- taking into account the high degree of weeding in maize during the first stages of vegetation, we recommend the use of a pre-emergent herbicide (Guardian extra 5 l/ha or Dual Gold 1.5 l/ha), applying during vegetation herbicides depending on the floristic composition of the weed species. For broad-leaves species, we should apply the herbicide Oltisan extra (1 l/ha), and for perennial monocots the herbicides Equip (2 l/ha) or Mistral (1.5 l/ha);

- high content of clay in the soil (40%) requires the implementation of the variants tilled 28-30 cm + GD 3.2 (2 X), a variant with the highest yields;

- an important argument to support our research is also the high values of the main indicators of economic efficiency, values that attest maize cultivation profitability.