The Taguchi Method Application to Improve the Quality of a Sustainable Process

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Abstract. Taguchi's method has always been a method used to improve the quality of the analyzed processes and products. This research shows an unusual situation, namely the modeling of some parameters, considered technical parameters, in a process that is wanted to be durable by improving the quality process and by ensuring quality using an experimental research method. Modern experimental techniques can be applied in any field and this study reflects the benefits of interacting between the agriculture sustainability principles and the Taguchi's Method application. The experimental method used in this practical study consists of combining engineering techniques with experimental statistical modeling to achieve rapid improvement of quality costs, in fact seeking optimization at the level of existing processes and the main technical parameters. The paper is actually a purely technical research that promotes a technical experiment using the Taguchi method, considered to be an effective method since it allows for rapid achievement of 70 to 90% of the desired optimization of the technical parameters. The missing 10 to 30 percent can be obtained with one or two complementary experiments, limited to 2 to 4 technical parameters that are considered to be the most influential. Applying the Taguchi's Method in the technique and not only, allowed the simultaneous study in the same experiment of the influence factors considered to be the most important in different combinations and, at the same time, determining each factor contribution.

1. Introduction

By analyzing the evolution of agricultural production during the last years, it has been observed that traditional agriculture, still used on a large scale by Romanian farmers, is currently unsatisfactory and insufficient. The production is met at minimum quotas, sometimes even lacks due to drought and low precipitations, the lack of crop irrigation systems or insufficient ones, the human effort made for sustaining the harvest is immense and the quality of the finite product is poor, the soil is degraded, the fertility is low and there are significant economic losses [1].

Taking into consideration the effects of traditional agriculture presented before, is considered the fact that it is the time of applying the sustainable agriculture concept, that represents the future and can be defined by long-term action aimed at overcoming the problems and constraints confronting
conventional agriculture and even society in general in order to ensure economic viability, good environmental status and acceptance of the alternative farming system [1].

Agricultural experiences are all the more necessary as agriculture is more developed and the more numerous and more varied the factors are, because the harmonic intertwining of the factors action produces the maximum productions. Farming experiences are of permanent importance, as new plants varieties and hybrids are developed annually and their production capacity needs to be studied under different technological and environmental conditions. Modern experimental technique allows the simultaneous study, in the same experience of several factors in different combinations and the precise determination of each contribution.

Global corn production is ranked third and this is a basic food source for most people as well as for domestic animals [2]. Respecting clear agronomic principles and the proper crop irrigation, it has been noticed that good harvest can be achieved, but the varied and numerous factors influencing a maize crop are preventing it from reaching maximum gains. There is a close interdependence between the development of research and the progress of agricultural practice, as production reflects the level of research.

In this paper, an experimental agricultural research has been carried out, i.e. the optimization of the main parameters directly influencing a corn crop in an irrigated system in the Baragan Plain, in order to have the desired production and profit.

Modern experimental technique can be applied in any field [3] and this case study reflects the benefits of the interaction between the principles of sustainable agriculture and the application of experimental research methods, respectively the goals are achieved in a very short time, the working method is fast, simple and does not entail costs, and economic losses are non-existent, thus providing an efficient and lasting agricultural management system.

2. Research method
2.1. Experimental methods used in research
As the success of an experiment depends essentially on its preparation, the experimental method used in this case study is the Taguchi Method.

The Taguchi method is effective because it allows 70-90% of the desired optimization of parameters to be reached quickly, the missing 10-30% can be obtained with one or two complementary experiments, limited to 2-4 parameters considered to be those more influential [4, 5].

The experimental method used in this case study is the Taguchi Method, which consists of combining engineering and statistical technologies to achieve rapid improvement in quality costs, seeking optimization at existing processes and key parameters [6].

An experience plan is a series of attempts to determine with a minimal number of attempts and with maximum precision the influences of different parameters in order to optimize the performance of a process or system. Taguchi experience plans use the average and variability of measured values. They use the Signal / Noise ratios, which simultaneously account for: the desired value (signal) to be reached and the undesired variable of this counter-noise value (3) as performance indicators [7]. The use of this performance indicator makes it possible to find "the first shot" to combine the levels of controlled factors that prove to be the least sensitive to noise factors.

2.2. Research objectives defining
In the present case study, two major objectives were sought. The first was to upgrade a 50 ha agricultural land in the Baragan Plain to meet the requirements of agricultural good practice to ensure the need for corn crops and to build the concept of sustainable agriculture. Given that natural resources are found to be ever more limited, quantitative and qualitative, it is only natural to have perspectives that sustain and develop this sector, which is the insurer of the basic needs of human existence.

This first objective has provided with the culture from an agricultural point of view, ie it will result a medium production. In order to have a production close to the maximum value, the main factors influencing a maize harvest must be brought to an optimal value. Traditional methods commonly used
to optimize factors that influence a maize harvest involve soil sampling and practical experiments on it, pedological, chemical, bacteriological, biological research, all of which add up to high costs, increased human effort but also a long time in reaching objectives, for years.

That is why this optimization was carried out by an experimental method, using the Taguchi method, which allowed the simultaneous study of the most important factors in different combinations and, at the same time, the determination of the contribution of each factor [8]. This process was the second objective of this paper, and more precisely, the purpose of applying the experimental method means a profit of 500 € / ha and a production of 14-15 t / ha of corn grain.

The most important factors directly affecting a maize harvest are the plant density due to the fact that it has been shown that greater density is inevitably linked to increased production [9, 10], the watering standard must be applied correctly to ensure the water demand and the distance between rows is also the key to big productions. The amount of fertilizer and the amount of herbicide applied are two factors that if left unchecked or applied correctly, can pollute the aquifer, the hydrological networks in the area and inevitably reach the body of animals.

3. Research method planning

In this scientific paper, it has been decided to optimize the main factors directly affecting a maize harvest on a 50ha plot of the Baragan Plain in order to achieve the desired goals, a profit of 500 € / ha and a production of 14-15 t / ha corn grain.

The most important 5 controllable factors were identified, according to Table 1, the numbering being from A to E as well as the decision to adopt 2 levels.

| No | Controlled factor          | Level 1          | Level 2          |
|----|---------------------------|------------------|------------------|
| A  | Density of plants         | 65.000 pl./ha    | 75.000 pl./ha    |
| B  | The watering standard     | 155 mm/mp        | 175 mm/mp        |
| C  | Distance between rows     | 65 cm            | 70 cm            |
| D  | The amount of fertilizer applied | 500 kg/ha | 700 kg/ha |
| E  | The amount of applied herbicides | 6 l/ha | 8 l/ha |

A complete factorial experience plan has been adopted, resulting in 25 attempts because there are 5 factors at 2 levels.

The superiority of the Taguchi method in relation to the classic method of experience plans results from the use of the performance indicator: Signal / Noise ratio. The signal noise coefficient is an indicator of variability, its use leads to obtaining of products that are robust enough to be able to function / develop accordingly to the conditions of the variations to which they are subjected.

One of the objectives of this study is to achieve a target profit of 500 € / ha, and in Table 2 the value of the Signal / Noise ratio for this measured feature was calculated.

Expression of the Signal / Noise (dB) ratio for a commonly used target criterion is: $S / N = 10 \log \left[\frac{y^2}{s^2} - 1 / n\right]$ (dB) where:

- $y$ = arithmetic mean of measured values;
- $s$ = standard deviation of measured values;
- $n$ = the number of measurements made.

The higher the S / N algebraic value, the lesser the loss will be, resulting a better performance of the product or of the process to be optimized.

Regarding the corn production, the criteria that should be maximized at 14-15 t / ha value, in Table 3 the value of the Signal / Noise ratio was calculated using the following formula: $S / N = -10 \log \left[\frac{(1 / y2) (1 + 3 * (s2 / y2))}{(1 / y2) (1 + 3 * (s2 / y2))}\right]$ (dB), where:

- $y$ = arithmetic average of measured values;
s = standard deviation of measured values; 
n = the number of measurements made.

### Table 2. The value of the Signal / Noise ratio.

| No. tries | CONTROL FACTORS | Measured values | Average | Standard Deviation | S/N dB |
|-----------|-----------------|-----------------|---------|--------------------|--------|
|           | A    | B    | C    | D    | E    | Nr. 1 | Nr. 2 | Nr. 3 |         |        |        |
| 1         | 1    | 1    | 1    | 1    | 1    | 313   | 326   | 329   | 322.67  | 6.94   | 5.02   |
| 2         | 1    | 1    | 1    | 1    | 2    | 320   | 337   | 319   | 325.33  | 8.26   | 5.02   |
| 3         | 1    | 1    | 2    | 2    | 1    | 330   | 345   | 328   | 334.33  | 7.59   | 5.05   |
| 4         | 1    | 2    | 1    | 1    | 1    | 323   | 337   | 319   | 326.33  | 7.72   | 5.03   |
| 5         | 1    | 1    | 2    | 1    | 2    | 346   | 324   | 338   | 336.00  | 9.09   | 5.05   |
| 6         | 2    | 1    | 1    | 1    | 2    | 319   | 325   | 343   | 329.00  | 10.20  | 5.03   |
| 7         | 1    | 1    | 2    | 2    | 1    | 346   | 369   | 357   | 357.33  | 9.39   | 5.11   |
| 8         | 2    | 1    | 2    | 1    | 1    | 386   | 362   | 379   | 375.67  | 10.08  | 5.15   |
| 9         | 1    | 2    | 2    | 1    | 2    | 410   | 427   | 399   | 412.00  | 11.52  | 5.23   |
| 10        | 2    | 2    | 1    | 2    | 1    | 386   | 416   | 420   | 407.33  | 15.17  | 5.22   |
| 11        | 1    | 2    | 2    | 1    | 2    | 437   | 421   | 440   | 432.67  | 8.34   | 5.27   |
| 12        | 2    | 1    | 2    | 1    | 2    | 428   | 400   | 432   | 420.00  | 14.24  | 5.25   |
| 13        | 1    | 2    | 2    | 1    | 2    | 448   | 468   | 451   | 455.67  | 8.81   | 5.32   |
| 14        | 2    | 2    | 1    | 2    | 2    | 478   | 489   | 446   | 471.00  | 18.24  | 5.35   |
| 15        | 2    | 1    | 2    | 1    | 2    | 462   | 449   | 486   | 465.67  | 15.33  | 5.34   |
| 16        | 2    | 2    | 2    | 2    | 1    | 492   | 475   | 499   | 488.67  | 10.08  | 5.38   |
| 17        | 1    | 2    | 1    | 2    | 2    | 501   | 480   | 496   | 492.33  | 8.96   | 5.38   |
| 18        | 2    | 2    | 2    | 2    | 1    | 503   | 486   | 499   | 496.00  | 7.26   | 5.39   |
| 19        | 2    | 1    | 2    | 1    | 1    | 507   | 511   | 498   | 505.33  | 6.66   | 5.41   |
| 20        | 2    | 2    | 1    | 1    | 2    | 489   | 493   | 513   | 498.33  | 10.50  | 5.40   |
| 21        | 1    | 2    | 2    | 2    | 2    | 519   | 501   | 500   | 506.67  | 8.73   | 5.41   |
| 22        | 1    | 2    | 2    | 1    | 2    | 521   | 517   | 511   | 516.33  | 4.11   | 5.43   |
| 23        | 2    | 1    | 2    | 2    | 2    | 531   | 528   | 503   | 520.67  | 12.55  | 5.43   |
| 24        | 2    | 2    | 1    | 2    | 2    | 519   | 526   | 542   | 529.00  | 9.63   | 5.45   |
| 25        | 2    | 2    | 2    | 2    | 2    | 548   | 522   | 515   | 528.33  | 14.20  | 5.45   |
|           |      |      |      |      |      |        |        |        | Overall answer rate | 434.11 | 5.26   |

### Table 3. The value of the Signal / Noise ratio.

| No. tries | CONTROLED FACTORS | Measured values | Average | Standard Deviation | S/N dB |
|-----------|-----------------|-----------------|---------|--------------------|--------|
|           | A    | B    | C    | D    | E    | Nr. 1 | Nr. 2 | Nr. 3 |         |        |        |
| 1         | 1    | 1    | 1    | 1    | 1    | 10    | 10.4  | 10.1  | 10.17   | 0.17   | -0.04  |
| 2         | 1    | 1    | 1    | 1    | 2    | 10.4  | 10.8  | 10.2  | 10.47   | 0.25   | -0.07  |
| 3         | 1    | 1    | 2    | 2    | 1    | 10.5  | 11    | 10.3  | 10.60   | 0.29   | -0.10  |
| 4         | 1    | 2    | 1    | 1    | 1    | 10    | 10.7  | 11.2  | 10.63   | 0.49   | -0.24  |
| 5         | 1    | 1    | 1    | 2    | 1    | 10.3  | 11.1  | 10.7  | 10.70   | 0.33   | -0.12  |
| 6         | 2    | 1    | 1    | 1    | 1    | 10.9  | 11.3  | 11.7  | 11.30   | 0.33   | -0.12  |
| 7         | 1    | 2    | 2    | 1    | 1    | 11.1  | 11.8  | 10.9  | 11.27   | 0.39   | -0.16  |
| 8         | 2    | 1    | 2    | 1    | 1    | 11.7  | 12    | 11.2  | 11.63   | 0.33   | -0.12  |
| 9         | 1    | 2    | 2    | 1    | 2    | 11.3  | 11.8  | 12    | 11.70   | 0.29   | -0.10  |
| 10        | 2    | 1    | 1    | 2    | 1    | 11.7  | 12.4  | 12.1  | 12.07   | 0.29   | -0.10  |
Table 3. The value of the Signal / Noise ratio.

| No. tries | CONTROLED FACTORS | Measured values   | Average | Standard Deviation | S/N dB |
|-----------|-------------------|-------------------|---------|-------------------|--------|
|           | A  | B  | C  | D  | E  | Nr. 1 | Nr. 2 | Nr. 3 |         |        |
| 11        | 2  | 2  | 1  | 1  | 2  | 12.5  | 12.1  | 11.9  | 12.17   | 0.25   | -0.07 |
| 12        | 2  | 1  | 1  | 2  | 1  | 12.4  | 12.8  | 11.9  | 12.37   | 0.37   | -0.15 |
| 13        | 1  | 2  | 2  | 1  | 2  | 12.7  | 12.5  | 13.2  | 12.80   | 0.29   | -0.10 |
| 14        | 2  | 2  | 1  | 2  | 2  | 13.9  | 14.2  | 12.8  | 13.57   | 0.54   | -0.28 |
| 15        | 2  | 1  | 2  | 1  | 2  | 13.7  | 12.9  | 13    | 13.20   | 0.36   | -0.14 |
| 16        | 2  | 2  | 2  | 1  | 1  | 14.1  | 13.6  | 13.4  | 13.70   | 0.29   | -0.10 |
| 17        | 1  | 2  | 1  | 2  | 2  | 13.5  | 13.3  | 14.3  | 13.70   | 0.43   | -0.19 |
| 18        | 2  | 2  | 2  | 1  | 1  | 14.2  | 13.7  | 13.9  | 13.93   | 0.21   | -0.05 |
| 19        | 2  | 1  | 2  | 1  | 1  | 14    | 13.4  | 13.9  | 13.77   | 0.26   | -0.08 |
| 20        | 2  | 2  | 1  | 1  | 2  | 13.8  | 13.5  | 14.1  | 13.80   | 0.24   | -0.07 |
| 21        | 1  | 2  | 2  | 2  | 2  | 14.2  | 14.7  | 13.9  | 14.27   | 0.33   | -0.12 |
| 22        | 1  | 2  | 2  | 1  | 2  | 14.8  | 14.4  | 14.7  | 14.63   | 0.17   | -0.04 |
| 23        | 2  | 1  | 2  | 2  | 2  | 14.4  | 14.8  | 14.9  | 14.70   | 0.22   | -0.06 |
| 24        | 2  | 2  | 1  | 2  | 2  | 14.7  | 14.8  | 15    | 14.83   | 0.12   | -0.02 |
| 25        | 2  | 2  | 2  | 2  | 2  | 15    | 14.8  | 15    | 14.93   | 0.09   | -0.01 |
|           |    |    |    |    |    | Overall answer rate | 12.68 |        | -0.11   |        |        |

To evaluate the average effect of each factor on the noise coefficient, calculate the arithmetic average of all experiments corresponding to the same level, values that are found in Table 4 for the measured profit characteristic and in Table 5 for corn harvest.

Table 4. Profit.

| S / N ratio effect | No. factor | Effect on measured value |
|--------------------|------------|--------------------------|
| Level 1            | Level 2    |                          |
| -0.07              | 0.06       | A                        | -32.63 | 30.12 |
| -0.08              | 0.07       | B                        | -39.38 | 30.94 |
| -0.06              | 0.05       | C                        | -28.89 | 22.70 |
| -0.05              | 0.06       | D                        | -24.70 | 26.75 |
| -0.09              | 0.08       | E                        | -42.55 | 39.28 |

Table 5. Corn harvest.

| S / N ratio effect | No. factor | Effect on measured value |
|--------------------|------------|--------------------------|
| Level 1            | Level 2    |                          |
| -0.01              | 0.01       | A                        | -0.75  | 0.69  |
| 0.01               | -0.01      | B                        | -0.77  | 0.60  |
| -0.02              | 0.02       | C                        | -0.53  | 0.42  |
| 0.00               | 0.00       | D                        | -0.56  | 0.60  |
| -0.01              | 0.01       | E                        | -0.83  | 0.77  |

In order to choose the optimal variant of the studied factors, it was chosen for each one the level which, for each factor, optimizes this criterion and the corresponding S / N ratio.
Table 6. The configurations.

| Controlled factor               | PROFIT  | CORN HARVEST |
|---------------------------------|---------|--------------|
| Optimal level                   | 2       | 2            |
| Contribution                    | 0.06    | 0.01         |
| Plant Density                   |         |              |
| Optimal level                   | 2       | 2            |
| Contribution                    | 0.07    | 0.01         |
| Watering standard               |         |              |
| Optimal level                   | 2       | 1            |
| Contribution                    | 0.07    | 0.01         |
| Distance between rows           |         |              |
| Optimal level                   | 2       | 2            |
| Contribution                    | 0.05    | 0.02         |
| The amount of applied fertilizer|         |              |
| Optimal level                   | 2       | 2            |
| Contribution                    | 0.06    | 0.00         |
| The amount of applied herbicides|         |              |
| Optimal level                   | 2       | 2            |
| Contribution                    | 0.08    | 0.01         |

Analyzing the obtained results by Table 6, the configuration that ensures the achievement of goals is: A2B2C2D2E2.

For the presented case study, the following working model was recommended:

- Plant Density - 75,000 plants / ha;
- Watering standard - 175 mm / square meter;
- Distance between rows - 75 cm;
- Amount of fertilizer applied - 700 kg / ha;
- The amount of applied herbicides - 8 l / ha.

4. Conclusions

The importance of agriculture to humans has been known since ancient times and continues to remain a vital field for humans in nowadays society, a source of food and raw material [11, 12]. The problems encountered in practicing agriculture can be overcome by respecting good agricultural practices, irrigating the right culture and implementing the principles of sustainable agriculture. It describes a system of production capable of maintaining productivity, used by society at infinity and requires the recycling of resources, protecting the environment and being commercially competitive.

However, this system is not fully economically satisfactory for farmers because production and profit do not reach the maximum threshold. The factors that influence a corn crop are numerous and varied, but optimizing the most important factors is the key to rich production and a profitable gain. Using a method of experimental research, the Taguchi Method, it was possible to simultaneously study the five factors in different combinations and it was possible to determine the contribution of each factor. The objective of this optimization process, 14-15 t / ha of corn and a profit of 500 € / ha, was achieved in accordance with the resulting configuration, ie all factors will be at level 2.

In this scientific paper we can see the beneficial effect of the experimental methods in the agricultural field. Traditional methods commonly used to optimize factors that influence a maize harvest involve soil sampling and practical experiments on it, pedological, chemical, bacteriological, biological research, all of which add up to high costs, increased human effort but also a long time in reaching objectives, expanding for years [1].

Noteworthy is that level 2 means a higher profit of 200 € / ha and about 4 t / ha of extra corn grain, and the process has had insignificant costs and has reached notable results in a short amount of time.

Experimental techniques can be applied in any field, and agriculture, due to its development, requires as many experimental research as possible to provide the resources needed for future generations. What we are looking for today, we'll be picking tomorrow!!!
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