Final report
on the common bean (*Phaseolus vulgaris* L.) landrace research project No. 120941 funded by the National Research, Development and Innovation Office

Short summary of the project results:

Regarding seed yield – being our main component – the virtually variety level large sample size experiments carried out in three subsequent years with extreme weather conditions lead to sad conclusions. For bean as a species and a crop category it is difficult to overcome the challenging weather extremities caused by climate change.

By contrast, or rather for this reason the most important result of our research is that finally a few landraces have been selected which could be promising elements of breeding, pre-breeding or landrace rehabilitation based on their ecological plasticity. The latter two categories are especially important for the Centre for Plant Diversity since they belong to the competency of the institution, this way allowing for further steps to be directly taken. According to the free accessibility of genetic resources provided by law, the Centre for Plant Diversity continuously hands over gene bank samples to the interested ones, mostly farmers. Since feedback is required on the agronomic and other traits of the gene bank samples, a kind of pre-breeding is implemented this way.

Based on the monitoring of bean landraces useful information can be given to the interested people not only on the agronomic, but also on the phenotypic, the morphological and the most important composition, Rhizobium and mycorrhiza related traits.

Declaration of the practicality of the research

The concept of the project is based on the global recognition that the mobilization of genetic resources – accumulated during several years of gene conservation – need to be speeded up for enhancing the results of sustainable plant production and breeding and also for ensuring healthy nutrition.

Deviation from the original plan of the experiment

The Centre for Plant Diversity made own examinations, and will publish the results of the research on the occurrence of root nodules (Rhizobium contamination) including 332 landraces with 3 replications (meaning 996 plots).

The Centre for Plant Diversity also analysed the crude protein content of 120 seed samples originating from the experiment containing 40 bean landraces with 3 replications, and will publish the results.

Appendix of the scientific publications

Horváth L, Horváth B, Málnási Cs. G. (2018) Veteménybab tájfajták géntartalékainak vizsgálata. XXIV. Növénynemesítési Tudományos Nap. Összefoglalók. MTA. Budapest. 92.p

L. Horváth, B. Horváth, G. Málnási Csizmadia, O. Szalkovszki (2018) The study of genetic reserves of common bean landraces at the CPD, Hungary. TRUE C-LIN Workshop, Budapest, Poster.

Detailed report on the project results

Title: The utilization of common bean genetic resources for sustainable plant breeding and healthy nutrition

The concept of the project is based on the global recognition that the mobilization of genetic resources – accumulated during several years of gene conservation – need to be speeded up for enhancing the results of sustainable plant production and breeding and also for ensuring healthy nutrition. This is especially true in the case of seed legumes – regarded as alternative crops from the point of human nutrition and protein consumption –, including common bean (*Phaseolus vulgaris* L., hereinafter: bean), which is facing a critical situation in public production in Hungary.

In order to reach our objective, potential landrace items need to be selected first, and then they should be disseminated. Selection is based on statistically comparable yields and the summary of the observed phenotypic, morphological, nutritional value related and agronomic traits. Dissemination may facilitate ongoing and future prebreeding and breeding programs, but could also help the launching of an immediate public production rehabilitation process.

The joint Slovenian-Hungarian project was proposed and submitted by the Agricultural Institute of Slovenia. Also this institute is the professional coordinator of the project; consequently the Ministry of Education, Science and Sport of the Republic of Slovenia is the major national supporter of the project. The Centre for Plant Diversity (NöDiK) is the representative of Hungary, also being a project partner country. Activities carried out here have been financed by the National Research, Development and Innovation Office of Hungary as a co-financer.

The work plan of the project included the following tasks:

1. Morphoagronomic analysis of at least 300 bean landraces per institute or country for the selection of potential items.
2. Carrying out the phaseolin analysis of the set of 300 items, and taking molecular "fingerprints" by using genetic markers. Developing a bean "core" collection of 40-80 items based on the collected molecular data.
3. Performing the phenological and the morphological analysis of the "core" collection through field experiments implemented in Slovenia and Hungary.
4. Assessing the occurrence of mycorrhizal symbiosis by taking samples from the root system of the varieties.

The Centre for Plant Diversity participated in all of the tasks except for some part of task No. 2 where laboratory analyses needed for the development of the "core" collection were carried out by the Agricultural Institute of Slovenia. The Centre for Plant Diversity produced and provided plant materials required for performing the tests. (The work we did for the AIS is detailed in the "Notes" section.)

On the other hand, the Centre for Plant Diversity expanded the assessment of landraces beyond the originally planned activities, and also investigated the occurrence of Rhizobium species (root nodules) besides analysing some of the composition parameters of dry seeds.

Material and method

The Centre for Plant Diversity has a bean gene bank collection composed of 4500 accessions from which 2500 items are Hungarian, and 600 items originate from the neighbouring countries. Consequently, the number of landraces originating from the Carpathian Basin reaches 3100.

Field experiments have been carried out in the area of the Centre for Plant Diversity in Tápiószele by growing the plants on meadow soils all the 3 years. Crop rotation was used every year without any fertilization.

Originally, the project aimed to investigate 300 accessions, but due to the diversity of our landrace bean collection this number had to be increased in the first year, since this was the only way we could guarantee a "fair representation" of our genetic reserves for the further scientific analysis of the 300 landraces and also for providing the amount of seeds required for the field experiments and the laboratory tests in the subsequent work phases. As a result, we started to investigate 1300 accessions in 2016. From them, 669 landraces have been multiplied and evaluated in 2017 by using one replication each year. Finally, we had 332 landraces taking part in the main experiment in 2018 by using 3 replications. In other words, the amount of seeds necessary for setting a complex and statistically interpretable experiment on the planned number of varieties could be produced only by 2018, after performing the necessary preceding multiplications. In the first year mostly geographical (origin related) factors, while from the second one the results of the performed analyses defined if a landrace was to be further investigated and included in the experiment or not. Picture 1 shows the map of the collection sites of the landraces. The number of indicated points is less than that of the varieties, because it happened often that more landraces have been collected from the same settlement.

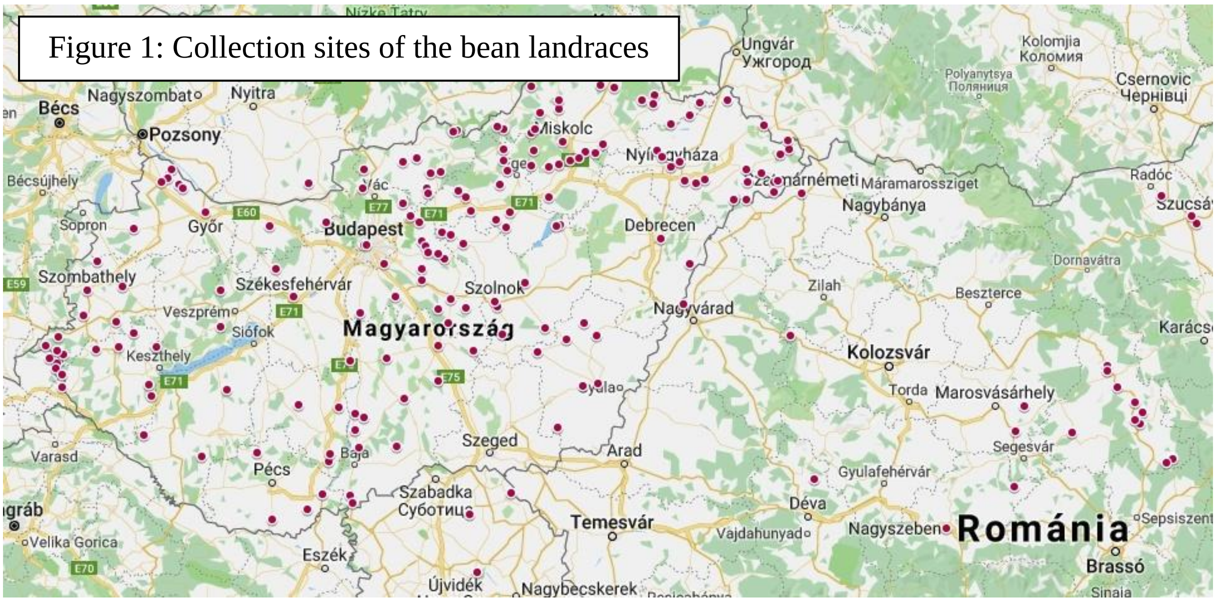

Figure 1: Collection sites of the bean landraces

During the 2018 experiment including 332 landraces with 3 replications we sowed the seeds on 10th May by using machines and sowing 60 seeds per running metre in 4 the metre long rows with 80 cm of row spacing. (Picture 2.) (From now on, due to the large number of figures, we will place them in the Appendix.)


Figure 2: The bean landrace experiment in 2018

Runner type beans were supported by nets fixed on bean poles. At the beginning of the growing season mechanical weed control was carried out by using machines and manual labour, but after the establishment of the supporting structures it could be performed only manually. Plant protection and watering activities have been continuously performed. (The used plant protection agents included: Folpan 80 WDG, Merphan 80

WDG, Topsin-M 70 WDG, Champ DP and Cosavet DF.) Harvesting was done manually; while during threshing machines and manual labour (for shelling) also have been used.
Regarding the weather, it can be stated that conditions were unfavourable for bean production every year. Since the report mostly focuses on the results and observations of 2018 – including the evaluation of yield levels –, the climatic conditions of this year is to be assessed now. As shown by Figure 1, weather anomalies – becoming more and more common – have been witnessed during the vegetation period. The most extreme events included the drought in May, the heat wave at the beginning of June and erratic precipitation patterns sometimes causing drought in July-August, which were harmful also for the beans. Similarly, significant fluctuations of daily temperature and that of relative humidity in July potentially leading to atmospheric drought are also unfavourable, since bean is very susceptible to such phenomena. Unfortunately, these have been experienced in both former production years (Unk, 1984).
Carrying out the tasks of the project required the use of complex methods including the morphoagronomic description of the different plant traits of the varieties, the recording of plant health status, the investigation of Rhizobium and mycorrhiza occurrence and performing composition related laboratory tests. Some of these analyses have been carried out in all three years of the project, while others – evidently– took place only from the second or the third year.

The so-called “descriptor list” of traits investigated during the morphological and phenological assessments included the following elements: number of days to flowering, growth type, leaf form, colour of the wings and the standard, vascularity of the standard, position and boniness of the pod, colour of the green and the mature pod, size and shape of the seed, thousand seed weight, and the colour and pattern of the seeds. (Although it was planned to also evaluate the “vascularity of the standard”, virtually it was impossible to do so.) Besides, the health status and the seed yield of the populations were also recorded. The above mentioned elements of the list of traits significantly overlapped with that of the descriptor list compiled decades ago by the Centre for Plant Diversity, mostly developed according to the descriptors of the International Plant Genetic Resource Institute (IPGRI) and the International Union for the Protection of New Varieties of Plants (UPOV). The trait called “colour and pattern of the seeds” represents the most significant difference among the three sources which is described by 15 basic level and 112 lower level characteristics in the descriptor list developed by the Centre for Plant Diversity in order to overcome this very difficult problem of been variety description. (For example the white basic colour has 5 varieties, yellow has 10 kinds, and brown has 13 types, meaning shades in fact.)

Parallel to the morphoagronomic, phenological and biological description activities, the quantification of the occurrence of Rhizobium root nodules and mycorrhiza have been continuously performed.
The soil improving impact of plants belonging to the Papilionaceae family has been known for long, but *Rhizobium* bacteria, the leading contributors in the formation of root nodules have been discovered only in the second half of the 19th century (Horváth 1960).
Nitrogen fixing endosymbiosis is one of the oldest, and, due to the frequency and the abundance of the Papilionaceae species, is one of the most significant plant-microbe symbioses, fundamentally affecting the nitrogen balance of a specific ecosystem through biological nitrogen fixation. During the formation of symbiosis, special organs – so-called nodules – are developed on the roots in which symbiont bacteria, called bacteroids, can be found. More than 90% of the plants belonging to the Papilionaceae family have this kind of symbiosis, primarily with the species of the *Rhizobium* genus.

During root nodule examinations 3 plants of each item were dug out, on which root nodules were counted after proper washing.
Fungi living on the roots of plants are called mycorrhiza. 95% of vascular plants have some kind of mycorrhiza. Thanks to the mycorrhiza, plants have an increased drought, heat and acid tolerance besides having a better resistance to heavy metals (Varga 1999, Jakucs and Vajna 2003). Vesicular-arbuscular mycorrhizae (VAM) belonging to the endomycorrhizae is the most common of all mycorrhizae, being the most frequently observed symbiont relationship between fungi and plants. Hyphae grow intracellularly within the plant cells, and they form hydatic vesiculae and dichotomous arbusculums with many branches there.
There are more staining methods for the detection of arbuscular mycorrhizae. Within this project we used the aniline blue staining method elaborated by Carol Grace and David P. Stribley (1991). The gist of this labour-intensive method is that the cleaned (fixed) small root pieces of the different samples are incubated in Eppendorf tubes filled with 10% potassium hydroxide (KOH) solution at 60°C for 15 minutes (Mini Block Heater). After incubation roots are washed in distilled water using three replications (15, 5 and 5 minutes), and then are put into an acidic medium (lactic acid solution) for 5 minutes, followed by a 2 minutes long leaching in aniline blue stain. After being washed in distilled water following the staining phase root samples have been analysed by using a light microscope with 40x and 100x magnification.

Research results and conclusions

As indicated above, the results of the research have been assessed based on the 2018 experiment containing 332 varieties, and using three replications. The data of the former two years are mentioned only if it is necessary to compare them with that of 2018.

Traits analysed from morphoagronomic points of view need to be assessed one by one. It is worth paying special attention to some of the elements – especially when compared to other categories –, while other features are used only as differentia during the identification of a given landrace.

Due to the objectives of the project, it is evident that the yield level of landraces has priority over the other investigated traits.

By taking into account the yield results of the 2018 production year – which was acceptable also from statistical points of view – during the comparison of yield levels, differences grouped based on practical aspects have been found (see Figure 2).

According to this, one item reached the “fantastic” yield level of 3 t/ha, while 5 landraces produced 2 tons of seeds per hectare, which is also very good. Altogether 40 varieties – amounting to 12% of the total number of items (332 pieces) – exceeded the acceptable 1 t/ha yield level (Figure 13). The majority (72%) of the items failed to reach the 0.5 ton/ha yield level, which is regarded to be poor. Apart from the formerly mentioned extremely unfavourable weather conditions it must be noted that we have guiding information neither on the level reached by this index at the producer of the used basic material nor on the related expectations of the producer. This means that absolute yield levels defined by us may not coincide with the level satisfying the original producer, meaning, lower yield may also be sufficient, if the taste is good.

Similarly to seed yield, plant health status is especially important. The occurrence of diseases was difficult or, in some cases, impossible to estimate due to the various symptoms, which could not be distinguished. The traces of the well known bacterial and fungal diseases of the bean could easily combine with the signs of the inevitable sunburn or viral infections in the stand. This latter issue is verified by the fact that the Agricultural Institute of Slovenia investigated the occurrence of 5 virus groups in 276 items from the stands of August 2017. According to their report, the occurrence of alfalfa mosaic virus was 1%, cucumber mosaic virus reached 75%, bean mosaic virus was observed in 85% of the cases, while, common bean mosaic necrosis was found only in 1% of the samples. Bean yellow mosaic virus has not been detected in the analysed samples.

In order to overcome the above mentioned challenges, we recorded a general plant health status two times during the vegetation period – with one month difference – based on a uniform approach. The received data clearly demonstrated the continuous deterioration of the bean stands during the extreme summer period (see Figure 3).

Figure 4 verifies the correctness of the above mentioned method through the total seed yields of the landraces.

One of the major criteria of bean production is the growth type of the variety in use. (Scientific and common languages use different phrases for the specific growth types. For example determinate growth type can be called bush type, semi determinate is often referred as semi runner bean, while indeterminate is called runner.) It is evident that bush beans are preferred in large scale production. However, as shown by Figure 5, during the production of landraces and home garden varieties it is not so important, because supporting structure and harvest related issues are easier to be solved in this case. Based on the diagram it can be also stated that runner type beans reached significantly higher yields in the experiment. Of course, generally this also can be traced back to the biological advantages of this growth type – e.g. that extended flowering period and pod formation can partially mitigate the negative impacts of droughts –, which became more significant due to the experienced unfavourable weather conditions. It is also a fact that Hungary was a "famous bean producer" when the majority of bean production originated partly from runner type beans planted between the rows of maize. Unfortunately, the agronomic significance of this practice is neglected today - except for home gardens (Balassa 1960, Velich - Unk 1995).
The ripening time of beans is an important phenological trait – which is very diverse in the case of the different varieties due to the differences experienced between bush beans and runner type ones –, and can be taken into account only during the production of bush beans. For this reason, we used the criterion called "number of days to flowering", which is slightly different from the above mentioned one. It was typical that at the beginning of the flowering period– in the 2nd decade of June – 93% of the flowering landraces were bush beans, while no flowers could be observed in this group by the end of the period (see Figure 6). Anyways, 165 items started flowering in the 1st decade of June, 101 items in the 3rd decade of June, 56 items at the beginning of July, and 8 items in the 2nd decade of July. The relation between yield levels and the beginning of flowering is described by Figure 7. Regarding the relation between seed colour and flowering time white beans must be highlighted, as they proved to be late flowering, which was the reason behind their higher yields. Their presence in the decade-long intervals increased from 12% to 25%.The shorter flowering period of determinate bush beans proved to be a serious drawback due to the witnessed heat waves.
In fact, it is difficult to select green bean type populations in such a variety comparison experiment. In our case a descriptor, called the boniness of "green ripening pod" (meaning the bone, which can be detected at the dorsal side when breaking the pod into half), is used for this purpose. Varieties where this bone cannot be detected can be cooked as green bean. (Of course, after proper cleaning almost every bean variety can be used for such purpose.) Regarding our experiment, 9% of the beans proved to be suitable for this kind of utilization, 39% were bony, while 51% had mixed features from this point of view.

The colour and pattern of the beans is mostly connected to traditions and aesthetic quality, but other factors – e.g. culinary aspects – also need to be considered. Sometimes these may provide exceptional value for a specific variety, like in the case of the foreign “pinto” or “red bean”, but the Hungarian “chestnut” and “silver” varieties also have this kind of charm.

Our former experts covered the regionalization of different landraces, based on the colour of their seeds, and the connection between seed colour and geographical location in a smiliar context. (Unk, 1984, Velich J., Unk J. 1995). According to the data mostly collected until the second half of the previous century, many smaller and larger regions had specific landraces, such as the white “Dunai középbab” (Danube middle bean) or the “Békési libamáj” (goose liver from Békés).

Today it is difficult to verify whether these regional production areas still exist, or they disappeared during the process of diversity decease and vanishing localization due to the increased mobilization of the producers and the significant decline experienced in sowing seed trade and production activities.

During the investigation of the seed colour of the selected varieties we used 75 of the 112 seed colour types included in the descriptor list of the Centre for Plant Diversity. Although this huge number of seed colours is very important when identifying landraces, larger colour groups are advised to be merged during evaluation (see Figure 8).

According to the figure it can be stated that one-third of the studied landraces (113 varieties) belonged to the so-called “brownish-streaked” colour group. Besides, 61 varieties proved to be plain brown type, and the third richest variety group was that of the white beans including 51 landraces.

The higher yield level of the investigated white beans is verified by the fact that the first three best performing landraces are white, and that 18 of the 40 items exceeding the seed yield level of 1 ton/ha are also white. Within this group 10 landraces are brownish-tabby, 1 landrace is striped, 3 landraces are yellow, 3 landraces are plain brown, and 5 landraces have a mixed seed colour. On Figure 8 it can be seen that – also for mathematical reasons – a unique so-called “békahátú” (frog back) colour type is the first one. It is somewhat surprising that the group having a mixed seed colour ranked second with a relatively large number of varieties. So far the intentional use of colourful bean seed mixes was neglected by all. The reason is evident: producers regarded it as natural inadvertency, while collectors thought that it is some kind of neglect that cannot be charged. The use of variety mixes is not common in the case of the other plant species; however it is not exceptional either. (Prasad, R.C. et al., 2016) It was more common centuries ago, and is less frequent in the current “species-centred” world, but sometimes still can be observed today. The reason behind using variety mixes is diverse, as sometimes it is accidental, while in other cases it is intentional. This latter resulted in the creation of the wheat-rye mix, called “abajdóc” or maslin, in order to guarantee the required yield levels through a

species mix. (Cserháti S., 1905) We do not have such old or newer information on common bean from Hungary, except for this current phenomenon to be further researched. In our experiment the majority of mixed items originated from Transylvania.
Naturally, the colour of the flower – defined by the colour of the standard and the wings – is variety specific. Contexts related to the research results are based on the colour of the standard. According to Figure 9, light purple was the most frequently observed standard colour followed by white, which ranked first from the point of average yields. Regarding the flower colour of the different growth types, light purple was the dominant colour in the case of bush beans, and also covered 50% of semi determinate varieties. White standard colour was most frequently observed in the case of indeterminate varieties.
The relation between the colour of the seeds and that of the standard is an interesting issue to investigate. The standard of the majority (234 items) of the somehow colourful or spotted beans (279 items) had some kind of purple shade. The 51 pieces of white beans – except for one – had white or whitish standard. Anyways, white corolla is regarded to be recessive by literature (Mándy Gy. 1963).
As mentioned above, the other analysed traits such as the leaf form, the vascularity of the standard, the position of the pod, the colour of the green and the mature pod, the size and the shape of the seed are primarily used during the identification of the landraces.

Thousand seed weight (TSW) can replace the index of seed size, which is difficult to assess. Average thousand seed weight was slightly higher in the case of bush beans, amounting to 363 g, while it reached 324 g for semi determinate varieties, and was 325 g for indeterminate varieties.
When comparing seed yields and thousand seed weight values, we found a weak correlation (0.28), and observed higher yields than in the case of lower thousand seed weight values (see Figure 10). However, it must be noted that this tendency does not necessarily reflect the objectives of the owner of the given landrace. This might be traced back to the fact that the numerous poor yielding items compensated the small number of their seeds with larger seed size.
Regarding mycorrhizal contamination, altogether 279 items have been studied. In the case of 32 items all the three replications have been analysed. 173 of the investigated landraces had no fungal contamination on the root system, while mycorrhizae have been found in the case of 106 varieties.
9 varieties of the 32 items, which were analysed by using three replications, proved to be contaminated. 4 further items also contained mycorrhizae. We found them three times when using two replications, and once when applying one replication. The presence of the more or less mixed state – which was observed only a few times – indicates that different varieties may have different sensitivity regarding mycorrhizal contamination.

There is no literature data available on the analysis of naturally developed bean related mycorrhizae. All of the found publications deal only with artificial inoculation by using arbuscular mycorrhizae. Based on this, Erdinc with his colleagues (2017) and Kasymbekov and Faleyev (2012) experienced increase in more dimensional or quantifiable parameters in the case of the analysed plants.
We detected 11% increase in seed yields in the case of items contaminated with mycorrhizae.
Regarding the relation between the presence of myocrrhizae and flowering time, we found that the ratio of mycorrhizal contamination reached 60% in the case of varieties flowering in the 2nd decade of June, 71% for those flowering in the 3rd decade of June, 52% in the next decade and 40% in the following one. This contradicts with the assumption that the length of time spent on the fields has a positive impact on the development of mycorrhizae.
Regarding the colour of the flower and the standard, the ratio of contaminated and non-contaminated items ranged between 31-48%. In the case of the two most important seed colour groups – brownish-streaked and white – the ratio of contaminated populations reached 40% and 41% respectively, which is also not a significant difference. On the contrary, white spotted beans had a mycorrhizal contamination level of 83%, which is a fairly high value (see Figure 11).
Compared to other members of the Papilionaceae family – e.g. chickpea, peanut, etc. – the root nodule contamination of bean is not a common phenomenon (according to our own local observations). In the case of Phaseolus species, for example, high soil temperature can be a significant factor hindering both infection and nitrogen fixation (Ködöböcz 2007). Such circumstances have been observed in both years of Rhizobium analysis. Furthermore, the salt concentration of the soil may also affect nodule formation and the number of microbes (Khalif and colleagues (2005)), although this factor has not been investigated.
Although chemicals used during plant protection activities may also have an impact on the development of root nodules (Baijukya and Semu (1998)), this is not so important in our case, since – apart from the formerly mentioned plant protection agents – there were no chemicals sprayed on the fields.

Regarding the presence of *Rhizobium* species, average root nodule number reached 1.4 in the case of determinate landraces, amounted to 2.6 for semi determinate ones, and was 5.3 for indeterminate varieties (based on the mean values of 2017 and 2018). Obviously, this phenomenon is related to the length of time these bush beans spend in the fields until their full harvest.
We found a 0.3 correlation value between the number of root nodules and seed yield. In addition, this weak correlation is also distorted by the fact that – as mentioned earlier – the average yield level of the experiment has been increased by the runner type varieties having a longer growing season that is staying in the soil for a longer time.

By investigating the relation between growth type and the number of root nodules, the advantage of runner type beans having a longer growing season is unequivocal. Results on the relation between flowering time and the number of root nodules do not contradict with this finding. According to this, early flowering varieties had higher root nodule numbers. Regarding the colour of the seeds – as mentioned earlier – white beans having a longer growing season reached the highest average root nodule numbers, but also similar average values were experienced in the case of landraces with seeds of mixed colour (see Figure 12).
Baird and Caruso (1994) published on the "joint presence" of mycorrhizae and Rhizobium root nodules after the inoculation of beans with *Rhizobium* strains and mycorrhizal fungus spores under artificial conditions. According to their results, the root nodules of the plants inoculated with both symbionts were more developed, and formed larger groups on the roots.
According to our results, both the mycorrhizae inoculated varieties and those without it had an average root nodule number of 1.7, which, in our case, does not verify the assumption that the presence of the two symbionts is more likely to be observed due to the easier contamination of the plants.

As a final analysis we investigated the protein content of the three replications of the 40 best performing varieties regarding yield levels in the laboratory of the Centre for Plant Diversity. Tests have been carried out according to the relevant protocols, especially standard MSZ EN ISO 5983-2 on the determination of nitrogen content.
Results demonstrated in Figure 13 also reflect the significant – more than 4% – difference among the landraces. When assessing this data, relations between the protein content and the other traits of the given landrace also need to be considered.
Regarding bush beans, crude protein content (dry matter basis) was almost 3% higher in the case of indeterminate varieties than for determinate ones. It seems that flowering time did not affect this correlation. Seed colour resulted in a difference of 2% on the average, and brown colour combinations reached slightly higher values than white beans.

Regarding the relation between crude protein content (dry matter basis) and the impacts of the two symbiont groups – separately and also together –, we came to the following results:
The presence of root nodules caused by Rhizobium contamination alone lead to a slight increase in protein content (see Figure 14), while mycorrhizal contamination decreased the protein level by 0.41%, which is negligible. The presence of the two symbionts together increased protein content by 3%, which seems to be the positive impact of Rhizobium bacteria.

Conclusions/Summary

Regarding seed yield – being our main component – the virtually variety level large sample size experiments carried out in three subsequent years with extreme weather conditions lead to sad conclusions. For bean as a species and a crop category it is difficult to overcome the challenging weather extremities caused by climate change.

By contrast, or rather for this reason the most important result of our research is that finally a few landraces have been selected which could be promising elements of breeding, pre-breeding or landrace rehabilitation based on their ecological plasticity. The latter two categories are especially important for the Centre for Plant Diversity since they belong to the competency of the institution, this way allowing for further steps to be directly taken. According to the free accessibility of genetic resources provided by law, the Centre for Plant Diversity continuously hands over gene bank samples to the interested ones, mostly farmers. Since feedback is required on the agronomic and other traits of the gene bank samples, a kind of pre-breeding is implemented this way.

Based on the monitoring of bean landraces useful information can be given to the interested people not only on the agronomic, but also on the phenotypic, the morphological and the most important composition, Rhizobium and mycorrhiza related traits.

There is no need to assume that people asking for gene bank samples will collect these informations from prestigious or foreign publications. For this end, the Centre for Plant Diversity will make a special publication on the required partial results of the research and the description of the landraces, which will be made available for those interested in joining this activity. It would be especially important because the majority of the selected promising landraces are runner beans, which are rather suitable for small-scale production.

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Note

Regarding that part of the project implemented together with the Agricultural Institute of Slovenia, the following activities have been carried out in the reporting period: the Agricultural Institute of Slovenia used DNA analysis for selecting the items of the Central-European “core collection”. In the first phase 278 Hungarian landraces had been investigated, which became the basis for further selection activities. After selection the Agricultural Institute of Slovenia asked for the testing of 12 landraces from the Centre for Plant Diversity this year. Investigations included 6 bush beans (determinate varieties) and 6 runner beans (indeterminate varieties). The international analysis had to be carried out by using a joint protocol. The recording of the necessary traits and the harvesting and the cleaning of the landraces were implemented in this case as well, and the collected data have been sent to the Slovenian partner.

Appendix (Figures)

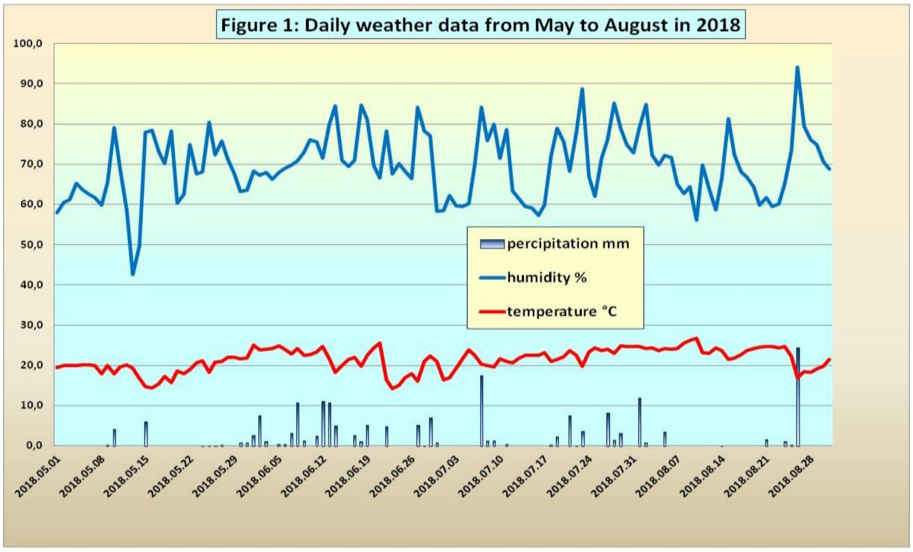

Figure 1: Daily weather data from May to August in 2018

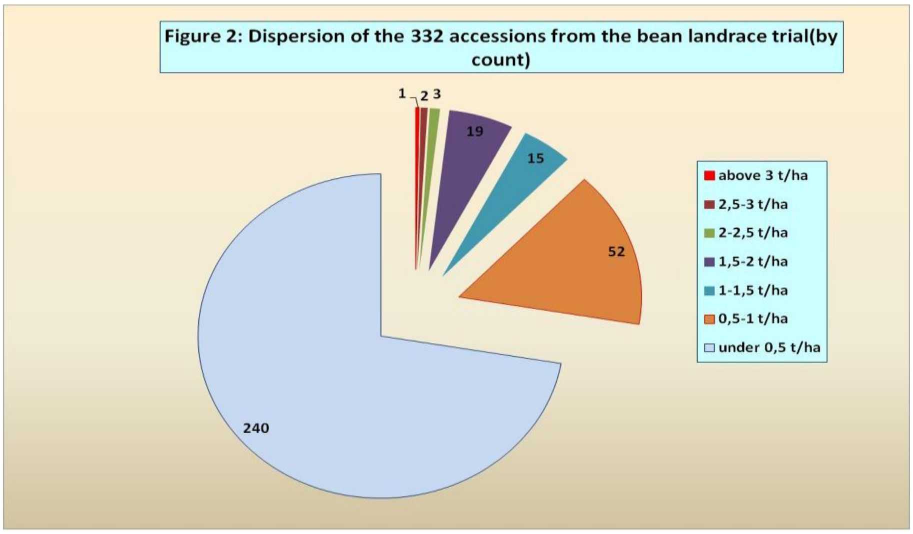

Figure 2: Dispersion of the 332 accessions from the bean landrace trial(by count)

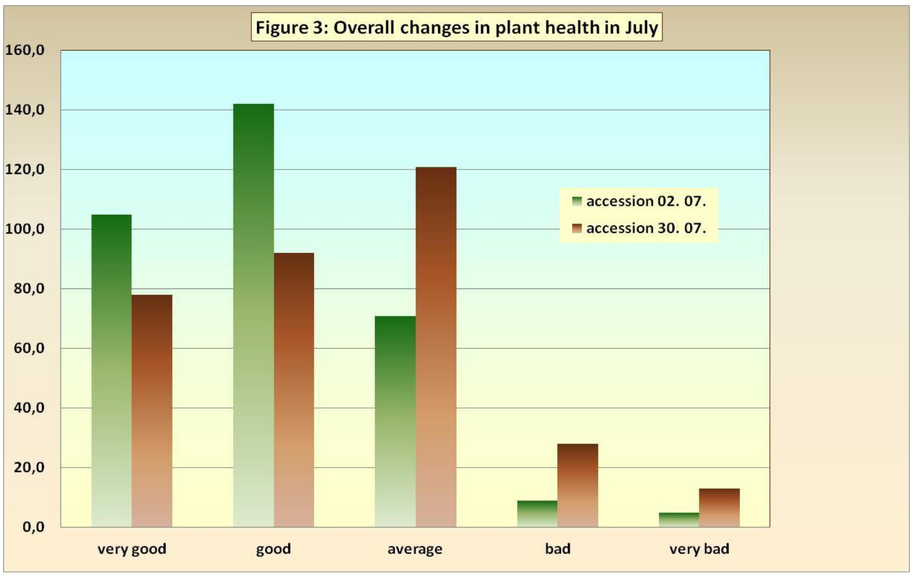

Figure 3: Overall changes in plant health in July

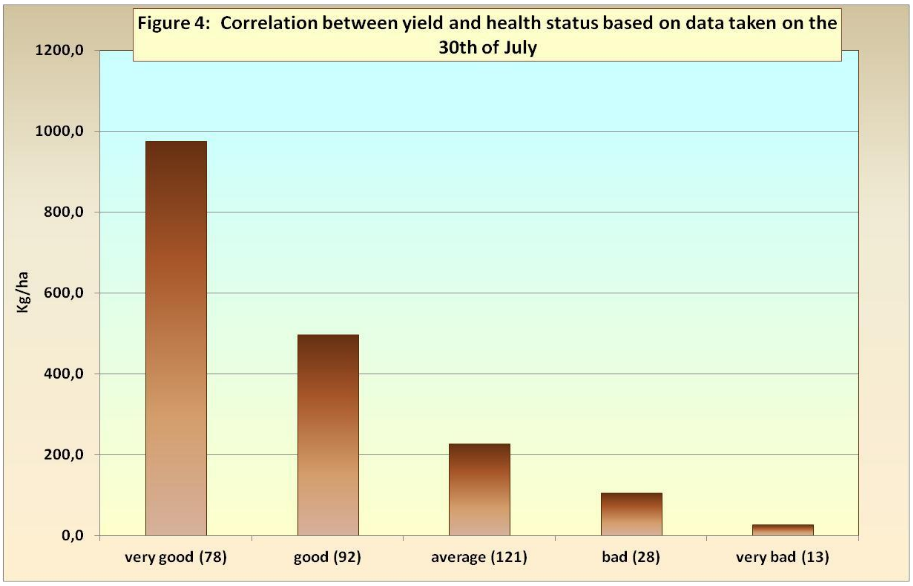
Figure 4: Correlation between yield and health status based on data taken on the 30th of July
Kg/ha
1200,0
1000,0
800,0
600,0
400,0
200,0
0,0
very good (78)
good (92)
average (121)
bad (28)
very bad (13)

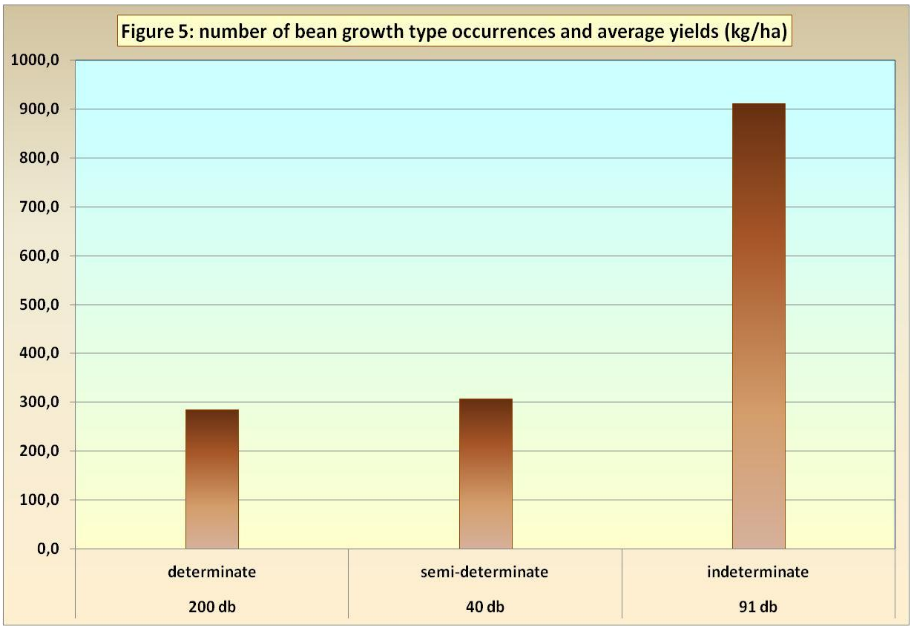
Figure 5: number of bean growth type occurrences and average yields (kg/ha)
1000,0
900,0
800,0
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
determinate
200 db
semi-determinate
40 db
indeterminate
91 db

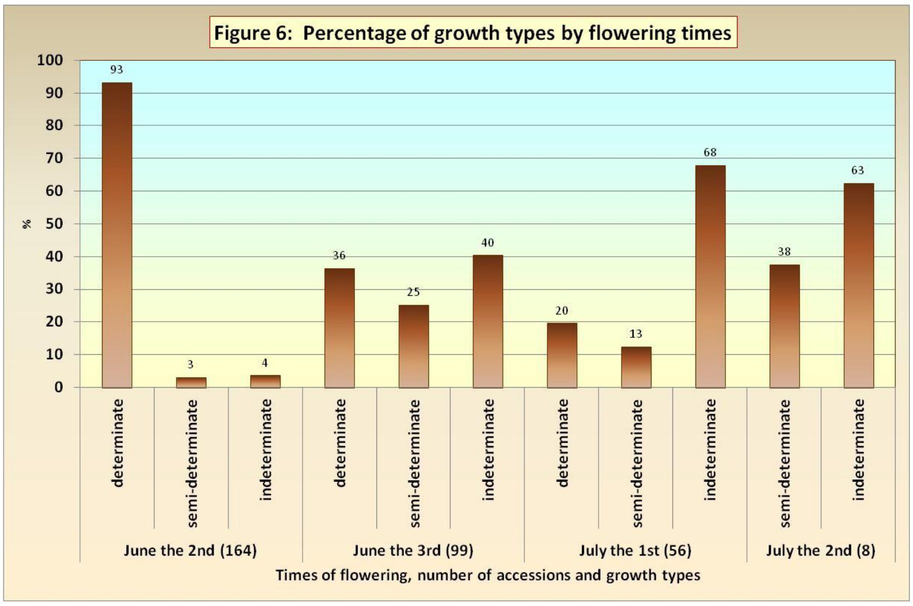
Figure 6: Percentage of growth types by flowering times
%
100
90
80
70
60
50
40
30
20
10
0
93
3
4
36
25
40
20
13
68
38
63
determinate
semi-determinate
indeterminate
June the 2nd (164)
June the 3rd (99)
July the 1st (56)
July the 2nd (8)
Times of flowering, number of accessions and growth types

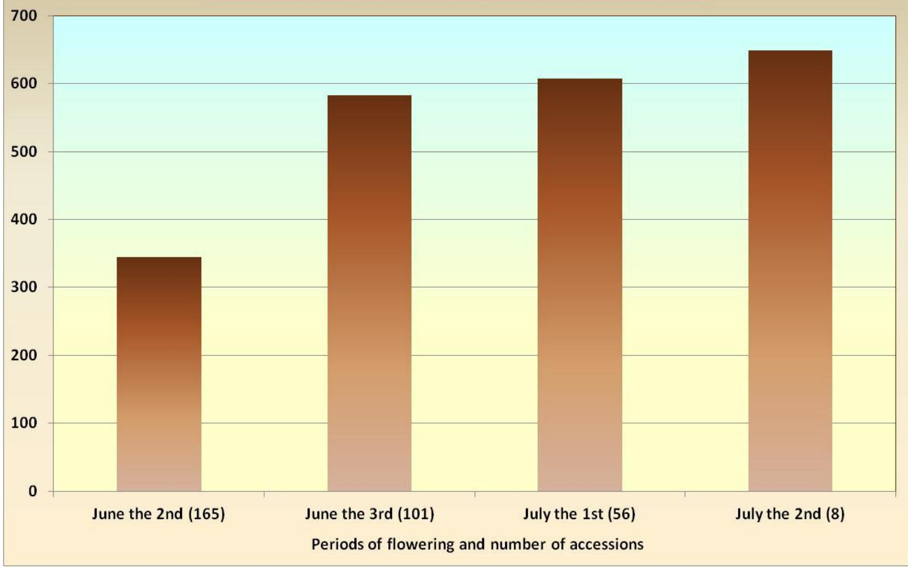

Figure 7: Average yields by times of flowering (kg/ha)

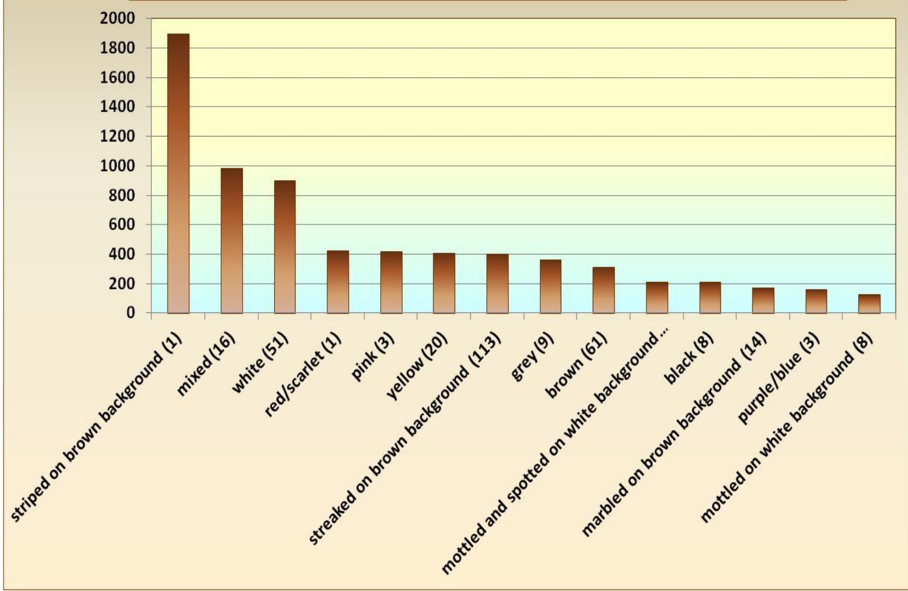

Figure 8: Groups of seed colors in bean landraces, their occurrence in numbers and their average yields (kg/ha)

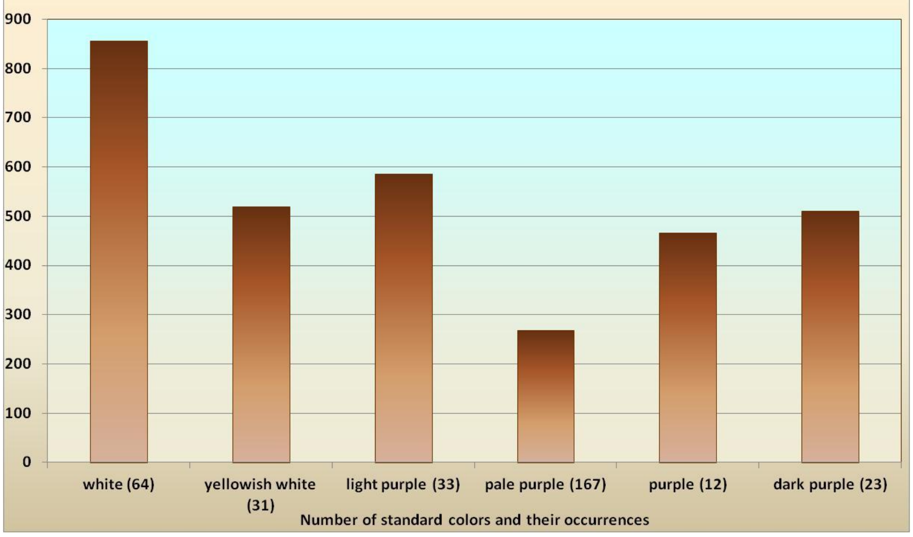

Figure 9: Average yields for individual flower-standard colors (kg/ha)

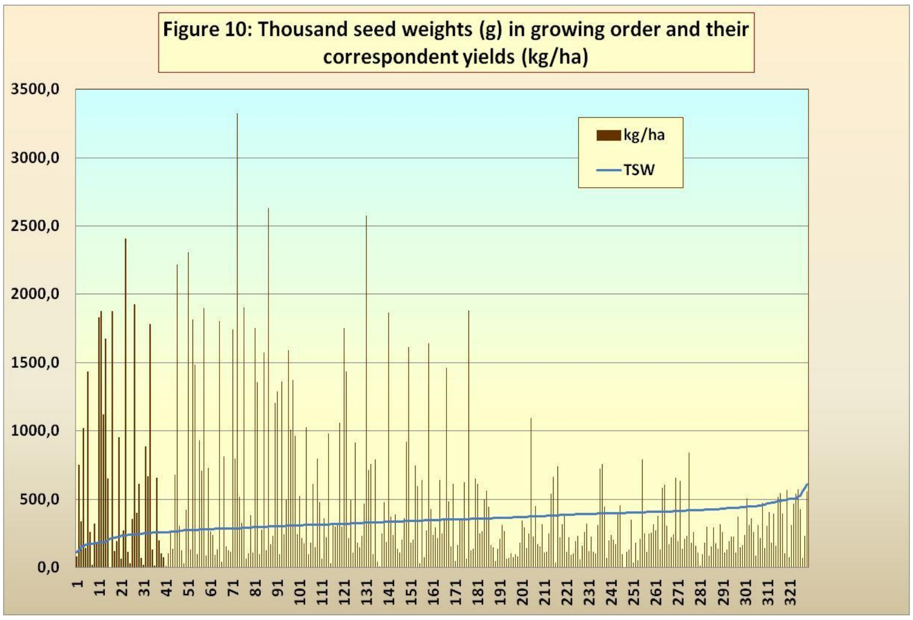
Figure 10: Thousand seed weights (g) in growing order and their correspondent yields (kg/ha)
kg/ha
TSW
3500,0
3000,0
2500,0
2000,0
1500,0
1000,0
500,0
0,0

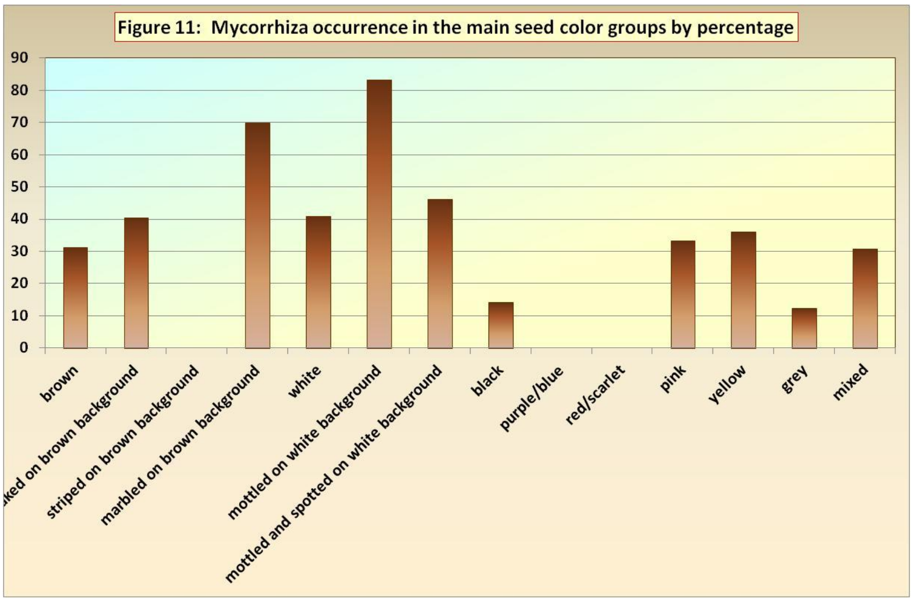
Figure 11: Mycorrhiza occurrence in the main seed color groups by percentage
brown
white
black
purple/blue
red/scarlet
pink
yellow
grey
mixed
striped on brown background
marbled on brown background
mottled on white background
mottled and spotted on white background

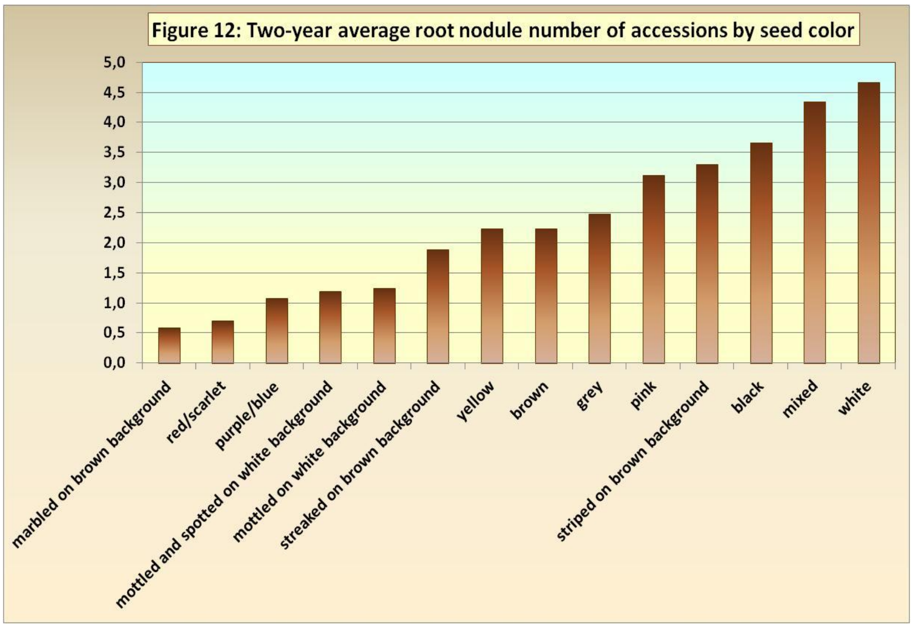
Figure 12: Two-year average root nodule number of accessions by seed color
marbled on brown background
red/scarlet
purple/blue
mottled and spotted on white background
mottled on white background
streaked on brown background
yellow
brown
grey
pink
striped on brown background
black
mixed
white

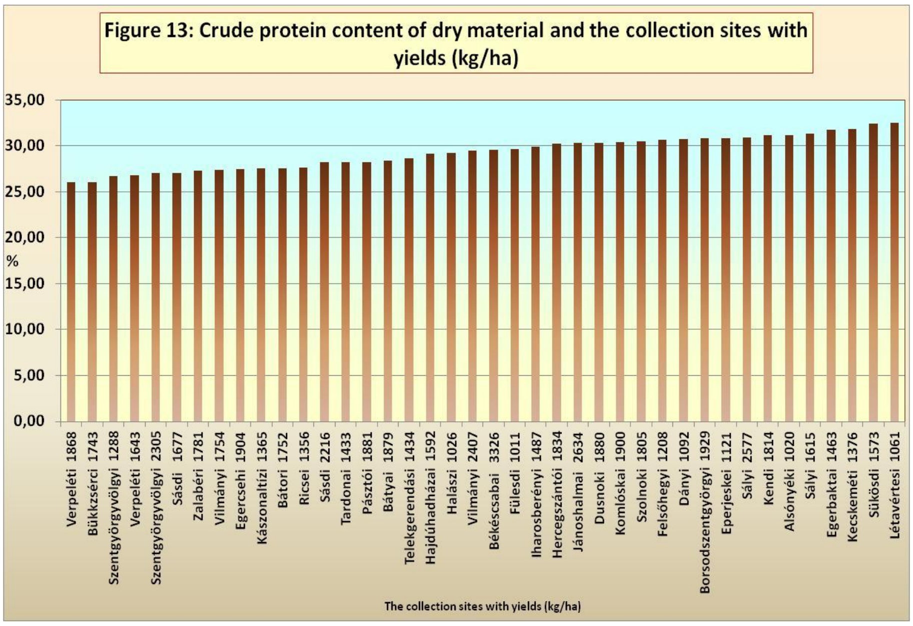

Figure 13: Crude protein content of dry material and the collection sites with yields (kg/ha)

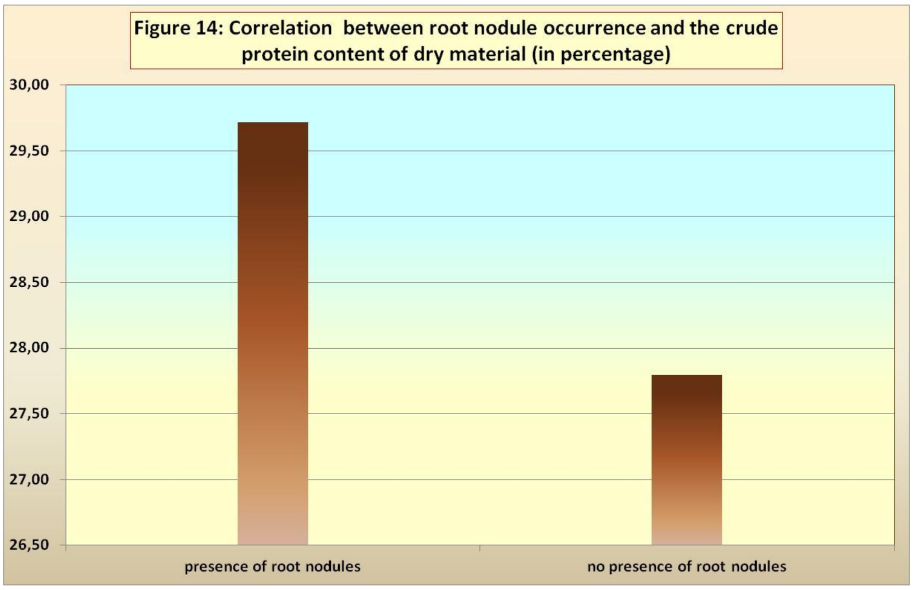

Figure 14: Correlation between root nodule occurrence and the crude protein content of dry material (in percentage)