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AGRONOMIC PERFORMANCE OF CLIMBING BEAN CULTIVARS IN INTERCROPPING WITH SWEET MAIZE - A PILOT EXPERIMENT FOR PHENOTYPING PROTOCOL DEVELOPMENT

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Abstract

Bean maize intercropping is an old cultivation scheme practiced at small scale by traditional farmers in Romania. Literature highlights the benefits of intercropping and the constrains related extension of this practice on largest areas. Studies on interspecific interactions have paramount importance in view of development of feasible approaches of environmentally friendly cultivation practices and for genetic improvement specific for performance in intercropping. Five climbing bean varieties were evaluated in sole cropping and in intercropping with one type of sweet maize cultivar. Sowing was successively caried out in an interval of 30 days, bean following maize. The performance of bean genotypes in each cropping system was assessed by phenotyping, of different traits. The results show a significant bean genotype × cropping system interaction for flowering and for seed yield. The most competitive bean varieties were taller, more vigorous, and late to maturity. Diversification of cultural systems by implementing bean maize intercropping seems to be an effective strategy in pest management, and further research will provide a basis for incorporating practical pest control schemes into intercropping systems.

Key words*: Phaseolus vulgaris, cropping, phenotyping, yield.*

INTRODUCTION

Progress has often come with social and environmental costs, including water scarcity, soil degradation, ecosystem stress, biodiversity loss, high levels of greenhouse gas emissions, so on. The productive potential of our natural resources has been damaged in many areas around the globe, compromising the future fertility of the planet. Currently, the impact of climate change continually reduces the capacity of these ecosystems to sustain the world's rising food demand. With levels of prosperity as diverse as the cultures, climates, and landscapes, a 'one-size-fits-all' approach does not apply to this dynamic part of the world (FAO, 2021).

Innovative actions are needed to face the emerging threats to food security and nutrition, and to improve resilience.

Diversity of cropping systems as intercropping, crop rotation and crop sequencing may be promising and innovative solutions especially in rain-fed farming areas. A well-designed intercropping system can restore the detrimental effects of intensive farming and monoculture applications, unable to support healthy plant production and contributing cause of plant pests and diseases. Moreover, considering the biochemical profile of species introduced in these cropping systems the natural substances and their secondary metabolites can play an active role as allelopathic or insect repellent to protect the natural sources and the environment by limiting the use of chemicals in weed and pest management and by promoting soil structure and productivity. The system including rotational cropping of cereals with grain legumes and/or cereals with the intercrops of cereals and grain legumes have significant contribution in soil health and N nutrition, as well as breaking the cycles of reducing factors, including insect pests, weeds, and diseases (Nassary et al., 2020). Furthermore, the innovative intercropping system with legume-based rotations promotes farming crop diversification and provide an insurance effect against crop failures and market fluctuations.

More sustainable agricultural systems are necessary to avoid environmental risks with dramatic consequences for inhabitants of rural areas and cities. Such technologies include the use of integrated soil fertility management practices (ISFM) which promote intercropping cereals with legumes as one of its main components (Mucheru-Muna et al., 2010). This practice is an attractive strategy to smallholder farmers for increasing productivity and land labor utilization per unit of area of available land through intensification of land use (Seran and Brintha, 2010). Furthermore, intercropping cereals with legumes retain a huge capacity in replenishing soil mineral nitrogen through the ability to biologically fix atmospheric nitrogen and in reducing interference attributable to weeds and other pests (Giller, 2001). Intercropping of cereals with legumes has emerged as a common cropping system in rain-fed. Intercropping of cereals with legumes improves soil conservation (Anil et al., 1998), favours weed control (Banik et al. 2006), provides better lodging resistance (Anil et al., 1998), yield stability (Lithourgidis et al., 2006), hay curing, and forage preservation (over pure legumes) and may increase crude protein percentage, protein yield, and length of optimum harvest period over grass crops (Qamar et al., 1999). Several factors can affect the growth of the species used in intercropping, including cultivar selection, seeding ratios, and competition between mixture components (Carr et al., 2004).

Brooker et al. (2015) highlighted the challenge of understanding the processes and mechanisms of intercropping could facilitate its manipulation with the purpose to maximize its benefits in terms of yield, soil quality, biodiversity conservation, and farmers' profitability.

To assess the performance of intercropping one pilot experiment was established using bean and maize. The aim was to evaluate the crops growing and development to develop a specific protocol for phenotypic and agronomic investigation of intercropping system.

It is expected that intercropping experiments to contribute to minimizing the soil degradation, nutrient loss and reduced soil and fertility quality, thereby promoting a sustainable soil productivity and microbial community.

Relevant target groups-users, farmers need to be identified, engaged, and involved in the co-design, monitoring, and evaluation possible adoption of this cropping system.

MATERIALS AND METHODS

The experiment was conducted in kind, frame of INCREASE, Intelligent Collections of Food Legumes Genetic Resources for European Agrofood System**,** project as a pilot experiment the major characterisation evaluation intercropping experiment for 2022-2023 planned with three maize varieties and 200 beans varieties. The experiment was also a part of the National project 529 / 2018, aimed to test and develop best cultivation practices for new certified varieties of the unit, as for example in this case, Deliciosul, maize variety.

The location was the experimental field of VRDS Bacău 46.585205 N, 26.950087 E., featured by a climate with 620 mm annual precipitation, and average of multiannual temperature 10.5°C. The soil is well-developed, loamy-sandy textured polished cambic chernozem.

The pilot experiment included five climbing bean varieties in intercropping with one type of sweet maize cultivar.

The bean varieties are the subject of conservation program developed at VRDS Bacau and will be discussed in this work under the codes of CB 1 to CB 5.

The sweet maize used in experiment is a registered variety, *Deliciosul*, highly cultivated all over the county.

'Deliciosul' variety was created at VRDS Bacau. The shape of the cob is cylindrical and the length ranges between 18-22 cm. The number of rows of grains is 13 to 14. The weight of the cob in 300 g at 75% humidity, and the weight of dry cob - 160-200 g, and the diameter 4.2-5.6 cm.

Sowing was manually realised for both crops, and successively caried out in an interval of 30 days, bean following maize.

The performance of bean and maize genotypes was assessed by phenotyping, of different traits. Table 1 includes a part of investigated traits and also traits proposed for the complete protocol of phenotyping. Moreover, during the experimental period monitoring and control of disease and pest species that affects the crops were realized. The observations were accomplished every 10 days. The attack estimation was determined using the following indicators: frequency of attack (F%), intensity

of attack (I%), the degree of attack (DA%). The results are useful to control diseases and pests and to manage the number of applied treatments.
The experiment was conducted in three replicates. For each bean variety 20 plants of maize were intercropped. The scheme included one plant of bean for each maize plant. The distance between rows was 70 cm and 20 cm between plants per row.
Previously to sowing fertilization using Linzer Complex NPK and herbicide using Dual Gold were applied.
No inoculation with rhizobia was applied. Two treatments against pest and pathogens using Bactospeine 54% *Bacillus thuringiensis* subsp. Kurstaki and Mospilan 20 SG were applied.
To facilitate the assessment, of influence of intercropping on different traits as flowering, pod sets and maturity, a sole system including same climbing varieties was conducted, using a traditional support system with individual ropes for each bean plant.

RESULTS AND DISCUSSIONS

Intercropping is claimed to be one of the most significant cropping techniques in sustainable agriculture, and much research and many reviews attribute to its utilization several environmental benefits, from promoting land biodiversity to diversifying agricultural outcome. In this sense, intercropping is thought to be a useful means of minimizing the risks of agricultural production in many environments, including those typical of underdeveloped or marginal areas.
This pilot experiment was a preparatory phase for an intercropping experiment developed in three EU locations in Romania, France and Italy, in frame of INCREASE project, during 2022 and 2023. The main purpose was to develop small-scale proof-of-concept studies using maize-bean intercropping, considering the biotic environments as key factors to assess the performance of a system. Maize was considered as a biotic environment for the bean in this agroecosystem. Further we will seek the genomic determinants in bean of the co-adaptation to this intercropping cultivation. The final goals are (1) to predict phenotypic values of individuals and their performance in a given environment for a given trait from their genotype, thereby facilitating the exploration of phenotypically uncharacterized germplasm (2) to develop new cultivation schemes for 'Deliciosul' variety, in order to highlight its cultivation potential.
Our experiment showed is extremely important to select proper varieties in terms of flowering and total vegetation period in close relation with experimental conditions that need to ensure conditions for proper maturation of both crops. The importance of this topic was considered also by Nassary et al., 2020. His approach specified the imperative need of studies to identify the most suitable time of introducing bean in the cropping system. The proposed strategy included moments such as early sowing, sowing mid in the season after a maize crop is well established, and late sowing, in close relation with specificity of environmental conditions.

Table 1. Included traits to phenotypic protocol in order to assess agronomic performance in intercropping

Maize investigations	
days to anthesis (MDA)	days
plant height (MPH)	cm
number of cobs s per plant (MEP)	number
total seed mass per plant (MTSMP)	grams
length and diameter of the cob (CL, CD)	cm
weight of the cob (CW)	g
symptoms of pests and disease (MSPD)	score
Bean investigations	
50% of seeds have emerged (BG)	days
flowering on 50% of the plants (BF)	days
50 % of plants have at least one visible pod (BP)	days
foliage density (BFD)	score
pods placement (BPP)	score
first harvest (maturated pods) (BH)	days
number of pods per plant (BPP)	number
total seed mass per plant (BTSM)	grams
weight of 1000 seeds (MTS)	grams
symptoms of pests and disease (BSPD)	score

Considering maize growing and development during experiment we observed the anthesis occurred in 66 to 78 days, with an average of 66 ± 3 days. During anthesis plants were evaluated in terms of height which variated from 266.33 cm to 290.67 cm.
The shape of the cob was cylindrical, the length registered a small variation between 18 and 22 cm. The weight of the fresh cob varied from 300 g to 375 g.
As a characteristic of investigated variety maize plants developed two cobs per plant.

The bean varieties needed six to eleven days for registering 50% germinated seeds.
Flowering of 50% bean plants was assessed counting the number of days from sowing to half of the plants in the plot had one visible open flower. The variation was large from 27 to 82, with an average value of 54 ± 0.7 days.
Pod set process occurred in 50 to 93 days with an average interval of 60 ± 1.4 days.
The harvest was realized at full maturity when the pods were dry, and the seeds matured. The earliest dry pods were collected after 77 days after sowing and the latest after 134 days. The average value of the interval needed for pods maturation was 96 ± 0.7 days.

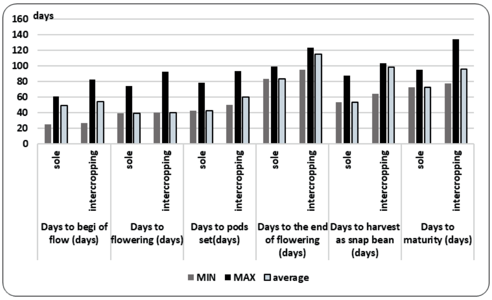

Figure 1. Flowering, pod set, maturity traits of beans in sole and intercropping system

A screening of pest and diseases appearance in bean plots, evidenced the presence of Anthracnose.

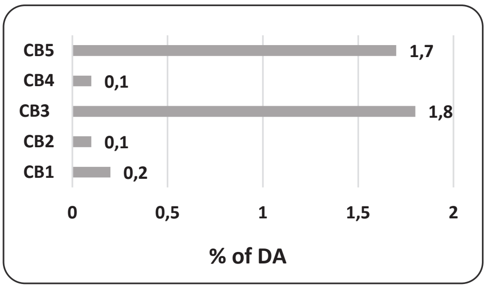

Figure 2. Degree of Anthracnose attack

The symptoms were present on plants starting the middle of June, and attack decreased in July and August. At the harvest moment of bean pods, Anthracnose was observed sporadically on plants of CB3 and CB5 (Figure 2).

Among the pests in the bean plots, the black bean aphid and bean weevil exceeded the economic threshold (ET) and required the application of control treatments.

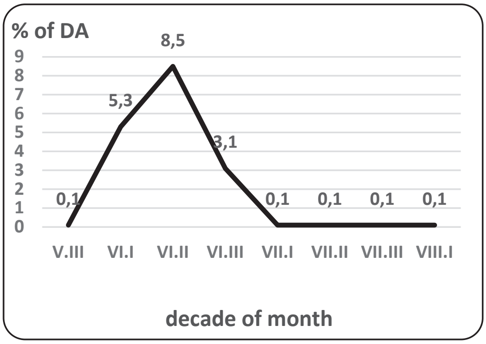

Figure 3. DA% of black bean aphid

The assessment of land utilization advantages of common bean in maize mixtures are recommended to be inserted in the protocol, in respect to specification (Willey, 1979)

This pilot experiment act as support for development of a protocol to be applied in intercropping for characterization and evaluation. The impact is strongly related to bean variability in yields along the years and with the need adapt the intercrop system to certain conditions and influences.

CONCLUSIONS

Our bean maize intercropping pilot experiment provides reasons to include species in cropping in same land, targeting productivity and management of pests and pathogens.
The success of maize bean intercropping system largely depends on the choice of varieties in terms of maturity and capacity to stand (maize), to climb (bean).
Our pilot experiment showed an earliness in case of traits as flowering, pot set up, harvest in case of bean sole system, comparing intercropping. Advantage of maize-bean intercropping system is pronounced in the greater utilization of available resources, benefits in weeds, pests and disease management. More investigations need to be realized to assess the intercropping influence on both crop yield.

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