

THE EFFECTS OF CLIMATE CHANGE ON SOYBEAN (GLYCINE MAX L.) CULTIVATION AND PRODUCTION IN HUNGARY

Boglárka Bozóki*, Gergő Péter Kovács, Csaba Gyuricza

Plant Production Scientific Institute, Hungarian University of Agriculture and Life Sciences,
Páter Károly st. 1., Gödöllő, 2100, Hungary

Abstract

*Due to its importance in supplying oil and animal feed, soybean (*Glycine max* L.) is one of the four most important crops in the world. Compared with other crops, soybean has superior ability to provide high quality raw material for human consumption as its nutritional values are outstanding. Soybean global production is constantly rising, however, in recent years, a decrease in the interest has been registered in Hungary from 2017. Soybean yield decline can be affected by various biotic and abiotic stress factors in all growing seasons. In addition to this, changes in climatic conditions and abiotic stress factors directly affect the level of yield potential which is very important for improving sustainability of agricultural systems. In order to profitably adapt to a changing climate and guarantee food security in Hungary, improved crop varieties are needed to bring in to cultivation. Due to changing climatic conditions, farmers are interested in growing soybean since crop rotation diversity influences soil microbial communities and often increases crop productivity. The increase in cost of agricultural inputs and loss of soil fertility drive the search for sustainable strategies. Therefore, the objective of the present work was to study the effect of climate change on soybean cultivation and grain yield since this crop plant can be described with high yield stability even under changing weather conditions which adversely affects all ecosystems. Agriculture is one of the most affected branches due to its dependence on the evolution of the weather throughout the entire plants growing season. The variance of climate requests the use of a variety of agronomic strategies and good crop choices. Thus, searching for optimal tillage management is crucial for the maintenance and improvement of soil functions.*

Keywords: soybean, climate change, Hungary, soil tillage, production

INTRODUCTION

Among seed legumes, soybean (*Glycine max* L. Merrill.) has the greatest global area harvested representing the main source of relatively-cheap protein and vegetable oil (Mutava et al., 2015). Soybean is one of the strategic crops which contributes to provide a part of food for 43 countries. Soybean planting area and production are 102 million hectare and 261 million tonnes respectively (Younesabadi et al., 2021). Leguminous crops with their high protein content and nutritional values play a prominent role in crop rotation. In the 60s it was a strong agricultural development in Hungary, which favoured to keep fodder-need animals. Thereby feed protein demand surpassed on domestic production. Currently 40% of the feed protein demands come from import, which cannot be able to change supports and applications (Vályi-Nagy. et al., 2019).

Due to the crop loss caused by unfavourable weather, stock reduction caused by animal diseases, agriculture could not repeat the previous year's performance. Moreover, as a result of the recovery from the Covid-19 epidemic input products are more difficult to obtain than before. Among the other branches of the national economy, the added value of the agriculture decreased (by 2.2%) compared to the previous year, reducing the GDP by 0.1 percentage point. However, due to unfavourable weather conditions, the production volume of plant cultivation is 6.3% lower, but its price level is higher than a year earlier. According to statistical analysis, it is caused by the strong demand on the market. Regarding the production of two of the important plant species, the role of the country is significant: the production value of corn is 8.5% and 8.8% of oil seeds. Hence, the European Union ranked Hungary in the 5th place of the oilseed production among the other countries of the EU (Vukovich, 2022).

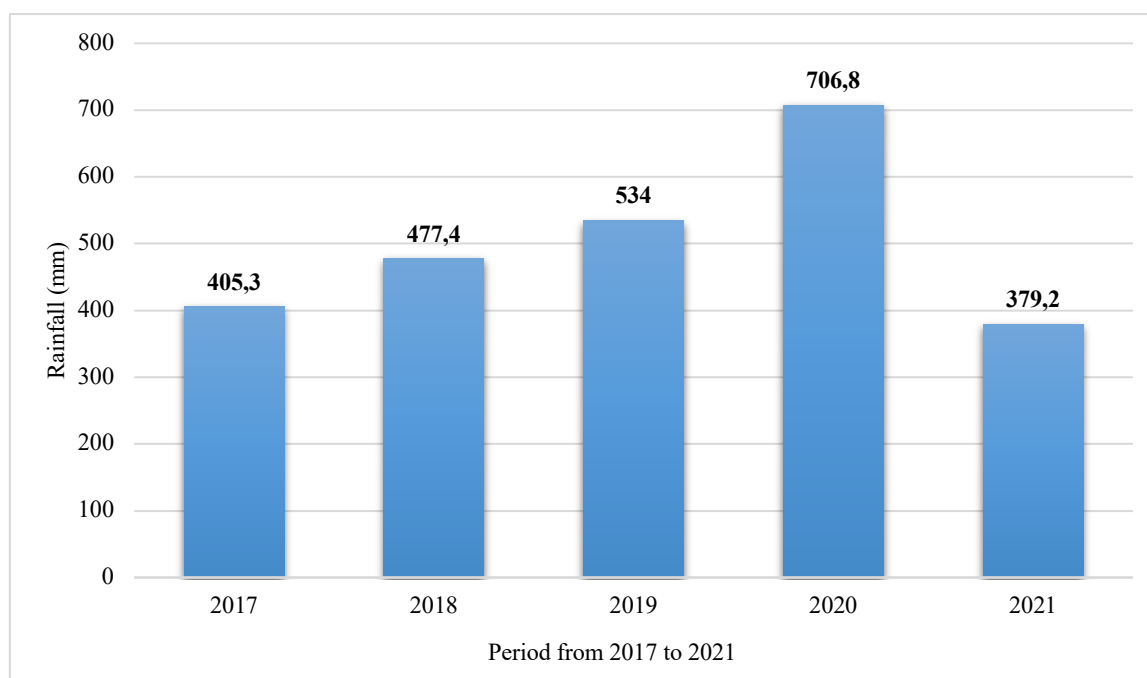
Today, the annual demand for soybeans is 500-600 thousand tons in Hungary, but 90% of this is imported from South America (Kövics et al., 2020). The domestic and international market would also require GMO free soybean seed and meal. In *Table 1* it can be seen that Hungarian soybean production area is the sixth (58 230 ha in 2019) after Italy, France, Romania, Croatia and Austria in the European Union (FAOSTAT, 2019).

Table 1. Hungarian soybean harvest and production from 2015 to 2020

Year	2015	2016	2017	2018	2019	2020
Harvested area (thous.ha)	72	61	76	62	58	59
Yield production (tons)	145 853	184 725	179 282	181 240	169 565	165 757

The local climatic conditions make it possible to increase the soybean production area in Hungary, however, successful soybean production depends on many factors (Dordevic et al., 2020; Tar et al., 2021). Increasing number of water scarcity and drought stress can be seen as it presented in *Figure 1*.

Figure 1. Meteorological data of total rainfall from 2017 to 2021 in Gödöllő, Hungary



However, soybean adapts to non-extreme soil types effortlessly, which is demanding of soil water management, is highly affected by many abiotic stresses (Fan et al., 2013) that intensively increased over the past decades, affecting the world's food security (Vukuronda et al., 2016). Soybean is considered highly-sensitive to abiotic stresses compared to other crops (Maleki et al., 2013) especially during certain periods of plant lifecycle (Liu et al., 2004). Basal and Szabó (2019) found that drought stress has noticeable effects on soybean; it results in reducing the yield to distinctive levels; however, it measurably increases protein concentration while slightly decreases oil concentration. These type of stresses negatively affect soybean morphology, physiology and, consequently, the final seed yield (Basal & Szabó, 2020). It is genetically accepted that high yield in soybean is negatively correlated with protein concentration (Liang et al., 2010); moreover, oil and protein concentrations are usually negatively correlated as well (Chung et al., 2003).

Climate change is an emerging issue which negatively contributing many sectors in the world is considered to be one of the most serious threat to sustainable development (Gain et al., 2012; Auerbach et al., 2015). This issue will cause many economic challenges and social impacts in agriculture (TerAvest et al. 2015; Vanneuville et al. 2012). Climate change contributes some negative impacts on agriculture. The increase in rainfall is evidence of climate change, reduced water availability, and other unsuitable weather (Osman, 2018). However, increased rainfall as a part of climate change can provide some local benefits. There will also be several adverse effects, including reduced water availability and other extreme weather conditions (Arnell et al. 2011; Gosling and Arnell, 2016; Mancosu et al. 2015; Ummenhofer et al. 2017).

Adaptation assists farmers to cope with climate change by reducing adverse effect and increasing productivity of agricultural production. Modification of agronomic techniques and farm strategies in order to cope with climate change is necessary to meet growing demand of agricultural produces (Khatun et al., 2021). Farmers considered deforestation as the main cause of climate change, perceived changes in climate and recognized droughts, frosts and high temperature as events with the greatest negative impact on soybean production, perceived changes in rainy seasons and less precipitation, longer droughts, increase in temperature and frosts during the year. They also considered agroecological practices important to adapt to climate variability (Panadero-Navas, 2022). Adaptation reduces the negative effect of climate change only (Adger et al., 2003).

A number of studies have been conducted on the adoption and profitability of soybean worldwide. Studies on adaptation strategies followed by crop farming in Hungary, however, are limited. Islam et al. (2019) conducted a research on farmers' adaptation strategies to drought conditions and found that the association between the implemented adaptation measures and selected variables suggests that the farm size, irrigation accessibility, monthly household income, land ownership status, literacy level, and poverty status played significant role in the implementation of adaptation measures.

Researches evaluate the effect of soil management systems, mainly between conventional tillage and no-tillage, however, these research studies evaluate the effects on the soil or the plant, is isolation, thus leaving a gap to be filled, on responses of these managements jointly, so as to facilitate the understanding of the soil-plant system (da Silva, 2022). Adoption of non-conservative agricultural practices and the succession of soybean have contributed to an increase in the incidence of plant diseases, pests and weeds, resulting in enlarged expenditures on labor, equipment and pesticides, since there are no plants in the system that contribute to inhibit the development of such harmful agents. In this way, the growing interest in the sustainability of agricultural systems has led to significant developments in farming practice, with emphasis on the prevention of erosion and degradation, through the direct system and minimum tillage. There is also a growing interest in alternative forms of nutrient management, particularly the role of leguminous plant in N supply to non-legumes species through intercropping and crop-rotation (Piletti et al., 2022).

By reducing the negative effect of climate change on specific soybean, total production in Hungary can be increased which will contribute to cut off the import. For this reason, it is required to evaluate the production efficiency under different climate variability (Khatun et al., 2021). These practices have been increasingly adopted, given the greater attention to factors such as erosion, degradation, water storage capacity and thermal variability in the soil (Piletti et al., 2022).

Our experiment aimed to determine the influence of applying different soil tillage methods on the field of soybean cultivar since the search for cultivation practices that provide increased soybean yield has been recurrent lately.

MATERIALS AND METHODS

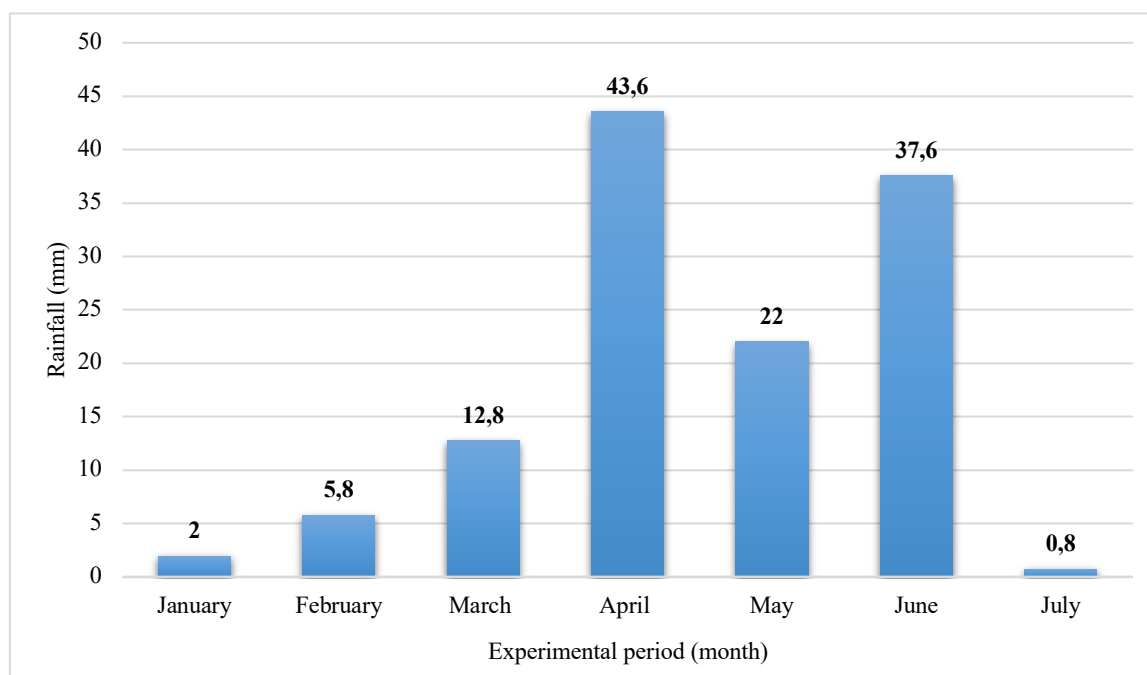
This paper presents the preliminary results of research on the efficiency of the soybean cultivation by applying various tillage systems under climatic and soil conditions of the Agricultural Research Station in Gödöllő, Hungary. The experiment of this study was to establish a connection between yield parameters of soybean (plant height, thousand seed weight, and seed yield) and the most important

physical characteristics of soils and to determine applicability of obtained models in estimation of plant yield.

The soil is sandy with organic matter of 1.3, pH of soil paste 7.21, 3.0 mg kg⁻¹ total N, 147 mg kg⁻¹ available P and 178 mg kg⁻¹ available K in the top 30 cm depth.

The climate, according to the classification of Koppen is Dfb which means humid continental climate with mean annual rainfall of 500 to 650 mm and the average annual temperature is 10.9 °C. The meteorological data of the actual experimental period was collected and presented in *Figure 2*.

Figure 2. Meteorological data of growing season 2022



The soybean cultivar; '*Aliz*' (00 maturity group) was sown in the experimental site of Hungarian University of Agriculture and Life Sciences (Gödöllő) (N. latitude 47° 59', E. longitude 19° 35') in 2022 growing season. Seeds of the soybean genotype were obtained from the Agricultural Research Institute of Iregszemcse, Hungary. The experiment was performed in 4 repeats, on 30 square meter randomized complete block design (RCBD).

Plant height is an important characteristic within the evaluation of the agronomic performance of soybean, given that it can be one of the factors that favours lodging and is linked to the generic conditions of the plant, to the growing environment and to the plant population (Souza et al., 2013). It is known that plant height, pod insertion height and number of branches per plant are genetic characteristics of the cultivar, which can be influenced by the environment, mainly by soil fertility and climate conditions (Mancin et al., 2009).

RESULTS AND DISCUSSION

The world population is constantly growing, while the agricultural area is limited. The aim of our researches is to find correlations between sustainable soybean production under the conditions of climate change factors. We found that agro-climatic conditions of Hungary are suitable for the cultivation of soybean. There is a need to work on the adaptability of new technologies under different climatic conditions of Hungary to ensure the self-sufficiency in quality food, feed, and edible oil production, ultimately a step forward for achieving sustainable food security along with significant improvements

in soil health. By proper education system, climate change awareness and extension contact have significant positive relationship with choosing and using different climate change adaptation strategies in soybean cultivation. The climatic conditions recorded during sowing and caring of the crop had to extent a favourable influence of the physical properties studied in soybeans. Applying the obtained results in practice can contribute to the efficiency of soybean production.

With the use of different climate adaption strategies, farmers can make them to be technically inefficient. Using the right combination of different adaptation and resources at the present technology level will make farmers to be more efficient. Thus, to be more efficient technically as well, government and non-governmental organizations should help the participants of the agricultural field by making climate resilient variety and technology available so that their production and profit can be enhanced in the face of changing climate.

REFERENCES

- Adger, W. N., Huq, S., Brown, K., Conway, D., Hulme, M. 2003: Adaptation to climate change in the developing world. *Progress in Development Studies*, vol. 3, no. 3, pp. 179-195.
- Arnell, N. W., van Vuuren, D. P., Isaac, M. 2011: The implications of climate plicy for the impacts of climate change n global water resources. *Global Environmental Change*, vol.21, no.2, pp. 592-603.
- Auerbach, L. W., Goodbred, S. L., Mondal, D. R., Wilson, C. A., Ahmed, K. R., Roy, K., Steckler, M. S., Small, C., Gilligan, J. M., Ackerly, B. A. 2015: Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain. *Nature Climate Change*, vol. 5, no. 2, pp. 153-157.
- Basal, O., Szabó, A. 2020: Ameliorating drought stress effects on soybean physiology and yield by hydrogen peroxide. *Agriculturae Conspectus Scientificus*. vol. 85, no. 3, pp. 211-218.
- Basal, O., Szabó, A. 2020: Yield and Quaity of Two Soybean Cultivars in Response to Drought and N Fertilization. *Journal of Tekirdag Agricultural Faculty*. vol. 17, no. 2, pp. 203-210.
- Basal, O., Szabó, A. 2019: The Role of P Fertilizer in Soybean's Yield and Quality under Moderate Drought Conditions. Abstract Book. *Alps-Adria Scientific Workshop*. ref. 10, pp. 24-25.
- Chung, J., Babka, H. L., Graef, G. L., Staswick, P. E., Lee, D. J., Cregan, P. B., Shoemaker, R. C., Specht, J. E. 2003: The seed protein, oil, and yield QTL on soybean linkage group I. *Crop Science*. vol. 43, no. 3, pp. 1053-1067.
- Dordevic, V., Malidza, G., Vidic, M., Milovac, Z., Seremesic, S. 2020: Best practice manual for soybean cultivation in the Danube Region, viewed 20 July 2022.
- Fan, X. D., Wang, J. Q., Yang, N., Dong, Y. Y., Liu, L., Wang, F. W., Li, H. Y. 2013: Gene expression profiling of soybean leaves and roots under salt, saline-alkali and drought stress by high throughput Illumina sequencing. *Gene*. vol. 512, no. 2, pp. 392-402.
- FAOSTAT, 2019: <http://www.fao.org/faostat/en/#data/QC>, viewed 27 July 2022.
- Gain, A. K., Giupponi, C., Renaud, F. G. 2012: Climate change adaptation and vulnerability assessment of water resources systems in developing countries: A generalized framework and a feasibility study in Bangladesh. *Water*, vol. 4, pp. 345-366.
- Gosling, S. N., Amell, N. W. 2016: A global assessment of the impact of climate change on water scarcity. *Climatic Change*, vol.134, pp. 371-385.
- Islam, M. S., Hossain, M. Z., Sikder, M. B. 2019: Farmers' adaptation strategies to drought and their determinants in Barid tract, Bangladesh. *SAARC Journal of Agriculture*, vol. 17, no. 1, pp. 161-174.
- Khatun, M., Begum, M. E. A., Rashid, M. A., Miah, M. A. M., Hasan, M. K. 2021: Effect of climate change adaptation strategies on production efficiency of chickpea and lentil in Rajshahi district. *Bangladesh Journal of Agricultural Economics*, vol. 42, no. 1, pp. 55-72.

- Kövics, Gy., Tarcali, G., Csüllög, K., RÁCz, D., Bíró, Gy., Csótó, A., Szarukán, I., Nagy, A., Szanyi, Sz., Szilágyi, A., Kovács, G., Radócz, L. 2020: A szója integrált védelme. *Növényvédelem*, vol. 86, no. 56, pp. 251-275.
- Liang, H., Yu, Y., Wang, S., Yun, L., Wang, T., Wel, Y., Gong, P., Liu, X., Fang, X., Zhang, M. 2010: QTL Mapping of Isoflavone, Oil and Protein Contents in Soybean (*Glycine max* L. Merr.). *Agricultural Sciences in China*. vol. 9, pp. 1108-1116.
- Liu, F., Jensen, Ch. R., Andersen, M. N. 2004: Pod Set Related to Photosynthetic Rate and Endogenous ABA in Soybeans Subjected to Different Water Regimes and Exogenous ABA and BA at Early Reproductive Stages. *Annals of Botany*. no. 94, pp. 405-411.
- Maleki, A., Naderi, A., Naseri, R., Fathi, A., Bahamin, S., Maleki, R. 2013: Physiological Performance of Soybean Cultivars under Drought Stress. *Bulletin of Environment, Pharmacology and Life Sciences*. vol. 1, no. 6, pp. 38-44.
- Mancosu, N., Snyder, R. L., Kyriakakis, G., Spano, D. (2015): Water scarcity and future challenges for food production. *Water*, vol.7, no.3, pp. 975-992.
- Martens, J. R. T., Hoepfner, J. W., Entz, M. H. 2001: Legume cover crops with winter cereals in southern Manitoba: establishment, productivity, and microclimate effects, *Agronomy Journal*, vol. 93, no. 5, pp. 1086-1096.
- Mutava, R. N., Prince, S. J. K., Syed, N. H., Song, L., Valliyodan, B., Chen, W., Nguyen, H. T. 2015: Understanding abiotic stress tolerance mechanisms in soybean: A comparative evaluation of soybean response to drought and flooding stress. *Plant Physiology and Biochemistry*. vol. 86, pp. 109-120.
- Osman, K. T. 2018: Management of soil problems. Springer.
- Panadero-Navas, A. 2022: Perceptions of small producers about changes in climate change and their effect on milk production systems. *Revista de Investigaciones Veterinarias del Perú (RIVEP)*, vol. 33, no. 3, pp. 51.
- Piletti, L. M. M. da S., Souza, L. C. F. de., Secretti, M. L., Albertoortiz, T., Costa, A. M., Viegas-Neto, A. L., Lima-Junior, I. dos S. de. 2022: Agronomic performance of soybean in crop rotation systems. *Australian Journal of Crop Science*, vol. 16, no. 1, pp. 64-72.
- Souza, C. A., Figueriredo, B. P., Coelho, C. M. M., Casa, R. T., Sangoi, L. 2013: Arquitetura de plantas e produtividade da soja decorrente do uso de redutores de crescimento, *Bioscience Journal*, vol. 19, pp. 634-643.
- Tar, M., Irmes, K., Vályi-Nagy, M., Kristó, I. 2021: Effect of different seed inoculation methods to nodulation, yield and quality of soybean cultivars. *Research Journal of Agricultural Science*, vol. 53, no. 2, pp. 248-254.
- TerAvest, D., Carpenter-Boggs, L., Thierfelder, C., Reganold, J. P. 2015: Crop production and soil water management in conservation agriculture, no-till, and conventional tillage systems in Malawi. *Agriculture, Ecosystems and Environment*. vol.212, pp. 285-296.
- Ummenhofer, C. C., Meehl, G. A. (2017): Extreme weather and climate events with ecological relevance: a review. *Philosophical Transactions of the Royal Society B*. vol.372, no. 20160135.
- Vályi-Nagy, M., Tar, M., Irmes, K., RÁCz, A., Kristó, I. 2019: The effect of winter pea on grain yield and crude protein content of winter wheat in intercrop. *Acta Agronomica Óvariensis*. vol. 62, no. 2, pp. 159-173.
- Vanneuville, W., Werner, B., Kjeldsen, T., Miller, J., Kossida, M., Tekidou, A., Crouzet, P. 2012: Water resources in Europe in the context of vulnerability: EEA 2012 state of water assessment. EEA Report, no. 11/2010. European Environment Agency.
- Vukovich, G. 2022: Hungary, 2021. Issue of Central Statistical Office. vol. 28, pp. 141-149. ISSN: 1416-2768

Vukuronda, S. S. K. P., Vardharajula, S., Shrivastava, M., SkZ, A. 2016: Enhancement of drought stress tolerance in crops by plant growth promoting rhizobacteria.

Younesabadi, M., Nouralizadeh-Otaghsara, M., Habibian, L., Savarinrad, A. 2021: Evaluation the Effect if Imazethapyr, Pendimethalin and Oxyfluorfen in Soybean Weed Control. *Journal of Plant Protecion*, vol. 35, no. 1, pp. 103-115.