Thesis of doctoral (PhD) dissertation

# STUDY OF THE EFFICIENCY OF THE GENOTYPE AND NUTRIENT SUPPLY IN WHITE ASPARAGUS

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## 1. THE HISTORY AND OBJECTIVE OF THE RESEARCH

In these days the number of potential consumers of asparagus (*Asparagus officinalis* L.) is around 1.1 billion people worldwide. Solvent demand is evolving in the market because of the high-quality demand of asparagus spear in every season in Western and Southern Europe. The production of asparagus is concentrated in regions with special features. In Hungary, in addition to the Homokhátság, the growing area has started to increase on the acidic – but with good condition – soil of the Nyírség. But currently we do not have production data from special growing areas, which is the basis of the efficient production. For this reason, it is important to select the most appropriate hybrid to grow, and to apply modern fertilization, irrigation and plant protection techniques in order to provide healthy and fresh spears.

In Hungary, the cultivation of asparagus has more than 100-year-old history, but its consumption is very low (100 g/person/year). The quantities and qualities of exports are good, which is a steady income for the domestic producers. There are no certificated Hungarian hybrids, so the cultivated varieties/hybrids were imported from either Western Europe or the United States. Thus, these imported hybrids were not bred under Hungarian climatic conditions, which could result differences in plant production and genetically determined properties from the registrated data of other ecological conditions. The comparative experiment of different asparagus hybrids provides opportunity to study which hybrids are the most suitable for growing in regional ecological conditions.

Asparagus is a perennial plant that can produce 15-20 years after planting, but in the case of intensive cultivation this time is limited to 10-12 years. Its root system consists of absorption and storage roots. Because of its rhizome the asparagus can overwinter. The storage roots enable the asparagus spear to be economically harvested without the root system being exhausted, so the growing area must always have enough nutrients. Asparagus requires big amount of nutrient that needs constant replacement. For these reasons, it conceived a nutrient supply experiment to be expedient, which allows us to determine the type of supply that yields the best quality and quantity.

The experiments took place in the white asparagus plantation of the University of Debrecen IAREF Research Institute of Nyíregyháza, Based on the results of my research in 2011-2017.

The main objectives of my research are the followings:

- evaluation of the performance of different asparagus genotypes in field experiments in the point of agrotechnical parameters, spear, and quality parameters;
- studying the effects of different nutrient forms (used in asparagus production) on plant parameters, spear yield and nutrient values;
- evaluation of the effect of crop-year to asparagus yield and other plant parameters;
- determination of the correlation between air and soil temperature and the initial development of spears;
- examining the effects of different nutrient types on the physical and chemical properties of the soil of the plantation;
- studying the possibilities of regional technological adaptation in terms of nutrient supply and genotype.

## 2. MATHERIAL AND METHODS

### *2.1. Description of the experimental field*

The soil of the experimental area is in a good cultural condition, its physical structure is sandy loam. The area is evenly flat.

Based on the result of the soil analysis of the experimental field it can be concluded that the soil is almost neutral, which is suitable for asparagus cultivation. The humus content is low and the lime content in the examined layer only occurs in the deeper layers. Nitrate, AL-soluble phosphorus content and AL-soluble potassium content are moderate.

The area is suitable for irrigation, does not contain waterproofing layers, which would be unfavourable for asparagus cultivation. The soil has high water absorption capacity, but its water retention capacity is low. In the experimental area the thickness of the humous layer can reach up to 85 cm, which is ideal for asparagus growing.

### *2.2. Experimental design*

The asparagus experiment was established on May 24, 2011, at 180 cm line width, and the plant stand density was 22,300 plant/hectare. The planting was carried out with a special planting machine. Three asparagus hybrids – *Vitalim*, *Cumulus* and *Grolim* – were planted.

Two experiments were made during the establishment of the plantation. The first experiment is the hybrid comparative experiment where these three hybrids (*Vitalim*, *Cumulus*, *Grolim*) were tested under the same nutrient supply and growing conditions. In the other experiment the parameters of *Grolim* hybrid were measured with different nutrient supplies. In this experiment, we created 36 $m^2$ plots in the field in a four-repetition.

In the comparative experiment of the *Vitalim*, *Cumulus* and *Grolim* hybrids, the applied nutrient was a high-quality cattle manure, which got out in every autumn in the amount of 40 t $ha^{-1}$.

In the case of the studied *Grolim* hybrid four different nutrient treatments were used: control, 20 t $ha^{-1}$ of sheep manure compost (72 kg/plot), 40 t $ha^{-1}$ manure (144 kg/plot) and 40 t $ha^{-1}$ manure fertilizer. The amount of the applied fertilizer – in the case of 36 m2 plots – was 3.24 kg N, 1.80 kg $P_2O_5$ and 1.44 kg $K_2O$.

The dose of the nutrient was determined by *Fehér B-né* (2005), which is in accordance with 240 kg $ha^{-1}$ N, 140 kg $ha^{-1}$ $P_2O_5$ and 240 kg $ha^{-1}$ $K_2O$ active agent.

The same manure was applied in both experiments. The sheep manure compost was also got out during the autumn. The compost is also commercially available (TERRASOL Compost), which is produced and distributed by the University of Debrecen IAREF research Institute of Karcag.

### *2.3. Meteorological data of the experimental field*

The meteorological data (temperature, moisture, soil temperature) were continuously measured from 1 January 2011 until 31 December 2017, with an uMetos measuring station at the beginning, and from 1 April 2016 with an AgroSense meteorological station and substations.

In May 2011, moderate warming was recorded (average daily temperature was 19.1 and 22.9 °C), but little precipitation fell (3 mm), so it was necessary to irrigate the plantation for the initial development of asparagus seedlings. In June, daytime temperatures reached 31.3 °C. In 2011 in terms of temperature data, the average temperature was higher by 1.5 °C, and the amount of fallen precipitation was lower by 110.1 mm in the region than the average for many years.

In 2012, as a result of the spring-summer moderate warming, the asparagus evolved steadily. At the beginning of May, the temperature reached 32 °C. In June, the average temperature varied between 16.9 °C and 26.2 °C. In 2012, the distribution of precipitation was unequal, the amount of moisture was lower than the 30-year average (564.5 mm) by 188.88 mm.

The weather in 2013 can be characterized by extreme parameters. After the early spring snowfall and frost in March, rapid warming occurred. During the harvesting period (from 28/04/2013 to 17/05/2013) the weather was warm and very dry, which continued during the summer. 2013 was unfavourable for asparagus due to the frosts and snowfall in March and the lack of moisture in August.

Based on the 2014 temperature values it can be concluded that the monthly average temperature was higher than the 30-year average every month, except May. On an annual basis, 539.4 mm precipitation was recorded in 2014, its distribution was very unsteady, 148.4 mm of precipitation falling just in July.

2014 was a contradictory year for asparagus production, because the drought in spring reduced the number of harvested spears, but the moisture in summer and the warm average temperature enhanced the vegetative development of the plantation.

In 2015, the temperature was unusually high, in every month – except in May and June – it exceeded the long-term average by 4 °C in January, August and December and around by 2 °C in the rest of the months. In 2015, the lack of precipitation was significant in the region, which had an impact on the yield of spear of 2016 and 2017, as well.

In February and March 2016, the minimum temperature at night sometimes dropped below 0 °C and the daily maximum temperatures were between 5 °C and 15 °C, but after 26 March, rapid and continuous warming occurred. In 2016, the distribution of moisture was balanced.

In 2017, continuous warming was observed since February. Harvesting of asparagus spears started on 9 April because the maximum temperature sometimes reached 25 °C in the second half of March. In 2017 the amount of precipitation was the same to the long-time average (552.8 mm), which ensured the further development of the plantation.

### *2.4. Studied parameters during the research*

We started the harvesting of asparagus in 2013, from the third year after the establishment of the plantation. The harvesting was done in the phenophase of underground spear development (BBCH 01-09). The beginning of the harvest period was determined by the temperature and the earliness of the hybrid. The length of the harvest periods was different, what was determined by the condition of the plantation and the weather conditions. The length of the harvest period was determined by examination of the daily spear yield.

In case, the daily spear yield showed a continuously decrease tendency, and it fluctuated greatly, or in addition, the daily harvested yield was less than 70% of the maximum, at that time the harvest was completed. After harvesting, the washing and cutting of the spears was done on the same day, and also the rating according to the quality (I., II. class and out of classes) were made.

Macro and microelement analysis were measured on the harvested spears in 2017. The content of phosphorus, potassium, magnesium, calcium, manganese, zinc, copper and boron has been studied in order to determine the effect of different hybrids or different nutrient supply on the macro- and microelement content of the spears. The analysis was carried out in the Magyar Kertészeti Szaporítóanyag Kft. laboratory in Újfehértó.

After the harvest period the plant height, shoot diameter and shoot number of asparagus hybrids were measured four times in a year. The studies were carried out by using the asparagus BBCH scale (*Feller et al.,* 2012).

The plant height was measured by a measuring rod from the surface of the ridge to the top of the plant. At the same time as the plant height was measured, the shoot diameter of the stems was measured. The diameter of basal shoots was measured at the base of the stems above the ground using a digital caliper. In addition to these measurements, the shoot number per plant was determined in the experimental plots.

### *2.5. Statistical analysis*

For statistical analysis of yield results, macro- and microelements of spears and morphological data, one and two-factor variance was performed using Microsoft Excel and SPSS 13.0 for Windows. 5% significance level was determined during the run of the Duncan test within the repeated measurement model.

Pearson's correlation method was used by the SPSS program, where the correlation between environmental factors (daily average temperature, daily moisture, daily average soil temperature) and measured parameters (daily spear yield, plant height at the end of the growing season, diameter of the basal shoots, number of shoots per plant, seasonal yield) was determined.

## 3. RESULTS

### 3.1. Effect of genotype on the yield and agronomic parameters of asparagus

#### *3.1.1. Synthetic evaluation of the number of shoots per plant*

The number of shoots per plant increased continuously from the beginning of experiments to 2014 and thereafter the shoot number decreased due to unfavourable weather occurred in 2015. After 2015 further increase could be observed although results obtained in 2017 were only similar to those from 2014 (*Figure 1.*).

Effect of genotype on the shoot number per plant was confirmed in the case of tested hybrids. Differences could be detected between hybrids: the highest shoot numbers were found in *Vitalim* while the least number of shoots were observed in *Grolim,* which hybrid tends to produce larger but fewer shoots. Differences between hybrids were proven to be significant in the majority of crop years.

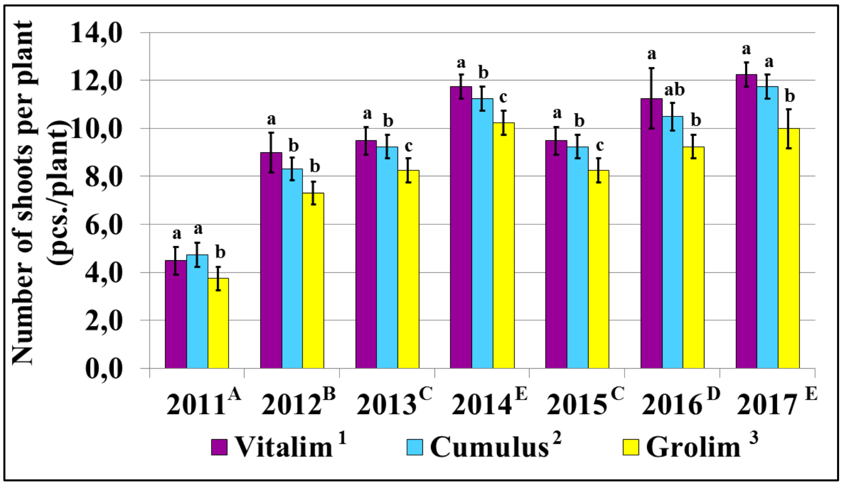


**Figure 1.** Effect of genotype on the shoot number per plant
(a-c – different small letters indicate the significant difference (P< 0.05) between hybrids within a crop year, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-3 - different numbers indicate the significant difference (P< 0.05) between hybrids)
(Nyíregyháza, 2011-2017)

The number of shoots per plant was significantly affected by crop year, and differences could also be detected between hybrids in the average of crop years. According to the results of seven-year evaluation the *Grolim* hybrid produced significantly lower shoot number comparing to *Vitalim* and *Cumulus* hybrids. There was no significant difference between *Vitalim* and *Cumulus* hybrids considering the number of shoots.

The differences between crop years during experiments were statistically justified between the first two years of the plantation (2011, 2012) and subsequent years. This result can be explained by the perennial nature of the asparagus plant. However, there is no significant difference between results of the crop years 2013 and 2015. This may be due to the fact that the unfavourable weather occurred in 2015 greatly hindered the development of the plantation. The results show that as a result of the drought that occurred in 2015, the further development of asparagus rhizomes was weak, and because of water deficiency the buds formed in previous year were not able to develop to shoots. Moreover, fewer buds formed in 2015 because of water and nutrient deficiency, which affect the number of shoots developed in 2016. Even though results were higher in 2016 (9.25, 10.50 and 11.25 shoots per plant in *Grolim, Cumulus* and *Vitalim,* respectively) comparing to 2015 (8.25, 9.25 and 9.5 shoots per plant in *Grolim, Cumulus* and *Vitalim,* respectively) these results were similar those obtained in 2014 (10.25, 11.25 and 11.75 shoots per plant in *Grolim, Cumulus* and *Vitalim,* respectively). The number of shoots increased in 2017 (10.00, 11.75 and 12.75 shoots per plant in *Grolim, Cumulus* and *Vitalim,* respectively) comparing to those obtained in 2014, however differences were not significant statistically.

### *3.1.2. Effect of the genotype on diameter of shoot base*

Evaluating the examined period (*Figure 2.*) for the diameter of shoot base, it can be concluded –similarly similar to the number of shoots per stem - that the parameter increase was continuous until 2014. However, in 2015, during the lack of rainfall, although the shoot base size decreased, there was no such significant decrease as in the case of shoot numbers. In 2016 and 2017, shoot base diameter data showed balanced and increasing tendencies.

While in the case of the number of shoots per plant, the genetically determined differences between the hybrids could be observed from the second year; in the case of the diameter of the shoot base these differences could be detected only from the fourth year. At the peak of the state of development of the plantation in 2017, the difference between the hybrids was clearly visible, mainly in the larger shoot diameter of the *Grolim* asparagus hybrid.

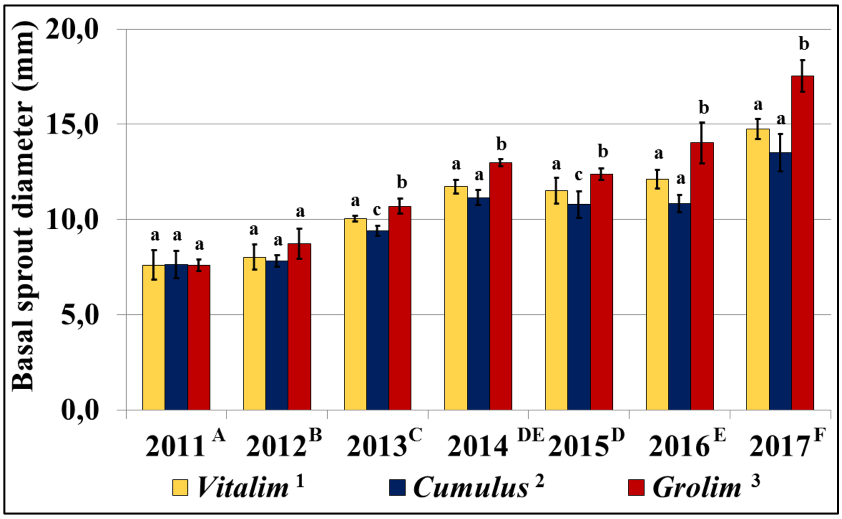


**Figure 2.** Effect of genotype on the diameter of shoot base of asparagus hybrids (a-c – different small letters indicate the significant difference (P< 0.05) between hybrids within a crop year, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-3 - different numbers indicate the significant difference (P< 0.05) between hybrids)

(Nyíregyháza, 2011-2017)

During the variance analysis of the shoot base diameters, we found a statistically verifiable difference between the years and between the hybrids in the average of the years. As a result of the seven-year study, significant differences could be detected between the three hybrids with respect to this parameter. When examining the growth rate of the plantation, we concluded that there is no statistically significant increase in the diameter of shoot base between 2014 and 2015 and 2014-2016, which is closely related to the lack of precipitation in 2015. In the other years, the uniform development of the plantation could be continuously observed according to the manifestation of the genetically determined property.

### *3.1.3. Effect of the crop-year on the height of plant*

Based on the results of the examined period, it can be stated that, in terms of plant height, the lack of precipitation in 2015 interrupted the development, negatively influenced the growth of the plant height (*Figure 3*.). In 2016 and 2017 we again could register growing trend for all three hybrids. In 2011 and 2012, the *Cumulus* hybrid was the highest, followed by the *Vitalim* hybrid, while the *Grolim* hybrid was the shortest. Between 2013 and 2017, *Vitalim* had the highest plant height, followed by the *Cumulus* and the *Grolim* asparagus hybrid.

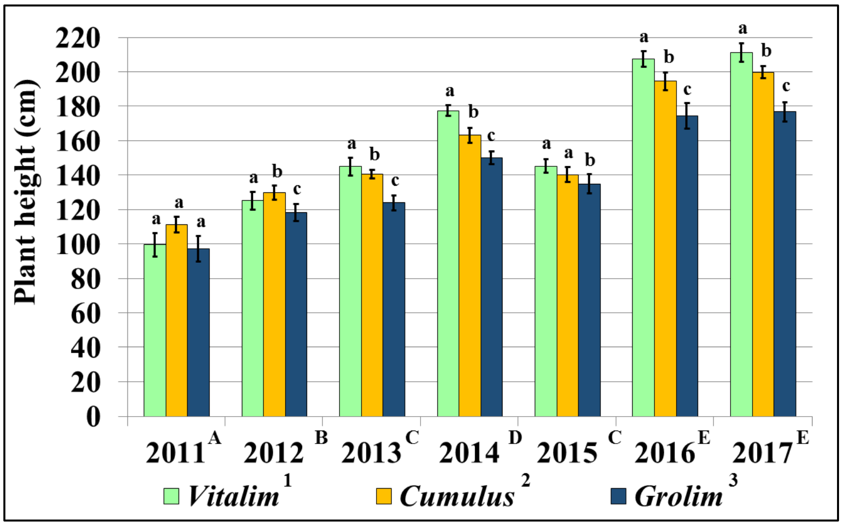


**Figure 3.** Effect of genotype on the height of the tested asparagus hybrids (a-c – different small letters indicate the significant difference (P< 0.05) between hybrids within a crop year, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-3 - different numbers indicate the significant difference (P< 0.05) between hybrids)

(Nyíregyháza, 2011-2017)

In terms of plant height, we found a statistically verifiable difference between the years studied and between the hybrids in the average of the years. As a result of the seven-year study, the *Grolim* asparagus hybrid reached a significantly lower plant height than the *Vitalim* and *Cumulus* hybrids. Moreover, the *Cumulus* hybrid was significantly lower than *Vitalim* hybrid. There were statistically significant differences between the crop-years. Starting from the year of planting (2011), we measured significantly higher plant heights in every year. The results showed that there was no statistically significant difference between 2013 and 2015. The plant height values measured in 2015 declined to the level of the two years earlier. There is no significant difference between 2016 and 2017, which may indicate that the growth rate of hybrids slowed down to the sixth and seventh year after planting, which predicted that the plantation has reached the limit of genetically determined plant height.

### *3.1.4. Effect of crop-year on the yield and quality of the spear*

In the examined period (2013-2017), the highest spear yield was obtained in the *Vitalim* hybrid, while the *Cumulus* hybrid produced less. In *Grolim* we measured the lowest yield. In 2015, the decline in yield was due to the lack of precipitation. In 2016 and 2017, due to the further development of the plantation, it achieved a higher spear yield (*Figure 4.*). The Duncan test showed significant differences (P <0.05) between the hybrids and the years.

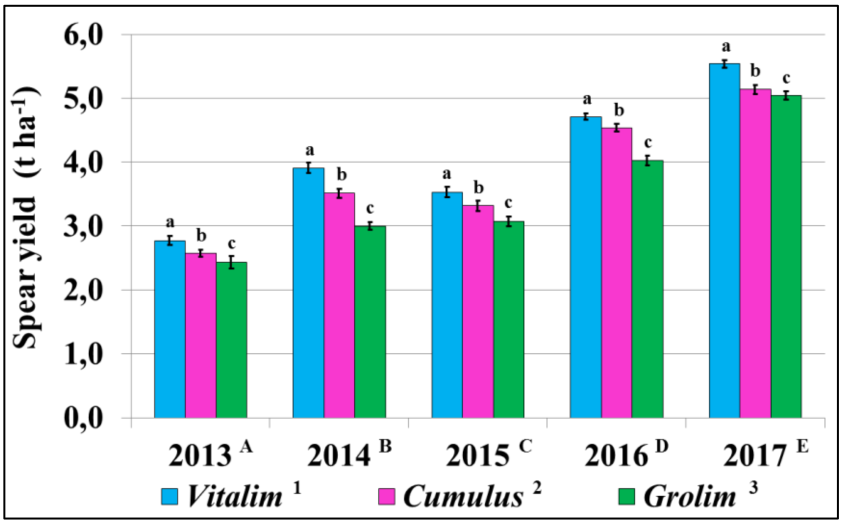


**Figure 4.** Results of the qualified spear yield in the case of tested hybrids (a-c – different small letters indicate the significant difference (P< 0.05) between hybrids within a crop year, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-3 - different numbers indicate the significant difference (P< 0.05) between hybrids)
(Nyíregyháza, 2015-2017)

When evaluating the quality parameters, it can be concluded that there were statistically significant differences between hybrids in the average of crop-years. In 2015, the proportion of Class I spears was significantly lower than in the other years. The quality parameters obtained in 2013 and 2017 were significantly better than the quality values of the other three years evaluated.

### 3.2. Effect of nutrient supply form on agronomic parameters and yield of asparagus

#### *3.2.1. Evaluation of the effect of different nutrient supplementation methods on the shoot number per plant*

Based on the results of the seven-year studies, it can be concluded that the increase of the number of shoots was continuous until 2014, but the steady development of plantation was decrease because of the unfavourable weather in 2015. After 2015, the development of the plantation continued, but by 2017 the shoot number reached the values of 2014. This was observed both studied experiments.

There were still no significant differences between the treatments in point of the number of shoots per plant in 2011. The differences between treatments were increasingly apparent in proportion to the age of the plantation. In the period from 2012 to 2017 the lowest shoot number was detected in the case of the control treatment, followed by the manure, the sheep manure compost and the fertilizer. *Figure 5.* clearly shows that due to the lack of precipitation in 2015 not only the change in the intensity of development can be observed, but in the following years the differences between treatments also increased. Between 2015 and 2017, the high shoot numbers were achieved by fertilization could not be approached even by the treatment of the sheep manure compost. Also, in this period, the sheep manure compost and the treatment with manure showed similar shoot number results. In the case of treatments, it can be observed that the adverse effect of the lack of precipitation in 2015 was dampened by the appropriate nutrient supply. There were significant differences (P <0.05) in the shoot number between the years and between nutrient supply treatments in the average of years. As a result of the seven-year study it can be concluded that the control plots achieved significantly lower shoot numbers (2014-2017) than in the case of the other three applied nutrient supply.

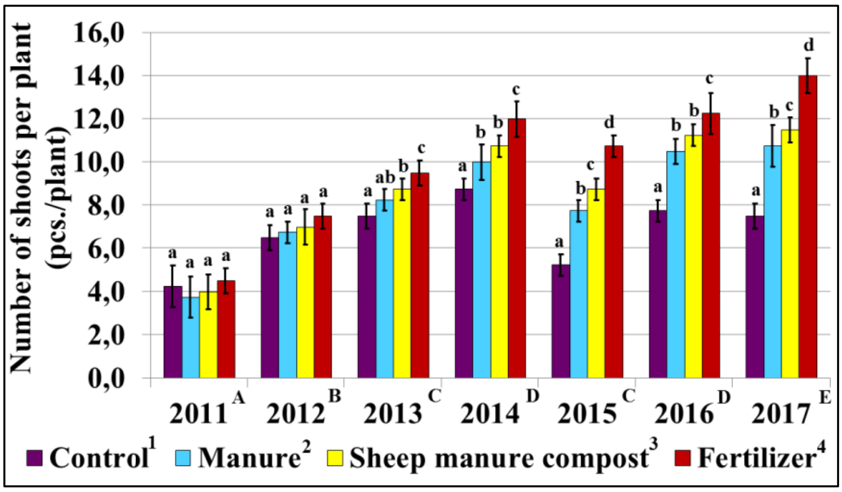


**Figure 5.** Effect of different nutrient supply to the shoot number per plant of *Grolim* asparagus hybrid

(a-d – different small letters indicate the significant difference (P< 0.05) between treatments, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-4 - different numbers indicate the significant difference (P< 0.05) between treatments) (Nyíregyháza, 2011-2017)

The statistical evaluation of the comparison of years shows that there is no significant difference between 2013 and 2015 based on the shoot numbers measured on the last September, due to the unfavourable weather of 2015 the development of the plantation decreased. There is no significant difference between 2014 and 2016 in the case of shoot numbers in the average of treatments.

### *3.2.2. Evaluation of different nutrient supply methods to the diameter of basal shoot*

During the seven-year period there were significant differences between treatments and years (*Figure 6.*). Despite the lack of precipitation in 2015 there was no significant change in the size of the diameter of basal shoot, unlike in the case of the shoot number.

Based on the results of the studied period, it can be concluded that during the 2011-2014 period, the differences between treatments have become more higher; but the lack of moisture in 2015 moderated these differences. In 2016 and 2017 the weather conditions were favourable, so the differences were higher again in the diameter of basal shoots.

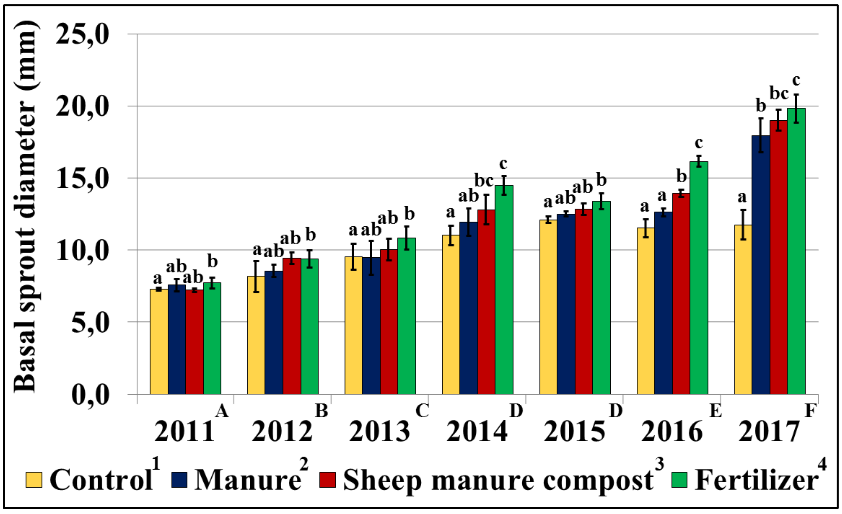


**Figure 6.** Effect of different nutrient supplies on diameter of basal shoots of *Grolim* asparagus hybrid

(a-d – different small letters indicate the significant difference (P< 0.05) between treatments, A-F- different capital letters indicate the significant difference (P< 0.05) between crop years; 1-4 - different numbers indicate the significant difference (P< 0.05) between treatments)

(Nyíregyháza, 2011-2017)

During the variance analysis of the changes of diameter of basal shoots significant (P <0.05) difference was detected between the years and treatments in the average of the years.

Over the years the rate of growing has shown that there are no significant differences between 2014 and 2015 in the case of diameter of basal shoots, which is closely related to the lack of precipitation in 2015. In the rest of the years the steady development of the plantation can be observed continuously in relation to this value.

### *3.2.3. Evaluation of different nutrient supply methods to the plant height*

The plant height of the asparagus increased steadily from the planting up to 2015, when the continuous growth was declined due to the lack of precipitation (*Figure 7.*). After 2015 the plantation developed steadily in terms of plant heights.

We found slight differences between the plant height when compost and fertilizer was used in 2012, but this difference was significant after 2013. Due to the lack of precipitation in 2015 the plant height was reduced and the difference between treatments was also reduced. The appropriated climatic conditions also contributed to the more detected differences between treatments in 2016 and 2017. In 2017 there was significant difference between the control and fertilizer treatment; the differences in plant height of about 20 %.

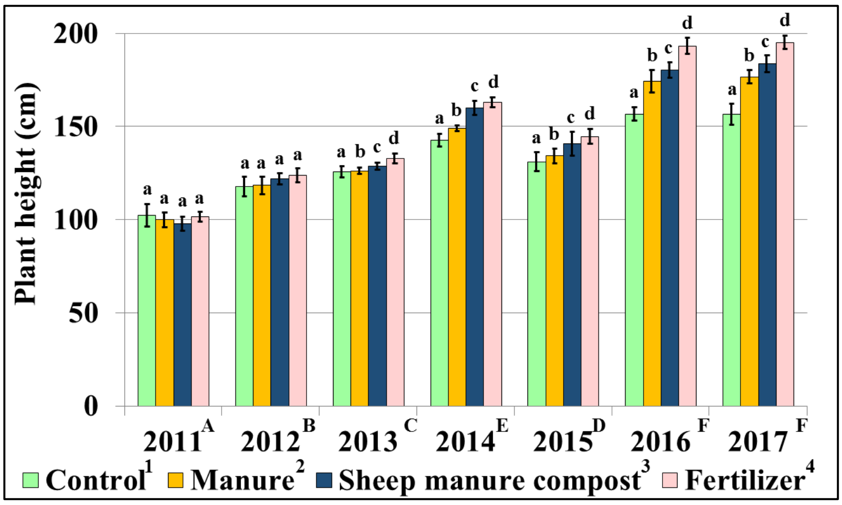


**Figure 7.** Effect of different nutrient supplies on plant height of *Grolim* asparagus hybrid (a-d – different small letters indicate the significant difference (P< 0.05) between treatments, A-F - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-4 - different numbers indicate the significant difference (P< 0.05) between treatments) (Nyíregyháza, 2011-2017)

We found a significant difference in terms of plant height between the years and the average over the years between nutrient supply treatments. Our studies have shown that there was significant difference between all four treatments over the years. There is no difference between the plant height data in 2016 and 2017, suggesting that the plant heights approached the maximum with available nutrients.

### *3.2.4. Evaluation of different nutrient supply methods to the spear yield*

There were significant differences between the effects of different nutrient supplementation methods on spear yield in the research period. The nutrient supply and environmental factors also play a significant role in the development of asparagus spears, but similar results were observed every year. The lowest yield was achieved in the control, but more yield was measured in manure treatment. The highest yields were measured each year in the case of the sheep manure compost and fertilizer treatments (*Figure 8.*). There were significant differences between the treatments and years. Our studies show that the elimination of rhizomes can be prevented with adequate nutrient supplementation and the potential productivity of the plantation can be maintained.

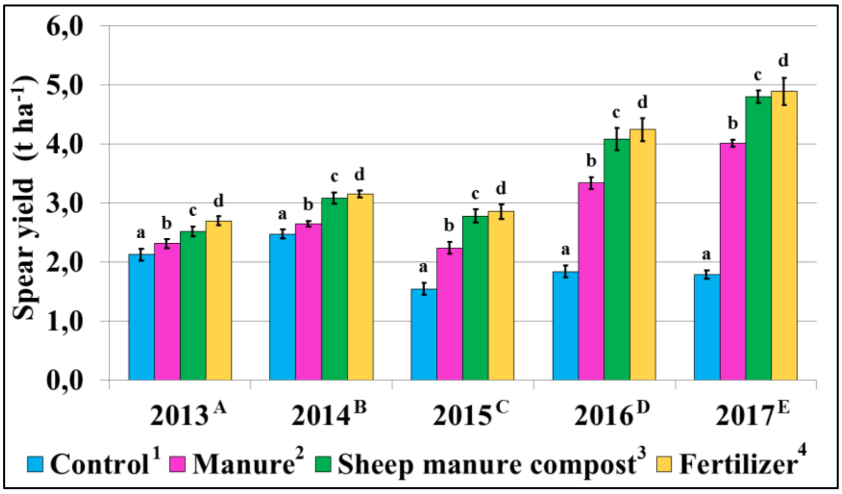


**Figure 8.** Effect of different nutrient supplies on the qualified spear yield of *Grolim* asparagus hybrid

(a-d – different small letters indicate the significant difference (P< 0.05) between treatments, A-E - different capital letters indicate the significant difference (P< 0.05) between crop years; 1-4 - different numbers indicate the significant difference (P< 0.05) between treatments) (Nyíregyháza, 2013-2017)

During the quality classification of asparagus spears we received the weakest spear quality from the control plot, and we measured better quality after the manure treatment. The best quality spears have been developed after sheep manure compost and fertilizer application. Concerning the Duncan test there was no significant differences between the treatments.

It can be concluded that there were no significant differences between 2014 and 2016 in the quality parameters, but in 2017 we harvested significantly higher quality spears than in 2013 and 2015, similar to the hybrid comparative tests, which show the effect of the crop-year.

### 3.3. Pearson Correlation Analysis of major ecological factors and plant parameters

In the Pearson correlation matrix, the daily average temperature of the harvesting period, the daily moisture and the daily average soil temperature values were analysed as environmental factors. The daily spear yield and the plant height (at the end of the growing season), the diameter of basal shoots, the shoot number per plant and the seasonal yield were the base during the correlation.

#### *3.3.1. Pearson Correlation Analysis of major ecological factors and plant parameters for different genotypes*

We found a weak but significant positive correlation between daily mean temperature and daily spear yield (r=0.204) of *Vitalim* hybrid. A similar finding can be made with the soil temperature at a slightly higher correlation coefficient (r=0.310). In terms of plant height, we could show more and closer relationships between the studied parameters. The plant height shows a medium, statistically proven correlation with the air temperature (r=0.456) and the soil temperature (r=0.681) from the weather parameters (from 1 March to 31 May). Only the daily spear yield does not correlate with the plant height; but shows strong positive correlation with the diameter of the basal shoot, shoot number per plant and yield. In the case of the *Vitalim* hybrid, the diameter of basal shoot and air temperature shows r=0.566, closer relationship is shown with the soil temperature (r=0.746). The diameter of shoot showed the strongest positive correlation with the plant height (r=0.879) and yield (r=0.885) from all the studied plant parameters of *Vitalim* hybrid. There was a smaller but close positive correlation (r=0.708) between the diameter of shoot and the shoot number, suggesting the specificity of vegetative development.

In the case of the shoot number, only the influence of soil temperature on the meteorological parameters proved to be decisive (r=0.561). No correlation was found between the number of shoots and the daily yield of the harvesting period, it can be concluded that during the vegetative phase the development of shoots was not influenced by the harvesting period. The plant height (r=0.842), the diameter of shoots (r=0.708) and the yield (r=0.721) show a strong positive correlation with the shoot number. We detected a medium, positive correlation between the yield and the air and soil temperature (r=0.509 and r=0.548, respectively). The yield also shows a strong positive correlation with the plant height and the diameter of shoot, respectively (r=0.894, and r=0.885), while the correlation with the shoot number is lower, but similarly strong (r=0.721).

In the case of the *Cumulus* hybrid, the daily spear yield was affected by temperature values slightly, but statistically proved to be positively influenced (r=0.236 for air temperature, r=0.391 for the soil temperature). In contrast to *Vitalim* hybrid, plant height of *Cumulus* has not proved to be decisive in our studies. None of the meteorological factors showed a correlation with the parameter, but a strong positive correlation (r=0.942) was observed in spear yield. From the studied plant parameters both the shoot number (r=0.743) and the diameter of shoot (r=0.673) can be characterized by weaker but positive correlation. Among the studied hybrids, this hybrid showed the most correlation between the shoot diameter and other parameters. Among the meteorological factors, the air temperature showed stronger negative correlation (r=-0,563) with the diameter of basal shoot, so due to the intensive increase of temperature, the diameter of basal shoot decreased. There was strong, positive correlation between the amount of daily moisture of the harvesting period and the diameter of shoot (r=0.608), which was noticed only in this hybrid. Among the plant parameters, a medium or close positive correlation was observed between the plant height and the number of shoots per plant, as well as between the spear yield and the shoot diameter. The meteorological parameters did not influence the number of shoots per plant but showed a strong positive correlation with other plant parameters (plant height, shoot diameter and yield). The yield showed a strong positive correlation with the studied plant parameters, the highest correlation was found between plant height and yield (r=0.942). Among the meteorological parameters, a negative correlation with air temperature could be statistically proved (r=-0.458).

The daily yield of the harvesting period of *Grolim* hybrid was only influenced by the meteorological parameters statistically in our studies. The air temperature showed a weak positive correlation (r=0.229), but in the case of the soil temperature this correlation was stronger (r=0.396). The plant height did not correlate with meteorological parameters, but similarly to the previously assessed hybrids, there was a close positive correlation with the other vegetative parameters (shoot diameter, number of shoots per plant and yield). In the case of the shoot diameter, we also found a verifiable negative effect of the air temperature with a medium correlation value (r=-0.477). The parameter shows a strong positive correlation with the yield (r=0,947) but shows a weaker correlation with the plant height (r=0,836) and with the shoot number per plant (r=0,604). The shoot number – similarly to the shoot diameter – did not correlate with meteorological data, but it showed a positive correlation with the vegetative parameters, much less than in the previous studied hybrids. The hybrid is genetically characterized by fewer but thicker shoots, which is proven by statistical studies. In terms of yield, the strongest positive correlation (r=0.947) was obtained with the shoot diameter, which proves the specificity of hybrid production. In terms of yield, the diameter of the shoot, the plant height (r=0.869) and the number of shoots per plant in medium (r=0.478) were decisive.

The results of the three studied hybrids showed the effect of air and soil temperature from all measured environmental factors. The daily yield showed a weak positive correlation with both air (r=0.220) and soil temperature (r=0.359). There was weak positive correlation (r=0.307) between the plant height and soil temperature. None of the examined plant parameters showed significant correlation with the daily yield. The plant height was varied with the examined plant parameters, but in each case, it showed a positive correlation [r=0.580 for the shoot diameter; r=0.825 for the shoot number, but the strongest correlation was detected with the yield (r=0.921)]. In terms of yield, the diameter of shoot and the number of shoots per plant showed an almost equal positive correlation (r=0.719 and r=0.723, respectively).

### *3.3.2. Pearson Correlation Analysis of major ecological factors and plant parameters for different nutrient supplies*

Pearson correlation was used to investigate the direction and strength of the relationships between the observed parameters in our nutrient supply experiment based on the results of different nutrient supply forms. In the correlation matrix, similarly to the results of study of the genotype effect, the daily average temperature of the harvesting period, the daily moisture and the daily average soil temperature values were analysed as environmental factors. The daily spear yield, the plant height at the end of the growing season, the diameter of the basal shoot, the number of shoots per plant and the seasonal yield was the base during the correlation. That factors were determined which affected the plant parameters during the evaluation. Pearson's correlation analysis was performed in each nutrient supply method in 2013-2017 years.

There was a weak but significant positive correlation between the daily average temperature and the daily spear yield in the control (r=0.401). Similarly, the soil temperature was slightly correlated with higher correlation coefficient (r=0.418). In the treatment without nutrient supply, there was a moderate or strong negative correlation between daily spear yield and plant height (r=-0,614) and shoot diameter (r=-0,730). We can conclude that the lack of nutrient supply, normal vegetative development has resulted in a decrease in spear yield. From the meteorological factors, the shoot diameter showed a strong negative correlation with the air temperature (r=0.783), in the case of the soil temperature we could not prove the negative effect. In the control treatment, a strong negative correlation (r=-0,730) was found between the shoot diameter and the daily spear yield; in the case of the yield this proven relationship was lower (r=0.506). We can conclude that in the control plots not the developed and healthy shoots gave the yield, but the bigger number of spears. There was a strong, positive correlation between yield and shoot number (r=0.789).

Several correlations were found between the examined parameters during the application of the manure. The daily spear yield was no affected negatively by plant height due to the availability of additional nutrients. Among the meteorological factors, the air and soil temperature showed a moderate positive correlation (r=0.317 and 0.599, respectively) with the daily spear yield. The plant height, like in the control, showed a negative, but lesser correlation with daily spear yield. The plant height showed a strong positive correlation with the other studied plant parameters, the strongest correlation was detected in yield (r=0.937). The negative effect of the air temperature (r=-540) to the shoot diameter was also shown in this treatment. In the case of the shoot diameter, the negative correlation with the daily yield was also observed in this treatment (r=0.460), but less than the control. The plant parameters showed a medium or strong positive correlation with the diameter of the shoot. The number of shoots showed the strongest positive correlation (r=0.813) with the plant height, unlike the values observed in the control. This suggests that nutrient replenishment has contributed significantly to the vegetative growing. The yield showed a strong positive correlation with the measured plant parameters, the most determinatives are the plant height (r=0.937) and the diameter of shoot (r=0.825).

In the case of compost treatment, only the meteorological factors influenced the daily spear yield. We received r=0.297 in the case of air temperature, and r=0.601 between soil temperature and daily spear yield. To the effect of the compost nutrient supply form, close positive correlation was found between the examined plant parameters (plant height, shoot diameter, shoot number per plant and yield). The strongest positive correlation was detected between the yield and plant height (r=0.940), but a clear positive correlation could also be detected with the shoot diameter (r=0.903) and the shoot number (r=0.824).

In the case of fertilizer treatment, we found similar relationships, like in the compost treatment. In relation to the correlations, only the relationship between the air temperature and the number of shoots was different from the previous nutrient supply, and there was a medium negative correlation between the two parameters (r=-0.473). The strongest positive correlations were between the vegetative parameters and the yield, and we found the following correlation values: r=0.949 between the crop and the plant height; r=0.932 between the yield and the shoot diameter; and r=0.827 between the yield and the shoot number.

**3.4. Effect of genotype and nutrient supply on nutritional value parameters of asparagus**

In our research, besides the different agrotechnical parameters of the asparagus, we considered the examination of the nutritional values as an important aspect. Macro and microelement content of white spears was investigated in the last year of harvest (2017). Our aim was also to evaluate the effect of different nutrient supply on the content of macro- and microelements.

***3.4.1. Effect of genotype on macro- and microelements of asparagus***

Among the hybrids, the highest amount of phosphorus is detected in the *Grolim* hybrid (8391.25 mg $kg^{-1}$). Potassium is the highest in the *Vitalim* hybrid (31877.75 mg $kg^{-1}$). The spears of *Vitalim* hybrid contained the highest amount of calcium (3124.00 mg $kg^{-1}$). In our studies, we found the highest magnesium content in the spears of *Vitalim* hybrid (1444.75 mg $kg^{-1}$). The highest amounts of iron were presented in the spears of *Cumulus* (243.25 mg $kg^{-1}$) and *Vitalim* hybrids (236.50 mg $kg^{-1}$). The largest amount of manganese was found in the *Vitalim* hybrid (34,400 mg $kg^{-1}$). Zinc is found in the *Vitalim* hybrid in the highest amount (54.175 mg $kg^{-1}$). Spears of *Grolim* (15.525 mg $kg^{-1}$) and *Vitalim* hybrid (13.575 mg $kg^{-1}$) contain the highest levels of copper. The *Vitalim* hybrid had the best nutritional values between the studied hybrids in terms of mineral and trace element content.

There were significant differences between the asparagus hybrids in phosphorus, potassium, calcium, magnesium, manganese and copper content. The iron content of *Vitalim* and *Cumulus* is significantly higher than the *Grolim* hybrid. Zinc in the *Vitalim* hybrid was significantly higher than in the other two hybrids. There was no significant difference in the boron content between the spears of the genotype.

### *3.4.2. Effect of nutrient supply on macro- and microelements of asparagus*

The highest amount of phosphorus (7477.00 mg $kg^{-1}$), potassium (30995.50 mg $kg^{-1}$), calcium (3403.25 mg $kg^{-1}$), magnesium (1523.75 mg $kg^{-1}$) and copper (16.575 mg $kg^{-1}$) was found in the case of the sheep compost treatment in the nutrient comparative experiment. In contrast, in the case of manure treatment, the lowest macro- and microelement content of phosphorus (6723.00 mg $kg^{-1}$), potassium (26273.00 mg $kg^{-1}$), magnesium (1267.00 mg $kg^{-1}$), manganese (34.700 mg $kg^{-1}$), zinc (47.300 mg $kg^{-1}$), and copper (12.275 mg $kg^{-1}$) was detected. The calcium mineral element is the lowest (2637.00 mg $kg^{-1}$) while iron (331.50 mg $kg^{-1}$), manganese (42.525 mg $kg^{-1}$), zinc (60.300 mg $kg^{-1}$) and boron (21.500 mg $kg^{-1}$) were presented in the highest amount in the control. Summarizing, the highest amount of macro and meso elements of spears were detected from the sheep manure compost treatment. In the case of the microelement, we received the best results from the control, except of the copper.

## 4. NEW SCIENTIFIC RESULTS

1. The minimum soil temperature for asparagus shoot induction on sandy soil was 10 °C under the climatic conditions of Nyírség. The daily spear yield positively affected by the soil temperature until it reached 15 °C.
2. The asparagus spear yield was least influenced by the amount of precipitation during the growing season. The increase in air temperature resulted in a decrease in the growth intensity of the diameter of shoots.
3. The results of the number of shoots per plant shows significant genetic and crop-year effects. After plantation the number of shoots per plant increased by 2.5-2.7 by 2017, depending on the hybrid. The lack of precipitation resulted in a 17.78-19.51% reduction in the number of shoots per plant but did not affect the diameter of the basal shoot because of its genetic determinacy.
4. The seasonal yield was mainly influenced positively by the fertilization. The highest spear yield was measured for fertilizer (2.70-4.89 t $ha^{-1}$) and sheep manure compost (2.52-4.80 t $ha^{-1}$), in the case of manure treatment less yield was obtained (2.31- 4.01 t $ha^{-1}$), the lowest yield was measured in the control (2.12-1.79 t $ha^{-1}$).
5. The vegetative parameters are strongly related to the spear yield. Without nutrient supplementation, the rate of the relation is reduced, there was negative correlation between the shoot diameter and the yield, while there is a positive correlation between the shoot number and yield. In the case of nutrient treatments, there is a positive correlation between spear yield and plant parameters.
6. Based on the results of the macro- and microelement content of the genotypes it can be concluded that the *Vitalim* asparagus hybrid has the highest concentration (K, Ca, Mg, Mn, Zn, B). The nutritional values were positively, while the microelement content was negatively affected by the nutrient supply.

## 5. PRACTICAL USE OF THE RESULTS

1. The length of the harvesting period affected by the soil temperature in our experiments. The optimum soil temperature was found to be between 10-15 °C.
2. The highest spear yield was measured for the *Vitalim* hybrid in each test year (2.78-5.45 t $ha^{-1}$) in the climatic condition of Nyírség.
3. Among the hybrids, the largest shoot diameter was measured for the *Grolim* hybrid. The initial (2012) size (7.59 mm) of shoot diameter reached 17.54 mm by 2017.
4. In the Nyírség conditions, the seasonal spear yield changed between 2.78-5.45 t $ha^{-1}$ in *Vitalim*, 2.58-5.14 t $ha^{-1}$ in *Cumulus*, and the 2.43-5.05 t $ha^{-1}$ in *Grolim* hybrid.
5. Among the nutrient supplementation methods, we measured the highest spear yield in the treatment of fertilizer (4.80 t $ha^{-1}$) and compost (4.89 t $ha^{-1}$) application.
6. Classification of spears was influenced by different nutrient methods. We found the weakest quality in the control in every examined year (79-81%). The rate of the spears belong to class I was the highest in the treatment of fertilizer (85-88%), sheep manure compost (83-84%) and manure treatment (81-83%), which resulted in a lower rate of good quality of asparagus spears.
7. After the unfavourable year (2015), in the case of a non-nutrient plots, the vegetative and crop parameters were reduced, while in the case of nutrient replenishment the parameters increased during the examined period of the plantation, which suggests the importance of nutrient supply.

# 6. PUBLICATIONS IN THE TOPIC OF THEDISSERTATION

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Nyilvántartási szám: DEENK/332/2018.PL
Tárgy: PhD Publikációs Lista

Jelölt: Erdős Zsuzsa
Neptun kód: YQCNEQ
Doktori Iskola: Kerpely Kálmán Doktori Iskola
MTMT azonosító: 10045306

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