

## HIGH BEAN PRODUCTION IN SLOVENIAN HOP FIELDS

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### Abstract

*The importance of growing legumes is highlighted in many strategical documents. However, without adequate support for the production of grain legumes, production is less commercially attractive. In 2015, in EU 28 dry pulses were cultivated on 2.1 % of arable land (all together 107 million ha). In Slovenia, grain beans, second most important dry pulse in the country, are grown largely on hop fields in the Savinja Valley, in the years between the grubbing-up of the old and the planting of a new hop plantation. The grain yield at the treatment with half of the common rate of nitrogen (20 kg N/ha) for topdressing (at beans height 15 cm) and at the treatment with no N added for topdressing did not differ significantly from the yield at the treatments with full rate of N (40 kg N/ha). Therefore, the N amount of 20 kg/ha at sowing was sufficient under the experimental conditions and no nitrogen topdressing was required. Nmin soil content is advisable to be measured, followed by fertilization to the target value. Fertilizer with extended N release did not appear to have better impact on the grain yield compared to KAN fertilizer at the same N rate; however, the yield was more stable between the years at fertilizer with extended N release. The achieved yield of grain beans on the field experiment on a hop field was at all treatments and both years higher than the Slovenian (2.4 t/ha) and European average (1.8 t/ha to 2.6 t/ha); 2.7–3.0 t/ha depending on the treatment and the year.*

**Keywords:** grain beans, yield, nitrogen fertilization, topdressing

### 1. INTRODUCTION

The importance of growing legumes is highlighted in many strategical documents. Dry pulses are key crops because of their high protein content and ability to fix atmospheric nitrogen in the soil. They are a good source of protein for livestock and also for humans. Secondly, cultivating dry pulses increases the nitrogen level in the soil (Eurostat Statistics Explained, 2021). They also contribute to reduced ammonia emissions, affect the improvement of water retention capacity of the soil, improve the availability of nutrients and reduce the impact of weeds and pests.

Among the topics for reducing the negative effects in the field of agriculture growing grain legumes are often mentioned. They are an important part of sustainable agriculture and provide many environmental benefits and ecosystem services. The share of legumes in the crop rotation is a direct indicator of a sustainable and modern approach to farming in order to improve biodiversity, maintain production intensity and reduce the impact of agriculture on the environment, which are the goals defined in Slovenian agricultural policy in the future programming period. However, without adequate support for the production of grain legumes, production is less commercially attractive than the production of other main crops (wheat, barley and maize for grain). Both at the EU level and in Slovenia, production analyses often mention one of the most important limitations for the wider interest in the production of legumes low yields compared to corn and wheat.

In Slovenia, grain beans are grown largely on hop fields (to take advantage of trellis that are conducted) in the Savinja Valley, in the years between the grubbing-up of the old and the planting of a new hop plantation (Sinkovič et al., 2020). On the hop fields, beans are sown at a distance of 2.4 m to 3.0 m between rows, as is usual with hop plants, and in rows, a twine is installed from the top of the trellis to each planting site (Jesenko et al., 2018) at a distance of 50-70 cm between each other. They sow 8-10 seeds per twine – making two holes with hoe and plant half of the seed quantity in each of them. Then they cover seeds with soil.

On the roots of all legumes, small tubers (nodules) can form during growth, in which there are nitrifying bacteria of the genus *Rhizobium* spp. They are able to bind nitrogen from the air, which can be exploited

by legumes (Sinkovič et al., 2020). Symbioses with a certain legume species are usually capable specific bacterial species. The following species usually enter into a symbiotic relationship with beans: *Rhizobium leguminosarum* bv. *phaseoli*, *R. tropici*, *R. mongolense*, *R. gallicum* and *R. etli*. In most European soils, *R. leguminosarum* bv. *phaseoli* is naturally the most abundant (Jesenko et al., 2018). Beans have a beneficial effect on subsequent crops, as they enrich the soil with nitrogen, since they can leave 75 to 120 kg of nitrogen per hectare in the soil after harvest. And they also have ameliorative effect on the soil.

In addition to the appropriate soil reaction (pH), the successful functioning of nitrifying bacteria is also influenced by soil temperature and soil moisture. The optimal soil temperature for the establishment and course of symbiotic fixation in beans is 25–30 °C, while it stops at 30–33 °C. The content of micro (Mo, Fe, Co) and macronutrients (Ca, P) in the soil also plays an important role in establishing a symbiotic relationship. Too much nitrogen in the soil solution, especially of mineral origin, inhibits or even prevents the development of symbiosis between beans and nitrifying bacteria. Excessive rates of nitrogen can also cause a lot of leaf mass and less flower set. A suitable soil reaction is at pH between 5.5 and 6.7 (Jesenko et al., 2018). Under no circumstances, beans should be sown in the soil with a pH below 5.5, because the normal development of nitrifying bacteria will be prevented (Sinkovič et al., 2020). Due to the symbiosis with bacteria, the soil must be airy throughout the growing season. Beans do not tolerate stagnant water and compacted soil, so the soil must be well prepared – deeply ploughed in autumn and loosened before sowing.

With the expected yield of 2.5 t/ha of grain, we uptake from the soil: 90 kg/ha N, 40 kg/ha P<sub>2</sub>O<sub>5</sub>, 150 kg/ha K<sub>2</sub>O, 20 kg/ha MgO and 200 kg/ha CaO (Technological..., 2020). Before sowing, ½ to ¾ of the total dose of nitrogen is applied, while the rest is added in one or two topdressings. Before topdressing, it is recommended to measure plant available nitrogen in the soil (N<sub>min</sub> or rapid soil nitrate test) (Sinkovič et al., 2020).

The goal of a two-year experiment with high beans on a hop field was to determine whether we could reduce the dose of nitrogen for topdressing or even we can avoid it. We compared topdressing at the bean plants height 15 cm with a standard amount of nitrogen 40 kg/ha N, as it is done in the current practice with conventional fertilizer (KAN) (control) with: i) 40 kg/ha N in the form of a sustained-release nitrogen fertilizer, (ii) a reduced dose of nitrogen (20 kg/ha N; KAN) and (iii) production without nitrogen topdressing. We also wanted to compare the area dedicated to grain bean production in Europe and in Slovenia.

## 2. MATERIALS AND METHODS

### 2.1 The area of dry pulses and the share of grain beans in the fields of Europe and Slovenia

We search databases of Eurostat and Slovenian Statistical Office for dry pulses area, grain beans area and calculate the shares that they represent on the fields.

### 2.2 Field experiment

Description of Site and Weather Conditions. The location of the experiment was in a hop field in Lower Savinja Valley, Slovenia. Soil analysis results, performed by the AI method before the start of the experiment is shown in Table 1. In 2019, the experiment was in one part of the hop field and in 2020 in another part of the same hop field.

**Table 1.** Soil analysis in spring 2019, before experiment conduction

Soil sample	pH in KCl	pH in Ca-acetat	P <sub>2</sub> O <sub>5</sub> (available) mg/100g	K <sub>2</sub> O (available) mg/100g	Organic matter (%)
Hop field	4,2	6,6	31 <b>D</b> *	22 <b>C</b> *	3,0

\* D = oversupplied; C = good supplied

May 2019 was cold and wet, in June there were many hailstorms and already temperatures over 30 °C. July and August were wet and warm with temperatures over long-term average. September was wet as well. In the period from June to September, there was 527 mm of precipitation, which is 30 mm more than the long-term average. On the contrary, in spring of 2020 there were air temperature fluctuations and continued lack of rainfall until end June. Summer of 2020 was extreme wet with many showers and storms. From the last decade of June to the end of September, there was 601 mm of precipitation and it was warm. In the 2020 growing season, there was 779 mm of precipitation and an average temperature of 17.3°C.

**Experimental Design and Treatments.** Field experiment was conducted as a block field trail in four replications. The size of the experiment was 0.4 ha, the size of certain plot was 250 m<sup>2</sup>. Treatments are presented in Table 2. Fertilization with nitrogen (N) fertilizers was performed manually when the bean plants were about 15 cm high, just before the first hoeing (June 26, 2019 and June 12, 2020). Granular KAN fertilizer contains 27% nitrogen, half in ammonium form and the other half in nitrate form. Rhizovit 31 N-Process fertilizer is urea-ammonium sulfate (MgO-SO<sub>3</sub>) with microelements (31% N, 2% MgO, 25% SO<sub>3</sub>) in granular form. With a special envelope, MeTA (95% coverage) increases bioavailability and nitrogen utilization (Timacagro..., 2020). Immediately after fertilization, the soil was shallowly tilled throughout the experiment so that the fertilizer was incorporated in the soil.

**Table 2.** Treatments in the experiment; N rate and fertilizer used at bean plants height cca 15 cm (for topdressing)

Nitrogen fertilization
40 kg N/ha (KAN 27)
40 kg N/ha (Rhizovit 31 N- Process)
20 kg N/ha (KAN 27)
0 kg N/ha

**Plot Establishment and Management.** Soil preparation before sowing was carried out in both years according to established agricultural techniques. In the autumn, we ploughed the soil to a depth of 25 cm and levelled it in the spring to close the winter furrow. Because of low pH, liming was performed in early spring 2019 with limestone (8 t/ha). Fertilization with P and K fertilizers was made each year just before sowing, according to the soil analyse results. At the same time, nitrogen was fertilized (20 kg/ha each year all over the field). This was followed by pre-sowing soil preparation with a rotary harrow. Sowing took place on May 8, 2019 and May 6, 2020. Spacing between row was 2.8 m, which is usual for hop plantations (2.4 m to 3.0 m; this is how the trellis are made). We knotted twines on the trellis later and fix them in the soil at a distance of 50 cm in a row. 2x6 bean seeds were sown by hand in a ditch on each top of a pre-fixed twine. Then we covered the seeds with soil by hoe. Agrotechnical measures during the growing season included: shallow tillage four times in a season to destroy weeds and break up soil crusting. There was no irrigation. Spraying was carried out in both years in August with the systemic broad-spectrum fungicide Ortiva at a dose of 1 l/ha.

**Data Collection, Computation and Statistical Analysis.** Soil samples for Nmin analysis were taken in both years in June (before topdressing at plant height 15 cm). During the maturity of the bean plants (October 25, 2019 and October 30, 2020), we manually took the bean plants of the middle rows from each plot separately on a tractor-trailer, harvest grains and weighed them. Sample of grains per plot was taken for moisture content analyse, so we could calculate the dry matter yield per unit area. The data were processed using the computer programs Excel and Statgraphics Centurium. Differences between treatments were detected by Duncan multiple test (p=0.05).

### 3. RESULTS

#### 3.1. The area of dry pulses and the share of grain beans in the fields of Europe and Slovenia

The area used to cultivate dry pulses in the EU increased by 64.7 % between 2013 and 2015 at EU-level and up to 350.7 % in Latvia, 253.6 % in Lithuania and 181.4 % in Bulgaria (Eurostat ..., 2021). According to Eurostat Statistics explained (2021) this was largely a result of the Common agricultural policy (CAP) greening measures, which introduced the green direct payment scheme, which began to be implemented in 2015. In 2015, in EU 28 dry pulses were cultivated on 2.1 % of arable land (all together 107 million ha). In Spain, Poland and United Kingdom this share was 3.9 %, 3.7 % and 3.7 % respectively and in Estonia and Lithuania as high as 4.7 % and 7.3 % respectively. In Slovenia, it was 0.5 %, in Bulgaria 0.7 % (Eurostat ..., 2021).

Field peas, broad and field beans are the leading pulses area under dry pulses. In United Kingdom, the high share with dry pulses resulted in 170,000 ha of beans, followed by 86,300 ha in France and 61,400 ha in Lithuania; all together in EU 28 in 2015 on 624,200 ha (Eurostat ..., 2021). In Slovenia, beans were grown on 396 ha in that year (SURS, 2021). As soon as in the next year (2016) the area with grain beans jumped to 634 ha where it stayed for the next four years (SURS, 2021).

The largest area for dry pulses in Slovenia is devoted to soya, between 1,400 ha and 2,900 ha in the last five years, the second and third places are reserved for grain beans and peas, depending to the year (SURS, 2021; Figure 1).

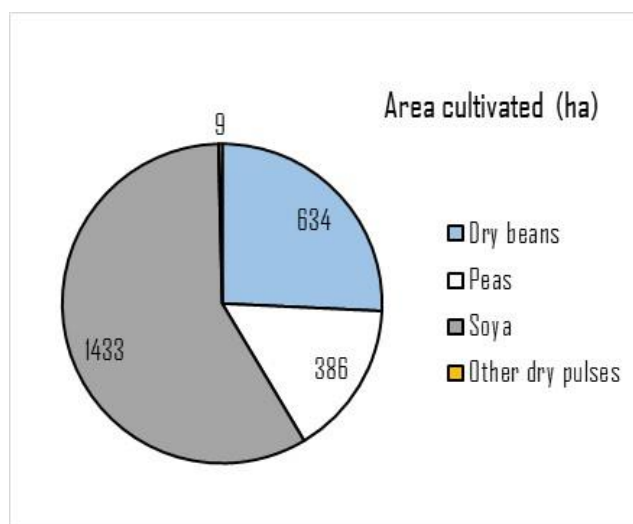


Figure 1. The area under dry pulses in Slovenia in year 2019 (in ha)

According to SURS, the average Slovenian yield is from 1.4 t/ha to 2.4 t/ha related to the year (2.4 t/ha in 2019), and in Europe in was in recent years from 1.8 t/ha to 2.6 t/ha related on the year, in the World 0.9 t/ha. The highest average yield is in Belgium, 4.3 t/ha (FAOSTAT, 2021).

#### 3.2. Grain yield related to the treatment and experimental year

Grain yield did not differ significantly among treatments and between years (Table 3). At the same time, the yield at all treatments was above Slovenian average yield (see Chapter 3.1). Despite the fact that the plants in these two treatments had lighter green leaves during the summer and were a bit lower, this did not reflect in the achieved yield.

Compared to KAN fertilizer, the fertilizer with prolonged nitrogen release had the same effect on the yield at the same amount of nitrogen (40 kg/ha). However, looking year per year separately, the use of stabilised N fertilizer gave a comparable yield in both years (2.7 and 2.8 t/ha in 2019 and 2020 respectively), while KAN fertilizer reflected in fluctuated yield (3.0 and 2.6 t/ha in 2019 and 2020

respectively). Treatments with half-N rate and no N for topdressing reflected in the same yield in both years (2.7 t/ha).

**Table 3.** Bean grain yield related the treatment and the experimental year

Treatment	Grain yield (t/ha dry matter)
40 kg N/ha (KAN 27)	2,8 a*
40 kg N/ha (Rhizovit 31 N- Process)	2,8 a
20 kg N/ha (KAN 27)	2,7 a
0 kg N/ha	2,7 a
2019	2,8 a
2020	2,7 a

\* The same letter in the column means that there is no significant difference between treatments within the same factor (treatment, year) (Duncan test,  $p=0.05$ ).

When analysing the results of Nmin (nitrate and ammonium form) in the soil in June (before topdressing), we found that in 2020 there was more available mineral nitrogen in the soil than in 2019; there was more mineralization in the soil in warm May/June 2020 compared to relatively cold May 2019. At the same time, in June 2020 we sampled 14 days earlier. In 2019 there was from 66 to 144 kg/ha Nmin across the field (from 23 to 95 kg/ha in ammonium form), in June 2020 as much as 144 to 220 kg/ha Nmin (from 22 to 26 kg/ha in ammonium form). According to guidelines (Mihelič et al., 2010), year target goal for Nmin is 130 kg/ha Nmin and minimum Nmin supply in soil 40 kg/ha. To keep the reflection from practise we made topdressing anyway in both years (treatments). However, it is clearly seen that hop fields are very fertile and Nmin soil analyse is very recommendable, so obviously topdressing was not needed at all and we hope farmers will be convinced by the data from our experiment.

#### 4. CONCLUSIONS

The area with dry pulses in the EU increased by 64.7 % between 2013 and 2015 at EU-level as a result of the Common agricultural policy greening measures, which introduced the green direct payment scheme. In 2015, in EU 28 dry pulses were cultivated on 2.1 % of arable land (all together 107 million ha). One of the most important limitations for the wider interest in the production of legumes are low yields compared to corn and wheat. As can be concluded, without adequate support for the production of grain legumes, production is less commercially attractive than the production of other main crops.

In Slovenia, grain beans are grown largely in hop trellis in the Savinja Valley, in the years between the grubbing-up of the old and the planting of a new hop plantation. The achieved yield of grain beans in the field experiment in a hop field in Slovenia was at all treatments and both years (2.7–3.0 t/ha of dry matter depending on the treatment and the year) higher than the Slovenian (2.4 t/ha) and European average (1.8 t/ha to 2.6 t/ha), which proves the reasonableness of growing high beans for grain in hop trellis in the time between two hop plantations. At the same time, not only because of the achieved good yield, beans are legumes, which have very good impact on soil fertility.

The grain yield at the treatment with half of the common rate of nitrogen (20 kg N/ha) and at the treatment with no N added for topdressing did not differ significantly from the yield at the treatments with full rate of N (40 kg N/ha). Therefore, we can conclude that topdressing with N fertilizers at the stage when the beans were about 15 cm high did not make sense. The N amount of 20 kg/ha at sowing

was obviously sufficient for the appropriate bean yield under the experimental conditions and no nitrogen topdressing was required. Nmin soil content was high in June 2020, and also quite high in June 2019, so it is advisable that before deciding about the N amount for topdressing that Nmin soil content is analysed and then fertilize according to the target value. In this way we care for environment and also save money for fertilizer and oil as well as we have less working hours.

Fertilizer with extended N release did not appear to have better impact on the grain yield compared to KAN fertilizer at the same N rate in the average of the experimental years; however, the yield was more stable between the years by using fertilizer with extended N release.

## ACKNOWLEDGMENTS

The article was prepared within the **EIP project Grain Legumes - Production, Processing and Use**, which takes place within the measure Cooperation from the Rural Development Program of the Republic of Slovenia for the period 2014-2020, sub-measure 16.2, financed by the European Agricultural Fund for Rural Development and the Republic of Slovenia.

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