Hungarian University of Agriculture and Life Sciences

STUDY ON GENETIC VARIABILITY AND HETEROSIS OF DIFFERENT AGRONOMIC CHARACTERISTICS, YIELD COMPONENTS AND GRAIN QUALITY IN MAIZE (*ZEA MAYS* L.)

THE THESIS OF THE PHD DISSERTATION

SUHANA BINTI OMAR

GÖDÖLLŐ

2024

PhD School

Name	:	Doctoral School of Plant Science
Discipline	:	Plant Breeding and Horticultural Science
Head	:	Professor Dr. Helyes Lajos, DSc Doctoral School of Plant Science Hungarian University of Agriculture and Life Sciences
Supervisor	:	Professor Emeritus Dr. Jolánkai Márton, DSc Associate Professor Dr. Kassai Maria Katalin Doctoral School of Plant Science / Institute of Crop Production Hungarian University of Agriculture and Life Sciences

....	…...
Approval of the Head of Doctoral School	Approval of the Supervisor(s)

1. INTRODUCTION AND OBJECTIVES

The development of maize crops requires accurate knowledge of genetic variability, heterosis, agronomic characteristics, and grain quality, as well as adequate fertiliser application. However, challenges such as global climate change, infertility, and unfavourable soil conditions hinder maize production. Additionally, ensuring food security is crucial, as hunger affects nearly 9 percent of the world population. This requires a sustainable agricultural industry that can enhance the quality of agricultural products and food by developing superior plant varieties or hybrids that adapt to global environmental changes.

Genetic variability is crucial in cross-pollinated crops like maize, as it allows individuals to adapt to the environment and ensure population survival. Maize breeding programmes aim to enhance yield characteristics by producing superior varieties. The effectiveness of selection depends on the relationship between yield and yield components, which is heavily reliant on genetic variability and diversity in maize inbred lines. This research aims to identify diverse genetic groups with higher heterotic effects for agronomic traits, yield components, and grain quality in maize, providing valuable tools for successful breeding programmes.

1.1 The objectives of this study

i. To determine the germination potential of variations in the performance of various hybridization pathways.
ii. To evaluate the impact of seed quality and hybrid types on maize germination, emphasising seed viability and vigour and their influence on maize crops the yield and productivity.
iii. To quantify the effect of N fertilization on grain yield and its components and grain quality parameters (moisture, oil, protein, and starch contents) for maize crops, and
iv. To investigate the various genetic mechanisms that contribute to genetic variability and heterosis for yield and yield components in maize (inbred parents, single cross, three-way cross, and double cross hybrids).

2. MATERIALS AND METHODS.

This study consists of four experiments conducted in the laboratory, field, or both. The first two tests assessed the germination potential of different hybridization pathways, including parents, single cross hybrids, three-way cross hybrids, and double cross hybrids. The second experiment examined yield and its components in the field, focusing on seed viability and vigour's influence on maize crop yield. The third experiment examined the impact of different nitrogen levels on maize yield performance and grain quality, aiming to determine the optimal amount of nitrogen for maximum yield and high-quality grain. The fourth experiment focused on the genetic variability, heterosis, and genetic advance of different maize genotypes, which can influence the plant's agronomic characteristics.

2.1 Germination Characteristics of Different Maize Hybrids and Their Parental Lines.

The maize seed varieties in this study were obtained from the Agricultural Research Centre, Martonvásár, Hungary. Single cross (SC), double cross (DC), and three-way cross (TC) hybrids and their parental inbred lines were studied. Four parents, viz. B1026/17 (SC (F)), TKAPA/15/ DV (SC (M)), TK1083/19 (DC (F)), and MCS901/19 (TC (F)) together with three hybrids; B1026/17 × TKAPA/15/ DV (SC (F_1)), TK1083/19 × MCS901/19 (DC (F_1)), and MCS901/19 × B1026/17 (TC (F_1)) were tested in this trial.

Germination rate, root length, and shoot length were measured at 5, 7, 9, and 12 days, with 5 seeds per treatment and 4 replicates arranged in Completely Randomized Block Design (RCBD). Data analysis was done to examine variations between maize varieties and treatment (days).

2.2 Effects of Seed Quality and Hybrid Type on Germination and Yield in Maize.

The experiment was conducted in a laboratory and field plot at the Hungarian University of Agriculture and Life Sciences. Nine parental lines (GK131, GK144, GK150, GK154, GK155, B1026/17, MCS901/19, TK/15/DV, TK1083/18), four single crosses (SC) hybrids (V1 (B1026/17) × V3 (TKAPA/15/DV), V10 (GK154 X155), V11 (Szegedi 521), and V15 (GK144X150), one three-way cross (TC) (V6 (MCS901/19) × V1

(B1026/17)) and one double cross (DC) (V4 (TK1083/19) × V6 (MCS901/19)), and a commercial check hybrid (V16 (MV277)) being tested. The seeds were obtained from Szeged University and the Centre for Agricultural Research, Martonvasar, Hungary.

2.3 The Effect of Nitrogen Fertilization on the Yield and Quality of Maize.

A field experiment conducted in 2021 at the Hungarian University of Agriculture and Life Sciences in Hungary examined the impact of nitrogen levels on maize yield and quality. The maize hybrid seed variety MV 277 was examined in a replicated field trial.

The treatments were applied as sprays during the vegetative growth stage, with standard agronomic practices uniformly applied to all treatments. Grain yield was measured for cob weight, number of rows per cob, and grain number per cob. The weight and count of 1000 grains were determined. The starch concentration, protein, oil, and moisture content were analysed. The effect of N fertilisation on maize grain yield, components, and quality parameters were evaluated.

2.4 Assessment of Genetic Variability and Heterosis for Yield and Yield Components in Maize.

In this study, maize seed genotypes were obtained from the Martonvásár Agricultural Research Centre and the University of Szeged, including four single-cross (SC), one three-way cross (TC), and one double-cross (DC) genotypes, as well as their parents (9 inbred lines) and commercial check hybrid (MV 277). The study aimed to examine maize's genetic variability, heterosis, agronomic characteristics, and yield components in a field experiment conducted in spring 2022 at the Hungarian University of Agriculture and Life Sciences in Gödöllö, Hungary.

The study used a randomised complete block design (RCBD) including parents, hybrids, and a commercial check hybrid. Data collection included measurements of plant height (cm), days to 50% flowering, ear weight (g), ear length (cm), ear diameter (cm), row number per ear, kernel number per ear, and 1000-kernel weight (g). Variance components were analysed. The mean comparison was conducted using the DMRT. Genotypic variances ($\sigma^2 g$), phenotypic variances ($\sigma^2 p$), phenotypic coefficient of variability

(PCV), genotypic coefficient of variability (GCV), broad sense heritability (h^2b) and genetic advance (GA) were calculated.

3. RESULTS AND DISCUSSION

3.1 Germination Characteristics of Different Maize Hybrids and Their Parental Lines.

This investigation found that maize seeds germinated after the third day and fully germinated on the seventh day after sowing. Results showed that maize seeds germinated after the third day and reached 100% germination on the seventh day, while all F_1 hybrid seeds performed better and reached 100% germination on the fifth day. F_1 hybrid seeds germinate faster than parental lines due to their superior germination capacity and early onset of heterosis in radicle emergence. Germination rate is dependent on various factors and control seed germination, emergence, and vigour and have been demonstrated by genotypic variation in seedling growth.

Hybrid seeds have better shoot elongation abilities than their parents due to the heterotic effect of two parental genes. Three-way cross hybrids (TC (F_1)) were most uniform, followed by double-crossing hybrids (DC (F_1) and single cross hybrids (SC (F_1)). Root elongation was highest in three-way cross hybrids, followed by double-crossing hybrids (DC (F_1)) and single-cross hybrids (SC (F_1)). The findings revealed that maize seeds germinated after the third day and fully germinated on the seventh day. Varieties SC (F_1), DC (F_1), and TC (F_1) showed excellent germination performance with a 100% germination rate on the fifth day and produced the highest shoot and root lengths with 7.9 cm, 7.6 cm, and 6.9 cm (shoot length) and 12.9 cm, 13.9 cm, and 14.9 cm (root length), respectively. Thus, the results obtained reveal that the hybrid seeds have a higher germination rate (100%), and the seedlings were more vigorous than the parents.

3.2 Effects of seed quality and hybrid type on germination and yield in Hungary.

The results of the laboratory experiment showed a significant difference in seed viability and vigour between genotypes and days, with an average 79.69% germination rate observed for all maize genotypes studied. The highest germination rate (100%) was found in genotypes V3 (parent) and V6

(DC hybrid), followed by V2 (parent) and V13 (SC hybrid) with 95.83%. The greatest radicle length was found in genotypes V2 (parent), V3 (parent), and V12 (parent), with 18.95 cm, 18.45 cm, and 18.09 cm, respectively. The study also found a substantial difference between genotypes with the longest and shortest plumule lengths, with a grand mean of 7.73 cm. Germination began on the second day after seeds were placed in the incubation chamber, and data collection began on the third day. Germination percentage increased significantly from day 5 to day 9, with radicle length increasing sharply. The length of the plumule also expanded significantly as the number of incubation days rose (Omar et al., 2022).

Therefore, in the open-field experiment, maize genotypes showed significant differences in the mean and number of rows per ear. Thus, V14 (SC hybrid) produced the highest mean (15.07), followed by V8 (parent) and V13 (SC hybrid) with 14.53 and 14.27, respectively. V1 (the parent) had the fewest rows per ear (7.87), while V16 (the controlled hybrid) had a comparable number. V14 had the highest performance, followed by V5 (SC hybrid) and V7 (TC hybrid), with 329.13 and 325.67 kernels per ear, respectively. Thus, ear weight significantly influenced yield performance, with V14 dominating at 105.89 g. There was no significant correlation between germination rate, radicle length, and plumule length. However, the number of kernels per ear positively correlates with rows per ear and kernel weight, with ear weight being strongly connected to these factors.

Additionally, seed viability and vigour are complex traits determined at various maternal and seed development stages up to seed germination. Besides genetic influences, environmental factors will also affect seed germination, emergence, and seedling performance in the field. In this study, the results emphasised that parental lines performed better regarding germination percentage and radicle elongation, while SC hybrids produced better plumule length. superior varieties and benefit agriculture and the seed industries.

3.3 The effect of nitrogen fertilization on yield and quality of maize (*Zea mays* L.).

The investigation found no significant differences in grain yield, cob weight, row number/cob, grain number/row, 1000 grain weight, and grain oil content between groups for nitrogen treatments of 0, 50, 100, and 150 kg N per ha. According to literature various factors that impact maize grain yield, such as technology, biology, and the environment may have influence. These include agricultural practices, management decisions, climate, soil fertility, and water quality.

Nitrogen application significantly impacted cob number. Treatment T2 (50 kg N per ha) provided the maximum grain yield, while treatment T4 (150 kg N per ha) had the lowest. Nitrogen application did not affect 1000 grain weight. However, increasing nitrogen levels in maize crops can increase grain yields, as nitrogen positively affects plant growth. Nitrogen levels showed a significant impact for grain moisture content, with treatment T3 (100 kg N per ha) having the highest moisture content and treatment T4 (150 kg N per ha) having the lowest. Protein content and starch content were also affected by nitrogen levels. The optimal application between 50-100 kg N per ha could increase yield and protein and starch content. This boosts nutritional value and makes N fertilizer of greater agricultural importance. Further research and assessment are needed to maximize benefits.

3.4 Assessment of Genetic variability and heterosis for yield and yield components in maize (*Zea may* L.)

Study on experiment 4 found significant variation ($p < 0.01$) among maize genotypes in various characteristics contributing to yield and yield components. These characteristics include plant height, days to 50% flowering, ear weight, ear length, ear diameter, row number per ear, number of kernels per ear, and 1000-kernel weight. The SC hybrid of V10 (GK154 x 155) produced vigorous plant growth, enabling competition with weeds and light capture. Earliness is desirable in maize crops, helping plants avoid biotic and abiotic stresses in accordance with literature data. The ear weight is highly correlated with grain yield, and higher kernel rows per ear enhance grain weight and yield.

The environmental factors significantly influenced the phenotypic expression of plant height, days to 50% flowering, ear weight, number of kernels per ear, and 1000-kernel weight. The characteristics evaluated had low, moderate, and high phenotypic and genotypic coefficients of variation. The GCV value ranged from 1.44% for 1000-kernel weight to 91.47% for ear diameter, while the PCV ranged from 9.10% to 92.18% for ear diameter. The environment had little influence on these characteristics' phenotypic expression, indicating that selection can be beneficial for certain traits.

High heritability in ear length, diameter, and row number per ear indicates high genetic variation and low environmental influence, enabling high-yielding varieties (Belay, 2018). Moderate heritability is observed for plant height and days to 50% flowering, while low heritability is found for ear weight, kernels per ear, and 1000-kernel weight. Combining heritability and genetic advance estimation is essential for effective selection. The heterosis values of single cross hybrids (SC) outperformed three-way cross hybrids (TC) and double cross hybrids (DC) in terms of yield and yield components. SC hybrids showed higher uniformity, while double cross hybrids exhibited the highest heterogeneity, especially when different genetic backgrounds were used. The maximum positive heterosis was recorded in SC hybrid V15, with 103.38% for the mid-parent and 134.56% for a high parent. The SC hybrid V5 (TK623/18) contributed the maximum positive mid-parent and high parent heterosis for ear weights, lengths, and diameters.

The study reveals genetic variability among maize genotypes, which can be utilized for yield improvement. PCV is larger than GCV, indicating an environmental influence on phenotypic manifestations. High GCV, PCV heritability, and genetic advances for various characteristics may improve grain yields. Single-cross (SC hybrid) show more heterosis than TC and DC hybrids, but their performance is promising for future breeding programs. Further investigation is needed to consider environmental factors and population size in hybrid combinations.

4. CONCLUSION AND RECOMMENDATIONS

This chapter serves as an important component to conclude the findings of the study. Coupled with valuable recommendations for future research and practical application, ensuring that the results of the study have a lasting impact in the field.

4.1 Conclusion

Maize crop improvement requires information on genetic variability, heterosis, agronomic characteristics, grain quality, and fertilizer application. A comprehensive information package is crucial for research programs to meet increasing demand and address the impact of extreme global climate change on maize production. This is due to the lack of superior varieties and technology gaps, particularly in rural areas, which hinder yield production.

Improving agronomic characteristics is crucial for ensuring plant growth, development, and yield. These characteristics include plant height, leaf area, root system architecture, blooming period, and seed size. Understanding agronomic characteristics helps breeders and farmers develop drought-resistant varieties, select appropriate fertilizers and pest management strategies, optimize crop growth, and minimize losses.

The entire set of results that contribute to the potential improvement of maize in our study begins with the germination test, which demonstrated that the maize seeds germinated after the third day and fully germinated on the seventh day after sowing. Additionally, the length of the plumule expanded significantly as the number of incubation days rose. Moreover, the findings found that the germination test also provided valuable insights into the vigour of the maize seeds. Varieties SC, DC, and TC not only had high germination rates but also displayed faster and more uniform germination compared to the parents. This suggests that these hybrids possess superior seed quality and vigour, which can contribute to better crop establishment and overall productivity.

The study conducted on maize yield performance revealed that hybrid lines performed better than the parental lines. Specifically, the SC hybrids were found to be the most dominant in terms of yield. The results indicate that several factors contributed to the final grain yield. These factors include the number of rows and kernels per ear, 1000-kernel weight, and ear weight. Crop yield is affected by whether the other traits increase or decrease. The study also revealed that 1000-kernel weight performance was influenced by the number of rows and kernel number per ear, with hybrid lines being the most dominant and ear weight showing a favourable association. These factors play a significant role in determining the overall productivity of the crop and can be optimised through proper agricultural practices.

Furthermore, the study emphasizes the impact of nitrogen fertilisation on maize yield and quality, focusing on yield and its components as well as grain quality. However, the results indicated that nitrogen fertilisation did not have a significant effect on these factors, suggesting that nitrogen alone may not be sufficient to improve these aspects of maize production. However, an optimal nitrogen application between 50 and 100 kg N ha^{-1} led to a noticeable increase in yield, protein, and starch content. This highlights the crucial role of the quantity of nitrogen applied in enhancing these important characteristics of maize.

The study on maize genotypes showed significant genetic variability among them, indicating the potential for enhancing yield through selective breeding and genetic modification. Additionally, the study found that environmental factors influence the expression of these genetic characteristics, meaning that the same genotype may perform differently in different environments. Therefore, when selecting and breeding maize varieties, it is important to consider environmental factors. The findings also revealed that the environmental influence on the manifestation of these characteristics phenotypically was greater than the genetic influence. This study has shown a contrast from the previous study, in which single-cross hybrids (SC) have a more prominent heterosis effect on yield and yield components compared to three-way crosses (TC) and double-crosses (DC) over mid-parent and high-parent. However, the heterogeneity in TC and DC hybrids also showed promising performance and can be utilised in future breeding programmes.

Overall, the findings of the study suggest that a comprehensive understanding of genetic variability, heterosis, agronomic characteristics, and fertiliser application is crucial for developing superior maize varieties and optimising crop growth. This knowledge can help meet the increasing demand for maize and address the challenges posed by extreme global climate change, such as droughts, heatwaves, and changing pest and disease patterns. By developing maize varieties that are resilient to these challenges and maximising crop productivity through effective management practices, farmers can contribute to food security and sustainable agriculture.

4.2 Recommendations

Additionally, future studies should also consider the impact of different farming practices and techniques on crop yield. This could involve comparing traditional farming methods with more sustainable and environmentally friendly approaches, such as organic farming or precision agriculture. Furthermore, it would be beneficial for researchers to explore the potential effects of climate change on crop yield in different regions. This could involve analysing historical climate data and projecting future climate scenarios to understand how changing temperatures, precipitation patterns, and extreme weather events may impact crop production.

In order to obtain more accurate and reliable results, future studies should also aim to increase the sample size and diversity of the population being studied. This could involve including a wider range of crop varieties, as well as considering the influence of genetic factors on crop yield. Moreover, it would be valuable for researchers to investigate the socio-economic factors that may affect crop yield. This could involve analyzing the impact of factors such as access to resources, education, and market conditions on farmers' ability to achieve high crop yields.

In conclusion, further studies on this topic should focus on using different data sources, considering the population's size and various climate zones, and addressing the issue of repetition. Additionally, proper field preparation, including the implementation of irrigation systems, weed management systems, and appropriate fertilizer requirements, should be prioritized to minimize the detrimental effects of abiotic and biotic stress on crop yield. By expanding research efforts in these areas, we can gain a deeper understanding of the factors influencing crop yield and develop strategies to enhance agricultural productivity in a sustainable and resilient manner.

5. NEW SCIENTIFIC RESULTS

1. The research findings have shown that maize seeds germinate on the third day and fully germinate on the seventh day after sowing. However, the SC (F_1), DC (F_1), and TC (F_1) varieties demonstrated exceptional germination performance, achieving a 100% germination rate on the fifth day. These varieties displayed the longest shoot and root lengths, with shoot lengths of 7.9 cm, 7.6 cm, and 6.9 cm and root lengths of 12.9 cm, 13.9 cm, and 14.9 cm, respectively. Consequently, the hybrid seeds demonstrated a significantly higher germination rate (100%) and more vigorous seedlings compared to the parents.

2. The germination rate of the DC hybrid (100%) was higher than that of the parental lines (81.47%), SC hybrids (70.83%), and TC hybrids (66.67%). The parental lines had a better germination percentage and radicle elongation, while SC hybrids had better plumule length. In field evaluation, hybrid lines, particularly SC hybrids, outperform others in terms of the number of rows per ear, the number of kernels per ear, and the kernel weight and ear weight of 15.07, 436.27 g, 438.87 g, and 105.89 g, respectively.

3. The findings of the study show that increased nitrogen fertilisation does not significantly affect the yield or grain quality of maize. However, the use of an optimal amount of nitrogen, specifically between 50 and 100 kg N ha^{-1}, appeared to be the ideal amount that leads to higher yields and increased protein and starch content.

4. The research indicates that genetic variability exists among various types of maize, which can be utilised to improve crop productivity. The phenotypic coefficient of variation (PCV) surpasses the genotypic coefficient of variation (GCV), suggesting environmental factors significantly influence phenotypic expressions. Grain yield might be enhanced through an increase in the heritability and genetic advance of various traits, along with a high GCV and PCV. TC and DC hybrids show less heterosis than SC hybrids, but their performance is promising for future breeding programs. Moreover, further investigation is required to examine the influence of environmental factors and population size on hybrid combinations.

6. THE PUBLICATIONS OF THE AUTHOR IN THE RESEARCH FIELD

6.1 Publications

1. **Omar, S.**, Tarnawa, Á., Kende, Z. Abd Ghani, R., Kassai, M.K. and Jolánkai, M. (2022a). Germination characteristics of different maize inbred hybrids and their parental lines. *Cereal Research Communications*, 50(4), pp. 1229–1236.https://doi.org/10.1007/s42976-022-00250-9.

2. **Omar, S.,** Abd Ghani, R., Khaeim, H., Sghaier, A.H. and Jolánkai, M (2022b). The effect of nitrogen fertilisation on yield and quality of maize (*Zea mays* L.). *Acta Alimentaria*, 51(2), pp. 249–258. https://doi.org/10.1556/066.2022.00022.

3. **Binti Omar**, S., Binti Abd Ghani, R., Binti Khalid, N., Tarnawa, Ákos, Kende, Z., Kassai, M. K. and Jolankai, M. (2023). Impact of N Supply on Some Leaf Characteristics of Maize Crop. *COLUMELLA – Journal*

of Agricultural and Environmental Sciences, 10(1), 15–25. https://doi.org/10.18380/SZIE.COLUM.2023.10.1.15.

4. **Omar, S**., Abd Ghani, R., Khalid, N., Jolánkai, M., Tarnawa, Á., Percze, A., Mikó, P.P. and Kende, Z., 2023. Effects of Seed Quality and Hybrid Type on Maize Germination and Yield in Hungary. *Agriculture*, 13(9), p.1836. https://doi.org/10.3390/agriculture13091836.

5. Abd Ghani, R., Kende, Z, Tarnawa, Á, **Omar, S.,** Kassai, M.K., Jolánkai, M. (2021). The effect of nitrogen application and various means of weed control on grain yield, protein and lipid content in soybean cultivation. *Acta Alimentaria*, 50(4), pp. 249–258. https://doi.10.1556/066.2021.00095.

6. Khalid, N., Tarnawa, Á., Balla, I., **Omar, S**., Abd Ghani, R., Jolánkai, M. and Kende, Z., 2023. Combination Effect of Temperature and Salinity Stress on Germination of Different Maize (*Zea mays* L.) Varieties. *Agriculture*, 13(10), p.1932. https://doi.org/10.3390/agriculture13091836.

6.2 Conference Presentations

1. **Suhana Omar** - Rosnani Abd Ghani - Noriza Khalid - Marton Jolankai: Evaluation of maize inbred lines and hybrids for agronomic characteristics, yield, and grain quality (HUALS-Gödöllő).

2. Jolankai, M., Abd Ghani, R., **Omar, S**., Kende, Z., Kassai, M.K. & Tarnawa, A. (2021). Water footprint of protein yield of field crop species based on evapotranspiration patterns. Oral presented in *First National Interdisciplinary Climate Change Conference* (HUPCC), Online conference. 12 - 15 April 2021.

7. OTHER SCIENTIFIC PUBLICATIONS OF THE AUTHOR

7.1 Publications

1. Abd Ghani, Rosnani and **Omar, Suhana** and El Chami, Elias and El Chami, Josepha and Jolánkai, Márton (2021). Agri-environmental impacts on yield formation of soybean crop. *COLUMELLA – Journal of*

Agricultural and Environmental Sciences, 8 (2). pp. 5-10. ISSN 2064-7816. https://doi.10.1556/066.2021.00095.

2. Abd Ghani, R., **Omar, S**., Jolánkai, M., Tarnawa, Á., Kende, Z., Khalid, N., Gyuricza, C. and Kassai, M.K. (2023). Soilless Culture Applications for Early Development of Soybean Crop (Glycine max L. Merr). *Agriculture*, 13(9), p.1713. https://doi.org/10.3390/agriculture13091713.

3. Abd Ghani, R., **Omar, S**., Jolánkai, M., Tarnawa, Á., Khalid, N., Kassai, M.K. and Kende, Z. (2023). Response of Shoot and Root Growth, Yield, and Chemical Composition to Nutrient Concentrations in Soybean Varieties Grown under Soilless and Controlled Environment Conditions. *Agriculture*, 13(10), p.1925. https://doi.org/10.3390/agriculture13101925.

4. Abd Ghani, R., Jolankai, M., **Omar, S**., Khalid, N & Tarnawa, Á. (2023). Influence of temperature and variety on seeds germination and seedlings emergence of soybean (*Glycine max* L. Merr) at different germination times. Manuscript submitted for publication in *Acta Agraria Debreceniensis*.

7.2 Conference presentations

1. Asma Haj Sghaier - Noriza Binti Khaled - **Suhana Binti Omar** - Andras Varga - Zoltán Kende: Methodological approaches to the germination of sunflower and oilseed rape in vitro (HUALS-Gödöllő).

2. Rosnani Binti Abd Ghani - Zoltan Kende - Akos Tarnawa - **Suhana Binti Omar -** Maria Katalin Kassai - Marton Jolankai - Noriza Binti Khalid: Nitrogen nutrition and weed management effects on yield and chemical composition of soybean (*Glycine max L.* Merr) (HUALS-Gödöllő).