THESES OF PhD DISSERTATION

ÁDÁM ESZTERGÁLYOS

KESZTHELY

2022

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

ANALYSIS OF THE EFFECTS OF SOME ENVIRONMENTAL FACTORS AFFECTING MOTHER PLANTS ON THE TUBER DORMANCY OF POTATO GENOTYPES AND DORMANCY BREAKING POSSIBILITIES

DOI: 10.54598/003300

ÁDÁM ESZTERGÁLYOS

KESZTHELY

2022

Festetics György Doctoral School

Discipline of Crop Production and Horticultural Sciences

Head of the doctoral school:

Dr. Angéla Anda DSc

Professor

MATE, Institute of Crop Sciences

Department of Agronomy

Supervisor:

Dr. Zsolt Polgár CSc

Professor

MATE, Institute of Crop Sciences

Crop Production Research Center

....

Approval by the Head of the doctoral school

Approval of the Supervisor

1. Background and Objectives

A detailed knowledge of the tuber dormancy and the environmental and agronomic factors affecting it is necessary in order to store the produced tubers cost-effectively, and to plan the length of the storage period and the storage temperature for table or even seed potatoes. However, the relevant literature is rather incomplete, in many cases contradictory, and for Hungarian potato varieties, it is not known at all.

In the initial stages of seed potato propagation, it is important to maximize the number of tubers that can be produced during one growing season. One way could be to harvest twice within one growing season. This requires knowing the dormancy period of the propagated varieties and the possibilities of breaking their dormancy. During the last decades numerous ways to regulate dormancy duration were developed. However, the efficiency of these methods are strongly genotype dependent. Moreover, there are only a few publications about the side effects of treatments on later sprout development and tuber setting of progeny plants and these results are limited to a few varieties only.

Based on the above, the objectives of the thesis can be summarized as follows:

1. Investigation of the effect of environmental factors affecting the mother plant on the dormancy period.

In our experiments, we aimed to determine the dormancy period of 12 varieties bred in Keszthely, and the investigation of the impact of certain environmental-meteorological factors affecting the mother plants, individually and in relation to each other, on the tuber dormancy of these varieties.

2. Investigating the effect of nitrogen supply on the tuber dormancy.

In our experiments the aim was to investigate the effect of nitrogen supply of the mother plants on the tuber dormancy of potato varieties bred in Keszthely, with different growing seasons and genetic backgrounds.

3. Investigating the effect of physiological age and harvest timing on the tuber dormancy.

The aim of our experiment was to investigate how the tuber dormancy changes from tuber initiation through biological maturing to the industrial harvest. We wanted to test results of WRÓBEL et al. (2017) under Hungarian conditions, and in addition we wanted to determine the optimal harvesting time for the final purpose of using.

4. Examination of the possibilities of breaking tuber dormancy and its aftermath.

The aim of our experiments was to compare the chemical treatments suitable for breaking the tuber dormancy of the three newest potato varieties bred in Keszthely, and to investigate the effect of the treatments on the shoot development and tuber yield of the offspring plants.

5. Investigating the effect of heat treatments and storage temperature on tuber dormancy.

The purpose of our research was to analyze the changes in the tuber dormancy of three newest potato varieties bred in Keszthely, in relation to the applied heat treatments and the storage temperature.

2. Materials and Methods

2.1 Impact analysis of environmental factors

The preliminary test was carried out with 12 varieties bred in Keszthely having different maturity type. The detailed tests were carried out with two early-maturity type varieties (‘Balatoni rózsa’, ‘Botond’) and a medium early-maturity type variety (‘Démon’). We recorded data from two vegetation periods every year (spring and summer planting), between 2009 and 2019. The conditions for measuring tuber dormancy were: 20°C, 80% relative humidity (RH), complete darkness. The dormancy is considered to have expired when at least one 2 mm long sprout appeared on the tested tuber (CARLI et al., 2016). The length of dormancy period was given as the cumulative daily average temperatures absorbed in the storage (°C) (O'BRIEN et al., 1983).

The meteorological data was provided by a meteorological station. Measured values were: minimum, maximum and average air and soil temperature (°C); daily rainfall (mm); RH (%); leaf moisture coverage (min). Calculated meteorological variables were: sum of average daily temperature during the growing season; number of drought days; sum of the daily maximum temperatures of the growing season; rainfall during the growing season; aggregated relative humidity and leaf moisture cover; sum of mean, minimum and maximum soil temperature. We used the Sielianinov hydrothermal coefficient also (GRUDZIŃSKA, 2012). For the first 50 days of the growing season, we determined the sum of the photoperiod, the aggregated temperature fluctuation and the sum of night temperatures. We also determined the sum of average daily temperatures for the first and the last 50 days of the growing season.

The data was prepared and organized using MS Office, and the statistical analysis was performed using IBM SPSS software. First, we performed analysis of variance (multivariate) to see the effect of varieties, years, growing seasons and all investigated environmental variables on tuber dormancy. After that, we performed a correlation analysis, followed by Duncan's test (p=0.05).

2.2 Determination of the endodormancy period of potato varieties

The experiments were set up in three consecutive years (spring of 2018, 2019 and 2020) with 'Balatoni rózsa', 'Botond' and 'Démon' varieties. Plants were grown in 3 litre plant pots under controlled conditions (22°C, 85% RH, 5-21h photoperiod) in growth chamber until biological maturity. After that, the dormancy of progeny tubers was determined as described in **2.1**, the statistical analysis was performed using Duncan test (p=0.05).

2.3 Investigating the effect of nitrogen supply on the tuber dormancy

In our small plot study, the nitrogen treatments were the spring nitrogen applications. As a control, in practice usual nitrogen dose was included (N1, 100 kg/ha). The half-dose nitrogen treatment (N0.5) was 50 kg/ha; in the nitrogen-deficient treatment (N0, 0kg/ha), the tested varieties (Desiree, Arany chipke, Katica, White lady, Basa, Hópehely, Cleopatra, Botond, Balatoni rózsa, 09.200, 09.688) did not receive nitrogen fertilizer. The tuber dormancy was determined as described in **2.1**, the statistical analysis was performed using Duncan test.

2.4 Investigating the effect of physiological age and harvest timing on the tuber dormancy

The experiments were set up in three consecutive growing seasons (2018 spring and summer, 2019 spring) with 'Balatoni rózsa', 'Botond' and 'Démon' varieties. The experiment was started when the stolon of the mother plant reached a diameter of 2 cm. After that we harvested weekly until biological maturity. According to the different phenological phases of the mother plant they were: F1 – tuber formation; F2 and F3 – tuber increase; F4 – tuber maturity; F5 – biological maturity. Control harvesting (F0) was in the second week after biological maturity. The tuber dormancy was determined as described in **2.1**, the length of the dormancy period was expressed in days (DAH - days after harvest), stored at 20°C. The statistical analysis was carried out as described in **2.1** (multivariate analysis of variance: the effect of varieties, growing seasons and harvesting times on the tuber dormancy).

2.5 Examination of the possibilities of breaking tuber dormancy

The experiments were set up in three consecutive years (autumn of 2016, 2017 and 2018) with 'Balatoni rózsa', 'Botond' and 'Démon' varieties. The treatments were: soaking in an aqueous solution of gibberellic acid (GA) (10, 50 and 100ppm) for 1 hour; soaking in an aqueous solution of benzyladenine (BA) (20, 30 and 100ppm) for 1 day. Rindite treatment (7-3-1 proportion mixture of ethylene chlorohydrin, ethylene dichloride and carbon tetrachloride) for 2 days, and combined Rindite+GA100ppm treatment. The methods described in **2.1** were used to determine dormancy period and statistically analyze. In this study, the multivariate analysis of variance was performed to see the effect of varieties, years and chemical treatments on tuber dormancy.

2.6 Examination the effect of chemical treatments used for dormancy breaking on the number of stems and progeny tubers

After determining the dormancy period, progeny plants were grown from the sprouting tubers of **2.5** under controlled conditions as described in **2.2**. On the 20th day after planting, we recorded the number of developing shoots, and after biological maturity, the number of progeny tubers. For the statistical analysis we performed correlation analysis and then Duncan's test (p=0.05).

2.7 Investigating the effect of heat treatments and storage temperature on tuber dormancy

The experiments were set up in three consecutive years (summer of 2017, 2018 and 2019) with ‘Balatoni rózsa’, ‘Botond’ and ‘Démon’ varieties. After harvesting, the tubers were stored in unheated, ventilated room for two weeks. Then we stored them at different temperatures in climate cabinets. The treatments were:

H1 Cold shock, then heat shock treatment: 5°C for 2 weeks, then 35°C for 2 weeks;

H2 Continuous high temperature storage: 30°C until dormancy has expired;

H3 Short-term high temperature storage: 4 weeks at 30°C;

H4 Long-term high temperature storage: 8 weeks at 30°C;

H5 Heat shock treatment: 4 weeks at 35°C;

H6 Heat shock, then cold shock treatment: 2 weeks at 35°C, then 2 weeks at 5°C.

The control was stored at a constant 20°C until the dormancy expired. After the heat treatments, tubers of each treatment (except H2) were placed under control conditions. The method described in chapter **2.1** was used to determine the dormancy period. Dormancy was expressed in days (DAH) and also in sum of daily average storage temperature (°C), Duncan test was used during the statistical analysis.

3. Results

For the first time in Hungary, we determined the correlations between the maturity type and the length of tuber dormancy of 12 potato varieties bred in Keszthely. Our results confirmed that the dormancy of the studied cultivars differ significantly, which is not related to the maturity type of the varieties. In this regard, we were able to confirm the results of MUTHONI et al. (2014), ZARZYŃSKA (2004), WRÓBEL et al. (2017) and HASSANI et al. (2014). On average over several years, the longest dormancy had cultivar 'Rioja' (sum of accumulated temperatures: 2743°C, 137 days after harvest) and the shortest had 'Botond' (1952°C, 98 DAH). In our studies, the difference between varieties was 791°C, which is 40 days when stored at 20°C. This is a significant difference both in terms of storage economy and in use also.

We also observed that there are significant differences in the length of dormancy between different growing seasons within the same variety, confirming the significant effect of environmental factors modifying dormancy. Many factors can affect the length of dormancy within the same variety, such as the amount of heat during the growing season reaching the mother plant, day length, abiotic stresses, heat shock, and water deficiency. This difference averaged 1228°C for all species (61 DAH), which is also significant. Differences in susceptibility between cultivars were found to influence the dormancy-modifying effect of environmental factors. We determined the dormancy of three varieties, which were not influenced by external environmental factors. We compared the dormancy obtained in this way with the dormancy measured using long-term averages (2009-2019). We observed that the longer the endodormancy of a variety, the greater it can be reduced by environmental factors (in our experiment, it was shortened by 6-17-21 days in a row from cultivars having shorter to longer dormancy, on average, in 11 experimental years). Which environmental factors can modify the dormancy to what extent and in which direction justified a detailed analysis of the meteorological data.

We found that only temperature has a clear effect on dormancy under the tested climatic conditions. If the air temperature is below the optimum for the potato at the beginning of the growing season, it weakly, if optimal, or above, moderately modifies the dormancy in a positive (in the same) direction. If the temperature at the end of the growing season is above the optimum, it modifies dormancy in a negative (in the opposite), if it is below the optimum, in a positive direction. In the case of spring growing season, we found an opposite and medium relationship, so in the case of years with a lower temperature amount, we can expect a longer dormancy period. While in the case of summer growing season, it is on the contrary. We found a strong relationship here, and we can expect a longer dormancy in the ranking for higher temperature years. Based on these, the expected length of the dormancy, the storability can be predicted, which can largely determine the economics of storage.

The nitrogen supply of the mother plant can also greatly influence the tuber initiation. In most cases, the influence of half-dose nitrogen was prominent, resulting in a significant reduction in the dormancy. In contrast, total nitrogen deficiency prolonged the dormancy of most varieties. We are able to confirm the results of SZIRTES (1984), BURTON (1989), JACKSON (1999), FERNIE and WILLMITZER (2001), and AKSENOVA et al. (2012).

We determined how the dormancy of tubers harvested at different times and at different stages of physiological maturation changes and we determined which phenological phase of the mother plant is the most suitable for harvesting. We were able to confirm the results of WRÓBEL et al. (217), the length of dormancy increases from tuber initiation to biological maturation. However, the increase does not exceed the number of days that the offspring tubers remain in the soil. Therefore, instead of DAH, we introduced a new concept, DAI (days after initiation), which has not been used in the literature yet. The results show that until biological maturity of the mother plant, the later the tubers are harvested, the later they can be stored without sprouting.

A comparative study of chemical treatments for breaking tuber dormancy of some new Hungarian potato varieties was carried out. Results showed that the treatments largely influenced the length of tuber dormancy. Rindite and Combined (Rindite+GA) treatments significantly reduced the dormancy period for all the varieties in all growing season, with an average 65% reduction. Treatments had the greatest impact on the cultivar 'Balatoni rózsa', with an average 33% reduction in dormancy, while they had the least impact on the cultivar 'Démon', with an average 25% reduction. We didn't observe close relationship between the maturity type of cultivar and the effectiveness of treatments. We found influence of weather conditions in the vegetation period upon the duration of dormancy and the efficiency of chemical treatments.

Continuing this work we analyzed the effects of chemical treatments used for breaking dormancy on the number of stems and tubers of progeny plants. According to the results, applied treatments had a large effect on the number of developing stems and tubers of the progeny plants. Combined treatment (Rindite+GA), and GA at 100 ppm increased significantly the number of stems and tubers. Correlation between the efficiency of dormancy breaking and the number of developed tubers was found. Based on our results, Rindite and GA have an important role not only in breaking dormancy, but also in increasing the tuber number per plant. This positive effect could be utilized in seed potato production.

We also investigated the effect of six heat and cold treatments at different durations and degrees on the tuber dormancy of three Hungarian potato varieties. Results showed that the treatments largely influenced the length of tuber dormancy. The alternating storage temperature shortened the dormancy period to the greatest extent. Within this, warm pre-treatment (heat-shock, 2 weeks at 35 °C) was significantly more effective than cold pre-treatment (cold-shock, 2 weeks at 5 °C). Short-term high-temperature treatment reduced dormancy to a lesser extent; however, long-term high-temperature treatment increased it and resulted in prolonged germination. At low storage temperatures we observed that cultivars having longer internal dormancy had a longer dormancy period as a result of treatments, so the sequence of the cultivars was maintained. It changed as a result of high temperature treatments, not all varieties maintained this sequence.

4. Conclusions and recommendations

Based on our results, the tuber dormancy depends greatly on the variety, so its length is significantly influenced by the genotype. The hereditary properties of the variety therefore determine not only the yield quality and maturity type, but also the storability of the tubers to a great extent, which must be taken into account when planning the utilization goals: fresh consumption, industrial processing, or seed tubers.

We observed that there are differences in sensitivity between the varieties regarding the vegetation period effect. Therefore, it is advisable to use varieties whose dormancy can not significantly modified by environmental factors. Varieties, whose dormancy can be greatly modified by environmental factors, or have a short deep dormancy, should be used for fresh consumption, or their harvest should be planned for the beginning of the processing period.

By analyzing the meteorological data in detail, we determined which environmental factors modify the dormancy to what degree and direction. It should be noted, however, that the meteorological variables measured in our tests modify the dormancy together, examined them individually only provide approximate information on the changes of tuber dormancy. Based on our results so far, they are not suitable for completely reliable forecasting, which would require further investigations and the inclusion of additional meteorological variables.

The nitrogen supply of potato plants regulates the tuber initiation with the ratio of internal hormones, thereby the physiological age at harvest, which indirectly affects the tuber dormancy. However, the observation should be supplemented that the reaction to nitrogen supply is variety-dependent, although it can be generalized in most cases, but there are exceptions.

Based on our results, not only the physiological age is significant in the change of dormancy, it is influenced to a much greater extent by the vegetation periods effect. We also observed that the effect of harvesting time on the tuber dormancy (DAH) and the rate of sprouting differ from year to year. This also supports the importance of the modifying effect of the vegetation period. However, studying the physiological background of this requires more investigations.

During our experiments we also found that the weather conditions during the growing season had an effect on the deep dormancy period of the varieties, and also affected the effectiveness of the chemical treatments differently for each variety. Based on our results, the effects of GS100 and Rindite add up only to a small extent, and Rindite is the defining component of the combined treatment. Therefore, the use of GS to break the tuber dormancy is not justified in this combination. The BA treatments only slightly reduced the tuber dormancy, so we do not recommend using them in the examined concentrations to break the tuber dormancy of these three varieties. In order to understanding better the reason for the significant differences between varieties and vegetation periods in addition to the effect of the GS and Rindite treatments, as well as to extend our results to additional genotypes, further investigations will be necessary.

Based on our results, Rindite and GS have a significant role not only in breaking the tuber dormancy, but also in increasing the number of progeny tubers, which can be beneficial of seed tuber production. At the same time, the treatments must be adapted specifically to potato variety, because there are differences in genotypes between the reactions to the treatments. Based on our results, by application the optimal treatment of the variety, not only the multiple planting within one year can be promoted, but by increasing the number of progeny tuber, we can also increase the yield and the reproduction ratio.

Based on our results, shortening the tuber dormancy period with a relatively small energy investment can be solved, with a short-term, high-temperature, and then cold pretreatment. If the aim is to extend the dormancy period, then long-term high-temperature storage in winter cannot be economical due to the high energy demand. The most cost-effective solution is low-temperature storage, which is also used in practice. However, in the summer, if it is necessary to store the tubers for a longer period, constant high temperature storage can be effective. All of this supports the fact that the treatments must always be adapted to the variety in order to ensure the economy of storage and to optimization of sprouting.

The literatures on the study of potato tuber dormancy led to many generalizable conclusions that we confirmed. Our empirical results that differed from these emphasized the strong genetic specificity of the studied trait, the dependence of the genotype, and the different reaction of the varieties to environmental factors. Consequently, we consider it necessary to perform a similar series of experiments for each new variety or candidate variety in order to determine the optimal storage and treatment conditions suitable for the storage and propagation purpose.

5. New scientific results

1.

By growing potato mother plants under optimal environmental conditions, we proved that the dormancy period of varieties with a shorter endodormancy is only slightly modified by environmental factors, while varieties with a longer endodormancy is modified to a greater extent.

2.

We found, in the case of the examined varieties, among the environmental factors affecting the mother plant, only temperature has a clear effect on the dormancy of the progeny tubers under the examined ecological conditions. However, the sum of the temperature of the entire growing season alone is not suitable for objectively determining the modifying effect. That is why we introduced an indicator, the sum of air temperature for the beginning and end of the growing season, which is more suitable for predicting the dormancy period. In all cases, the temperature at the beginning of the growing season modifies the dormancy period in a positive direction (the same direction as the air temperature change), but to different extents. If the air temperature is below the optimum for potatoes, it is modified slightly, if it is optimal or above, then it is modified to a moderate extent. The temperature at the end of the growing season significantly modifies the dormancy period, but in different directions: If it is above the optimum, it is negative (opposite); if it is below the optimum, it is modified in a positive (same) direction.

3.

We found that nitrogen supply of potato mother plants modifies the dormancy of the progeny tubers, which does not change linearly with the nitrogen doses. Plants supplied with a half-dose of nitrogen initiate tubers earlier, so the tubers are physiologically older at harvest, and therefore have a shorter dormancy period. In the case of nitrogen deficiency, tuber initiation is delayed, and therefore the progeny tubers are physiologically younger at harvest, which results a longer dormancy period.

4.

In order to objectively determine the storage duration of the potato tuber without sprouting, we introduced a new concept, not yet used in practice, the number of days after tuber initiation (DAI - days after initiation). Based on our results, the optimal time for harvesting is biological ripeness of mother plant, when the foliage dries up. Measured from initiation, so can be the tubers stored for the longest time.

5.

Our results confirmed that the tuber dormancy can be significantly reduced with chemical treatments. The Rindite and gibberellic-acid treatments, or their combination, are suitable for significantly shortening the dormancy period. After harvesting, choosing the optimal treatment, the tubers of each tested variety can be replanted after 30 days.

Publications related to the topic of the dissertation

1. Scientific articles in peer-reviewed journals with impact factor

ESZTERGÁLYOS, Á. - POLGÁR, ZS. (2020) The Effect of Chemical Treatments on the Tuber Dormancy of Hungarian Potato Cultivars. In: *Potato Research,* 64 (3) 327-337. p. https://doi.org/10.1007/s11540-020-09479-5

2. Scientific articles in refereed journals

ESZTERGÁLYOS, Á. - POLGÁR, ZS. (2020) Effect of chemical treatments used for dormancy breaking on the number of stems and tubers of Hungarian potato varieties. In: *Acta Agraria Kaposváriensis*, 24 (2) 61-74. p. https://doi.org/10.31914/aak.2424

3. Hungarian scientific articles in peer-reviewed journals

ESZTERGÁLYOS, Á. - POLGÁR, ZS. (2020) Eltérő hőmérsékletű és időtartamú kezelések hatása magyar burgonyafajták gumónyugalmi idejére. In: *Növénytermelés,* 69 (4) 37-56. p.

4. Publications in full in peer-reviewed conference volumes

ESZTERGÁLYOS, Á. - POLGÁR, ZS. - CERNÁK, I. - HOFFMANN, B. (2017) Nitrogén-ellátás hatása tizenegy burgonya genotípus gumónyugalmi idejére. In: NAGY Z. B. (Szerk.) *A múlt mérföldkövei és a jövő kihívásai. LIX. Georgikon Napok.* Pannon Egyetem, Georgikon Kar, Keszthely, 119-127. p. ISBN: 978-963-9639-89-8

ESZTERGÁLYOS, Á. - POLGÁR, ZS. - HOFFMANN, B. (2017) A nitrogénellátás hatása a burgonyafajták korai fejlődésére. In: SZABÓ P. (Szerk.) *Kutatás-fejlesztés-innováció az agrárium szolgálatában*. Mezőgazda Lap- és Könyvkiadó, Budapest, 264-270. p. ISBN 978-963-286-726-7

ESZTERGÁLYOS, Á. - POLGÁR, ZS. - CERNÁK, I. (2018) Kémiai kezelések hatása burgonyafajták gumónyugalmi idejére, a hajtásfejlődésre és a gumóhozamra. In: BENE SZ. (Szerk.) *XXIV. Ifjúsági Tudományos Fórum – Konferencia Kiadvány*. Pannon Egyetem, Georgikon Kar, Keszthely, 1-6. p. ISBN: 978-963-9639-90-4 [CD:\4_Növénytermesztés_Kertészet\02_Esztergályos_Ádám_6o]

ESZTERGÁLYOS, Á - POLGÁR, ZS. - CERNÁK, I. (2018) Tenyészidőszak alatti környezeti tényezők hatása burgonya genotípusok nyugalmi idejére. In: *LX. Georgikon Napok - Konferencia Kiadvány*. Pannon Egyetem, Georgikon Kar, Keszthely, 69-78. p. ISBN: 978-963-9639-92-8

ESZTERGÁLYOS, Á - POLGÁR, ZS. (2018) Kémiai kezelések hatása burgonyafajták gumónyugalmi idejére. In: *II. Őshonos- és Tájfajták- Ökotermékek– Egészséges táplálkozás– Vidékfejlesztés Tudományos Konferencia*. *Minőségi élelmiszerek – Egészséges környezet: Az agrártudományok és a vidékfejlesztés kihívásai a XXI. században*. Nyíregyházi Egyetem, Műszaki és Agrártudományi Intézet, 141-147. p. ISBN: 978-615-5545-90-0

5. Summary in conference volumes

ESZTERGÁLYOS, Á. - POLGÁR, ZS. - CERNÁK, I. (2018) Keszthelyi burgonyafajták gumónyugalmi idejének vizsgálata. In: KARSAI I., POLGÁR ZS. (Szerk.) *XXIV. Növénynemesítési Tudományos Nap – Összefoglalók.* Magyar Tudományos Akadémia, Budapest, 55. p. ISBN: 978-615-00-1469-2

References

AKSENOVA, N. P. - KONSTANTINOVA, T. N. - GOLYANOVSKAYA, S. A. - SERGEEVA, L. I. - ROMANOV, G. A. (2012): Hormonal Regulation of Tuber Formation in Potato Plants. In: *Russian Journal of Plant Physiology,* 59 451-466. p

BURTON, W. G. (1989) Dormancy and sprout growth. In: *The potato (3rd Ed.).* Essex: Longman Scientific & Technical, 470-504. p.

CARLI, C. - MIHOVILOVICH, E. - BONIERBALE, M. (2016) Procedures for Standard Evaluation and Data Management of Advanced Potato Clones. In: Module 4: Assessment of Dormancy and Sprouting Behavior of Elite and Advanced Clones. International Cooperators' Guide. International Potato Center, Lima. 3-19. p. ISBN 978-92-9060-471-6

FERNIE, A. R. - WILLMITZER, L. (2001) Molecular and Biochemical triggers of potato tuber development. In: *Journal of Plant Physiology,* 127 1459-1465. p.

GRUDZIŃSKA, M. - MAŃKOWSKI, D. (2018) Losses during Storage of Potato Varieties in Relation to Weather Conditions during the Vegetation Period and Temperatures during Long-Term Storage. In: *The American Journal of Potato Research*, 95 130-138. p.

HASSANI, F. - ZAREIAN, A. - REZVANI, E. (2014) Effects of chemical treatments on dormancy breaking and some sprouting characteristics of two potato cultivars in different tuber sizes. In: *European Journal of Experimental Biology*, 4 98-102. p.

JACKSON, S. D. (1999) Multiple signaling pathways control tuber induction in potato. In: *Journal of Plant Physiology*, 119 1-8. p.

MUTHONI, J. - KABIRA, J. - SHIMELIS, H. - MELIS, R. (2014) Regulation of potato tuber dormancy: A review. In: *Australian Journal of Crop Science*, 8 (5) 754-759. p.

O'BRIEN, P. J. - ALLEN, E. J. - BEAN, J. N. - GRIFFITH, R. L. - JONES, S. A. - JONES J., L. (1983) Accumulated day-degrees as a measure of physiological age and the relationships with growth and yield in early potato varieties. In: *The Journal of Agricultural Science*, 101 613-31. p.

SZIRTES V. (1984) Hormonszemléletű irányított burgonyatermesztés. In: SZIRTES V. (Szerk.) *Hormonális szabályozás, levéltrágyázás II*. Budapest, Mezőgazdasági Kiadó, 231-278. p.

WRÓBEL, S. - KĘSY, J. - TREDER, K. (2017) Effect of Growth Regulators and Ethanol on Termination of Dormancy in Potato Tubers. In: *The American Journal of Potato Research,* 94 544-555. p.

ZARZYŃSKA, K. (2004) The length of tuber dormancy period in new potato cultivars. In: *Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin*, 232 5-14. p.