Appendix IIB

SUMMARY OF SCIENTIFIC ACHIEVEMENTS

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1. PERSONAL DATA:

First name and last name:

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2. DIPLOMAS, SCIENTIFIC DEGREES HELD:

- **2000 acquired degree: MSc degree in horticultural engineering**, Faculty of Horticulture, Agricultural University in Lublin (now the: Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin).

  Title of master`s thesis: „Chemical thinning of fruit buds of Arlet and Jonica apple tree varieties", made at the Department of Pomology
  Master`s thesis promoter: Prof. Justyna Wieniarska,
  Reviewer: Prof. Stanisław Wociór.

- **2004 acquired degree: PhD in agricultural sciences in horticulture, specialization Nursery and Pomology,** the Faculty of Horticulture, University of Agriculture in Lublin (now the Faculty of Horticulture and Landscape Architecture University of Life Sciences in Lublin).

  Title of doctor al dissertation: „Effect of some biological and technological factors on apple tree growth in nursery and productivity in orchard", made at the Department of Seed Production and Nurseries
  Dissertation promoter: Prof. Stanisław Wociór,
  Reviewers: Prof. Justyna Wieniarska,
  Prof. Jan Kopytowski.

- **2014 acquired certificate: postgraduate studies in enology,** Jagiellonian University in Kraków.

3. INFORMATION ON PREVIOUS EMPLOYMENT IN RESEARCH INSTITUTIONS/ARTISTIC UNITS:

- **01.10.2004 – 30.09.2005** – teaching assistant at the Department of Seed Production and Nurseries, the Faculty of Horticulture, University of Agriculture in Lublin (now the Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin),

- **01.10.2005 – 31.07.2017** – the adjunct professor at the Department of Seed Production and Nurseries, the Faculty of Horticulture, University of Agriculture

in Lublin (now the Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin),

- **01.08.2017 on –** the adjunct professor at the Department of Pomology and Nursery, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin,

- **01.10.2017 on** – the Head of Quality Laboratory of Enology, Department of Pomology and Nursery, the Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin.

4. INDICATIONS OF SCIENTIFIC ACHIEVEMENTS SPECIFIED IN THE ART. 16 (2) ON THE ACT ON ACADEMIC DEGREES AND TITLES AS WELL AS DEGREES AND TITLES IN ARTS OF MARCH 14, 2003 (DZ.U. (Journal of Laws) 2016 ITEM 882 AS AMENDED IN DZ. U. 2016 ITEM 1311)

a) title of the scientific achievement

Series of six publications entitled: "**Studies on the effect of hormonization operation on yield quantity and quality and antioxidant capacity of `Einset Seedless` variety grape".**

b) list of publications constituting a scientific achievement (scientific publications in a chronological order)

1. **Kapłan M.** 2009. Wpływ kwasu giberelinowego i kwasu 2-naftoksyoctowego na wielkość i jakość plonu winorośli odmiany 'Einset Seedless'. Zesz. Probl. Postęp. Nauk Rol., 539(1): 299-305.

   (MNiSW 4 pkt., IF =0)

   *(**100% contribution,** developing the paper design, realization of vegetation studies, data collection and compilation, manuscript preparation, corresponding author).*

2. **Kapłan M.** 2011. The effect of the method of application of growth regulators on fruit quality of "Einset seedless" grape (*Vitis* sp. L.). Acta Agrobot., 64(4): 189-196.

   (MNiSW 7 pkt., IF =0)

   *(**100% contribution,** developing the paper design, realization of vegetation studies, data collection and compilation, manuscript preparation, corresponding author).*

3. **Kapłan M.** 2013. Wpływ stężenia kwasu giberelinowego oraz terminu zabiegu na wielkość i jakość plonu winorośli (*Vitis* sp. L.) odmiany "Einset Seedless". Episteme (Krak.), 20(3): 327-338.

   (MNiSW 4 pkt., IF =0)

   *(**100% contribution,** developing the paper design, realization of vegetation studies, data collection and compilation, manuscript preparation, corresponding author).*

4. **Kapłan M.,** Najda A. 2014. Antioxidant activity of vine fruits depending on their colouring. Chemija (Liet. Moksl. Akad. (Spausd.), 25(1): 51-55.

   (MNiSW 15 pkt., IF =0,482)

   *(**80% contribution,** developing the concept and framework of the paper, realization of vegetation studies, compilation of part of data, input into manuscript preparation, corresponding author).*

5. **Kapłan M.,** Najda A., Baryła P., Klimek K. 2017. Effect of gibberellic acid concentration and number of treatments on yield components of "Einset Seedless" grapevine cultivar. Horticultural Science, 44(4): 195-200. DOI: 10.17221/51/2015-HORTSCI

   (MNiSW 25 pkt., IF =0,500)

   *(**70% contribution**, authorship of the concept and framework of the paper, realization of vegetation studies, preparation of manuscript part, preparation of some literature, corresponding author).*

6. **Kapłan M.,** Najda A., Klimek K., Borowy A. 2019. Effect of Gibberellic Acid (GA_3) Inflorescence Application on Content of Bioactive Compounds and Antioxidant Potential of Grape (*Vitis* L.) 'Einset Seedless' Berries. *S. Afr. J. Enol. Vitic.* Vol. 40 (1): 1-10, DOI: 10.21548/40-1-3004.

   (MNiSW 25 pkt., IF =0,636)

   ***(70% contribution,** developing the concept and framework of the paper, participation in part of the tests, data compilation, input into manuscript preparation).*

Total indices for the monothematic series of publications documenting the scientific achievement are as follows:

MNiSW - **80 points**

Total Impact Factor (TIF) - **1,608**

5-year TIF – **2,340**

I am the only author of three publications in the series, while the first author of the others, with my contribution percentage ranging between 70-80%.

Annex 6 presents the statements of the co-authors and specifies their individual input into each publication.

c) Discussion on the research objective of the aforementioned publications and their applicability

Introduction

Grapevine is regarded one of the most important economically plant species in the world and its global production reached over 74 million tons in 2017 (FAO 2019). In Poland,

grapevine cultivation is of minor economic importance but it has enjoyed high popularity reflected in fast increase in grapevine acreage. A trend of growing grapevine and production of wine from your own plantation in Poland has been on top of others along with developing enotourism. Grapevine was and has still been present in the backyard garden owing to its taste, pro-health and decorative qualities. Although the vines in Poland are exposed to freezing injury and frost losses, the grapes and wine produced here are of very high quality (Lisek 2004, 2008, 2009, Dobrowolska – Iwanek et al. 2014, Kapłan 2014). Annual grape production in Poland over last five years was around 3 thousand tons (Eurostat 2019), whereas in the marketing year 2017/2018, the producers registered in the National Support Centre for Agriculture (KOWR)obtained some 800 tons of grapes (KOWR 2019).

According to Yang et al. (2009),out of all grapes harvested globally, 80% is used for wine making, 13% as table fruit and the rest for raisin production. In the countries with winemaking practices, mainly the varieties coming from the common grapevine (*Vitis vinifera* L.) are cultivated. At some cooler climatic conditions like in Poland, other grapevine varieties derived from the following species are also chosen: fox grape (*Vitis labrusca* L.), summer grape (Vitis *aestivalis* Michx.), river grape (*Vitis riparia* Michx.), sand grape (*Vitis rupestris* Scheele), Berlandier`s grape (*Vitis berlandieri* Planch.) and muscadine grape (*Muscadinia rotundifolia* Michx., syn. *Vitis rotundifolia* Michx.)(Lisek 2002, 2011).

The last years in Poland were marked with the studies set out to explore the outdoor growing possibility of table grape cultivars (Lisek 2004, 2007, 2008, 2009, Kapłan 2009, 2011, 2017, 2019). Special attention was attached to seedless varieties which are very popular among consumers, however their small size is a problem for their commercialization (Weaver 1976).

An essential prerequisite for table grape production profitability is to meet the strict requirements of market concerning grape size, that is production of the excellent quality and equal size clusters, uniform shape and berry size, equal coloration and higher resistance to transportation. An important trait proves to be lack of seeds (Dimovska et al. 2014). Evidence has shown that seedless fruit were used for raisin production and highly appreciated by among others, Hippocrates and Platon or in the writing of ancient Egypt as early as 3000BC (Varoquaux et al. 2000). In the past, seedless grapes were grown using the natural methods and now, when they have become very popular among consumers and satisfy their preferences in terms of taste and quality, seedless grapes are used as both, table fruit and raisins (Artés-Hernández et al. 2006).

As a result of some American grape breeding programs conducted since 1940, there were released new interesting seedless grape cultivars recommended and well suited to cooler sites such as `Canadice`, `Challenger`, `Einset Seedless`, `Reliance`, `Saturn`, Suffolk

Red`. Although they possess many positive characteristics, their weaknesses include poor berry growth and severely thinned clusters (Zabadal and Dittmer 2000 a, b).

According to Myśliwiec (2009), `Einset Seedless` variety is the best among all seedless cultivars known in Poland and recommended for outdoor cultivation. It is highly appreciated due to its productivity, winter hardiness and berry taste. This variety fruit can be used for raisin production and as fresh table grape. However, the natural weight of `Einset Seedless` berries is too low for their commercial use as table grape.

Notably, new opportunities for agrotechnology appeared last years allowing production of very good quality grape varieties thanks to exogenous application of gibberellic acid. This acid stimulates cell division, induces flowering and increases fruit size (Khan et al. 2009, Nampila et al. 2010, Dimovska et al. 2014, Kapłan et al. 2017). A vast body of scientific evidence proved that gibberellin use in parthenocarpic fruit production is highly effective (Seçer 1989, Bora and Sarma 2006, Korkutal et al. 2008, Kapłan 2009, 2011, 2013). It is very important as consumers expect uniformly repeatable grapes, equal berry size, shape and coloration as well as higher resistance at transportation. Gibberellic acid treatments, apart from improved yield size and quality of parthenocarpic variety grapevines, have significant effect on berry firmness and elasticity (Yamada et al. 2003). Dokoozlian (2003) reports that GA_3 treated clusters are more resistant to rain-induced cracking, especially at harvest time.

The berry size is affected by both, the endogenous factors (nutrients and hormones) and exogenous (temperature, light, water availability) (Ojeda et al. 2001, Ollat et al. 2002). In order to increase the size of berries and clusters and their compactness, the countries with long vine-growing tradition have applied gibberellic acid for many years. These are India (Dass and Randhawa 1968), the USA (Halbrooks and Mortensen 1987, Lu 1996), Thailand (Surasak and Choopong 1988), Brasil (Pommer 1995, Formolo et al. 2010), Greece (Korkas et al. 1999), Chile (Perez and Gomez 2000), Spain (Casanova et al. 2009), Poland (Kapłan 2011, 2013, 2017, 2019), Jordan (Abu-Zahra 2010). However, despite many trials and research studies performed, there are no explicit guidelines as to the rate or number of application of this compound.

Owing to grapevine fruit taste qualities and dietetic properties, they make a valuable source of biologically active substances including vitamins (A, B1, B2, C, PP), minerals (potassium, phosphorus, calcium, iron, boron, magnesium), pectins, pigments, tannins, essential oils, easily digestible carbohydrates, amino acids, fruit acids and fiber). The most prominent grape polyphenols group with health-promoting benefits are: flavonoids, phenolic acids, flavons, flavonols, flavanones, flavanonoles, catechins and anthocyanin

pigments (Mazza 1995, Pezzuto 2008, Krośniak et al. 2009, Yang et al. 2009, Katalinić et al. 2010).

Consumption of grapes is associated with a considerably decreased risk for cardiovascular disease and cancer development (Arts and Hollman 2005, Erdman et al. 2007, Leifert and Abeywardena 2008). This beneficial effect results from the secondary metabolites presence, such as polyphenols and their properties: antioxidant, anti-inflammatory, anticancer, antiplatelet, neuroprotective, blood vessel dilation and boosting immune system. These compounds have been reported to be able to modulate and induce signaling pathways (Frankel 1999, Stevenson and Hurst 2007, Pezzuto 2008, Dohadwala and Vita 2009, Crozier et al. 2010, Xia et al. 2010, Vislocky and Fernandez 2010). Besides, polyphenols inactivate free radicals and chelating divalent metal ions and thus reduce their oxidation potential (Scalbert et al. 2005).

Qualitative and quantitative composition of polyphenols and their distribution and antioxidant activity in grapes are quite variable and related to a species, variety, localization in berry (skin, pulp, seeds, juice), soil-climatic conditions (exposition to light, temperature, soil type), agrotechnical practices (irrigation, fertilization, growth regulator application), harvest date, berry ripeness, size of yield and berry, post-harvest conditions and storage techniques and processing (Kim et al. 2003, Peña-Neira et al. 2004, Jiang et al. 2006, Montealegre et al. 2006, Orak 2007, Xia et al. 2010). Polyphenols are responsible for the major sensory attributes of products and beverages of plant origin as they determine their appearance, especially color and taste properties such as bitterness, astringency and aroma (Tomás-Barberán and Espin 2001, Es-Safi et al. 2007).

A lack of Polish research reports on hormonization usability in seedless vine grape cultivation and frequently divergent research results presented in the foreign literature give no grounds to their practical applicability under the Polish weather conditions. Therefore, it was essential to perform researches covering both, agrotechnical tests and analytical studies in many–year grapevine cultivation, taking into account the actual situation of three-year use of plants by plantation holders. In 2006 at the Department of Seed Production and Horticultural Nurseries (now the Department of Pomology and Nurseries) the studies were launched and still continued on the choice of growth regulators, their application mode and timing, determination of the effect of concentration and treatment number on yield quantity and quality, content of biologically active substances as well as antioxidant capacity of `Einset Seedless' variety grape. These studies are characterized by substantial practical potential that can improve yield efficiency of seedless grapevine varieties under the Polish soil-climatic conditions. My own observations pertaining to positive influence of these treatments on yield size and quality, the conclusions drawn by other grapevine plantation

holders, actual lack of complete research works on this topic, especially on comprehensive impact of hormonization on antioxidant potential of grapevine, pointed to the need of the research continuation. It should concentrate on development of reliable guidelines concerning types of preparations used, their application rates and timing. **I am personally the author of the conception and the only or the first author of the studies.**

The research outputs are presented in my research publications constituting the scientific achievement

The key research objective was:

- determine effectiveness of gibberellic (GA_3) and 2-naphtoxyacetic (NOA) acid and their application method on size and quality of grapes `Einset Seedless` variety,
- establish the influence of gibberellic acid concentration on yield quantity and quality, biologically active substances content and antioxidant activity of `Einset Seedless` berries,
- indicate the effect of hormonization treatment time on yield size and quality of `Einset Seedless` fruit,
- assess the impact gibberellic acid application number on yield quantity and quality, in that biologically active compounds and antioxidant potential of `Einset Seedless` grape,
- compare the content of some secondary metabolites and antioxidant activity,
- of `Einset Seedless` fruit at the background of the cultivars with different skin colour.

Observational study on effectiveness of gibberellic acid (GA_3) and 2-naphtoxyacetic acid (NOA) and their application mode for yield size and quality of `Einset Seedless` variety (publ. 1, 2).

Intentional application of gibberellic acid allows for optimization of seedless grapevine yielding by increasing the berry size and improved cluster structure. Effectiveness of such a treatment depends to a large extent on its application time considering inflorescence development stage, gibberellic acid concentration and the post-application conditions. For many years, the mixture of gibberellins (GA_3) and auxins (NAA; NOA or 2,4,5-TP) has been successfully used in the cultivation of sweet cherry, apple, plum and sour cherry trees (Jankiewicz 1997). With a view to this fact, the experiment was made with gibberellic acid GA_3 and 2-naphtoxyacetic (NOA) acid to test their usability for seedless grape cultivation.

The observations were conducted in the years 2006-2008 in the Faliszowice Vineyard (at present Nobilis) (50°39`N; 21°34`E) in the Sandomierz Upland. The grapevine parthenocarpic `Einset Seedless` grapevines (`Fredonia` x `Canner` Reisch et al. 1986) were planted in spring 2003 at the spacing of 2,0 x 1,0 (5000 units x ha^{-1}) on luvisol soil developed from loess that contained 2,1% of organic matter. The vines whose fruit made the research material in all the studies performed were trained at the trellis composed of the posts and four-steel wire system at height of 70, 110, 150 and 190 cm. The plants were trained to single Guyot system with the trunk of the vine kept at 40 cm height, one cane of about 0,9 m length and one two-bud spur. During the study period, regular plant protection against diseases, pests and weeds was provided according to the present protection program of grapevines. The shrubs were not watered, while soil pH ranged between 6.0 and 6.5 subject to a study year. Each year at the bud breaking stage, Hydrocomplex fertilizer (12N-11P-18K) was sprinkled at 300 kg·ha^{-1} application rate, whereas the other macro- and micro-elements were foliar applied if needed.

The trial aimed to assess quantity and quality of yield after gibberellic acid (GA_3) use in the form of Arbostim 100 SL (Varichem Comp.-T. Ostrowski, Warsaw Organic Chemistry) and 2-naphtoxyacetic (NOA) acid as Betokson Super 050 SL (PPH „TOMATEX" Barbara Plesińska). The growth regulators were applied at the plant bloom period, the inflorescences were sprayed or wholly immersed in the solution for 2-3 seconds. The aqueous solutions were prepared immediately before the treatment. The clusters were treated by a hand sprayer covering thoroughly the pedicles and berries. On average, 50 ml of the solution was sufficient to very thorough covering of all the clusters on one vine. The solutions were applied at the following concentrations: 100 mg $GA_3 \cdot L^{-1}$ – a single treatment at full flowering stage (70-80% of developed flowers), 50 mg $GA_3 \cdot L^{-1}$ – two treatments (total 100 mg $GA_3 \cdot L^{-1}$ applied) the first at the bloom start (20% developed flowers), the second at the flowering stage end (80% of decayed flowers), 50 mg $GA_3 \cdot L^{-1}$ +0,2% NOA – a single treatment at full bloom stage (70-80% of developed flowers) and 0,2% NOA – a single treatment at full bloom stage (70-80% of developed flowers).

The hormonization operation had beneficial effect on yield size. In the first and second study year, the application of 50 mg $GA_3 \cdot L^{-1}$ + 0,2 NOA mixture while 0,2% NOA in the third one has significantly increased yield quantity. On average for three study years, the statistical analysis did not show significant influence of the growth regulators on a level of the parameter under investigation, even though the yield after the 50 mg $GA_3 \cdot L^{-1}$ + 0,2% NOA mixture application was twice higher as compared to control (publication 1).

It was found that the growth regulators used affected positively the weight and number of berries in cluster. The plants treated with 50 mg $GA_3 \cdot L^{-1}$ and the mixture 50 mg $GA_3 \cdot L^{-1}$

+ 0,2% NOA, irrespective of an application mode and 100 mg $GA_3 \cdot L^{-1}$ in the form of flower immersion produced significantly heavier clusters with a higher number of berries as against control. Roper and Williams (1989), Dokoozlian (1999), Zoffoli et al. (2009), Abu-Zahra (2010) report that the GA_3 applications contributed to declined number of flowers and buds ,whereas its re-application after some time caused the increase in berry size. The present studies did not demonstrate significant effect of a growth regulator application method on cluster weight or number of berries per cluster.

The growth regulators used in the studies had beneficial impact on one berry weight. The fruit produced by flowers treated by regulators were slightly heavier than the control, yet the differences were significant only in the case of inflorescences sprayed with 100 mg $GA_3 \cdot L^{-1}$.There was not observed significant influence of preparation application mode on the feature under study. A favorable impact of gibberellic acid on cluster weight and berry weight was highlighted by Sarooshi (1977), Kasimatis et al. (1978), Lavee and Nir (1986), Lu (1996), Williams (1996), Zabadal and Dittmer (2000 a, b), Hyunggook et al. (2008) Casanova et al.(2009).

Gibberellic acid and 50 mg $GA_3 \cdot L^{-1}$ and 0,2% NOA mixture have significantly modified the cluster length and berry length, with the exception of fruit whose inflorescences were sprayed with 50 mg $GA_3 \cdot L^{-1}$.The negative effect of 0,2% NOA on the quality parameters studied was established. Significant influence of growth regulator application method on the cluster length was pointed out in the case of 50 mg $GA_3 \cdot L^{-1}$ combination, the clusters whose inflorescences were immersed proved to be significantly longer than those sprayed. Several research reports indicate a positive, still not always significant, GA_3 impact on cluster length and berry length of seedless varieties. These are, among others, Kasimatis and Jensen (1973), El-Banna and Weaver (1979), Surasak and Choopong (1988), Abu-Zahra (2010).

The growth regulators applied did not have significant effect on berry width.

There was noted unfavorable impact of a hormonization treatment on extract content in fruit. The fruit developed by the flowers treated with gibberellic acid, irrespective of an application method, and 50 mg $GA_3 \cdot L^{-1}$ + 0,2% NOA mixture used as a spray had significantly lower extract level compared to control.

The research publications indicated that:

- The treatments applied affected positively yield quantity, cluster weight, weight and number of berries per cluster. The effect was not always significant and was dependent on the study cycle, the type of growth regulators used and concentration of solutions applied.

- Application of gibberellic acid and 50 mg $GA_3 \cdot L^{-1}$ and 0,2% NOA had significant influence on the length of berries and clusters, with the exception of the clusters developed from flowers sprayed with 50 mg $GA_3 \cdot L^{-1}$.
- Negative influence of the growth regulators applied was found on extract content in fruit.
- Application mode of growth regulators did not affect significantly the weight of clusters, weight and number of berries per cluster, the length and width of berries.
- Gibberellin GA_3 and auxin mixture had very positive impact on quantity and quality of yield and it can be used for hormonization operation.
- Use of 2-naphtoxyacetic acid (NOA), irrespective of application method, affected unfavourably most of yield quality parameters under assessment, yet as for the length of clusters and berries, this effect was significant. The 2-naphtoxyacetic acid used in single applications without gibberellin additive should not be recommended for the widespread use in practice.

The studies on the effect of gibberellic acid concentration on the yield quantity and quality parameters as well as biologically active compounds and antioxidant potential of `Einset Seedless` cv. (publ. 3, 5 and 6).

The research objective was assessment of the effect of gibberellic acid concentration on yield size and quality of `Einset Seedless` variety grapevine. The studies were conducted over the years 2010-2012 (publ. 3) and 2011-2013 (publ. 5). The research material included the grapes of `Einset Seedless` variety treated by gibberellic acid (GA_3) at the following application rates: 100, 200 and 300 mg $GA_3 \cdot L^{-1}$ for seven days after full flowering stage (when 70% of berries were 1mm in diameter, 14 days after full flowering (when 70 % of berries were 3 mm in diameter) and 21 days after full bloom (when 70% of berries had 6 mm diameter). Subject to a study cycle, the aforementioned rates were applied once a season (7 days after full bloom when 70% of berries per cluster reached 1 mm in diameter) (publ. 3 and 5), two times (7 and 14 days after full flowering stage when 70% of berries per cluster were 1 and 3 mm in diameter, respectively) or three times a season (7, 14 and 21 days after full bloom when 70% of berries per cluster had 1, 3 and 6mm diameter, respectively) (publ. 5). The solution was prepared using 99% gibberellic acid (Acros Organics™, Thermo Fisher Scientific Geel, Belgium) with a wetting and adhesion promoter SILWET Gold (Chemtura Europe Limited, Warsaw, Poland) at 0,015% concentration, that is 150 µl. The plants whose clusters were not treated with gibberellic

acid constituted the control. The studies aiming at assessing the effect of gibberellic acid concentration on biologically active compound content and antioxidant activity were carried out in the Laboratory Quality Vegetable and Medicinal Resources, Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin in cooperation with A. Najda D. Sc. Assoc. Prof. (publ. 6). The research material was made by `Einset Seedless` variety grapes hormonized by gibberellic acid. The inflorescences of the plants under study were sprayed with GA_3 solution at 100, 200 or 300 mg $GA_3 \cdot L^{-1}$ concentration once, twice or three times a season at the same development stages as discussed in publication 5.

The gibberellic acid treatments had positive influence on grapevine yielding, yet this effect was non-significant in most combinations. It was found that over the years 2010-2012 the application of 200 mg $GA_3 \cdot L^{-1}$ on 7 and 21 days after full flowering and 300 mg $GA_3 \cdot L^{-1}$ irrespective of the application time had significant impact on yield quantity of the plants investigated. Concentration of GA_3 modified the yield size only in few cases. In both research stages presented, it was noted that elevating GA_3 concentration made yield size increase. Significant influence was shown in the case of the application 7 days after bloom, between 100 mg $GA_3 \cdot L^{-1}$ and 300 mg $GA_3 \cdot L^{-1}$. Similar relationships were pointed out by Dimovska et al. (2014) assessing `Flame Seedless` (*Vitis vinifera* L.) after 5, 10 and 20 mg $GA_3 \cdot L^{-1}$ treatment.

Significant impact of hormonization operation on cluster weight was observed in the years 2010-2012 when the clusters treated with gibberellic acid were significantly heavier as compared to control, the exception made the fruits treated with 100 and 200 mg $GA_3 \cdot L^{-1}$ 14 days after full bloom. Significant effect of gibberellic acid concentration on the quality parameter under study was determined 7 days after bloom between the clusters treated with 100 mg $GA_3 \cdot L^{-1}$ and 300 mg $GA_3 \cdot L^{-1}$ and 14 days after full flowering between 100, 200 mg $GA_3 \cdot L^{-1}$ and 300 mg $GA_3 \cdot L^{-1}$. Considering the studies from 2011-2013, no significant influence of hormonization treatment and gibberellic acid concentration was noted on the parameter evaluated. Beneficial effect of gibberellic acid on cluster weight was highlighted by Halbrooks and Mortensen (1987), Lu (1996), Casanova et al. (2009), Abu-Zahra (2010).

Exogenous applications of gibberellic acid did not affect significantly the number of berries per cluster and berry weight. Negative impact of GA_3 operation was pointed out by Lu (1996) at the application rates of 50 and 300 mg $GA_3 \cdot L^{-1}$. It is not consistent with the results presented by Halbrooks and Mortensen (1987), Zabadal and Dmitter (2000 a), Casanova et al. (2009) who proved that gibberellic acid use had significant effect on berry weight.

Only in few cases, hormonization operation had significant influence on grape size expressed by cluster length and width. In both research cycles, there was not determined significant impact of GA_3 concentration on the length and width of clusters of the grapevine under study. The influence of the substance concentration on cluster width was indicated by Dimovska et al. (2014).

The obtained results demonstrate that hormonization practice had significant influence on elongation of grapevine berries `Einset Seedless` variety, the clusters treated with gibberellic acid formed significantly longer berries as compared to control. No significant effect of gibberellic acid concentration was observed on the quality parameter tested (publ. 3, 5). Similar findings related to most of the GA_3 concentrations assessed were reported by Dimovska et al. (2014).

Slightly different influence of hormonization treatment was indicated in the case of berry width assessment. Application of GA_3 7 days after full bloom did not have significant impact on width (publ. 3, 5). However, significant influence of the above mentioned treatment on the parameter under investigation was shown at 300 mg $GA_3 \cdot L^{-1}$ application rate 2 weeks after full bloom and 21 days after full flowering, irrespective of GA_3 concentration (publ. 3). In both research cycles, significant effect of gibberellic acid concentration on the fruit quality parameter studied was not established. Similar findings were presented by Dimovska et al.(2014).

Sugars represent one of major components of fruit quality and are responsible for its sweet taste. The sugars/organic acids ratio in fruit determines the final flavour of grapes (Topalovic and Mikulic-Petkovsek 2010). In the first two research cycles (publ. 3, 5) in most of the combinations applied, no significant effect was observed of hormonization treatment and gibberellic acid concentration on extract content. The exception was made by the fruit whose buds were treated with 100 and 300 mg $GA_3 \cdot L^{-1}$ 7 days after full flowering in the years 2010-2012. The results obtained during the observational studies in 2014 do not confirm the earlier relationships as the statistical analysis made showed that irrespective of the GA_3 concentration, extract content in the hormonized fruits was significantly lower than in control. The significantly lowest level of the parameter under study was established in the fruit treated with 200 mg $GA_3 \cdot L^{-1}$. The studies of Al-Atrushy (2016) demonstrated that with increasing GA_3 concentration, total sugar level increased significantly. Dimovska et al. (2014) applied GA_3 at 5, 10, 20 mg $GA_3 \cdot L^{-1}$ concentration and did not note its significant impact on extract content in fruit of `Flame Seedless` cultivar.

Total vitamin C content was significantly dependent on GA_3 concentration applied. It was found that vitamin C level in the hormonized fruit was significantly lower as compared to control and the significantly lowest was detected in the fruit treated with

200 mg $GA_3 \cdot L^{-1}$. Significant effect of gibberellic acid concentration on vitamin C content was also confirmed by Rachna and Singh (2013) and Awad and Al-Qurashi (2012).

Grape acidity is correlated with its taste due to the presence of tartaric and malic acids that account for as much as 90% of acids in grapes (Laszlo and Saayman 1990, Topalovic and Mikulic-Petkovsek 2010). Total acidity of fruit that underwent hormonization treatment in the years 2011-2013 (publ. 5) did not differ significantly from the control. In 2014 a different relationship was presented, namely the fruit treated with 100 and 300 mg $GA_3 \cdot L^{-1}$ were shown to have significantly higher total acidity than control (publ. 6). The available literature related to the hormonization operation effect on total acidity level provides inconsistent information. The studies of Kok (2017) did not show significant impact of GA_3 application on acidity of grape `Cardinal` variety. A negative influence of hormonization treatment on acidity level was demonstrated by Al-Atrushy (2016) and Rachna and Singh (2013).

Antioxidant activity of grape material is ascribed to the presence of the secondary metabolites, such as phenolic acids, anthocyanins, flavonoids and tannins. Phenololic acids content in the fruit studied was significantly dependent on GA_3 concentration. It was demonstrated that treatment of fruit with 100 and 200 mg $GA_3 \cdot L^{-1}$ concentration had significant effect on the increase of phenolic acid content.

Hormonization operation contributed to elevated anthocyanin level, yet it was non-significant. The fact was confirmed by the studies of Dimovska et al. (2014) that also did not show significant impact of hormonization practice on a level of these compounds in grapes of `Flame Seedless` cultivar.

Antioxidant activity of extracts of fruit studied determined by DPPH method was dependent significantly on GA_3 concentration. In most combinations, the treatments performed had significantly positive influence on the parameter investigated. It was demonstrated that the control fruit and those treated with 100 and 300 mg $GA_3 \cdot L^{-1}$ exhibited significantly higher antioxidative activity than those treated with 200 mg $GA_3 \cdot L^{-1}$. Gougoulias and Masheva (2010) proved positive impact of hormonization on enhanced antioxidative activity of seedless varieties of vines – 16-42%.

Hormonization treatment affected negatively flavonoid content in the fruit studied as those hormonized had significantly less flavonoids as compared to control. It was observed that flavonoids level increased significantly with elevating GA_3 concentration. The obtained results are consistent with those reported by Tiana et al. (2011) yet inconsistent with the observations of Gougoulias and Masheva (2010).

The analysis made showed that hormonization operation with gibberellic acid at 300 mg $GA_3 \cdot L^{-1}$ concentration had significant impact on tannin content. Similar relationships were

indicated by Awad and Al-Qurash (2012) who applied 100 and 150 mg $GA_3 \cdot L^{-1}$ in date palm tree `Barhee` variety cultivation. The available literature does not provide data on the effect of concentration and number of GA_3 applications on tannin content in vine fruit.

Pearson coefficient showed strong correlation between total extract content and concentration of 100 mg $GA_3 \cdot L^{-1}$, while strong negative correlation was determined between total extract content and 200 mg $GA_3 \cdot L^{-1}$ concentration, vitamin C and 300 mg $GA_3 \cdot L^{-1}$ concentration and between total acidity and 200 mg $GA_3 \cdot L^{-1}$ application rate. Analyzing the Pearson coefficient for the parameters specifying fruit antioxidant potential, strong correlation between total phenolic acid content and 100 mg $GA_3 \cdot L^{-1}$ concentration and 300 mg $GA_3 \cdot L^{-1}$ application was established. Besides, strong negative correlation was demonstrated between total phenolic acid content and 200 mg $GA_3 \cdot L^{-1}$ concentration and between DPPH parameter and 200 mg $GA_3 \cdot L^{-1}$ application rate.

The analysis of gibberellic acid influence on antioxidant operation level of grapevine `Einset Seedless` variety using the multivariate techniques facilitated to define similarities of concentration effect on the aforementioned parameters. The concentrations of 100 and 300 mg $GA_3 \cdot L^{-1}$ affected the antioxidative potential of fruit in a very similar way, opposite to 200 mg $GA_3 \cdot L^{-1}$concentration.

Performing principal component analysis (PCA) demonstrating a relationship between secondary metabolites content dependent on GA_3 concentration showed that the PC sum (PC1 and PC2) of integer variable of features for the GA_3 concentrations was 81,1%, in that PC1 52,47% and PC2 28,63%. PC1 was responsible for a content of flavonoids, vitamin C and phenolic acids, whereas PC2 for potential of sugars, tannins, acidity and DPPH. The control was characterized with high content of extract, flavonoids and low level of anthocyanins and phenolic acids. The PCA analysis demonstrated differences between the application rates, the fruit under 100 mg $GA_3 \cdot L^{-1}$ concentration had high vitamin C level. The applications of 200 and 300 mg $GA_3 \cdot L^{-1}$ contributed to high content of tannins, while 300 mg to acidity as well.

The studies performed led to formulate the following conclusions:

- Hormonization operation and concentration of GA_3 applied had beneficial effect on yield size and cluster weight, yet only in few cases this influence was significant and was dependent of research cycle.
- Hormonization treatment and gibberellic acid concentration did not affect significantly the number of berries per cluster or berry weight.
- Hormonization had significant impact on berry elongation, while gibberellic acid concentration did not have significant effect on quality parameter studied.

- Influence of hormonization operation on cluster weight, length, width and berry width was equivocal and differed subject to research cycle.
- There was not demonstrated significant impact of gibberellic acid concentration cluster length and width or berry width.
- Effect of hormonization treatment and GA_3 concentration on extract content and total acidity differed depending on research cycle.
- Gibberellic acid application rate modified significantly vitamin C content, a level of phenolic acids, flavonoids, tannins and antioxidant activity determined by DPPH assay.
- Gibberellic acid use, irrespective of its concentration, had negative impact on vitamin C and flavonoids content.
- Application of 100 and 300 mg $GA_3 \cdot L^{-1}$ increased significantly antioxidant potential established by DPPH protocol.

The studies on the effect of hormonization operation timing considering developmental stage of fruit buds on size and quality of yield of grapevine `Einset Seedless` variety (publ. 3).

The objective of the research was assessment of quantity and quality of grapevine `Einset Seedless` cultivar after gibberellic acid (GA_3) application at the following concentrations: 100, 200, 300 mg $GA_3 \cdot L^{-1}$ on 7, 14 and 21 days after full bloom. The control was made by the vines whose clusters were not exposed to gibberellic acid treatment. The studies were conducted over the years 2010-2012.

The analysis made did not show significant influence of hormonization operation time on cluster number per vine, yield size, number of berries per cluster, berry weight and length, or cluster width of the grapevine under study.

Gibberellic acid at 100 mg $GA_3 \cdot L^{-1}$ application dose at different dates did not have significant impact on the weight of clusters of the grapevine assessed. Significant effect of the treatment time on the parameter under study was established between the clusters treated with 200 mg $GA_3 \cdot L^{-1}$ 7 and 14 days after full flowering and 300 mg $GA_3 \cdot L^{-1}$ 7 and 21 days after full bloom. It was observed that along with rising gibberellic acid concentration, the weight of clusters of grapevine `Einset Seedless` variety also increased with the exception of vines hormonized 21 days after full flowering. Casanova et al. (2009) found that treatment time did not affect significantly the weight of berries of grapevine `Emperatriz` cultivar. These authors observed that delayed time of hormonization operation

slightly reduced cluster weight. Similar relationship was noted in the present experiment when gibberellic acid was applied at 300 mg $GA_3 \cdot L^{-1}$ dose.

Significant impact of hormonization on the cluster length was established for the vines treated with 100 mg $GA_3 \cdot L^{-1}$, those that underwent the treatment on 7 and 21 days after full bloom produced significantly longer clusters as compared to those treated 14 days after full flowering. As for the other combinations, such relationships were not determined. Positive, yet non-significant impact of GA_3 impact on cluster length and width was reported by Surasak and Choopong (1988) and Casanova et al.(2009).

Significant effect of hormonization time on berry width was shown for clusters treated with 300 mg $GA_3 \cdot L^{-1}$ dose 7 and 21 days after full bloom. This finding was confirmed by Surasak and Choopong (1988) who highlighted positive, but implicit and largely dependent on a variety, influence of gibberellic acid on grape width.

The GA_3 application time did not have significant impact on extract content in most of the combinations evaluated. As it was noted, the extract level tended to decline with delayed hormonization date, yet it was non-significant at most. Significant differences were established only in the case of 300 mg $GA_3 \cdot L^{-1}$ application rate between the first and third treatment date.

The research demonstrated that:

- Hormonization operation time did not have significant effect on the number of clusters per vine, yield quantity, number of berries per cluster, weight and length of berries as well as cluster width of the grapevine under study.
- Significant influence of the treatment time on cluster weight was determined between the clusters treated with 200 mg $GA_3 \cdot L^{-1}$ 7 and 14 days after full bloom and 300 mg $GA_3 \cdot L^{-1}$ 7 and 21 days after full flowering.
- Significant effect of hormonization date on cluster length was established for the vines treated with 100 mg $GA_3 \cdot L^{-1}$, those that underwent the treatment 7 and 21 days after full bloom produced significantly longer clusters as compared to those 14 days after full flowering.
- The GA_3 application date did not have significant impact on extract content in most of the combinations studied. It was noted that extract level tended to decline with delayed hormonization operation time, yet it was non-significant at most. Significant differences were observed only in the case of 300 mg $GA_3 \cdot L^{-1}$ dose between the first and third application date.

Studies on the effect of gibberellic acid application number on quantity and quality of yield and biologically active compounds content as well as antioxidant activity in grapes of `Einset Seedless` variety (publ. 5, 6).

The studies were conducted in the years 2011-2013 (publ. 5). The research material included grapes of `Einset Seedless` variety treated with gibberellic acid (GA_3) at the following application rates: 100, 200 and 300 mg $GA_3 \cdot L^{-1}$ on 7, 14 and 21 days after full bloom. These application rates were performed once, twice and three times a season and the vine unexposed to the treatments made the control. The studies aiming at assessment of the number of gibberellic acid applications on biologically active compounds content and antioxidant capacity of grapes of `Einset Seedless` cultivar were carried out in 2014 (publ. 6). The research material comprised the grapes hormonized with gibberellic acid. Inflorescences of the vines studied were sprayed with GA_3 solution at 100, 200 or 300 mg $GA_3 \cdot L^{-1}$ concentration on 7, 14 and 21 days after full bloom. The vines whose clusters did not undergo the GA_3 treatment made the control.

The fruit yield was significantly modified by the number of gibberellic acid application. It was shown that irrespective of GA_3 concentration, the vines with clusters sprayed three times gave the significantly highest yield. On average during the three-year studies, no significant differences were reported in yield size between the control vines and those sprayed once and between those sprayed once and twice. Similar observations were presented by Dimovska et al. (2014), while Lu argued the opposite (1996).

There was found significant effect of the number of gibberellic acid treatm significantly the value of parameter under study, however, no significant differences were noted only for the application of 100 mg $GA_3 \cdot L^{-1}$ between single and two applications. It was observed that weight of fruit whose inflorescences were sprayed once, irrespective of concentration, had cluster only slightly and non-significantly larger than the control. Notably, weight of clusters sprayed three times, irrespective of GA_3 concentration, was 2-fold larger as compared to control, whereas when applied twice was half larger, i.e. by 50%. The studies of Dimovska et al. (2011, 2014) indicated that 20 mg $GA_3 \cdot L^{-1}$ dose applied three times caused increased cluster weight from 19 up to 66% subject to a variety.

The treatments performed were found not to have significant impact on the berry number per cluster. However, it was observed that an increasing application number tended to increase the berry number per cluster with the exception of the clusters sprayed with 200 mg $GA_3 \cdot L^{-1}$ once in which the berry number was slightly lower as against the control. A similar negative influence of GA_3 application was reported by Lu (1996) at 50 and 300 mg $GA_3 \cdot L^{-1}$ application dose.

The number of gibberellic acid treatments modified significantly berry weight. The fruit whose buds were sprayed three times were significantly heavier than the control. Significant effect of the number of applications was demonstrated only in the case of the highest concentration, that is 300 mg $GA_3 \cdot L^{-1}$ when the three treatments affected significantly one berry weight as compared to single and two applications.

It was found that the length and width of clusters treated with gibberellic acid were significantly higher as against the control. The exception was made by the clusters treated once at 200 mg $GA_3 \cdot L^{-1}$ and whose length did not differ significantly from the control. The following trend was noticed, namely for increasing cluster length and width with rising number of treatments, yet the effect was non-significant. The impact of application number on cluster width was proved by Dimovska et al. (2014).

The three-year research period did not show significant effect of gibberellic acid application number on berry shape of the grapevine studied, which is consistent with the observations of Dimovska et al. (2014). In the present research it was established that the growing number of treatments caused the increase in berry length and as for 200 and 300 mg $GA_3 \cdot L^{-1}$ concentration the significant differences were observed between a single and three time applications. Gibberellic acid used for three times at 300 mg $GA_3 \cdot L^{-1}$ concentration had significant influence on berry width.

The statistical analysis did not demonstrate significant impact of the number of gibberellic acid treatments on extract content or total acidity level in the fruit of grapevine variety under investigation (publ. 5). As for fruit analyzed in 2014 (publ. 6), extract content in those subjected to two and three applications of GA_3 was significantly lower than in the control. Gibberelic acid applied three times was found to reduce this parameter value significantly and most potently. According to the studies by Al-Atrushy (2016), sugar content was significantly growing along with rising number of applications, whereas Dimovska et al. (2014) did not indicate significant effect of application number on extract content.

Hormonization operation had significantly reduced vitamin C level and the significantly lowest content of this parameter was established when GA_3 was applied three times.

Fruit treated with single and twice applications of gibberellic acid solution demonstrated significantly higher total acidity against the control. The opposite was reported by Al-Atrushy (2016).

Application number modified significantly phenolic acid content, while single and three time-treatments had significant influence on the increase of this parameter.

Hormonization, irrespective of the application number, contributed to elevated anthocyanin content, yet it was not significant. Similar results were obtained by Gougolias

and Masheva (2010) after twice GA_3 applications which caused a 30% rise in anthocyanin level in `Kishmish Tjurkmenski` variety fruit.

Number of GA_3 applications modified significantly the antioxidant activity in fruit under study. Fruit subjected to hormonization operation had significantly higher DPPH level than the control but with increasing application number the level significantly declined. The studies of Gougoulias and Masheva (2010) indicated similar positive effect of hormonization on enhanced antioxidant activity level in seedless grapevine varieties.

Fruit that underwent hormonization practice demonstrated a significantly lower level of flavonoids compared to control and the significantly lowest level was detected at three time application. The obtained findings are confirmed by the studies of Tian et al. (2011), who reported that GA_3 considerably reduced a total flavonoid level in grape pulp and skins. Gougoulias and Masheva (2010) obtained different results.

Single application has significantly modified tannin content.

Pearson coefficient showed a strong correlation between total extract content and single GA_3 application; vitamin C content and a treatment performed once. A strong negative correlation was noted between the total extract content and GA_3 applied twice; vitamin C and two and three time applications.

Analyzing the Pearson coefficient for the antioxidant activity parameters in fruit, there was determined a strong correlation between flavonoid level and the application number as well as tannin content and single GA_3 application. There was also established a strong negative correlation between total phenolic acid content and treatment made three times as well as flavonoid level and single GA_3 application and performed twice.

Using the multivariate analyses, it was demonstrated that single and two time application of GA_3 had very similar impact on antioxidant potential level, whereas GA_3 applied three times exhibits similarity to the control.

The PCA analysis indicating a relationship between secondary metabolites content and the number of GA_3 applications showed that PC sum of integer variable for the GA_3 application number analyzed was 84% (60,73 and 23,27%, respectively). PC1 was responsible for phenolic acid level, while PC2 for the other secondary metabolites and content of vitamin C and extract. The control fruit were characterized by a high level of flavonoids, vitamin C and extract, while low content of other components. Hormonization operation, irrespective of a number of applications, had beneficial effect on a level of phenolic acids, anthocyanins, DPPH and fruit acidity.

The results presented in the research publications:

- Fruit yield and cluster weight were significantly altered by the number of gibberellic acid applications. It was found that, regardless of GA_3 concentration, the vines whose clusters were sprayed three times gave the significantly highest yield and produced the significantly highest clusters out of these hormonized.
- There was no significant effect of the number of GA_3 treatments on the berry number per cluster, length and width of clusters and berries but an upward trend was noted of the studied parameters along with increasing number of gibberellic acid applications. However, the effect was non-significant.
- The number of GA_3 treatments at the highest concentration, i.e. 300 mg $GA_3 \cdot L^{-1}$ has significantly modified a berry weight.
- Influence of application number on extract content and total acidity differed subject to a research cycle.
- Number of gibberellic acid applications has significantly changed a level of vitamin C, phenolic acids, flavonoids, tannins and antioxidant capacity assayed by DPPH method.
- Hormonization operation, irrespective of the application number, affected positively the anthocyanin content and significantly positively antioxidant activity as determined by DPPH assay.
- The increase of treatment number was shown to significantly decrease a level of extract, acidity and antioxidant potential.

Observations on some secondary metabolites content and antioxidant capacity of `Einset Seedless` variety grapes against the cultivars of different skin colour (publ. 5).

The research material included fruit of three vinegrape varieties of different skin colours, that is `Regent` with blue-black colored grape, `Einset Seedless` - pink and `Jutrzenka` - white grape. The field trial was carried out in the Faliszowice Vineyard (now Nobilis) in 2010 and 2011. The vines of three varieties were planted in spring 2003. Fruit of the cultivars studied were subjected to comparative analysis of some metabolites content.

Extract content in the fruit under study differed significantly between the varieties evaluated and it was as follows: `Einset Seedless` - 17,5%, `Jutrzenka` - 18,3%, `Regent`- 19,3%. The studies of Krośniak et al. (2009) showed that extract content in fruit grown in Poland is quite divergent and cultivar-related.

Antioxidant activity of grapevine fruit studied depended significantly on their coloring. `Einset Seedless` and `Regent` fruit contained significantly more polyphenols than

`Jutrzenka` cv. Whereas `Einset Seedless` cv. with pink grapes had only slightly more polyphenols as compared to `Regent` cv. with deep color fruit. The obtained finding confirm the Krośniak et al. (2009) results.

Phenolic acid level in the fruit analyzed depended significantly on a variety. It was proved that `Regent` variety grapes of deep dark colour contained significantly lower phenolic acids content as against `Einset Seedless` and `Jutrzenka` cv. Similar research results were reported by Yang et al. (2009) and Bunea et al. (2012).

Tannin content in the grapevine fruit studied was significantly related to their coloring. The significantly highest tannin concentration was determined in `Einset Seedless` grapes, while the significantly lowest in `Jutrzenka` cultivar. According to Matthews and Nuzzo (2007), tannins occur in the peel, seeds and peduncles and their content in fruit juice (must) and wine is linked to a crop technique, shrub loading and climatic conditions, maceration techniques and fermentation circumstances. These compounds possess numerous vital properties affecting wine colour, colour stability, astringency and depth of mouthfeel (Weston 2005).

Flavonoid content in the fruit analyzed differed significantly between the varieties assessed. It was observed that an increase in fruit color intensity coincided with significant elevation of flavonoid level. This finding is inconsistent with the studies of Yang et al. (2009) which did not demonstrate explicitly the impact of grapevine fruit color on the tested parameter.

The anthocyanin level in the fruit analyzed depended significantly on grape coloration. Fruit of `Regent` variety showed significantly higher anthocyanin fraction as compared to `Einset Seedless` cv, and `Jutrzenka` cv. Notably, anthocyanin content in `Regent` grape variety was nearly 150 times greater as against `Jutrzenka` cv. and 62 times larger than in `Einset Seedless` cv. A vast body of studies show that anthocyanin and tannin contents rely largely on a variety, species, ripeness degree of the fruit, fruit production site and climate (Mazza 1995, Mattivi et al. 2002, Munoz-Espada et al. 2004, Yang et al. 2009).

Antioxidant activity of extracts of the studied fruit assayed by DPPH method was significantly dependent on a variety. It was found that `Regent` and `Einset Seedless` cv. fruit are characterized by higher antioxidant potential compared to `Jutrzenka` cv. The research of Katalinić et al. (2010) did not report significant effect of vine fruit colour and cultivar on DPPH value.

The research work proved that antioxidant capacity of grape under study determined as the total polyphenols and the DPPH parameter was significantly associated with berry color. Fruit of `Regent` and `Einset Seedless` cv. exhibited significantly higher antioxidant capacity than `Jutrzenka` cv. It was found that fruit of `Einset Seedless` variety with pink-

colored skin had significantly more phenolic acids and tannins as against other fruit. Besides, enhancing coloration intensity of grapes contributed to a significant increase in flavonoid content.

Resume

The above discussed research results of many-year studies presented in the series of six publications for the postdoctoral degree proceeding constitute the first and comprehensive work aiming at improvement of technology of parthenocarpic grapevine variety `Einset Seedless` under the Polish weather conditions. Determination of the effect of gibberellic acid concentration and application number on a content of biologically active compounds of grapevine is of innovatory nature and brings novel knowledge components on a global scale. The obtained findings prove that the cultivation of parthenocarpic varieties including hormonization operation is possible and can give positive results under the Polish climatic conditions.

The mixture of GA_3 with auxin NOA used for hormonization had beneficial impact on yield quantity and quality. This mixture can be recommended to optimize yielding of `Einset Seedless` variety grapevine. Single applications of 2-napthoxyacetic (NOA) acid affected negatively the cluster length and berry length and width so this compound used in single treatments without gibberellin additive is not suggested as a good practice. The three-year study period did not indicate significant effect of growth regulator application method on hormonization practice effectiveness.

Complex observations demonstrated that gibberellic acid application number had significantly and explicitly modified the yield size, weight of clusters and berries. The vines whose buds were sprayed three times were found to yield significantly the highest and produced the significantly heaviest clusters out of these hormonized. There were not significant differences recorded in the size of yield between the control vines and those under single treatment as well as between those treated with GA_3 once and two times.

Gibberellic acid concentration affected positively the yield quantity and quality only in few cases. Alike, hormonization operation did not have significant impact on most of the evaluated parameters of size and quality of yield, whereas in the situation where the statistical analysis confirmed it, the impact was implicit and it did not imply a trend.

The obtained results are at the interdisciplinarity level, they combine horticulture science and practice with medical science research. Concentration and application number of gibberellic acid modified significantly a level of vitamin C, phenolic acids, flavonoids, tannins and antioxidant activity assayed by DPPH method. The GA_3 applications, except for 200 mg concentration, significantly increased antioxidant capacity and 300 mg $GA_3 \cdot L^{-1}$ the

significantly highest. Gibberellic acid used three times modified yield size and cluster weight to the greatest degree, but on the other hand it reduced significantly the antioxidant capacity level as compared to a lower application number. It is worth noting that increasing application number decreased significantly the antioxidant activity level. Gibberellic acid employment had negative influence of vitamin C and flavonoid level.

Assessment of some secondary metabolites and antioxidant capacity of `Einset Seedless` grape variety against the varieties of different skin coloration demonstrated that this cultivar is valuable as regards health benefits. The `Einset Seedless` variety fruit had very high content of polyphenols and high antioxidant potential, yet the values of these aforementioned secondary metabolites did not differ significantly from the level determined in `Regent` cultivar grapevine with very dark-skinned berries. Besides, `Einset Seedless` variety contained significantly more phenolic acids and tannins as compared to other cultivars.

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5. OTHER SCIENTIFIC RESEARCH ACHIEVEMENTS

The area of my research interests covers three following domains: agrotechnics and modern technologies in horticultural nursery, orchard crop cultivation and enology.

5.1. Nurseries

The first research experiments in which I cooperated with Prof. St. Wociór during my Ph. D. studies in 2000-2004 were designed to improve the technology for maiden cherry tree production considering the effect of rootstock cutting time on growth and branching of young trees under study. The observations did not indicate significant influence of mahaleb rootstock cutting time on maiden tree branching or the nursery performance. It was found that the April cutting time evidently caused the maiden trees to weaken their growth and therefore, it is not a recommended practice (annex IV, publ. **B4**).

My dissertation „Effect of some biological and technological factors on apple tree growth in the nursery and their productivity in orchard" as well as research works carried out in the successive years concentrated on the problems vital for science and practice, i.e. production of high quality apple tree nursery material. My trials aimed to assess the impact of biological factors (annex IV, publ. **C7**) and determine effective activity of growth regulators towards growth and quality of maiden trees and two-year old apple trees (annex IV, publ. **C9, C11, C13, C27, C28**). I also studied the effectiveness of Arbolin 036 SL and Promalin® preparations for young tree branching, namely their concentration, application modes and timing, number of application as well as the influence of mechanical operations such as twisting the central leaf tips by 180 and pinching out some apical leaves. These studies demonstrated beneficial effect of growth regulators on branching degree of apple maiden trees. A single application of growth-stimulating preparations used in the form of lanolin paste in the years of adverse weather conditions proved to be insufficient to bring good results. The genetic traits of a variety and weather conditions at the time of young shoot appearance had significant influence on maiden tree growth. The studies conducted by me are of high practicality providing valuable information on optimization of nursery productivity. This type of experiments was performed in response to the suggestions and urgent needs of the nursery management practices as well as close cooperation with the Association of Polish Nurseries. The results of my research were presented at the Training Conferences for nursery stock producers under the Association of Polish Nurseries (annex V, item **2.1.16, 2.1.19**) and published in the trade press (annex IV, publ. **G2, G3, G6, G10**).

I also participated in the studies supervised by Piotr Baryła E.D. on the influence of a rootstock type, timing and budding method on growth, quality and performance of sour

cherry and sweet cherry young trees. These studies yielded a number of publications (annex IV, publ. **C2, C4, C8, C10, C15, C18, C22**) in which together with a co-author, I indicated significant relationships between a rootstock type, timing and grafting method and development of plant morphological characteristics improved.

I conducted observational studies with Prof. St. Wociór to explore the effect of different pruning time of Berberis thunbergii in the nursery on quality of the cuttings produced (annex IV, publ. **C16**). In the years 2008-2011 I investigated the influence of rose blooms removal on growth and quality of rose shrubs 'Arthur Bell' and 'Burgund' cultivars at the nursery production stage (annex IV, publ. **C21**).

5.2. **Pomology**

The area of pomology has been my interest for years as it started in my family who always grew fruit and predominantly apple trees. The first research works in cooperation with Prof. St. Wociór discussed the impact of rootstocks and varieties on flowering, fructification and growth of apple trees (annex IV, publ. **B1, B2, B3, C6**).

Much of my research work over the years has focused on improvement of cultivation technology of apple tree 'Szampion' cultivar attempting to assess the effect of a rootstock type and the age of tree on yield growth, quantity and quality (annex IV, publ. **C3**), the influence of hand fruit thinning on fruit quality (annex IV, publ. **C1, C5**) as well as the impact of N Pro and Complex Seactive (fertilizers based on ,among others, marine algal extracts) on growth, yield quantity and quality in the Sandomierz Upland (annex IV, publ. **A1**). The many-year studies demonstrated that yield quantity of apple tree 'Szampion' cultivar was dependent on a rootstock type, the age of tree and intensity level of hand thinning operation, whereas growth and productivity on the age of trees. Besides, I participated in the research project conducted by Piotr Kiczorowski E.D. aimed to determine and compare a level of dry matter, protein and nutrients (total), dietary fiber, sugars, vitamin C and minerals (K, Na, Mg, Cu), phenolic compounds in flesh and skin of apple fruit 'Szampion' grafted on four different rootstock types: M.26, P2, M.9, P22 in the years 2014-2015 (annex IV, publ. **A7**). The observational studies showed that apples harvested from the P22-grafted apple trees had the highest level of dry matter, crude protein, fiber, easily hydrolysable sugars and vitamin C. The highest concentration of mineral compounds was recorded in the apples obtained from the trees grown on the rootstocks P22, P2 and M.9. The highest phenolic acid level was determined in the skin of fruits from the trees developed on P22 and M.9. The observations proved that the rootstocks characterized by the lowest growth rate (P22, M.9) ensure the highest accumulation of nutrients in 'Szampion' variety.

At the same time I launched collaboration with T. Lipa E.D. and Prof. B. Dobrzański with the research objective to specify lightness parameters and chromaticity of 'Szampion Arno' cultivar apples using a method irrespective of light conditions and to detect visible changes in colour caused by fruit damage and bruising during storage, shelf life on the fruit skin from both sides, that is from the blush side and the opposite of the base colour (annex IV, publ. **C30**). The next study aimed to establish and compare susceptibility to bruising of pear fruit `Konferencja`, `Lukasówka`, `Concord` and `Amfora` varieties. In the impact test applied in this study, a 25,68g glass ball was dropped from the height of 20, 40 and 80cm obtaining energy of 0,5 , 0,1 and 0,2J. The impact method allows assessment of the pear susceptibility to bruises and facilitates the comparison of the varieties. Comparing the amount of bruising under the influence of 0,2J impact energy, after storage it was observed that the determined volume of bruising of the `Concord` fruit (312,47 mm^3) was more than three times smaller than the volume of `Amfora` bruising (1075,13 mm^3). Owing to its low susceptibility to bruising and resistance to mechanical damage as well as the highest content of extract and sugars in fruit, `Concord` pear variety proves to be much promising (annex IV, publ. **C33**).

My another research area I worked on over the years 2011-2013 was evaluation of growth and yielding of four sweet cherry tree cultivars `Kordia`, Regina`, `Summit` and `Vanda` grafted on the rootstocks GiSela 5 and Colt (annex IV, publ. **C29**). During the experiment, the trees developed on the GiSela 5 rootstock had significantly decreased trunk cross-sectional area and the crown volume, while significantly higher cropping efficiency coefficient, crown productivity and average yielding over the entire study period as compared to trees produced on the Colt rootstock. The significantly highest fruit and fruit stone weight was reported for the `Regina` variety. Fruit of `Kordia` and `Regina` cultivar had significantly higher extract content as against other varieties. However, no significant influence of a rootstock type was established on sweet cherry fruit and stone weight, stone percentage in fruit or extract level.

At the same time, I participated in the studies of Prof. A. Borowy working towards the comparison of some biometric features, yield, content of some biologically active compounds in fruit and antioxidant activity in three sour cherry varieties cultivated in the Lublin Province (annex IV, publ. **A9**). Out of the varieties under study, `Łutówka` appeared to be the most productive cultivar with fruits of the highest concentration of vitamin C and flavonoid content, whereas the lowest total sugars and monosaccharide level. The least productive variety was `Nefris`, while `Kelleris' 16` was determined the medium productive characterized by the widest leaf blades and smallest fruit, the highest content of total sugars

and monosaccharides as well as the lowest concentration of anthocyanins and phenolic acids.

5.3. Enology

I am very well acquainted with the problems of viticulture and technology of vinification as I have personally grown grapevines from 2001, while in 2015 I started production of grape wines. In 2013 I completed my post-graduate study program in enology in the Jagiellonian University in Kraków. During my studies I began the cooperation with J. Dobrowolska-Iwanek D.Sc., the assistant professor in the Department of Bromatology, Faculty of Pharmacy, the Jagiellonian University, Collegium Medicum, Kraków. During this cooperation, concentration of some organic acids was determined in fruit juice of `Rondo` and `Jutrzenka` cultivars subject to a training system of grapevines (annex IV, publ. **C19, C20**). The obtained results were presented at the XXII Polish Symposium in Bromatology, Kraków.

In 2014 I worked jointly with the Vet-Agro Trading Company in Lublin which, among others, produces nanotechnology foliar fertilizers (annex IV, publ. **C26**). Then I performed the studies aiming at establishing the effect of Complex PA preparation on wholesomeness, yield quantity and quality of grapevine `Marechal Foch` cultivar. The application of this fertilizar did not affect significantly the number and weight of clusters per vine or the yield converted into area unit. However, the shrubs sprayed with Complex PA were found to have higher extract content as compared to those protected with traditional methods. Both protection systems, i.e. traditional and with nanomaterials have effectively protected clusters and leaves of `Marechal Foch` variety against pathogenic fungal infections. Besides, Complex PA has significantly reduced the occurrence of physiological leaf necrosis and significantly increased leaf weight and leaf surface area of the studied vines which is very important from a practical standpoint.

Over the years 2012-2014, my research activity was related to the influence of grapevine rootstocks (Millardet et de Grasset 101-14; Couderc 161-49; Kober 5BB; S04; SOR1) on `Regent` grapevine yield quantity and quality (annex IV, publ. **A8**). This type of study is innovatory considering the Polish weather conditions and with high practical insights. It is critical taking into account the fact that in the present commercial vineyards, rootstocks are chosen according to the European standards which not always work in practice in Poland. My cooperation with K. Klimek D. Sc in the Department of Mathematics and Informatics Application allowed to develop multivariate statistical methods in the analysis of the research results. Finally, it was found that a grapevine grafted on Kober 125AA rootstock yielded the highest out of those evaluated and, notably, produced a higher

number and weight of clusters and weight of berries. The grapevine budded on 161-49C rootstock gave the lowest yield and had the lowest cluster number per shrub.

At the same time I was working on a project supervised by Prof. A. Borowy designed to establish a content of biologically active compounds and antioxidant potential of flowers and leaves of tailwort (*Borago officinalis* L.) (annex IV, publ. **A6**), influence of white mustard as cover crop on emergence, growth, yield and chemical composition of carrot and beet root as well as weed occurrence in the no-till system (annex IV, publ. **C23**), the effect of mycorrhiza on growth and yield of tomato in field cultivation (annex IV, publ. **C24**), influence of EM preparation on peppermint growth and yield (annex IV, publ. **C31**). I also took part in the studies on the impact of low-frequency magnetic field LFMF on the germination of radish seeds of different quality, with a special concern to old seeds (annex IV, publ. **A2**) as well as the influence of the pre-sowing laser stimulation by several expositions to low radiation doses on germination, emergence and yield of scorzonera (*Scorzonera hispanica* L.) (annex IV, publ. **C25**).

6. AUTORSHIP OR CO-AUTORSHIP OF SCIENTIFIC RESEARCH OR OTHER WORK

My research achievements include:

- 10 original works having Impact Factor;
- 37 original papers published in journals without IF ;
- 42 popular science works;
- 13 poster presentations at international and national conferences;
- 11 papers presented.

Table 1. Compilation of the total scientific achievements, taking into account the scientific achievements that are the basis for applying for the degree of the habilitated doctor

No.	Name of journal	Number of publications	IF (according to the year if issue)	5 – year IF[2017]	Points acc. to MNiSW	Number of points
Scientific publications in magazines in the Journal Citation Reports database (JCR)						
1.	Acta Sci. Pol. Hort. Cultus	2	0,522	0,534	20	40
		4	0,448	0,534	20	80
2.	S. Afr. J. Enol. Vitic.	1	0,636	1,108	25	25
3.	Horticultural Science	1	0,500	0,819	25	25
4.	Food Sci. Technol. Res.	1	0,357	0,593	15	15
5.	Chemija	1	0,472	0,413	15	15
Together		**10**	**4,801**	**6,137**	**-**	**200**
Scientific publications in magazines listed in part B of the MNiSW bulleted point magazines						
6.	Acta Agrobotanica	2			14	28
		3			8	24
		2			7	14
		4			4	16
7.	Acta Agrophysica	6			14	84
8.	Acta Sci. Pol. Hort. Cultus	4			4	16
9.	Annales Horticulturae	2			6	12
10.	Annales UMCS, sec. EEE	1			6	6
		4			4	16
		1			1	1
11.	Bromatol. Chem. Toksykol.	2			5	10
12.	Episteme	1			4	4
13.	Folia Hortic	1			9	9
14.	Zesz. Nauk. Inst. Sadow. Kwiac. Skiern.	1			3	3
		1			2	2
		1			1	1
15.	Zesz. Probl. Postęp. Nauk Rol.	1			4	4
Together		**37**	**-**	**-**	**-**	**250**
Together (including for scientific achievement)		**47 (6)**	**4,801 (1,608)**	**6,137 (2,340)**	**-**	**450 (80)**

7. BIBLIOMETRIC SUMMARY OF SCIENTIFIC RESEARCH

The aggregate Impact Factor of scientific publications by Journal Citation Reports (JCR), according to the year of publication is IF= 4,801

Total MNiSW score of all published works: 450

Number of citations of publications (without autocitations) by Web of Science (WoS): 6

Number of citations of publications (without autocitations) by Scopus: 12

Hirsch publication index by Web of Science (WoS): 2

Hirsch publication index by Scopus: 2

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