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The Influence of the Application Technique and Amount of Liquid Starter Fertilizer on Corn Yield

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Abstract: The aim of this research was to study the impact of application technique and rate of liquid starter fertilizer applied with a novel device on the production of corn. Starter fertilizer was applied in the root system range of freshly germinated plants in the 'belt' and 'point' forms at different quantities (35, 50, 70, and 100 L ha^{-1}), which led to intensive plant growth in the initial stages of development. This adapted system was used for sowing and for application of the liquid starter fertilizer at the same time. The field trial was set up at two sites (two different land types), in the conditions of the natural water regime of the soil during the three vegetation seasons in the period 2016–2018. For this purpose, a prototype of the electronic device EUKU-01 was designed. The starter fertilizer was applied at 5 cm laterally from the row where the sowing was performed and 5 cm below the depth at which the corn seeds were sown. Data were statistically analyzed by two-factor analysis of variance, where the influence of mineral fertilizer treatment and the influence of liquid starter fertilizer treatment were observed as factors. The results showed that the optimal choice of the technique of liquid starter fertilizer application can result in fertilizer savings by 30% without reducing yield.

Keywords: starter fertilizer; application technique; corn; yield; corn planter; an electronic device

1. Introduction

Over the last two decades of the 20th century and the first decade of the 21st century, the average corn yield in the world has increased by 70%. This increase has been the result of constant progress in the breeding and development of increasingly fertile hybrids, application of different types and forms of fertilizers, but also the development of agricultural machines that are used to perform the necessary technological operations [1–3].

Sowing of corn, as a technological phase of production, is one of the most important elements of production technology because it directly affects the achieved yield [4,5]. Shortcomings and irregularities made during sowing can hardly be corrected by other cultural measures, which directly leads to a reduction in yield [6].

The choice of certain types of fertilizer, and especially the methods and techniques of their application, is one of the specific cultural practices that can significantly affect the increase in yield. Fertilizers must be used in a timely way and at sufficient quantities [7–11]. One of the directions for increasing the obtained yields is the introduction of the application of starter fertilizers in the technology of corn production [12–15]. Starter fertilizer is defined as "the insertion of a small amount of nutrients near the place where the seeds will be placed during sowing" [16,17]. The basic fertilizer has the important task of providing the necessary and easily available nutrients (primarily phosphorus) to newly germinated seeds that are very sensitive to its lack or inaccessibility [18]. Over the phenophase of germination and emergence of corn, the nutrients contained in the starter fertilizer have a favorable effect on the rooting, growth and development of the root system of the plant [19–21]. Phosphorus (P) as a nutrient is crucial in the energy processes of the plant, and in synergy with zinc (Zn) directly affects the strong growth and development of roots [20,21].

The root system with a larger mass, volume and number of rootlets develops better in terms of the depth and width of the soil profile and uses the available reserves of nutrients and water in the soil more efficiently. A well-nourished and developed young plant is more tolerant of unfavorable climatic conditions as well as to pathogen attacks [22,23]. Faster, intensive and efficient growth of plants in the initial stages lead to uniform growth of corn plants throughout the field, less weed growth, as well as better moisture storage in the soil [23].

The application of starter fertilizers can be done in different ways depending on the type and chemical composition. When the starter fertilizer is applied together with the seed in the same furrow, there is a possibility of damaging the seed by the fertilizer, which can lead to a decrease in the number of plants and the total yield of corn [24]. Numerous studies show that the most favorable way is the application of starter fertilizer laterally from the row in which the sowing was done and below the depth at which the seed is placed [25–28]. If the starter fertilizer is applied in this way, it is easily accessible to the root of young newly germinated plants and the risk of seed damage is reduced [29]. The fertilizer band must be placed close enough to the seedling to provide nutrients but far enough away to avoid salt or ammonia injury. The most common placement is 5 cm below and 5 cm to the side of the seed row, although distances vary from 3 to 8 cm [29]. Technology of corn production implies the seeding in rows with the distance between the seeds of 15–22 cm [4,6].

The majority of available research usually deals with the starter fertilizer application in 'belt' form at specific distance from the seed. In that form of application, the starter fertilizer was applied close to the plant, as well as away from the plant, in a zone that newly developed root system of corn can be difficult to reach. The novelty of this study is to apply the starter fertilizer only in a zone reachable by the root system. Therefore, the starter fertilizer must be entered intermittently, i.e., 'point' forms. The assumption was made that this form of the application of the starter fertilizer will have unchanging impact on plant growth with a reduced amount of fertilizer applied at the same time. The current research was aimed at studying the impact of application technique and rate of liquid starter fertilizer applied with a novel applicator on the production of corn.

2. Materials and Methods

2.1. Agro-Climatic Conditions

The field trial was set up at two sites. Site 1—the village of Banja (44°18′31.3″ N, 20°38′25″ E), Sumadija district (Republic of Serbia), land type—Smonitza (44°18′31.3″ N, 20°38′25″ E). Site 2—the village of Ratari (44°38′21.3″ N, 20°06′00.6″ E), Belgrade district (Republic of Serbia), land type—Hydromorphous Black Soil (44°38′21.3″ N, 20°06′00.6″ E) [30,31]. At the aforementioned sites, the research was performed in the conditions of the natural water regime of the soil during the three vegetation seasons in the period 2016–2018.

The trials were set up on soil types mentioned above. Soil samples were taken at depths of 0–30 cm and 30–60 cm before basic tillage for each year of study. Methods for chemical analysis of soil are used [32–41] and the results are shown in Table 1.

Table 1. Basic chemical properties of soil at sites 1 and 2.

Year	Site	Depth (cm)	pH		Humus	Total N	$CaCO_3$	Ca	P_2O_5	P	K_2O	K
			H_2O	1 M KCL	(%)				mg/100 g			
2016	1	0–30	6.79	6.08	2.75	0.31	0	0	15.9	6.94	25.7	21.42
		30–60	6.51	5.95	2.69	0.26	0	0	12.3	5.37	24.9	20.75
	2	0–30	6.72	6.42	3.26	3.46	0	0	17.9	7.81	22.1	18.42
		30–60	7.10	6.69	2.77	2.93	0.5	0.2	12.1	5.28	24.9	20.75
2017	1	0–30	6.54	6.14	2.29	0.22	0	0	16.9	7.38	20.9	17.42
		30–60	6.32	5.97	2.35	0.26	0	0	14.3	6.24	19.1	15.92
	2	0–30	6.93	6.31	3.29	2.71	0	0	18.6	8.12	24.4	20.33
		30–60	7.43	6.50	2.71	2.8	0.1	0.04	15.0	6.55	20.5	17.08
2018	1	0–30	7.21	6.31	2.47	0.28	0	0	17.3	7.55	19.9	16.58
		30–60	6.77	6.35	2.46	1.98	0	0	15.1	6.59	21.3	17.75
	2	0–30	6.80	6.79	2.82	3.25	1.2	0.48	16.6	7.25	22.7	18.92
		30–60	7.11	6.85	2.60	2.72	1.6	0.64	14.9	6.51	18.1	15.08

During the research in the experimental variants (Figure 1), conventional mineral fertilizers NPK (N:P:K = 15:15:15) and KAN with 27% N (13.5% NH_4-N and 13.5% NO_3-N) were applied in the following amounts: 0 + 0 kg ha^{-1}; 150 + 100 kg ha^{-1} and 300 + 200 kg ha^{-1}. Based on available research [30,31,42,43], the amount of 100 L ha^{-1} of starting fertilizer was taken as the optimal value. Also, some of the research in the field [38] indicates that, in case of 'belt' form application, corn plants effectively adopt only 70% of the total amount of applied starter fertilizer. Therefore, in this research it was assumed that the same effect will be achieved if 'belt' form amounts were replaced with 30% less than the amounts in 'point' form. In addition to the above, liquid starter fertilizer Starter-A (N:P:K 10:40:10, inorganic, liquid) was applied in the amounts of: 100 L ha^{-1} 'belt' form (i.e., 30% less is 70 L ha^{-1} in 'point' form) and 50 L ha^{-1} 'belt' form (i.e., 30% less is 35 L ha^{-1} in 'point' form). The chemical composition of the applied liquid starter fertilizer is shown in Table 2.

Table 2. The chemical composition of the applied Starter-A fertilizer.

Nutrients	Content
Nitrogen (N)	10%/−1.1% (8% of NH_4-N, 2% of NO_3-N)
Phosphorus (as P_2O_5)	40%/−1.1% (water-soluble)
Potassium (as K_2O)	10%/−1.1% (water-soluble)
Boron (B)	0.02%/−0.004%
Copper (Cu) EDTA	0.015%/−0.003%
Iron (Fe) DTPA	0.04%/−0.008%
Manganese (Mn) EDTA	0.04%/−0.008%
Molybdenum (Mo)	0.008%/−0.0016%
Zink (Zn) EDTA	0.015%/−0.004%
Heavy Metals	**Maximum Content in mg/kg by Dry Weight of Plant Nutrition Products**
Lead (Pb)	100
Cadmium (Cd)	75 mg/kg P_2O_5
Chrome(Cr)	500
Nickel (Ni)	100
Mercury (Hg)	1

2.2. Trial Design and Applied Corn Production Technology

Field trials were carried out using the split-plot method, from experimental plots E1 to E15 (see Figure 1). The size of all plots on which different treatments were applied was 11.2 × 90 m. Each of the plots, from E1 to E15 contains 16 rows.

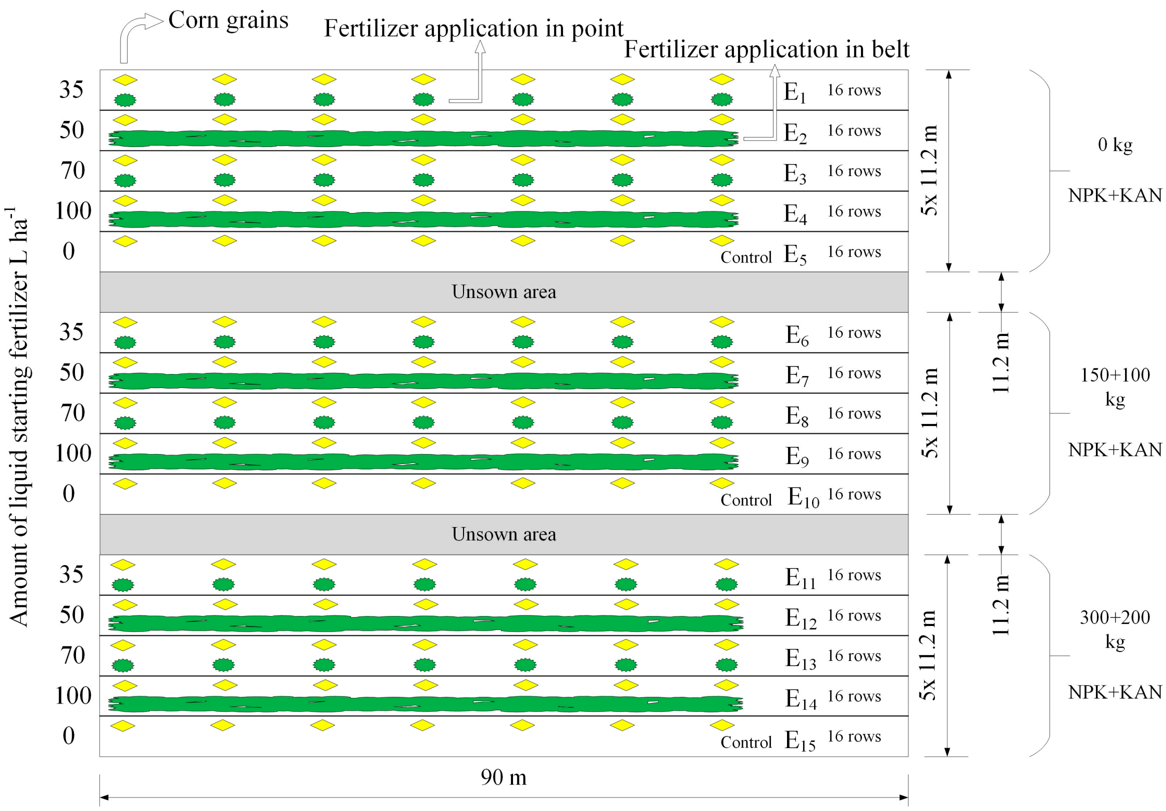

Figure 1. A scheme of the established trial.

In all three years of research, winter wheat was a preceding crop to corn at the aforementioned sites. After the wheat harvest, the plant remains were removed and the stubble was plowed down to a depth of 10–15 cm. In the fall, before plowing (30 cm depth), mineral fertilizers were spread in different amounts. Mineral fertilizer was not applied to the plots from E1 to E5. Moreover, 150 kg ha^{-1} was applied to the plots from E5 to E10, and 300 kg ha^{-1} of NPK fertilizers were applied to the plots E10 to E15. In the spring, immediately before the preparation of the land for sowing, the mineral fertilizer KAN was applied in the amount of 100 kg ha^{-1} to plots E5 to E10 and 200 kg ha^{-1} to plots E10 to E15. After the application of mineral fertilizers, pre-sowing preparation was performed on two swaths using a corn planter and a spike harrow.

Sowing of medium-early corn hybrid ZP 427 (Maize research Institute "Zemun Polje", Belgrade, Republic of Serbia) was performed using an IMT634.454 (Industry of Machinery and Tractors, Belgrade, Republic of Serbia) corn planter with a row spacing of 70 cm and 65,000 ha^{-1} plants. Sowing was done in the second decade of April for all three years of research using the IMT-634.454 corn planter on all plots from E1 to E15. No starter fertilizer was applied to plots E5, E10 and E15 (Control plot). The adapted corn planter was used on the other plots where the liquid starter fertilizer (Starter-A) was applied. Adapting the corn planter and installing the prototype of the electronic device EUKU-01 enabled automatically sub-surface applying of the set doses of liquid starter fertilizer at the same time when sowing corn.

Within the conducted research, using the prototype of the electronic device EUKU-01, two technical systems of automatic subsurface application of liquid starter fertilizer were applied. The fertilizer was applied to the 'point' and 'belt' forms (Figure 2). The application of liquid starter fertilizer in the belt form meant the application of fertilizer in the form of a continuous belt 25 mm wide next to the row in which the corn seeds were sown. The second method of application meant that the liquid starter fertilizer was applied to the point form (diameter r = 25 mm) individually next to each sown seed. In both cases, the liquid starter fertilizer was applied laterally from the row in which the corn seed was sown, at a distance of 5 cm, as well as below the depth of 5 cm at which the corn seed was sown. Two-by-two placement of starter fertilizer was used by Gatiboni [44].

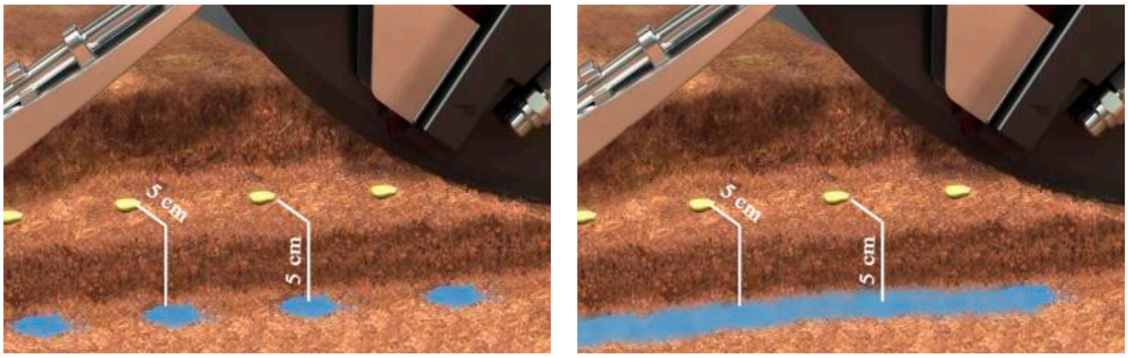

Figure 2. Applied methods of applying liquid starter fertilizer to the point and the belt.

For weed control, a combination of the herbicides Laudis (2 L ha^{-1}) and Callisto (200 g ha^{-1}) was applied to all plots (E1 to E15) in all three years of research at both sites. A tractor in aggregate with an AGS 440 (Agromehanika, Kranj, Republic of Slovenia) sprayer was used for the application of herbicides. Interrow cultivation was performed using an IMT-626.40 (Industry of Machinery and Tractors, Belgrade, Republic of Serbia) interrow cultivator.

The yield of pure corn grain was obtained by separately harvesting each variant and reducing it to 14% grain moisture. Harvesting was performed in the optimal time, with a universal grain harvester CLAAS LEXION 430 (CLASS Group, Harsewinkel, Germany), and before calculating the yield for each trial variant, the water content in the corn grain was determined by drying at 105 °C. Grain yield with the water content of 14% was calculated by the Equation (1):

$$Q = P \times (100 - U)/100 - H \quad (1)$$

2.3. The Working Principle of the Prototype of the Electronic Device EUKU-01

Schematic and basic construction components of the prototype of the electronic device EUKU-01 (Ciga Factory, Aranđelovac, Republic of Serbia) is shown in Figure 3.

During sowing, the sowing apparatus of the corn planter performs individual sowing of corn seeds which after separating from the sowing plate fall into the open sowing furrow. Photoelectric sensors (position 2) placed under the sowing devices; at the moment of falling (movement of the grain from the sowing plate to the sowing furrow) generate signals which are sent to the electronic control unit (position 3) via an electrical conductor (position 5). After receiving the signal from the sensor of the sowing sections, the electronic control unit processes and generates the output signals which control the operation of the electric injectors (opening/closing) (position 1). With an electric pump (position 10), which is located in the tank (position 9), the liquid starter fertilizer is delivered under pressure to the electric injectors.

In the moment of time when it is necessary to apply liquid starter fertilizer, the electronic control unit sends a signal that opens the valve of the electric injector and in that way enables the application of fertilizer (Figure 4). By adjusting the operating parameters of the electronic control unit, it is possible to automatically apply the liquid starter fertilizer in different amounts (L ha^{-1}) and by different application techniques.

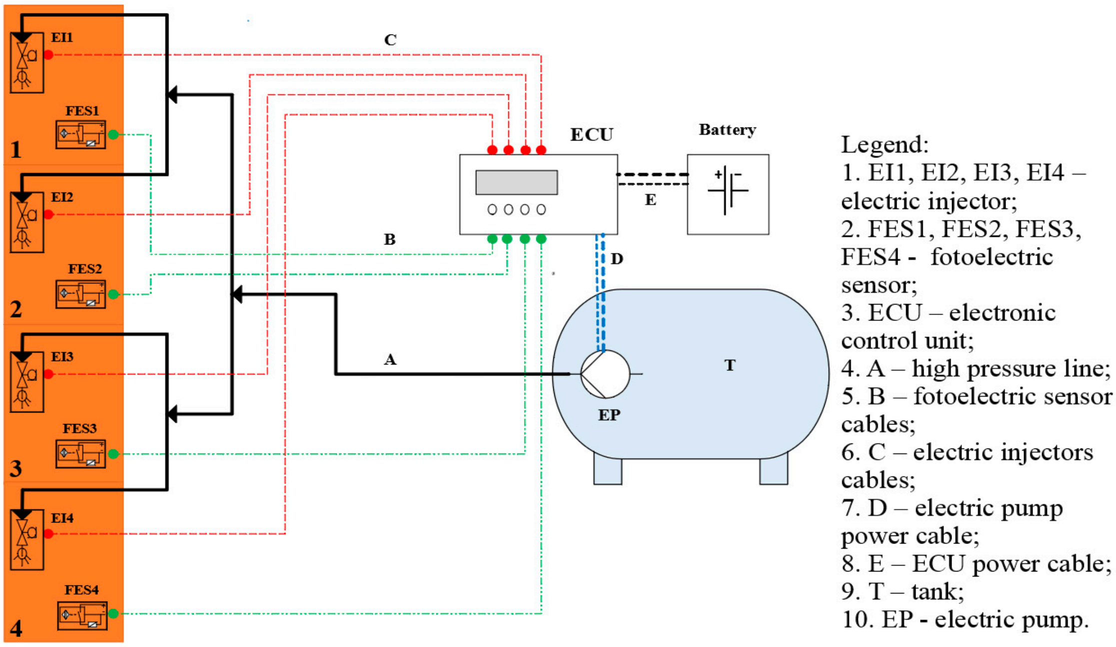

Figure 3. The electronic device EUKU-01 schematic (Source: Original).

Figure 4. Photo electric sensor and the electric injector (Source: Original).

An electric injector with sprayers from the manufacturer 'Lechler' shown in Table 3 was used for the application of the starter fertilizer.

Table 3. Basic parameters of the starter fertilizer application technique.

Starter Fertilizer Application Technique	Sprayer Designation	Working Pressure (bar)	Starter Fertilizer Amount (L ha^{-1})
Application in belt	TR 80-02	3	100
Application in point	ID-120-08	8	70
Application in belt	TR 80-01	3	50
Application in point	ID-120-04	8	35

By applying different application techniques, the amount of starter fertilizer and the amount of mineral fertilizers on plots from E1 to E15, a total of 5 different treatments were obtained, as shown in Table 4.

Table 4. Treatments, amounts and techniques of application of applied fertilizers.

Liquid Starter Fertilizer Treatments	Amounts of Starter Fertilizers (L ha^{-1})	Amounts of Mineral Fertilizers -Sub Treatments (kg ha^{-1})		
	Starter-A	T_0 NPK + KAN (Plots E_1–E_5)	T_1 NPK + KAN (Plots E_6–E_{10})	T_2 NPK + KAN (Plots E_{11}–E_{15})
TT_0–control	0			
TT_1–point form	35			
TT_2–belt form	50	0 + 0	150 + 100	300 + 200
TT_3–point form	70			
TT_4–belt form	100			

2.4. Data Analysis

A set of 90 observations of corn yield, collected and measured during this research was subjected to statistical data analysis. Mean values and standard deviations were calculated and visualized to obtain an insight into the overall trend. Differences between mean values of achieved yields obtained by applying different treatments were analyzed by two-factor analysis of variance and post-hoc Tukey honest significant difference (HSD) test, where the influence of mineral fertilizer treatment and the influence of liquid starter fertilizer treatment were observed as factors.

All calculations, tests and data visualization were carried out using R programming language, v4.0.0, with a significance level of $p = 0.05$.

3. Results

Data on the amount of precipitation and mean monthly air temperatures for the observed sites are shown in Table 5. The conditionally optimal values of precipitation and air temperature [35,36] are presented along with the monthly values for the period 2016–2018.

Table 5. Mean monthly air temperatures, precipitation amounts at sites 1 and 2, conditionally optimal average temperature values and conditionally optimal precipitation amounts.

Year	Locality	April	May	June	July	August	September	Unit
2016	1	60.5 17	138.3 17.4	125.9 22.8	79.1 24.4	124.7 22.1	55 20	mm °C
	2	57.9 20.4	63.4 22.2	156 27.4	34.7 28.7	50.6 27.8	60.1 25.3	mm °C
2017	1	81.2 13.2	77.3 18.5	47.4 24.2	26.5 26.3	46.1 27.3	63.1 19.3	mm °C
	2	45.6 17.7	82.1 23.2	35.8 29.4	37.7 31.1	26.6 32.3	58.2 23.7	mm °C
2018	1	50.5 19.1	88.7 21.1	198.5 21.6	216.1 21.7	6.6 25.2	17.7 20.6	mm °C
	2	39.7 23.1	42.6 26.3	78.7 27.1	89.9 27.4	30.8 30.8	15.2 26.2	mm °C
Conditionally optimal precipitation		50	75	90	100	95	80	mm
Conditionally optimal temperature		15	18.3	20	23.3	22.8	18	°C

Based on the presented values, it can be stated that the amount of precipitation during July and August at both sites was less than conditionally optimal. Lack of water and average temperatures higher than conditionally optimal led to a decrease in yield during the research in relation to the genetic potential of the cultivated corn hybrid ZP 427.

Corn yield measured in this research ranged from 1.86 t ha^{-1} up to 6.50 t ha^{-1}, having overall mean of 3.73 t ha^{-1}. Mean values of yield observed in different years depending on the liquid fertilizer treatment are presented in Table 6.

Table 6. Mean corn yields from all three years of the research, depending on the liquid fertilizer treatment (TT_0–TT_4).

Year	Treatment (t ha^{-1})					
	TT_0	TT_1	TT_2	TT_3	TT_4	Overall Mean
2016	3.73	4.14	4.17	4.42	4.51	4.19
2017	2.75	2.95	2.89	3.21	3.21	3.00
2018	3.70	3.89	3.99	4.29	4.12	4.00
Overall mean	3.39	3.66	3.68	3.97	3.95	3.73

p-values from two factor analysis of variance for treatments TT_0–TT_4 and sub treatments T_0–T_1 are given in Table 7. Statistically significant values are marked with (***) for significance level of 0.001 and (**) for significance level of 0.01. There was no interaction between treatment and sub treatment.

Table 7. *p*-values from two factor analysis of variance for treatments TT_0–TT_4 and sub treatments T_0–T_1.

		p-Values		
	df	2016	2017	2018
Sub treatment	2	1.143×10^{-11} ***	1.644×10^{-5} ***	1.968×10^{-8} ***
Treatment	4	0.00575 **	0.4944	0.1437
Sub treatment × Treatment	8	0.94973	0.9998	0.9982

Note: Statistically significant values are marked with (***) for significance level of 0.001 and (**) for significance level of 0.01.

4. Discussion

Distribution of the yield values is presented with boxplots in Figure 5 (yield for each year), Figure 6 (yield for each treatment with liquid fertilizer) and Figure 7 (yield depending on the treatment with liquid fertilizer by year), showing interquartile range (IQR), minimal, median and maximal values for each data subset presented.

Distribution of the values of the yields obtained by years (Figure 5) revealed lower values in 2017 for all variants of mineral and starter fertilizer application. The low values of the yields obtained were caused by the insufficient amount of precipitation, significantly less than the conditionally optimal ones, which was especially noticeable during July and August 2017 at both sites.

Figure 6 shows the obtained yield values depending on the amount of applied starter fertilizer. There was an increase in the value of yield with an increase in the amount of applied fertilizer TT_1-TT_2-TT_3-TT_4, regardless of the technique of application ('point' or 'belt') of this fertilizer. It was noticed that 'point' form application and smaller doses of starter fertilizer achieved approximate values of corn yield in relation to the 'belt' form application at higher doses. The difference in the amount of applied starter fertilizer between TT_1 and TT_2, as well as between TT_3 and TT_4, was without a statistically significant difference in the values of yields of the observed treatments.

Obtained values of yield depending on the liquid starter fertilizer treatment for the period 2016–2018 are shown in Figure 7. Grain yield per hectare varied statistically significantly depending on the applied fertilization system at both sites during the years of study. The lowest yield values were obtained in treatments where minimal amounts of mineral and starter fertilizers were applied. The sub treatment with mineral fertilizer (T_0, T_1, T_2) gave statistically significant differences in yields in all three years (with values of $p < 0.001$). The highest values of achieved yields at both sites were obtained in the sub treatments with the largest amounts of applied mineral fertilizers T_2 (Table 4). As for the mineral fertilization treatment, subsequent tests (Tukey HSD) showed the presence of a difference in all three sub treatments with p values less than 0.001. The treatment with starter fertilizer showed a statistically significant effect only in 2016 ($p = 0.00575$). Regarding the 2016 liquid fertilizer treatment, there was a statistically significant difference between TT_3 treatment and TT_0 control ($p = 0.01$), and TT_4 and TT_0 control ($p = 0.005$).

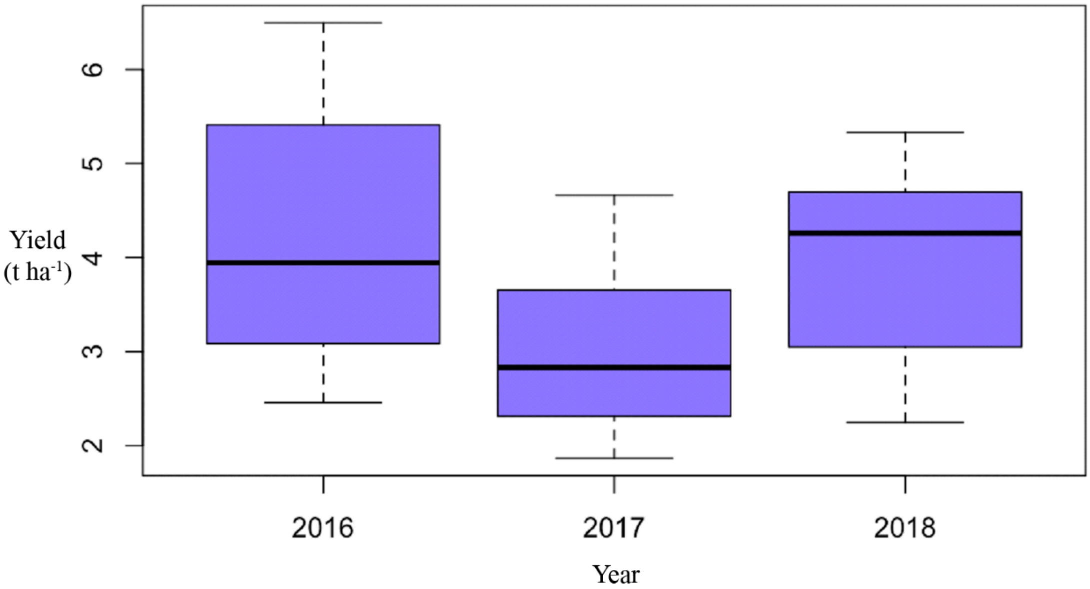

Figure 5. Yield values depending on the year.

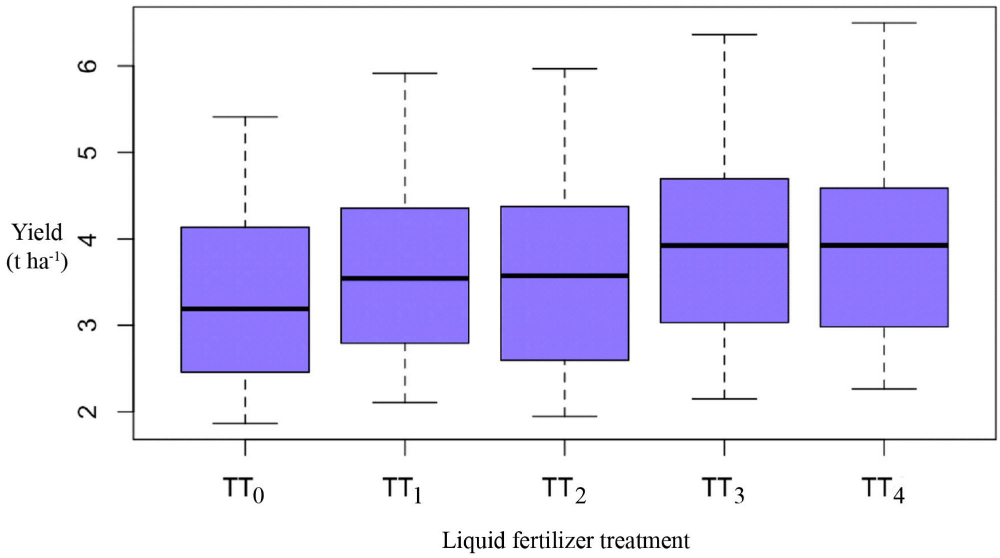

Figure 6. Yield values depending on the amount of applied starter fertilizer.

As expected, the highest overall mean values of yield were obtained in experiments where starter fertilizer was applied along with mineral fertilizer (NPK). These values were recorded in each year of the research on both experimental sites. The increase in corn yield (mean values), in comparison with control plot, was 7.9–17.1%, depending on the applied liquid starter fertilizer treatments (TT_1, TT_2, TT_3 or TT_4). Similar results were reported by [39–41,45–47]. It was noted that, during the all three years of research period, there is no significant differences between overall mean values of yield in treatments TT_1 and TT_2, i.e., TT_3 and TT_4. The highest difference in yield of 2.5% appeared in 2018 between the treatments TT_1 and TT_2. Respectively, the highest difference in yield of 4.1% appeared in 2018 between the treatments TT_3 and TT_4 (see Table 2). Experimental results showed that with the application of 30% less of starter fertilizer in the 'point' form, the achieved values of yield were approximately the same as the values as in the case of applying a larger amount in the 'belt' form.

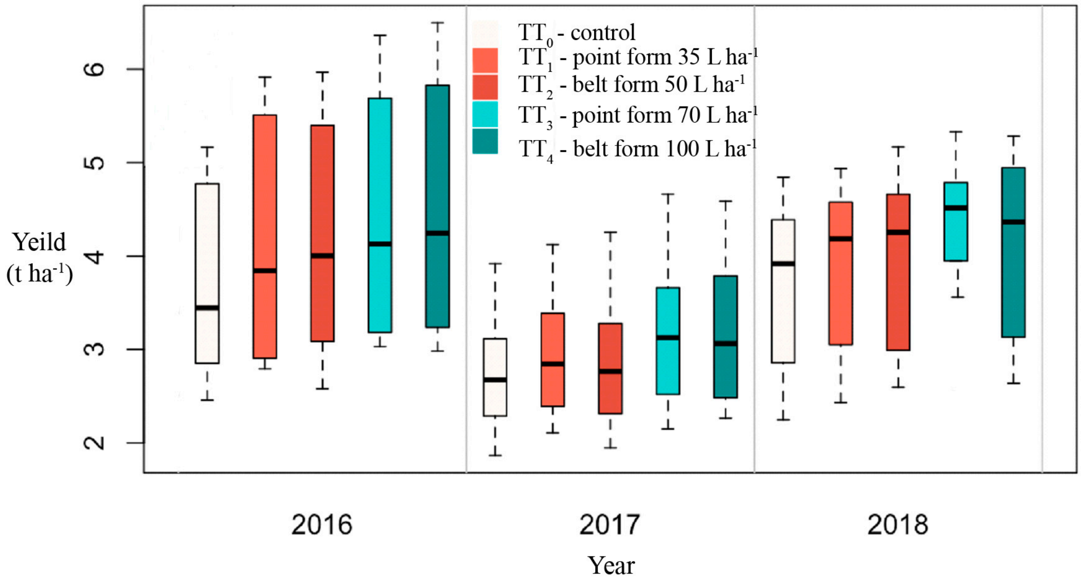

Figure 7. Yield values depending on the liquid starter fertilizer treatment.

5. Conclusions

The impact of application technique and rate of liquid starter fertilizer applied with a novel device on the production of corn was presented in this study. It shows that the yield results were obtained by applying mineral fertilizers (T_0, T_1 and T_2) and different application techniques and amounts of starter fertilizer (TT_0, TT_1, TT_2, TT_3 and TT_4). Starter fertilizer was applied in the root system range of freshly germinated plants in the 'belt' and 'point' forms at different quantities (35, 50, 70, and 100 L ha^{-1}), according to the two-by-two placement method, which led to intensive plant growth in the initial stages of development. The field trial was set up at two sites (two different land types), in the conditions of the natural water regime of the soil during the three vegetation seasons in the period 2016–2018. For this purpose, a prototype of the electronic device EUKU-01 was designed to provide a control of the seeding and fertilizing process. Data were statistically analyzed by two-factor analysis of variance, where the influence of mineral fertilizer treatment and the influence of liquid starter fertilizer treatment were observed as factors.

Corn yield measured in this research ranged from 1.86 t ha^{-1} up to 6.50 t ha^{-1}, having an overall mean of 3.73 t ha^{-1}. The lower values of the yields obtained were in 2017 and were caused by the insufficient amount of precipitation, significantly less than the conditionally optimal ones. The increase in the amount of applied mineral fertilizers, increased the value of yield. Grain yield per hectare varied statistically significantly depending on the applied fertilization system at both sites during all the years of study. The highest overall mean values of yield were obtained in experiments where starter fertilizer was applied along with mineral fertilizer. The increase in corn yield (mean values), in comparison with control plot, was 7.9–17.1%, depending on the applied liquid starter fertilizer treatments. The highest difference in yield of 2.5% appeared in 2018 between the treatments TT_1 and TT_2, i.e., 4.1% in 2018 between the treatments TT_3 and TT_4. Results obtained showed that with the application of 30% less amount of starter fertilizer in the 'point' form, achieved values of yield were approximately the same as the values in the case of applying a larger amount in the 'belt' form. The application of liquid starter fertilizer in the technology of corn production affects the increase in yield. The difference in the achieved values of yield between the aforementioned treatments was not statistically significant in relation to liquid starter fertilizer savings that can be achieved by applying 'point' form. This way, the corn can be produced at lower total production costs.

Further research will be oriented toward the justification of the 'point' form starter fertilizer application on other soil types and other field crops.

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Nomenclature

EUKU-01	electronic device name
NPK	mineral fertilizer (Nitrogen, Phosphorous, Potassium)
KAN	mineral fertilizer (Potassium, Ammonia, Nitrogen)
E1, E2, ... E15	experimental plots
T_0, T_1 and T_2	mineral fertilizer sub treatments
TT_0, TT_1, ... TT_4	starter fertilizer treatments
Q	yield of dry corn grain, with 14% of water, t ha^{-1}
P	yield of raw grain, t ha^{-1}
U	water content in the grain at the time of harvest, %
H	allowed water content in the grain (14%), %

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