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Effect of sowing time and fertilizer on the protein content, seed- and protein yield of dry beans (*Phaseolus vulgaris* L.)

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Effect of sowing time and fertilizer on the protein content, seed- and protein yield of dry beans (*Phaseolus vulgaris* L.)

Abstract: The beans are an important protein source. In our three-year experiment, we examined the effect of sowing times and fertilizer doses on the protein content of the seed and the protein yield per hectare. We set up the trial on sandy soil, without irrigation, in four replications with 300,000 plant per hectare in Nyíregyháza (Hungary). 10 m^2 plots were in randomized blocks, with three sowing times (in normal time, earlier and later) and three fertilizer doses (0 %; 100 % and 150 %). We measured the nitrogen content of the seed with a Vario-Max CNS analyzer. The protein contents were counted from that value. The data were evaluated with Excel and SPSS 22.0. In examined 3 years the largest protein contents were in the third sowing time with 150 % fertilizer dose. In 2016-17 the yield and protein yield of the third sowing time were larger than the value of earlier sowing times for all three fertilizer doses. This was because of favourable weather. The significant effect of increased fertilizer doses was not proved at a given sowing time. If the weather was favourable, then the significant relationship among the sowing time, protein content, yield, and protein yield was positive and strong.

Key words: bean, protein, yield, sowing time, fertilizer

Učinek časa setve in gnojenja na vsebnost beljakovin v semenu in pridelku beljakovin v suhem fižolu (*Phaseolus vulgaris* L.)

Izvleček: Fižol je pomben vir beljakovin. V triletnem poskusu smo preučevali učinek časa setve in odmerka gnojil na vsebnost beljakovin v semenu in na pridelek beljakovin na hektar. Poskus je bil zasnovan na peščenih tleh, brez namakanja, v štirih ponovitvah, s 300,000 semeni na hektar, v Nyíregyházi (Madžarska). 10 m^2 velike ploskve so bile razporejene v naključnih blokih, s tremi časovi setve (normalen čas, zgodnja in pozna setev) in s tremi odmerki gnojil (0 %; 100 % in 150 %). Vsebnost dušika v semenih je bila izmerjena z Vario-Max CNS analizatorjem. Vsebnosti beljakovin so bile izračunane iz teh vrednosti. Podatki so bili ovrednoteni z Excelom in SPSS 22.0. V treh letih poskusa je bila ugotovljena največja vsebnost beljakovin v tretjem času setve in pri odmerku gnojil 150 %. V letih 2016-17 sta bila pridelek in pridelek beljakovin v tretjem obdobju setve večja kot pri zgodnji setvi, pri vseh odmerkih gnojil. Vzrok za to je bilo ugodno vreme. Značilen učinek povečanja odmerka gnojil ni bil ugotovljen pri nobenem času setve. V primeru ugodnega vremena je bila značilna in močna povezava med časom setve, vsebnostjo beljakovin, pridelkom in pridelkom beljakovin.

Ključne besede: fižol, beljakovine, pridelek, čas setve, gnojila

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1 INTRODUCTION

Ensuring the protein requirement is an important aspect of both human nutrition and animal feeding. Legumes have 2-3 x more protein than cereals (Siddiq et al., 2010). The protein content of beans seed is 24-28 % (Chávez-Mendoza et al., 2019; Kahraman & Onder, 2013; Bildirici & Oral 2020). The ratio of protein and fiber is also important (Brick et al., 2022). Bean flour is excellent for supplementing lysine-poor wheat flours, improving the ratio of essential amino acids in bread while reducing carbohydrate content, thus improving the nutritional value of the bread produced (Hoxha, 2020; Singh, 2017). Its flour can also play a major role in the production of gluten-free products (Siddiq, 2010). In addition, the ethical question of the use of animal proteins and their effect on health is gaining more and more space. Bean protein is also used in the production of vegetable meats, muffins, mayonnaise and yogurt (Ferreira, 2022).

Grown of dry beans are strongly affected by climate change. In our country this appears with extremely high summer temperatures occurring, as well as the rather extreme distribution and intensity of precipitation.

In terms of consumption, it is important how much protein a unit of food contains, and in terms of production, how much protein we can produce from a unit of area. This gives one aspect of the economy.

Based on the role of beans in nutrition, we considered it important to investigate the effect of fertilizer dose and sowing time on the protein content of seed beans and the protein yield per hectare. Beans are an ecologically sensitive crop. With this experiment, we get an answer, to how we can reduce the effects of the extreme weather conditions experienced nowadays with the technological elements mentioned above.

In this publication, we present the response of seed protein content and protein yield of the Start pearl bean variety to sowing time and fertilizer treatments.

1.1 LITERATURE REVIEW

Factors affecting the protein content are the variety and the weather, soil, irrigation and through these, fertilization and sowing time (Singh, 2017; Bildirici & Oral, 2020). Barampama & Simards (1993) in their experiment statistically confirmed that the variety and locality affect the nutrient content of the plant. The effect of sowing time and fertilization can be lead back to favourable cultivation conditions of the variety.

The beneficial effect of fertilization can be only enforced under favourable weather conditions, especially the amount of precipitation (Ermolaev & Radkov, 1975; Unk, 1984; Kádár, 2005; Togay & Anlarsal, 2008; Bellaloui et al., 2011b, Bellaloui et al., 2013; Kawaka et al., 2018; Celmeli et al., 2018).

Islam et al. (2016) and Shehata et al. (2011) proved in their experiment that the amount of protein was affected to a different degree by the use of different types of manure. Nitrogen is involved in protein formation (Marschner, 1995). Several researchers have shown the effect of nitrogen (Kádár, 2005; Morshed et al., 2008; Balláné Kovács, 2011; Gulmezoglu & Kayan, 2011; Soratto et al., 2017; Varfolomeyeva et al., 2021), phosphorus (Yin et al., 2016; Kahraman & Onder, 2013; Bildirici & Oral, 2020) and potassium (Bellaloui et al., 2013) fertilizers to increase the protein content. Miya & Modi (2015) also statistically confirmed the effect of NPK fertilization on increasing total crude protein. When organic manure is applied with NPK fertilizer, it increases the protein content more than if they were applied separately (Dikshit & Khatik, 2002; Jagannath et al., 2002; Hegazi et al., 2011; Chaturvedi et al. 2012; Tomar et al., 2016; Saikia, 2018). In Singh's (2002) experiment different organic fertilizers and pesticides were used to influence yield and protein content. However, there is also literature where N fertilization did not increase the NPK content of the seed (Nascente, 2017; Ovacikli & Tolay, 2020).

The effect of the vintage is reflected in the higher protein content of the dryer year (Somos, 1983; Nemeskéri & Nagy, 2003; Asemanrafat & Honar, 2017), respectively the control had a higher protein concentration in non-irrigated conditions than the fertilized one (Bellaloui et al., 2011b). According to Celmeli et al. (2018), the protein content of cereal crops decreased as the crop grows. Asemanrafat & Honar (2017) confirmed this in the case of beans.

The effect of sowing time on the protein content of soybeans was shown by Bellaloui et al. (2011a). Based on their studies, they found that early-sowed soybeans had a higher protein content. Singh et al. (2012) investigated the protein content of wheat semolina at different sowing times under irrigated and non-irrigated cultivation conditions. It was established that the temperature during the period of grain saturation had an effect on the amount of protein quantity. In non-irrigated conditions, the early-sown wheat had a higher protein content due to the lower temperature. However, in irrigated cultivation, the protein content was higher in the late sowing period.

The role of weather is important because strongly influences utilization of fertiliser and crop yield. Beans are a water-intensive plant, one of the yield limiting factors is the lack of rainfall (Nagy, 2006). Its water requirement during vegetation is 300-400 mm, the most critical is the period of flowerbud formation, when it is very sensitive to drought. Its water-demanding period lasts from

budding to 12-16 days after the initial set. During this period, a single irrigation of 30 mm results in a 50 % yield increase of green pods (Tóth, 1979; Hadnagy, 1981). It needs a relative humidity above 65 % for pod set (Géczi, 2003).

The effect of temperatures above 25-30 °C during flowering and atmospheric drought is unfavourable for the yield (Kádár, 2005). The yield and element content were more influenced by weather conditions than row spacing and fertilizer treatments (Russo, 2006). At the legumes, the increase in yield often entails a decrease in the protein content of the seed (Varfolomeyeva et al., 2021).

There are differences in protein content between varieties (Már & Juhász, 2003; Köse et al., 2019). Cultivation of the short growing season (60-90 days) varieties is safer in drought-prone climates (CGIAR, 2016). The examined Start variety is also like this, in our country it can be safely sown until May 20, because it can ripen its crop.

2 MATERIAL AND METHODS

We set up the experiment with the institute's three dry bean *(Phaseolus vulgaris* L.*)* cultivars ('Start', 'Hópehely' and 'Diana') in Nyíregyháza (Hungary) in 2015-17. We examined the effects of sowing times, plant densities and nutrient supply on yield and yield characteristics. We describe in this publication the protein content test of the *Phaseolus vulgaris* 'Start' at a plant density of 300,000 plant ha^{-1} was examined over a 3-year period. *Phaseolus vulgaris* 'Start' is a white, pearl-shaped and small-seeded dry bean cultivar.

The experiment was set up on sandy soil (Table 1.) without irrigated conditions with randomized blocks in 4 replications on 10 m^2 plots. The first sowing was when the soil temperature has permanently risen to 14 °C. The second sowing was at the generally accepted beginning of May (~ May 8-10), and the third sowing happened until May 20. The plant densities were set 200 000; 300 000 and 400 000 germs ha^{-1}. Treatment of nutrient replenishment included the control (0 %), 100 % and 150 % NPK dose based on Antal (1983) and Velich (1994) recommended 95 kg N, 40 kg P and 80 kg K to achieve 1 ton grain yield. Used fertilizers: ammónium-nitrát (N 34 %), szuperfosz fát (P 18 %) and kálium-szulfát (K 50 %).

We calculated the protein content by the nitrogen values of the sample which was taken from 50 g minced dry seed crop. We measured the nitrogen values with a Vario-Max CNS analyzer and multiplied them with a conversion factor of 6.25. The study was in 3 replicates which were taken from the crop of field replicates. We used the SPSS software package for the evaluation. At the one-way analysis of variance, the homogeneous sample was tested by Tukey's-b, and the non-homogeneous sample was tested by the Games-Howel test at a 5 % SD level. Spearman's and Pearson's correlation analysis were used for the quantify relationship between the factors. The weather factors were analyzed with an Excel program.

The weather is discussed in more depth because the rainfall and temperature conditions during flowering have a significant impact on the yield of beans *(*Table 2*)*.

In 2015 in the third sowing time, the proportion of hours with relative humidity above 65 % was the lowest and the temperature also was very high strongly decreasing the yield. During the flowering of the 2nd sowing season, temperatures above 30 °C did not occur and the relative humidity was also favourable. 1st sowing time received the most rainfall during its flowering period.

In 2016 more rainfall fell (24 mm) during the flowering of the 1st sowing time than during the flowering of the other two sowing times. The number of hours of favourable relative humidity, which is necessary for generative processes, was the highest here. However, the number of hours of critical temperature values was the highest in this sowing time, and the yield was the lowest.

Table 1: Soil characteristics and GPS position of the experiment

	2015	2016	2017
GPS position	47.978401, 21.675888	47.974961, 21.691528	47.975930, 21.697846
$pH_{(KCl)}$	6,00	5,58	7,12
Plasticity index according to Arany	27	35	38
Water-soluble total salt (m m^{-1}) %	0,02	0,04	0,04
$CaCO_3$ (m m^{-1}) %	< 0,100	< 0,100	4,34
Organic carbon in humus (m m^{-1}) %	0,842	1,98	2,07
AL-soluble P_2O_5 (mg kg^{-1})	96,4	123	142
AL-soluble K_2O (mg kg^{-1})	247	211	328
KCl-soluble NO_3- + NO_2- - N (mg kg^{-1})	10,1	51,6	35,8

Table 2: Weather characteristics during flowering

	2015			2016			2017		
Sowing time	1	2	3	1	2	3	1	2	3
Length of flowering (day)	20	10	14	17	15	13	20	17	15
65 % < relative humidity (h)	379	195	220	334	272	235	397	336	317
Average of affected days (h)	19	20	16	20	18	18	20	20	21
In percentage of flowering hours	79	81	65	82	76	75	83	82	88
30 °C < number of hours	17	0	71	61	46	20	18	16	5
Average of affected days (h)	9	0	8	8	8	7	3	3	5
In percentage of flowering hours	4	0	21	15	13	6	4	4	1
25 °C < number of hours	66	42	152	156	129	87	144	122	58
Average of affected days (h)	7	6	12	10	11	9	10	9	7
In percentage of flowering hours	14	18	45	38	36	28	30	30	16
Rainfall amount	24	14	13	24	9	15	50	50	44

During the flowering of the 1st sowing season, the temperature was above 30 °C twice, through several days (5 and 3 days). In the 2nd sowing season, the temperature was above 30 °C through 3 days on two occasions. In the 3rd sowing season it happened only once, which lasted for 3 days.

In the 3rd sowing season, which had the largest yield, 15 mm of rainfall fell during flowering. This favoured crop formation. The number of hours of critical temperature values and the values of relative humidity were the lowest in the 3rd sowing times among the 3 sowing times. Lower temperatures also supported crop formation.

The percent of critical values within the flowering period is an important indicator. The relative humidity did not vary greatly between sowing times. However, in the first two sowing seasons, the proportion of hours above 30 and 25 °C during the flowering period was very high, which resulted in a low yield.

In 2017, there was no big difference in the flowering weather of the 1-2. sowing times. The rainfall amounts also developed similarly. However, the 3rd sowing time had a much lower proportion of values above the critical temperature during the flowering time, which was shown in a significant increase in yield. The value of the 3rd sowing time was also more favourable in the proportion of hours with relative humidity above 65 %.

The big differences between crop results could also be attributed to the weather.

3 RESULTS AND DISCUSSION

3.1 DIFFERENCES BETWEEN SOWING TIMES IN THE AVERAGE OF FERTILIZER TREATMENTS IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

In 2015-16-17, the seed yield of the 3rd sowing time had the highest seed protein content. Its significant difference was different from the other two sowing times in a given year. In 2016 we did not prove any difference between them using the GH method. The protein content of the 1st sowing time was significantly lower than that of the 3rd sowing time in 2015 and 2017. We verified a statistical difference between the seed protein content of the 1st and 2nd sowing times in 2015. In contrast to the other two years, the value of the 2nd sowing time was significantly lower than the protein content of the 1st sowing time (Table 3).

There was a significant difference between seed yields in all three years between each sowing time. In 2016-17, when the soil and weather conditions were more ideal, the yield increased as the sowing times were postponed. In 2015 acidic soil with little humus content, extremely high temperatures during the flowering period and a growing season with poor rainfall were unfavourable for beans, so the 3rd sowing time produced the least and the 2nd sowing time the most yield.

Table 3: Protein content, seed yield, and protein yield data of 3 years per sowing times (2015-2017)

	Protein content (%)			Seed yield (kg ha^{-1})			Protein yield (kg ha^{-1})		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
1. sowing time	27.9 a	23.4	21.6 a	200.9 a	98.8 a	248.5 a	55.8 a	22.3 a	53.9 a
2. sowing time	26.1 b	25.6	22.8 a	336.3 b	224.2 b	712.0 b	87.5 b	56.4 b	162.1 b
3. sowing time	32.1 c	26.4	28.8 b	19.7 c	751.7 c	1490.3 c	6.3 c	197.2 c	428.8 c

We also confirmed significant differences in protein yield between all three sowing times. In the average of the treatments, the 3rd sowing time had significantly the highest protein yield and the 1st sowing time had the lowest in 2016-17. In 2015, due to the extreme weather, different results were obtained. Despite significantly the highest protein content of the 3rd sowing time, its protein yield was the lowest because of the very low yield.

3.2 DIFFERENCES BETWEEN THE RESULTS OF FERTILIZER DOSES IN THE AVERAGE OF THE SOWING TIMES IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

We verified a significantly difference in protein content in 2016. The value of the treatment without fertilizers was statistically proven to be lower than the treatments with fertilizers (Figure 1-2). In 2015 and 2017, it was observed that the value of the treatment without fertilizers was the smallest and the value of the treatment with the most fertilizers was the highest.

In yield per hectare and protein yield, we did not show any statistically proven differences between the treatments and the differences were also small.

3.3 DIFFERENCES BETWEEN FERTILIZER TREATMENTS AT A GIVEN SOWING TIME IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

3.3.1 Seed protein content

The unfertilized treatment had the lowest seed protein content in all 3 sowing times and during all 3 years. The significantly deviation of this was different per year and per sowing time.

In 2016, we significantly verified that the protein content of the seeds of fertilized plots was higher than that of non-fertilized plots (Table 4). We established the same thing in 2017, with the clarification that in the 2nd sowing season, the protein content of the two fertilized treatments was also significantly different from each other: the treatment receiving 150 % had the highest protein

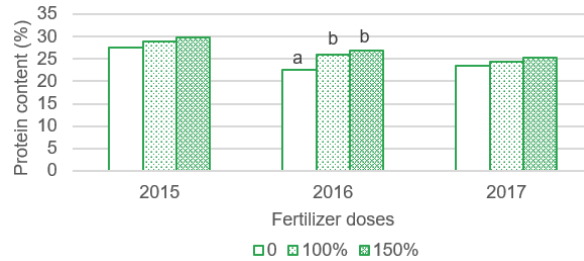

Figure 1: Effects of fertilizer doses in the average of the sowing times on protein content

content. This year, in the 3rd sowing time, the difference between the protein contents was minimal, we did not verify a significant difference between the fertilizer treatments.

In 2015, the protein content of the treatment with a 150 % fertilizer dose was significantly higher than that of the non-fertilized treatment in the first two sowing seasons. In the 3rd sowing season, the protein content of the 100 % fertilizer dose differs significantly from that protein of the unfertilized.

3.3.2 Yield (kg ha^{-1})

In 2015-16, when the fertilizer treatments were examined by sowing time, we did not prove a significant

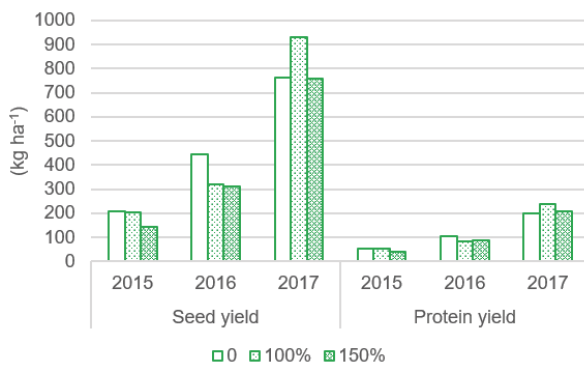

Figure 2: Effects of fertilizer doses in the average of the sowing times on seed yield and protein yield

Table 4: Effect of treatment combinations on protein content, yield and protein yield

	2015			2016			2017		
Fertilizer dose	1. sowing time	2. sowing time	3. sowing time	1. sowing time	2. sowing time	3. sowing time	1. sowing time	2. sowing time	3. sowing time
				Protein content (%)					
0	27,2 A a	24,9 A a	30,8 A b	19,0 A a	23,6 A b	25,1 A c	20,6 A a	20,8 A a	28,7 b
100%	27,6 A a	25,7 AB b	33,1 B c	25,1B	26,3B	26,7 B	22,3 B a	22,7 B a	28,1 b
150%	28,9 B a	27,7 B a	32,4 AB b	26,2B	26,9B	27,4B	22,0 B a	24,8 C b	29,5 c
				Yield (kg ha$^{-1)}$					
0	219,1 AB a	372,4 b	30,1 c	134,0 a	302,1 a	895,6 A b	274,4 a	531,1 A b	1482,0 c
100%	280,3 B a	312,6 a	23,0 b	110,1 a	171,3 a	647,8 B b	279,2 a	1039,8 B b	1473,0 c
150%	103,4 A a	323,9 b	6,1 c	52,2 a	199,1 a	711,8 AB b	191,8 a	565,2 A b	1516,0 c
				Protein yield (kg ha^{-1})					
0	59,6 A a	92,4 A b	9,4 A c	25,3 a	71,4 b	224,3 c	56,9 a	110,8 A b	424,6 c
100%	77,8 B a	80,2 B a	7,7 A b	27,8 a	44,9 ab	172 b	62,4 a	236,1 B b	415,5 c
150%	29,9 C a	89,8 A b	1,9 B c	13,8 a	53 a	195,2 b	42,4 a	139,2 A b	446,2 c

Note on the figures:
Capital letter: indicates a significant effect of fertilizer doses within the same sowing time and the same year
Lower case: indicates a significant effect of sowing times within the same fertilizer dose and same year

difference using the Tukey-b method between the fertilizer treatments. In 83 % of cases, the without fertilizers had the most yield. In 2015, at the 1st sowing time, at the LSD 5 % level, the 150 % dose fertilizer treatment had yield significantly less than the treatment that received the 100 % dose.

In 2016, in the case of the 3rd sowing time, at the LSD 5 % level, we verified a significant difference between the without fertilizer treatment with the highest yield and the treatment that received the 100 % dose.

In 2017, the difference in the yield of the earlier and later sowing times was minimal, so we did not detect a significant difference. In the 2nd sowing season, the yield per hectare of the treatment with a 100 % fertilizer dose was significantly higher than the yield of the treatment without fertilizer and treatment with a dose of 150 %.

In the 2nd sowing season of 2017, we statistically verified that the protein yield of the treatment with a 100 % dose of fertilizer was significantly higher than the yield of the treatment without fertilizer and with a dose of 150 %. This can be explained by its significant surplus of yield, which was able to compensate for its protein content, which was located in the average protein content of the other two fertilizer doses.

In 2015-16, except for the 1st sowing time, the treatment without fertilizers always had the highest protein yield, despite the lowest protein content. However, this difference in protein yield was not significant. We showed a significant difference at the LSD 5 % level between the lowest and the highest protein yield in 2015. In 2015, in the 1st and 3rd sowing times, the protein yield of the treatment with the highest fertilizer dose was significantly the lowest, but in the 2nd sowing time, the protein yield of the treatment with 100 % fertilizer dose was the lowest. In the 1st sowing seasons, the protein yield of treatments with the highest fertilizer dose was the lowest, which was also statistically confirmed in 2015. This trend was also observed in 2017. It was likely that the early sowing was unfavourable for the small-eyed, white-seeded Start variety, which was only amplified by the higher fertilizer dose.

In the case of a lower seed protein content, the protein yield may be higher due to the higher yield. For example: in 2017, in the case of 100 % treatment of the 2nd sowing time, and in 2015-16, regardless of the sowing times, in the treatments without fertilizers.

3.4 DIFFERENCES BETWEEN THE RESULTS OF SOWING TIMES AT A GIVEN FERTILIZER TREATMENT IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

3.4.1 Protein content

In 2015 and 2017, regardless of the fertilizer dose, the seed protein content of the 3rd sowing time had significantly higher than that of the previous sowing times

(Table 4). The 1st and 2nd sowing times were significantly different at the 100 % fertilizer treatment in 2015 and in the 150 % dose treatment in 2017.

In 2016, on the protein content of the fertilized treatments had no significant effect by sowing times. In the treatment without artificial fertilizers, the protein content of the 3rd sowing time was significantly higher than the that of 1st sowing time.

3.4.2 Yield (kg ha^{-1})

In 2017, regardless of the fertilizer doses, the yield increased significantly in the 2nd and 3rd sowing times. In 2016, the 3rd sowing time also had significantly the highest yield, however, the yields of the 1st and 2nd sowing times did not differ significantly from each other.

In 2015, regardless of the fertilizer doses, due to the extreme weather, the 2nd sowing time had significantly the highest yield. This was also significantly different from the result of the 3rd sowing time, except for the treatment with a 100 % fertilizer dose, where the yield of the 1st sowing season was not significantly lower.

3.4.3 Protein yield (kg ha^{-1})

The differences in protein yield (kg ha^{-1}) formed in accordance with the yield in 2015 and 2017. We observed a deviation from this in 2016, where the protein yield of the 3rd sowing time was significantly higher in all fertilizer treatments. In the case of those without artificial fertilizers, the protein yield of each sowing time differed significantly. In the treatment with a 100 % fertilizer dose, despite the large difference, the 2nd sowing time did not differ significantly from the protein content of the 3rd sowing time, even though the 2nd sowing time had 74 % less protein yield compared to the 3rd sowing time.

3.5 RESULTS OF TREATMENT COMBINATIONS IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

3.5.1 Protein content

In 2015 and 2017, the highest seed protein content was measured in the 3rd sowing time treatment combinations. In 2016, the protein content of without fertilizer treatments were the least. The largest protein content was measured in 150 % fertilizer dose of 2nd and 3rd sowing times.

3.5.2 Yield and protein yield (kg ha^{-1})

In 2015, treatments of 3rd sowing time produced significantly less than other treatments. The highest fertilizer dose treatment of 1st sowing time also produced little, so did not differ significantly from the yield of 3rd sowing times. The treatment without fertilizer of 2nd sowing time yielded the highest that did not significantly differ from the yield of treatment with fertilizer of 2nd sowing time and from the yield of treatment with 100 % dose of 1st sowing time.

In 2016-2017, the treatment combinations of 3rd sowing time were significantly more productive than treatments of earlier-sowing times. Accordingly, its protein yields also were significantly higher than those of earlier sowing times. The treatments with fertilizer were not significantly more productive than the control.

3.6 CORRELATIONS BETWEEN THE EXAMINED ELEMENTS IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

The yield volume, protein content and protein yield were correlated with each other at the 1 % significance level. In all three years, we showed a very strong, positive relationship between yield and protein yield (Table 5). Only the significant relationships are shown in the table.

Between the protein content and protein yield, we verified a very strong, positive relationship in 2017. The high protein content resulted in a high protein yield (also due to the increased yield per sowing time). However, we showed a strong, negative relationship between them in 2015. The reason for this was that the highest protein content of the 3rd sowing time was combined with the lowest protein yield because of the low yield. In 2017, the increasing yield was coupled with higher protein content, and in 2015, a lower yield was coupled with higher protein content.

In all three years, in most cases, the sowing time was related with protein content, yield per hectare and protein yield at the 1 % significance level. In 2016-17, we verified a very strong positive relationship with the protein yield, in 2017 we showed a very strong relationship with the yield per hectare, and in 2016 a strong significant relationship. We verified a medium significant relationship with the protein content in all three years.

In 2015, the sowing time had a negative, medium relationship with yield per hectare and protein yield because of the extreme growing conditions.

Table 5: Significant correlation values of 3 years between the examined factors

	Protein content (%)			Seed yield (kg ha^{-1})			Protein yield (kg ha^{-1})		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Protein content (%)	1	1	1	-,845**		,862**	-,811**		,909**
Seed yield (kg ha^{-1})				1	1	1	,995**	,996**	,992**
Sowing time	,536**	,425*	,798**	-,518**	,885**	,938**	-,530**	,920**	,938**
Fertilizer		,780**	,387*						

3.7 DISCUSSION IN THE CASE OF THE *Phaseolus vulgaris* 'Start'

The yield of beans is strongly defined by the weather. This was also reflected in the yield as Kádár (2005) and Russo (2006) established during their experiment that the temperature during flowering and the lack of precipitation greatly influence the yield. In 2016-17 the fertilizer was utilized by the effect of favourable weather, thereby the protein content of seed, yield, and yield protein were increased.

3.7.1 Effect of sowing times in the average of fertilizer treatments

The seed protein content of the 3rd sowing season was the highest in each of the 3 investigated years. In the case of Start beans variety, this was different from what was found in the literature in the case of soy and wheat. Bellaloui et al. (2011a) found that early-sowed soybeans had a higher protein content. Singh et al. (2012) determined that in non-irrigated conditions, the early-sown wheat had a higher protein content due to the lower temperature. Early sowing of the Start bean variety is unfavourable due to the small, white seed.

In case of favourable weather, the 2nd and 3rd yield of sowing times was greater than that of the 1st (early) sowing and their protein yield also increased.

3.7.2 The effect of fertilizer treatments at a given sowing time

The non-fertilized treatment had the lowest seed protein content in all 3 sowing times during 3 years, which is understandable, since many literatures support the protein-increasing effect of fertilization. The protein yield of the treatment that received a 100 % fertilizer dose in the 2nd sowing season of 2017 was significantly higher. In the early sowing times, the protein yield of treatments with the highest fertilizer dose was the lowest, that difference was significant in 2015. The reason for this was that the Start variety produced very little in the early sowings, because early sowing with a 150 % fertilizer dose was unfavourable for it.

3.7.3 Effect of fertilizer treatments in the average of sowing times

In 2016 the protein content of the treatment without fertilizer was significantly lower than that of the treatment with fertilizer. We did not verify a significant difference in protein yield per hectare between the fertilizer treatments.

3.7.4 The effect of sowing times in a given fertilizer treatment

In 2015 and 2017 independently of the fertilizer dose, the seed protein content of the later sowing was significantly higher than the values of the earlier sowing times. In a favourable weather, the later sowing times had significantly the highest yield and protein yield.

3.7.5 Results of treatment combinations

In examined 3 years the largest protein contents were in the third sowing time with 150 % fertilizer dose. In 2016-17 the yield and protein yield of the third sowing time were larger than the value of earlier sowing times. This was because of favourable weather. The significant effect of increased fertilizer doses was not proved.

If the weather was favourable, then the significant relationship among the sowing time, protein content, yield, and protein yield was positive and strong.

4 CONCLUSIONS

The observations of Ermolaev & Radkov (1975) and

Unk (1984) are still valid today, the yield-increased effect of fertilizers only takes effect in case of favourable weather. We verified significantly different on one time of 9 variations. Examining the effect of fertilizers by sowing times, we already showed significantly different in more cases. The protein content of treatments with fertilizer was higher than that of without fertilizer.

In 2015, we verified significantly that the protein yield of treatment with 150 % fertilizer dose was least at the 1st and 3rd sowing times, because its yield was very little by the unfavourable weather. In 2017, at the 2nd sowing time, the protein yield of treatment with 100 % fertilizer dose was significantly more than that of other fertilizer treatments.

Examining the sowing times, with the favourable weather, the 3rd sowing time was the more favourable at the protein content, yield and protein yield for the growing of the white and small-seed Start variety.

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