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ORIGINAL PAPER

The impact of new technological approaches upon establishing production components and yield randament in *Carthamus tinctorium* L culture

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Abstract

Due to an innovative and multidisciplinary approach, the entire production cycle of bio-diesel would constitute more effective solutions to produce bio-diesel in Romania, which will materialize in future industrial technologies. Research conducted in this respect were aimed at: determining the production potential of safflower cultivated in Romanian conditions and development of technology elements to provide increased yield per unit area and higher the seed oil content, all in terms of efficient economic environments. In these experiments, we tested the impact of foliar fertilization with Bonus K-Energy and of tillage system with billons (compared with the classical system of fertilization and tillage, taken as a control) on the establishment of the production components and on seed oil content. Foliar application of water soluble fertilizer is already a known method of supplementation and enrichment of plant nutrition. The takeover of nutrients through the leaves is considerably faster than that accomplished by roots and this is why the foliar feeding is considered extremely effective. Foliar application of the balanced fertilizers in critical stages of growth substantially promotes the level and quality of agricultural production. For these reasons we introduced this new method of fertilization in the safflower crop technology, by using a new formula, specifically designated to improve crop performances and to increase crop production efficiency of bio-fuels.

By analyzing the results it was found that there is great variability in the production of achenes obtained in the 12 experimental variants and in terms of oil content in the harvested achenes. The production differences are insignificant when using unfertilized variants, regardless of tillage system and cultivated genotype, while in the case of our experimental variants the combination of three technological production factors were tested and the differences were significant and very significant.

Key words*: safflower, tillage system, foliar fertilization, production, oil.*

Introduction

The issue of alternative energy sources came lately into attention, their use becoming more acute due to UE requirements, according to the Kyoto Protocol to The United Nations Framework Convention on Climate Change (1998**)**, to reduce sources of environmental pollution resulted from combustion residues of the fossil fuels (oil, natural gas, charcoal). Besides the global warming, concerns heighten about the energy insecurity because of the increased costs of the fossil fuels, of the prices fluctuations due to geographical and political factors and of the perspective of depleting resources of the fossil fuels in the near future. The efforts for identifying alternative energy sources are thus clearly justified and consequently, at the beginning of the third millennium, mankind has turned toward some solutions in terms of energy alternatives to fossil fuels, which are accessible, in terms of costs, feasibility and sustainability:

- plants, that are primary and sustainable producers of renewable biomass as energy source;
- solar energy (light and heat);
- soil and thermal energy.

From all these forms, the alternative energy sources based on renewable plant biomass are enjoying a privileged position, as they can significantly contribute to alleviate the dangers generated by global warming.

Various sources of plant biomass (sugars from sugarcane and from sugarbeet, starch from cereals and oil from oilseeds) have been evaluated and are already used for producing biofuels.

In the same time we must consider the objections raised inside some debates such as ” food versus fuel”, underlining the negative impact of the large scale cultivation of conventional plants for producing biofuels, by increasing the price of the food products and distorsioning the markets for agri-food products at the global level. Therefore it is not by chance that the researches turned toward plant species that can be cultivated in advantageous economic conditions, on ”marginal”, low biodiversity or abandoned land, with little fertilizers and water, generally on land that is unsuitable to the cultivation of cereals or of other main crops (10).

The safflower (*Carthamus tinctorius* L.), a member of the family Compositae or Asteraceae, is an interesting candidate among the plant species worth to be investigated for being prospective energy biomass producers.

Safflower is a very ancient crop, cultivated as an oilseed, birdseed or for its flowers, used as dye sources and for medicinal purposes, but compared to other oilseed crops it is one of relatively minor importance in world agriculture. The seeds contain 35-50% oil, 15-20% protein and 35-45% hull fraction. The seed oil has gained importance primarily for human nutrition, because it has a nutritional value that is similar to that of olive oil. The standard safflower oil contains about 6 to 8% palmitic acid, 2 to 3% stearic acid, 16 to 20% oleic acid and 71 to 75% linoleic acid, which has therapeutic values. The content of linoleic acid makes safflower oil to rank first in all kinds of edible vegetable oils, but at present the industrial uses of safflower oil are also expanded as a fuel extender, due to environmental concerns raised by the exclusive use of fossil fuels (6). The high content in oleic acid of the safflower oil has promise to use it as a pollutant-reducing diesel fuel additive to reduce smoke and particulate emissions, to reduce acid rains, the greenhouse effect and surface pollution, because safflower oil is virtually free of sulfur, totally lacks fossil carbon dioxide, and is biodegradable (2).

The strategy of producing energy biomass from renewable resources infers its achieving in highly productive agricultural systems, by integrated, multidisciplinary approaches of research and development.

Our researches aimed at establishing the production potential of safflower in the Romanian conditions by introducing new technological elements like the foliar fertilization with Bonus K-Energy and tillage system with billons, meant to insure, compared to the conventional cultivation (1), increased yield per unit area, increased seed oil content, and hence an increased economic efficiency.

Materials and Method

Two varieties of safflower, *CW 1220 and CW 1221*, were sown at the beginning of April, by using 14 kg seeds/ha, to provide a density of 200,000 plants/ha, in the tillage system with billons, compared to the conventional system of cultivation, taken as control.

A three-factorial experimental design was established, according to the tree factors randomized block method [9] as follows:

FACTOR A – tillage system with two variants:

a_1 – classic tillage system;

a_2 – tillage system with billons.

FACTOR B – safflower varieties experimented with two variants:
b_1 – variety CW 1220;
b_2 – variety CW 1221.
FACTOR C – foliar fertilization with Bonus K-Energy (provided from Haifa Chemicals LTD), with three variants:
c_1 – unfertilized;
c_2 – a single application of foliar fertilization with a dose of 5 kg/ha Bonus K-Energy – during branching stalk;
c_3 - application of two foliar fertilization with a dose of 5 kg/ha Bonus K-Energy –in the first phase of branching of the stem and the second stage of initiation of floral button.

In our experimental design the control consisted in an experimental variant in which the classical tillage system was used, respectively without billons and treatments with foliar fertilizer Bonus K-Energy type.

The studied production components were the followings: number of branches/plant, number of calatidia/plant, number of seeds/calatidium/plant, seed mass/ calatidium/plant, all reported to the surface unit.

The time between the two foliar fertilizations has been in our conditions of three weeks.

The first weeding was performed when safflower plants reached 35-40 cm in height, using a Heniker billons machine without the billons moldboard, which allowed the covering of the weeds with ground on the plants row and the maintaining clean, without weeds, of the space between rows.

The physical quality of the seed samples was assessed by determining the hectoliter mass with a Samovar balance and by determining the weight of 1000 seeds with an electronic balance (two repetitions of 500 seeds, randomly sampled). Seed oil content was determined by cold pressing method, exclusively by mechanical means [5, 8].

Comparison of means of the studied parameters was conducted by the Student *t* test for unequal variances. The differences were compared at $P_{5\%}$; $P_{1\%}$ and $P_{0.1\%}$.

Results and Discussions

The production components displayed significant differences from one experiment to another, the maximum values being obtained by combining the three technological factors such as: genotype grown, tillage system and foliar fertilization culture system with Bonus K-Energy.

Following the biometric determinations performed upon the safflower plants, a pronounced variability as regards plant height was recorded, with values as 36 cm in the control variant ($a_1b_1c_1$) and 75 cm in variant $a_2b_2c_3$, in which the foliar fertilizer K- Energy was applied, together with the billon tillage system (Fig. 1). The positive impact of the 2 technological elements on safflower plant growth and development was evident.

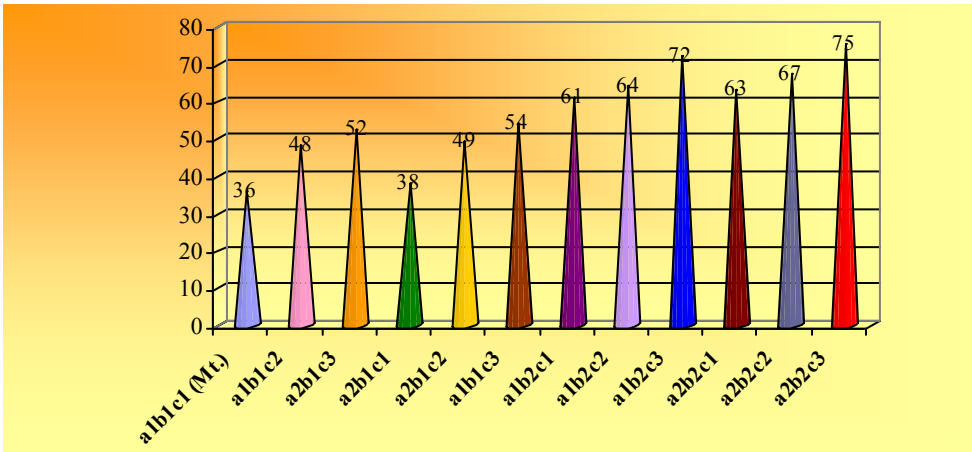

Figure 1. Variation of plant size as a production component, according to the experimental variant

The production components were differently expressed among experimental variants (Fig.2). While there were 7 branches/plant in the $a_1b_1c_1$ control variant, 34 branches/plant were recorded in the $a_2b_2c_3$ in which the effect of both technological elements was tested. The number of calatidia varied between 10 and 37, the maximal number being recorded in the $a_2b_2c_3$ variant, characterized also by the highest number of seeds/calatidium (43). It was obvious the benefic effect of the foliar fertilization on the production components of safflower, their values increasing in direct proportion with the number of the foliar fertilizations.

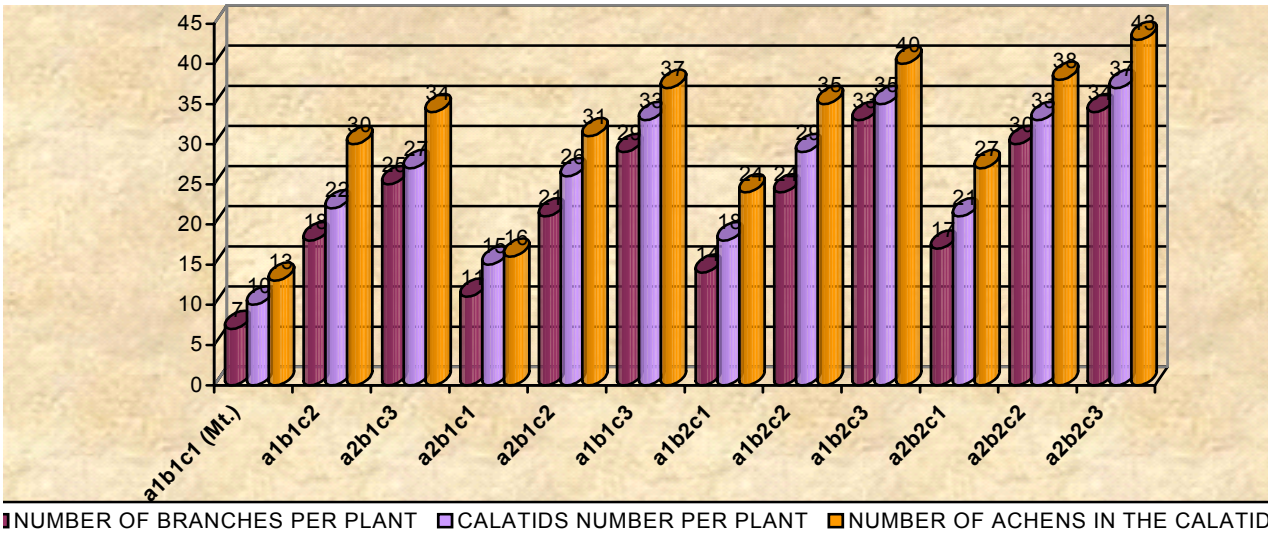

Figure 2. A general presentation of the main production components in safflower culture

The main studied physical indicators that reflect the safflower seed quality were the mass of 1000 seeds (MTS) and the hectoliter mass (HM). As regards the MTS, the values varied between 40 g for the control variant, in which plants were grown in the classic system of working the soil, without applying foliar fertilizers, and 53 g, recorded in the variant that has received two foliar fertilizations with Bonus K-Energy (Fig. 3.).

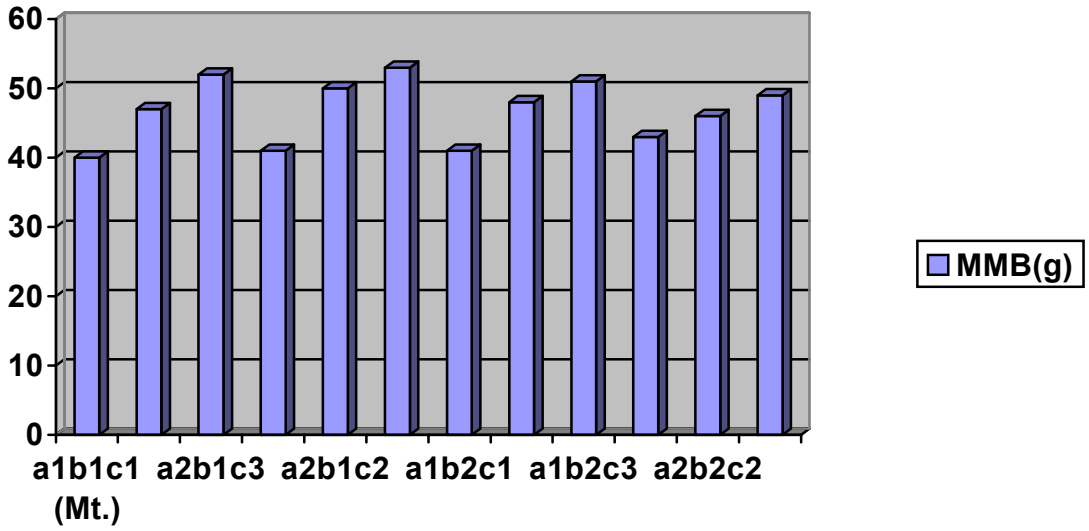

Figure 3. Mass determinations of 1000 safflower seeds.

Regarding the HM values of safflower seeds (Fig. 4.), they varied between 38 kg/hl recorded in the control variant and 59 kg/hl for the experimental variant where the combined effect of the two new technological elements was tested.

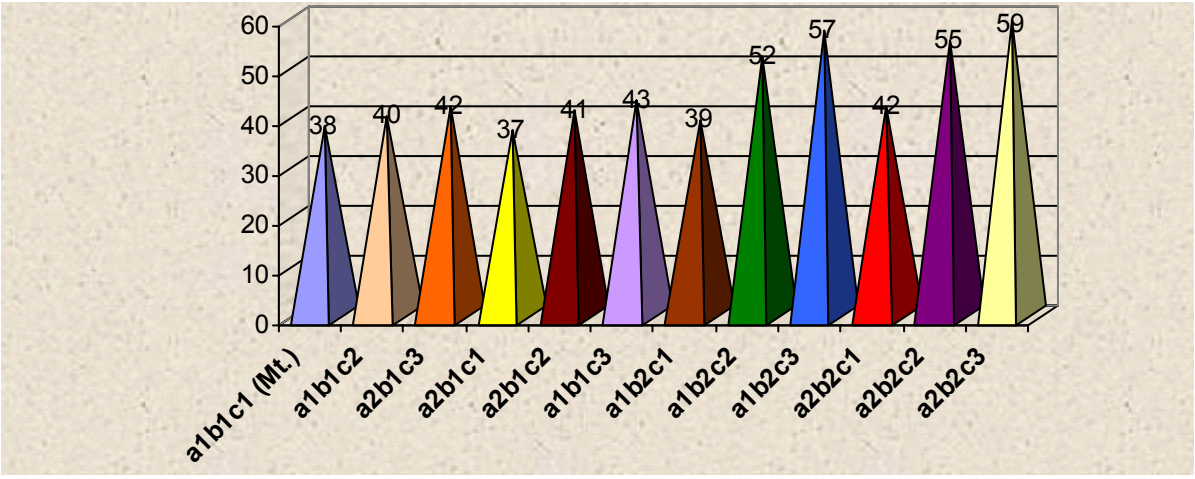

Figure 4. Values of the hectoliter mass of safflower seeds in the tested experimental variants.

The percentage of seed oil (Fig. 5.) recorded a minimum of 26.70% for the control variant, while the rest of the variants recorded values of over 28.25%, the maximal value being recorded in the variant $a_2b_2c_3$, proving that besides the two new technological elements the percentage of seed oil was influenced by the safflower cultivated genotype.

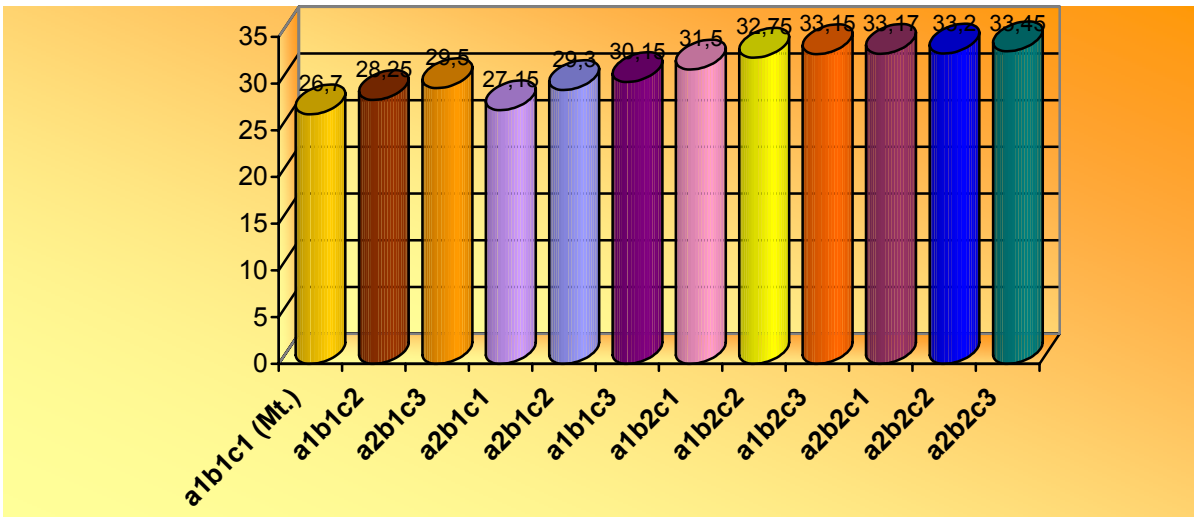

Figure 5. The percentage of safflower seed oil according to the experimental variant

The average production of seeds (Fig. 6) displayed considerable variations from one experiment to another. Thus, compared with the control variant where the achenes yield was of 1670 kg/ha, the rest of the experimental variants offered much higher values.

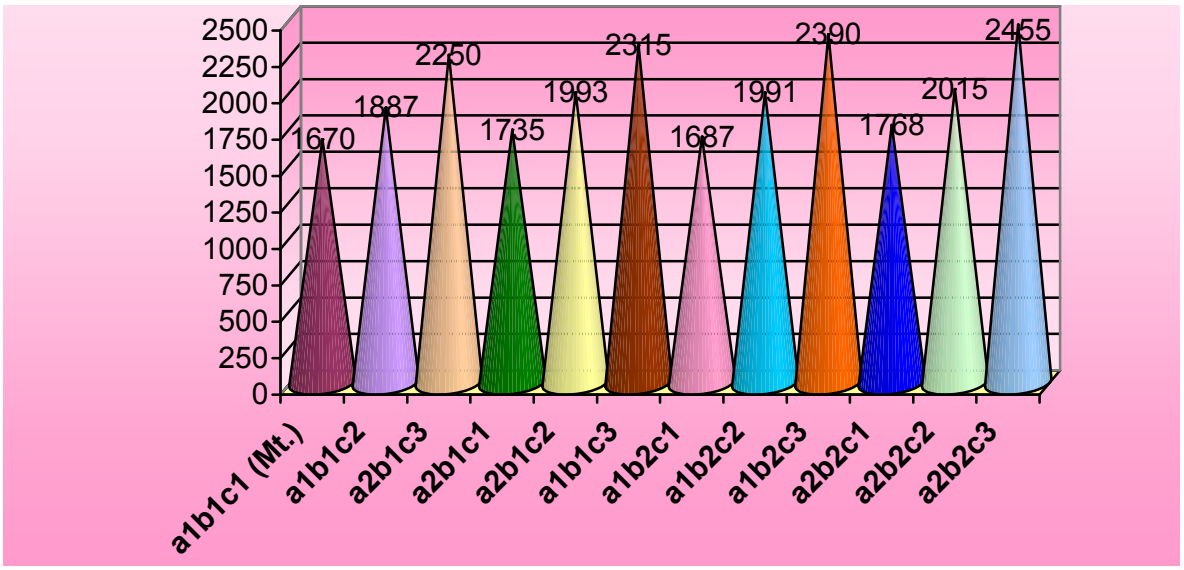

Figure 6. Average production of seeds registered in the safflower experience

The recorded production increases varied between 217 and 345 kg/ha for the variants with the tillage system practiced on billons but with a single foliar fertilization with Bonus K-Energy (in the stage of stem branching), the production increasing with the number of foliar fertilization with values between 580 and 785 kg/ha (Fig.7).

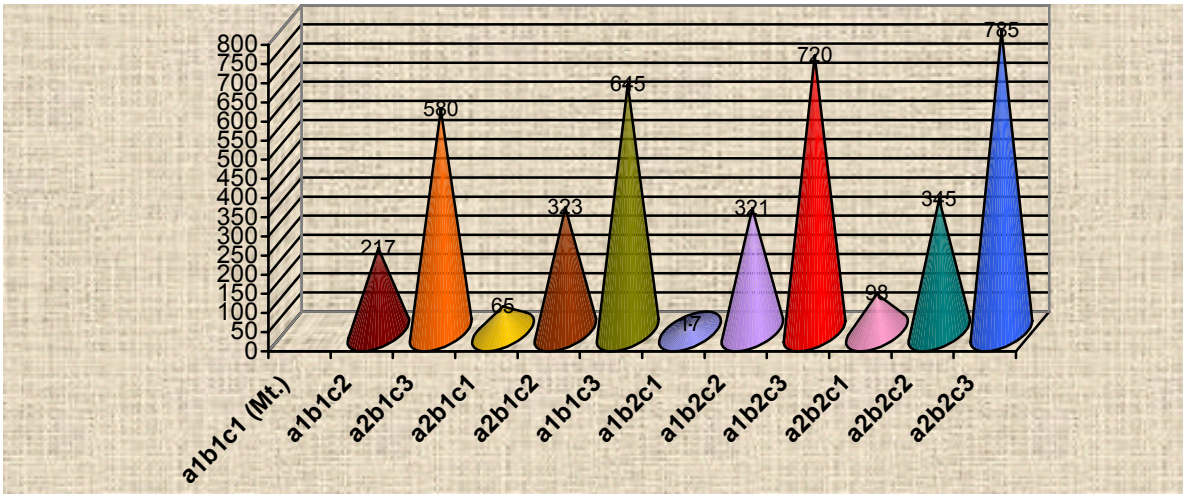

Figure 7. The registered production increases according to the experimental variants

These results proved that the introduction of the two new technological elements in safflower cultivation are essential for achieving higher returns in seed production compared to the traditional technology of cultivation in this species.

The analysis of oil production (Fig. 8) shows that it varied between 463 kg/ha for the variant $a_1b_2c_1$ and 617 kg/ha in experimental variant $a_2b_1c_3$, variant which benefited of two foliar treatments with Bonus K-Energy combined with the tillage system with billons.

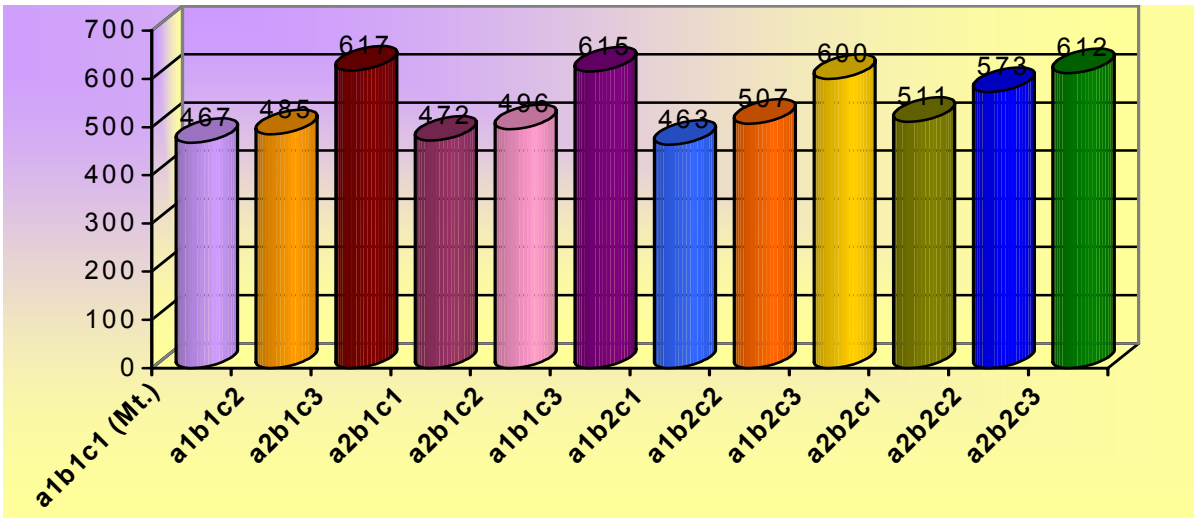

Figure 8. Average production of oil registered in seeds originated from the tested experimental variants.

The results of this analysis show that there is great variability as regards the oil content of the achenes harvested from the 12 experimental variants.

The oil production differences were insignificant in the variants with applied foliar fertilizers, regardless of the tillage system and cultivated genotype, while in the case of experimental variants were the combination of the three technological factors was tested the production displayed significant and very significant differences (Fig. 9).

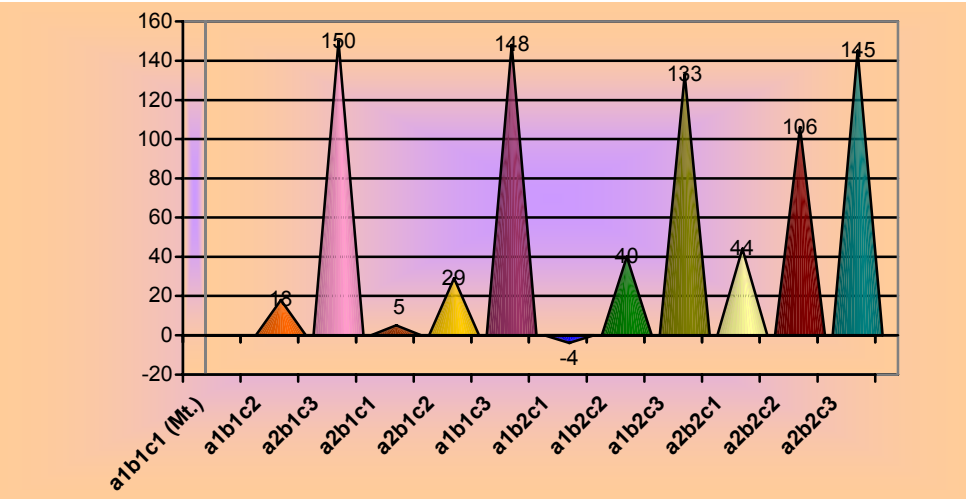

Figure 9. Differences registered in the safflower oil production experience

The production increases in oil content of the safflower seeds varied between 10 kg/ha for the variant $a_1b_1c_2$ and 150 kg/ha in the experimental variant $a_2b_1c_3$. The latter variant benefitted of 2 foliar fertilizations in the conditions of the cultivation in billon tillage system.

Our results demonstrate that in order to achieve higher returns in terms of quality and of economic efficiency in safflower seeds and oil production, the choosing of the most productive cultivars should be combined with those technological elements which require fewer inputs but have a direct positive impact on the final output.

The tillage system with billons is described as being advantageous for the following reasons (7):

- on sloping land, the general orientation of billons according to the contour of the level curves contributes to water retention, promotes its infiltration and reduces the erosion; at the beginning of spring and during the summer torrential rains, the plant residues from the surface of the billon reduce soil erosion;
- billons heat faster in spring,, with approx. 4^0C above the normal value, due to the mass of organic matter left on the soil and to drainage of the exceeding water, allowing earlier sowing; the ground water accumulated in the intervals between billons is used by plants in the first year of vegetation; Also, the work performed annually for making again the billons makes the soil to be lighter, thus increasing its permeability for water [8].

The second new technological link, represented by foliar fertilization of safflower with Bonus K-Energy (10-5-38+3%MgO), is an essential technology link for increasing quantity and quality of harvest.

Two foliar fertilizations were applied, during well established phases of the safflower plants growth process, namely:

- First foliar fertilization was performed by spraying, when safflower plants have reached the stage of branching of the stem, using 5 kg/ha Bonus K-Energy (10-5-38+3%MgO);
- The second foliar spraying was carried out before flowering, when plats were already heavily branched and as such displaying the maximum surface area, using 5 kg/ha Bonus K-Energy (10-5-38+3%MgO);

The foliar application of water soluble fertilizers is already a known method of supplementation and enrichment of plant nutrition. The way of nutrients takeover through the leaves is considerably faster than by the roots and this makes the foliar feeding extremely

effective. Therefore, the foliar application of a balanced fertilizer in critical stages of growth substantially promotes the level and quality of agricultural production.

As reported following the tests with other species, Bonus K-Energy fertilizer (10-5-38+3%MgO) contains a unique balance of macro and micro-nutrients and also special aids for a better adherence to the leaf surface to improve absorption and prolonged action, thus being able to increase the production of sugars and fats in plants [3,4].

Tests and studies undertaken have highlighted a number of advantages of these types of fertilizers, i.e. unlimited capacity for mixing and blending with each other and achieving the most favorable ratio between elements, able to meet the needs of a particular culture, with difference in dynamics throughout the entire growing season.

No other vapor pressure liquid fertilizers proved as compatible and miscible with most chemical plant protection products used in crop protection (herbicides, insecticides and fungicides).

Associations between pesticides create the possibility of concurrent performing of multiple links in the cultivating technology by a single pass of the mechanical aggregates over the ground, thus contributing to the rationalization of the energy consumption.

Foliar fertilization can help mitigate the effect of drought, a phenomenon with increased incidence recently, ensuring the normal functioning of plant nutrition.

By foliar application of fertilizers, it contributes to improving nutrient use coefficient, with values ranging between 6 and 18% of nitrogen and phosphorus 6 and 9% [3,4].

For these reasons we introduced in the technology culture of safflower this new method of fertilization by using the new formula - Bonus K-Energy- specifically designated to improve crop performances, including the increase of plant production efficiency as bio-fuels sources.

Conclusions

- ✓ Bonus K-Energy fertilizer (10-5-38+3MgO) contains a unique balance of macro and micro-nutrients and also special aids for a better adherence to the leaf surface to improve absorption and prolonged action, thus being able to increase the production of sugars and fats in plants;
- ✓ The maximum levels of production components have been obtained by combining the three technological factors such as: genotype (variety), tillage system and foliar fertilization with Bonus K-Energy, registering significant differences among the experimental variants;
- ✓ By determining the main physical indicators of the safflower seeds quality it was demonstrated that the maximum values were recorded in the experimental variants where was tested the combined effect of the two new technological links;
- ✓ The percent of seeds oil showed higher values in variant $a_2b_2c_3$ as a result of the combination of the two new technological links with the most suitable genotype.
- ✓ The effect of introducing the two new technology elements in safflower cultivation (the tillage system with billons and the foliar fertilization) was the increase both in terms of quality and yield, recording significant higher values compared with the experimental variants which used the classical crop technology (maximum values have been recorded in variants where the crop was established on billons and two treatments were applied using the foliar fertilizer Bonus K-Energy);
- ✓ Increased seed and oil production were recorded in variants where the appropriate variety was grown, it was established on billons and two treatments were applied with foliar fertilizer Bonus K-Energy; therefore, in order to achieve higher qualitative and quantitative

benefits in terms of economic efficiency in safflower crop, the combination of those links that require fewer technological inputs but have a direct impact on the final output is necessary.

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