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The impact of the Latvian plant physiologist Auseklis Veģis (1903 - 1973) in modern natural sciences

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Abstract

By showing that the dormant condition in plants is induced by external factors, Latvian plant physiologist Auseklis Veģis contributed to the formation of modern theory of plant dormancy. The present paper evaluates the impact of Veģis major publication, *Dormancy in higher plants,* published in the *Annual Review of Plant Physiology* in 1964, on modern natural sciences by means of citation analysis. This paper was cited 365 times within 40 years after its publication. In this respect, the Veģis paper ranks 86th among the most frequently cited papers of the 1082 review papers published in *Annual Review of Plant Physiology* from 1950 until 2001. It is interesting to note that the number of papers citing Veģis paper has been continuously increasing during the last six years. The increase is mostly contributed by publications in the field of seed dormancy and germination, dormancy of trees, and physical properties of disaccharide. The paper *Dormancy in higher plants* stands out among the most important and highly ranked plant physiology papers published so far.

Key words: citations, plant dormancy, plant physiology, seed germination.

Introduction

In 2003, along with several other scientific events, Latvian plant physiologists acknowledged the 100th anniversary of plant physiologist Auseklis Veģis. Born in Latvia in 1903 and starting his academic carrier at the University of Latvia in the 1930s, after 1945 Auseklis Veģis performed his investigations of plant dormancy in Sweden at the Institute of Physiological Botany, University of Uppsala.

His main contribution to plant physiology was a review paper published in 1964 in the *Annual Review of Plant Physiology* entitled *Dormancy in higher plants*. Now we can celebrate the 40th anniversary of the paper. The question addressed in the present paper is to assess the impact of this particular Veģis paper on plant physiology during these years.

Methods

Material for analysis of citations for plant physiology papers in *Annual Review in Plant Physiology* were found on Internet at the following address: http://www.garfield.library.upenn.edu/histcomp/annualreviews/annrevplantphys/. Data for citations of Auseklis Veģis papers were taken from the *Science Citation Index* (SCI) database (*Institute of*

Scientific Information, ISI). For other references, Internet searches were performed using freely available databases at http://www.scirus.com, http://www.altavista.com, http://www.google.com, http://www.hotbot.com, http://www.lycos.com.

Results and discussion

Regarding Auseklis Veģis major scientific achievements, it should be emphasized that the majority of investigators in the 1930s - 1950s believed that the dormant condition of plants originated autonomously during a particular season, and that it was hereditary characteristic. It was conceded, however, that external conditions might accelerate or delay the onset of dormancy, at least to a certain extent, but never prevent it. The crucial evidence against this point was given by Auseklis Veģis in the 1950s - 1960s, based on critical analysis of own experimental data as well as those of other investigators. He showed, that the dormant condition in plants is induced by external factors. In almost all plants that periodically become dormant, dormancy can be induced even in a season during normal active growth. This can be achieved only by changing external conditions, temperature, photoperiod, quality of light, nutritional conditions and water supply being most important. Environmental factors are important also for the termination of dormancy. As a result, a fundamental basis of the modern theory of plant dormancy was formed. The theory has also a great practical importance, as it predicts a possibility to control growth activity of plants by natural means.

By modern standards, the number of Veģis scientific publications is not especially high, and includes only 24. Nevertheless, the classic papers published by Auseklis Veģis still form the basis of modern textbooks in plant dormancy physiology. Most famous among them is a paper *Dormancy in higher plants* from the *Annual Review of Plant Physiology* published in 1964 (Vegis 1964). The ISI SCI database lists six papers published by Auseklis Veģis. Besides the mentioned paper, the remaining five account for 61 citations up to the year 2003. In contrast, the paper published in the *Annual Review of Plant Physiology* was cited 365 times within 40 years after its publication. The frequency of citation is better understood by analysis of citations for other papers from the same publication.

Within the particular volume the Veģis paper had second highest citation rate up to year 2001, with 308 citations. The highest citation rate (369) was for a paper of Cathey H.M. entitled *Physiology of growth retarding chemicals*. In comparison, the most ever cited paper from *Annual Review in Plant Physiology* was a paper by Hsiao T.C. entitled *Plant responses to water stress* published in 1973, which was cited 1300 times. The

Table 1. Relative distribution of papers (% of the total number) published in *Annual Review of Plant Physiology* within successive decades according to the number of citations up to the year 2001

Decades	No. of citations										
	0-49	50-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	>900
1950-1959	59.3	30.7	9.3	0.7	-	-	-	-	-	-	-
1960-1969	43.1	34.3	16.7	2.9	2.5	-	-	0.5	-	-	-
1970-1979	21.8	19.9	29.9	10.4	9.0	4.0	2.0	1.0	1.0	0.5	0.5

question is, how to evaluate the overall citation frequency of the particular Veģis paper? It is evident that, in terms of citation frequency, for a particular paper to qualify as a highly cited paper, certain criteria should be met. Direct comparison of the number of citations is a somehow misleading method because of an increase in the absolute number of citations for whole plant physiology over time, which reflects an increase in number of published papers. This trend is illustrated in Table 1 by comparing the change of relative distribution of papers according to citation numbers in successive decades. The highest rank among the top 10 % of papers in respect to the rate of citation in the period of 1950 - 1959 was achieved by a number of citations above 99, in 1960 - 1969 with a number of citations above 164 and in 1970 - 1979 with a number of citations above 383. Comparison with more recently published papers makes less sense because of a relatively shorter time allowed for citing of the particular paper. It is evident that the Veģis paper is among the top 2.5 % of highly cited papers for that particular decade. However, for the following decade, the paper with a particular frequency of citation (above 300) ranked only with a top 14 %. In spite of that, *Dormancy in higher plants* still holds as the 86th most frequently cited paper among all 1082 review papers published in *Annual Review in Plant Physiology* from 1950 until 2001 placing it among the top 8 %.

Is this high rank of the Veģis paper confirmed also when plant physiology papers from other publications are taken into account? The Veģis paper was mentioned among the 90 plant physiology articles published from 1949 until 1972 which were most cited during the period between 1961 and 1972 (Garfield 1975). With the number of citations as high as 51, the paper ranked number 85. Considering the total number of papers in plant physiology used for evaluation (obviously, several thousands yearly, the number itself was not given there) this value can be used to evaluate the Veģis paper as among the most important plant physiology papers of that period.

Another aspect concerning scientific publications is the longevity of their impact. This can be studied by analyzing a time course of citations of a particular paper. We conducted an analysis for *Dormancy in higher plants* for citations within the period from 1991

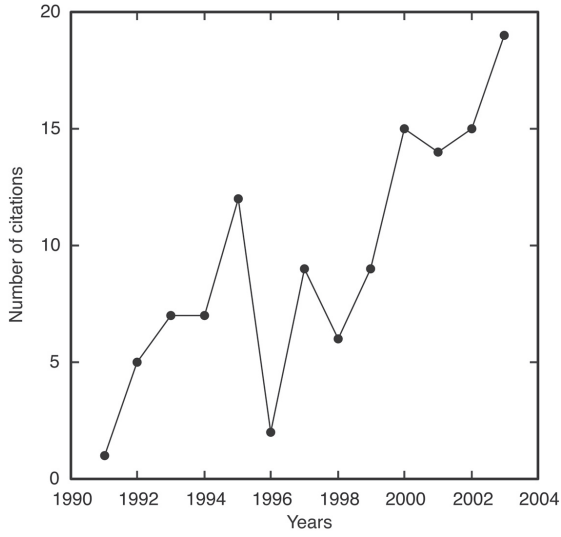

Fig. 1. Time course of number of citations of *Dormancy in higher plants* in scientific papers.

until 2003 inclusive using SCI database. With an average number of citations per year of 9.4, the present period is characterized by a relatively high frequency of citations in comparison with first nine years after the publication of the paper (in average 5.7 citations per year). A higher average yearly frequency of citation for the paper was for the period of 1973 - 1990 (10.7 citations per year). Data in Fig. 1 clearly shows that the number of papers citing Veģis paper has been continuously increasing within the last six years.

The complete list of journals where the papers were published citing Veģis paper in the period from 1991 until 2003 is given in Table 2 (according to ISI SCI). There is an impressive list of 67 journals from different branches of biology and even from material science, physical chemistry and other subdivisions of physics. In addition, when searching the Internet, we found five papers citing the paper of interest not included in the ISI SCI database (in order of publication):

– Friend A.D. 1995. PGEN: an integrated model of leaf photosynthesis, transpiration, and conductance. *Ecological Modelling* 77: 233–255;

– Alba F., Daz de la Guardia C. 1998. The effect of air temperature on the starting dates of *Ulmus*, *Platanus* and *Olea* pollen seasons in the SE Iberian penninsula. *Aerobiologia* 14: 000–000;

– Chytry M., Tichy L. 1998. Phenological mapping in a topographically complex landscape by combining field survey with an irradiation model. *Applied Vegetation Science* 1: 225–232;

– Schütz W. 2000. Ecology of seed dormancy and germination in sedges (*Carex*). *Perspectives in Plant Ecology, Evolution and Systematics* 3: 67–89;

– Jato V., Mendez J., Rodriguez-Rajo J., Seijo C. 2002. The relationship between the flowering phenophase and airborne pollen of *Betula* in galicia (N.W. spain). *Aerobiologia*

Table 2. Citation of *Dormancy in higher plants* in different journals within the period of 1991 - 2003. Data are from *Science Citation Index* database (*Institute of Scientific Information)*

	Journal	Year of citation
1	Acta Agriculturae Scandinavica sect. B	1995
2	Acta Botanica Neerlandica	1995
3	Acta Oecologica	1993; 1999; 1999; 2001
4	American Midland Naturalist	2000; 2003
5	American Naturalist	1993
6	American Potato Journal	1995
7	Annals of Applied Biology	1998
8	Annals of Botany	1994; 2002; 2003
9	Annals of the New York Academy of Sciences	1999
10	Applied Physics A - Materials	2002
11	Aquatic Botany	1997; 2000
12	Australian Journal of Ecology	1992
13	Australian Journal of Experimental Agriculture	2001
14	Biological Reviews of the Cambridge Philosophical Society	1992
15	Botanical Review	1994
16	Bulletin of the Torrey Botanical Club	1995
17	Canadian Journal of Botany	1992; 1994; 1995; 1996; 2000; 2002; 2003
18	Canadian Journal of Plant Science	1997; 2001

(continued)

	Journal	Year of citation
19	Climatic Change	1998; 2001
20	Comptes Rendus de l Academie des Sciences ser. III	1993
21	Ecological Research	1997
22	Euphytica	2002; 2003
23	Field Crops Research	2000
24	Forest Science	1992
25	Genetics	2003
26	Global Biogeochemical Cycles	1997
27	Global Change Biology	2000
28	Grana	2000
29	Heredity	1998
30	HortScience	1997; 2003; 2003; 2003; 2003
31	International Journal of Biometeorology	2001; 2003
32	International Journal of Plant Sciences	1992
33	Journal of Applied Ecology	1994
34	Journal of Chemical Physics	1999; 1999
35	Journal of Ecology	1991; 1995
36	Journal of Experimental Botany	2000
37	Journal of Molecular Structure	1999
38	Journal of Physical Chemistry B	1997; 1998; 1999; 2000; 2001; 2001; 2002; 2003
39	Journal of Physics - Condensed Matter	1999
40	Journal of Range Management	1995
41	Journal of the American Society for Horticultural Science	1998
42	Journal of the Japanese Society for Horticultural Science	1997
43	Journal of the Torrey Botanical Society	2000; 2001
44	Journal of Theoretical Biology	2000
45	Molecular Crystals and Liquid Crystals	2002
46	New Phytologist	2001
47	NMR Physica B	2000
48	Oecologia	1997; 2000
49	Philosophical Magazine B	2002
50	Physica Scripta	2001
51	Physica A	2002
52	Physica B	2001
53	Physiologia Plantarum	1993; 1993; 1993; 1997; 2001
54	Plant Biosystems	2003
55	Plant, Cell and Environment	1993; 1994; 1995; 2002
56	Plant Cell Tissue and Organ Culture	2000; 2003
57	Plant Ecology	2003
58	Plant Growth Regulation	2003
59	Plant Journal	2001
60	Scandinavian Journal of Forest Research	1998; 1999; 2001; 2003
61	Seed Science and Technology	2002
62	Seed Science Research	2000; 2000; 2001; 2002; 2003
63	Tree Physiology	1995; 1995; 2003
64	Vegetatio	1995
65	Weed Research	1995; 1996; 2002; 2003
66	Weed Science	1994; 2002
67	Wetlands	2002; 2003
	Total No. of citations	***122***

18: 55–64.

However, these papers were not included in a further analysis because even then we can not be sure that all the papers citing the particular Veģis paper are listed.

These 122 papers citing Veģis from 1991 - 2003 can be divided in the following general categories: (i) seed dormancy and germination (53 papers); (ii) dormancy of trees (20); (iii) properties of disaccharide in aqueous solution (18); (iv) climate change effects on forest trees (11); (v) dormancy in plant tissue culture (6); (vi) dormancy and flowering of herbaceous perennials, incl. grasses (6); (vii) flowering of trees (3); (viii) general aspects of dormancy and plant seasonality (2); (ix) effect of chilling stress on herbaceous perennials (2); (x) genetics of adaptive traits of trees (1). The time course analysis of publications from the three major categories (Fig. 2) revealed an increase of the overall rate of citations within the last years (Fig. 1) that was due mostly to papers from the present categories, namely, seed dormancy and germination, dormancy of trees, and properties of disaccharide.

Several recent papers (published in 2000 - 2003) representing the main general categories of the publications were analyzed further to reveal the context of citation of Veģis paper.

The majority of papers (52, about 43 % of the whole list) was devoted to different aspects of seed dormancy and germination. Seed germination ecology was one of the most widely used contexts among them. Objects investigated included weeds, endangered plant species, critical wetland plants, and samples stored in seed banks. The paper by Alvarado

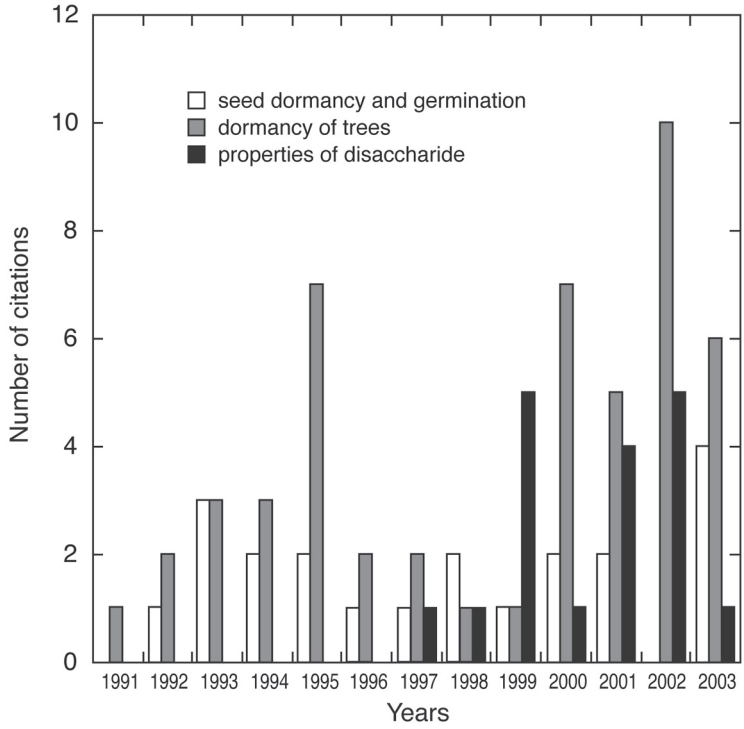

Fig. 2. Distribution of papers citing *Dormancy in higher plants* among major thematic groups.

and Bradford (2002) used Veģis results on a temperature range sensitive to the dormancy status of seeds to develop a hydrothermal time model that can describe seed germination timing and percentages at various temperatures. Further, the paper gave experimental evidence for that model. Data on shifts in the normal distribution in a threshold water potential that just prevents germination of the seed populations in response to dormancy-regulating factors were used by the authors to explain the common observation mentioned by Veģis that the temperature limits for germination widen as dormancy is released and narrow as dormancy is imposed.

The second largest group of papers citing *Dormancy in higher plants* was that of papers studying different aspects of tree dormancy. The paper from this group by Rinne et al. (2001) studied the mechanism by which cessation of morphogenic activity in shoot apex of overwintering perennials is regulated at the end of the growing season when the apex transforms into a bud which is dormant and freezing-tolerant. Veģis paper was cited in respect to an initial stage of the process, which depends on measuring the length of the photoperiod by means of the phytochrome system.

It was somewhat odd to find a relatively large group (18) of papers citing the Veģis paper in respect to properties of disaccharides in aqueous solution. On closer examination of one of them (Prabhu et al. 2002), it appeared that the particular group of papers focused on the physico-chemical mechanisms of disaccharide-associated protective effect against dehydration and freezing. The general hypothesis tested there was that disaccharides, in particular, trehalose, obstruct the crystallization process by reducing the amount of freezable water, namely destroying the network of water compatible with that of ice. This hypothesis was examined experimentally by means of ultrasonic techniques, Raman scattering, NMR etc. Veģis work was cited in these papers as providing an evidence for a biological phenomenon of trehalose biosynthesis in plants under stress conditions.

A substantial group of papers (11) dealt with various aspects of climate change on forest ecosystems. One of them (Price et al. 2001) analyzed recruitment algorithms in forest gap models with particular regard to their suitability for simulating forest ecosystem responses to a changing climate. In these models of forest regeneration, special importance is attributed to seed production and germination success, which are especially climate-sensitive processes. Veģis work was cited there as one of the papers giving evidence for a need of vernalization for successful germination.

Dormancy is a focus of extensive studies also in plant tissue culture. The dormancy-like condition called 'slow growth' is a method for long lasting plant preservation in tissue culture (Pruski et al. 2000). On the other hand, during propagation of bulbous plants by means of tissue culture, high temperature-induced dormancy is an undesirable phenomenon (Langens-Gerrits et al. 2003). The two above papers on the subject cite Veģis paper on dormancy. Tissue culture can be used as a means for investigation of the physiological basis of dormancy, as described by the paper of Kalengamaliro et al. (2003). In alfalfa (*Medicago sativa* L.) two contrasting types of cultivars exist in respect to dormancy. The dormancy in alfalfa is not a true physiological dormancy according to Veģis because alfalfa plants can be forced out of dormancy by favorable conditions. Kalengamaliro and co-workers prepared cell cultures from alfalfa cultivars that genetically differed in dormancy to study physiological basis of the phenomenon. High growth rates of cells derived from rapid growing, non-dormant alfalfa cultivars were associated with rapid sugar uptake and higher cell respiration rates when compared to cells derived from

dormant alfalfa cultivars.

Theoretical considerations of Veģis about differences in true dormancy and relative dormancy have been widely used also in studies of dormancy in other perennial herbaceous plants, including summer dormancy in grasses. The experiments described by Ofir and Kigel (2003) examined naturally occurring variation in the onset of summer dormancy in populations of the geophytic perennial grass *Poa bulbosum* collected along an aridity gradient. In controlled conditions, plant age at the onset of dormancy positively correlated with mean annual precipitation at the site of origin of the population.

Several papers used ideas about dormancy in a broader sense to analyze seasonal phenomena in plant life. In a paper entitled *Aspects of seasonality*, Battey (2000) looked at flowering seasonality in perennials compared with annuals from both molecular and whole plant physiology perspectives. At first it was mentioned that Veģis ideas concerning the proposed mechanisms of bud dormancy, namely, that metabolic limitations (oxygen reduction) were among the internal control factors during dormancy, were exceeded by these in favor of hormonal control. However, the author emphasized that the theoretical considerations of Veģis about dormancy placing a restriction on the temperature range over which buds will grow formed 'a foundation for an analysis of the way in which the environment allows bud growth in the spring'.

We can conclude that the *Dormancy in higher plants* stands out among the most important and highly ranked plant physiology papers published so far. Bearing in mind the extreme longevity of the impact of the paper, one can ask what was so special in the paper of Veģis to hold the attention of so many scientists for so long period of time? One possible explanation is that Veģis was the first to suggest common mechanisms for seed and bud dormancy. From the present point of view, given the fact that these parts of plants utilize the same environmental signals, mainly light and temperature, as a cues for adaptation in a form of dormancy, this seems to be a trivial consideration. However, within 40 years after publication of *Dormancy in higher plant*s no unifying general theory about the phenomenon has emerged. At least until that time, we will be waiting for further tribute to Veģis ideas in the form of citing his work.

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Latviešu augu fiziologa Ausekļa Veģa (1903 - 1973) ietekme uz modernajām dabaszinātnēm

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Kopsavilkums

Pierādot, ka miera stāvokli augos inducē ārējie faktori, latviešu augu fiziologs Auseklis Veģis piedalījās modernās augu miera perioda teorijas izveidē. Dotais raksts novērtē Veģa svarīgākās publikācijas (*Dormancy in higher plants*, *Annual Review of Plant Physiology*, 1964) ietekmi uz mūsdienu dabaszinātnēm, analizējot tās citējumus. Veģa raksts citēts 365 reizes 40 gadu laikā pēc tā publicēšanas un tāpēc tas ieņem 86 vietu visvairāk citēto rakstu vidū no 1082 apskata rakstiem, kas publicēti izdevumā *Annual Review of Plant Physiology* laikā no 1950. līdz 2001. gadam. Ir interesanti atzīmēt, ka to rakstu daudzums, kuros citēts Veģa raksts, ir pieaudzis pēdējo sešu gadu laikā. Šis pieaugums pārsvarā saistīts ar publikācijām tādās nozarēs kā sēklu miera periods, miera periods kokaugiem, kā arī disaharīdu fizikālās īpašības. Secināts, ka *Dormancy in higher plants* ir viena no pasaulē nozīmīgākajām publikācijām augu fizoloģijā.