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Photoperiod Response of Landraces and Improved Varieties of Buckwheat from Russia and from the Main Buckwheat Cultivating Countries

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ABSTRACT

Numerous recent investigations have shown that common buckwheat is photosensitive under short-day conditions. A study of buckwheat accessions from global plant genetics resources collection of VIR (N.I. Vavilov Research Institute of Plant Industry) has demonstrated that the strongest photoperiodic response is observed when buckwheat genotypes adapted to cultivation in low latitudes (tropics, subtropics) are cultivated at higher latitudes. This response is expressed in late maturity in plants by their absolute incapacity to produce seeds under long-day conditions. Buckwheat landraces and varieties from Eastern Europe, particularly many Russian ones, are less photosensitive than the Asian varieties. At latitudes 50-60° N, photosensitive genotypes have disappeared and a secondary centre of genetic diversity of buckwheat has developed.

Keywords: centres of genetic diversity, *Fagopyrum esculentum* Moench, genotype × environment interaction, photoperiodism
Abbreviations: $\mathbf{I_{PhS}}$, Index of Photoperiodic Sensitivity; **LD**, long day; **SD**, short day; **T**, duration of the seedling emergence - flowering period (days); **VIR**, N.I. Vavilov Research Institute of Plant Industry; **VIR-1252**, catalog number

INTRODUCTION

Photoperiodism is still a research issue for scientists from different countries (Gonzales *et al*. 2005; Thomas *et al.* 2006; Beales *et al.* 2007; Yang *et al.* 2009).

Investigations of plants' adaptation to light, particularly of the adaptive significance of photoperiodism, were launched at VIR by famous Russian physiologists V. Razumov and B. Moshkov over 80 years ago. It is well-known that the term 'photoperiodism' was proposed in 1920 by American scientists Garner and Allard who had discovered this reaction in plants. Its essence is in different responses of different plants to the length of day light. The photoperiodic response of flowering is one of the main manifestations of photoperiodism when plants transit from vegetative growth to flowering under the influence of specific day length. In general plants are differentiated into 3 basic and 4 less widespread groups on the basis of their photoperiodic response, namely day-neutral, short-day (SD), long-day (LD), and intermediate-day, ultra-short-day, short-long-day, and long-short-day groups (Garner and Allard 1920; Aksenova *et al.* 1973). A plant belongs to one of these groups depending on its geographic origin and distribution: SD plants grow in tropical and subtropical zones, while LD plants live mainly in temperate zone and northern latitudes (Lubimenko 1924; Razumov 1929, 1961). The day length response is a stable character which can be easily predicted from the geographic location. However, according to Skripchinskiy (1971) any taxon can contain biotypes that would differ in the degree and sign of their photoperiodic responses.

Buckwheat originates from South China and is currently cultivated worldwide: in Asia, Europe, South America, North America, countries of the former USSR and even in Australia. In the main Russian academic publications, common buckwheat is described, after Azzi (1932), as a day-neutral plant (Moshkov 1961; Zhuchenko 1988). However, practical buckwheat researchers consider *Fagopyrum esculentum* Moench as an obligate SD plant (Stoletova 1958; Krotov 1975).

Fig. 1 The photosensitive accession of common buckwheat grown under SD (left) and LD (right).

As was shown by Fesenko *et al.* (1998), common buckwheat is a SD crop, but it has forms with different degrees of sensitivity to photoperiod variation. Russian cultivars were ultra-early maturing in Hokkaido (Japan). At the same

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time, Japanese cultivars (summer type) behaved as very late maturing ones in Russia and failed to set practically any seed in the Orel region (Russia). Numerous publications (Matano and Ujihara 1981; Baniya *et al.* 1992; Chai *et al.* 1992; Rajbhandari and Hatley 1998; Michiyama *et al.* 2004, 2007) contain many facts about different degrees of sensitivity of buckwheat accessions from Nepal, Korea, China and Japan. In Denmark, two Canadian cultivars 'Manor' and 'Mancan' were very late and low-yielding, while the Polish cultivar 'Emka' had the highest yield and 'Siva' (from the former Yugoslavia) had the lowest one (Flengmark 1996).

In Russia, buckwheat is cultivated at more northern latitudes in regions differing in their water and temperature conditions, therefore plant material with low or no photoperiodic sensitivity is necessary for successful buckwheat breeding. The present study was aimed, on the one hand, to quantify photoperiodic sensitivity in buckwheat accessions, to find promising material with the lowest photoperiod response, and to demonstrate the geographical variation in the photoperiodic response of buckwheat, on the other hand.

MATERIALS AND METHODS

Accessions of common buckwheat

Accessions of common buckwheat from global plant genetics resources collection of N.I. Vavilov Research Institute of Plant Industry (VIR) were analysed. The examined set included accessions of different geographical origin: from Russia, Ukraine, Belarus, Estonia, Latvia, Lithuania, Italy, Sweden, Germany, Canada, China, India, Japan and Korea. More than 180 landraces included in the VIR collection between 1929-1961 and 20 improved varieties were used.

Experimental design

The experiments were conducted in pavilions at the Pushkin Branch of VIR (Leningrad Region) in 1999-2008. Plants were grown in plastic pots containing 5 kg soil under natural day length (from 18 to 18 h and 52 min - LD) and under 12-hour day length (SD). SD conditions were provided after the emergence of seedlings by rolling carts with pots from the open air into the light-proof pavilion, where they were placed from 9 p.m. to 9 a.m. For ensuring an equal temperature regime, plants grown under LD were put into a glass pavilion for 12 h (Koshkin and Matvienko 1996).

Two dry seeds were sown in each of 10 pits along the perimeter of the pot on 15 May. After germination, weak shoots were removed and only 10 strong shoots were grown in the pot for each accession.

When the first flower opened, each plant was supplied with a parchment label showing the date of flowering for calculating the duration of the 'seedling emergence to flowering' period. The photoperiodic response in buckwheat accessions was determined from the degree of flowering delay under LD in comparison with SD ($T_1 – T_2$), and the Photoperiodic Sensitivity Index (I_{PhS}) value was calculated by the formula $I_{PhS} = T_1/T_2$, where: T_1 and T_2 is the duration of the 'seedling emergence to flowering' period (days) under the LD and SD conditions, respectively (Koshkin 1998). The buckwheat accessions which had a 1-2 day delay in flowering under LD (in comparison with SD) and with an I_{PhS} value of 1.00-1.05 were classified as less photoperiodic-sensitive. The use of the index makes it possible to compare figures obtained during different years of study.

Statistics

The statistical analysis of experimental data was made according to Sachs (1976).

RESULTS AND DISCUSSION

The responses to LD and SD in accessions from European and Asian continents and Canada (42-65°N) were investigated. The method employed had been developed at VIR and successfully tested on wheat accessions, resulting in the creation of some isogenic lines (Merezhko *et al.* 2001). The method is based on the phenomenon of photoperiodic induction (Egiz 1928).

All accessions behaved as SD plants, as they shortened the duration of the 'seedling emergence to flowering' period under SD in comparison with LD. The delay in the beginning of flowering under LD varied from 0.6 to 14 days and was quite wide among the accessions, thus the standard error was in the range of 0.19-1.48. The difference between the average values of the characters was reliable, therefore it was possible to calculate the Photoperiodic Sensitivity Index (I_{PhS}).

In the experiments conducted by Michiyama *et al.* (2004), the summer eco-type variety 'Shinanonatsusoba' (photoperiodically neutral) delayed flowering for about 8 days when days were lengthened from 13 to 16 h, and flowering in the autumn eco-type variety 'Miyazakizairai' (photoperiodically sensitive) had a 30-days delay. As was mentioned above, summer type cultivars are not able to yield in the Orel region – one of the most suitable areas for growing buckwheat in Russia. That is why the autumn type accessions from Japan were not tested at all. **Fig. 1** shows a fully-flowering photosensitive accession subjected to a 12-h daylength, and another one grown under an 18-h day length, which has just entered the flowering stage and stopped its development. Under conditions of the Leningrad Region, such accessions could set from one to ten plump seeds, depending on the accession.

Numerical values of I_{PhS} varied in the tested accessions from 1.03 to 1.70. Two accessions that had I_{PhS} of 1.70 originated from Japan and India. The tested landraces were divided into four groups according to their origin: East Asia (8 accessions, I_{PhS}=1.55), Canada (4 accessions, I_{PhS}=1.60), Europe (7 accessions, I_{PhS}=1.21) and republics of the former USSR (161 accessions, I_{PhS}=1.16). The groups with the highest degree of photoperiodic sensitivity included accessions from Canadian and East Asia (**Fig. 2**). It should be kept in mind that the latter group did not include the extremely sensitive landraces and that is why the I_{PhS} value in the group was not as high as it could be. We suppose that similar photoperiodic response of buckwheat accessions from Canada and East Asia is explained by their close relationship. This premise is supported by the fact that almost all Canadian accessions included in the VIR collection between 1929 and 1970 are called either 'Japanese' or 'Tokyo'. The buckwheat accessions from the former USSR and Europe were less photoperiodically sensitive.

For comparing I_{PhS} values of 169 accessions from regions (republics) of the former USSR, the studied landraces were further subdivided into groups according to their origin: Ukraine (42 accessions), Belarus (12), Baltic Republics (8), Russia (93) and Primorsky Region of Russia (6). It was demonstrated that the landraces from Russia, Belarus and Baltic Republics (I_{PhS}=1.14) had the lowest photoperiodic sensitivity (**Fig. 3**). Buckwheat landraces from Ukraine with an I_{PhS} of 1.18 were closer to the European accessions (I_{PhS}=1.21). The most photoperiodic sensitive buckwheat landraces (I_{PhS}=1.38) from Russia were found in the Primorsky Region. The I_{PhS} values appeared to be almost equal within the entire republic and its regions: for example, it is valid for 42 landraces from 16 regions of Ukraine (**Fig. 4**). Some exceptions should be also mentioned. The identified sources of low photoperiodic sensitivity of buckwheat (**Table 1**) originate not only from such high latitude locations as Lithuania, Moscow and Leningrad regions, but also from Ivano-Frankivsk, Vinnytsya, and Kharkiv regions of Ukraine. 'Skorospelaya 86' (bred in the Orel Region of Russia) appeared to be the earliest variety among the sources of low photoperiodic sensitivity. It began to flower on the 22nd day after sprouting. A medium-ripening local accession from Kharkiv Region of Ukraine (VIR-1252) began to flower 11 days later. There are no late-maturing accessions in the low photoperiodic sensitivity group. However,

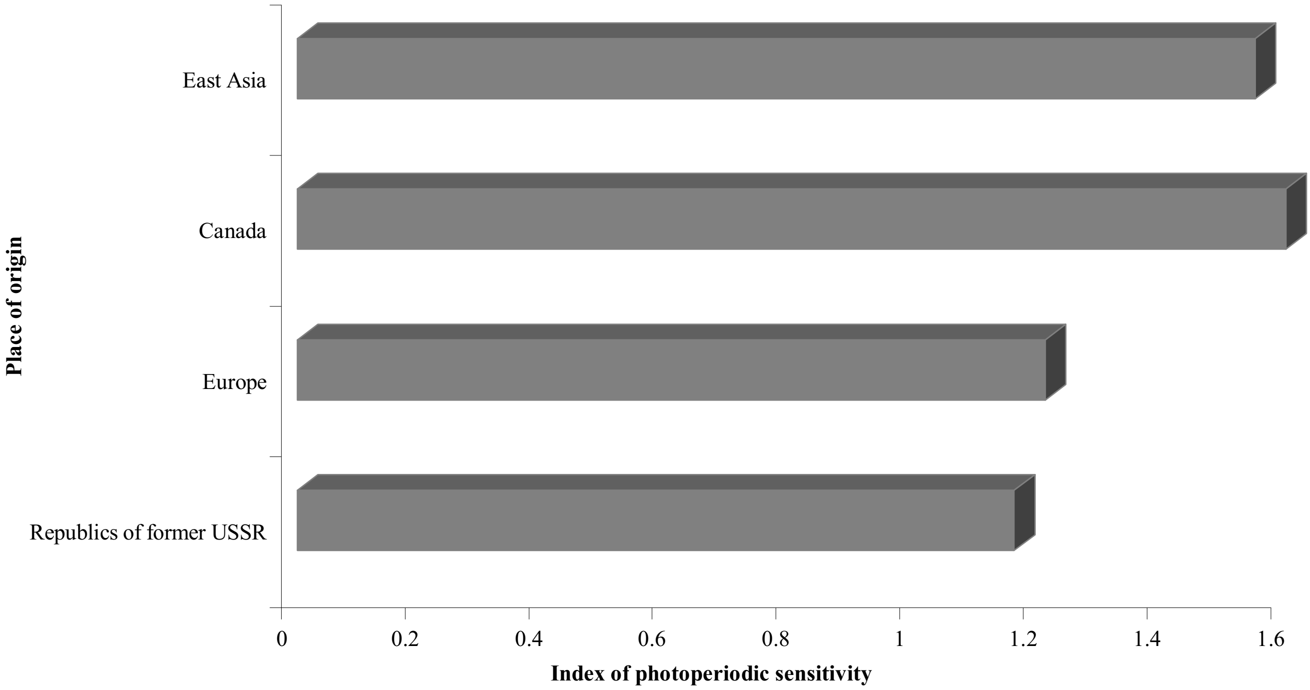

Fig. 2 Photoperiodic Sensitivity Index (I_{PhS}) of common buckwheat accessions from East Asia, Canada, Western Europe and republics of the former USSR.

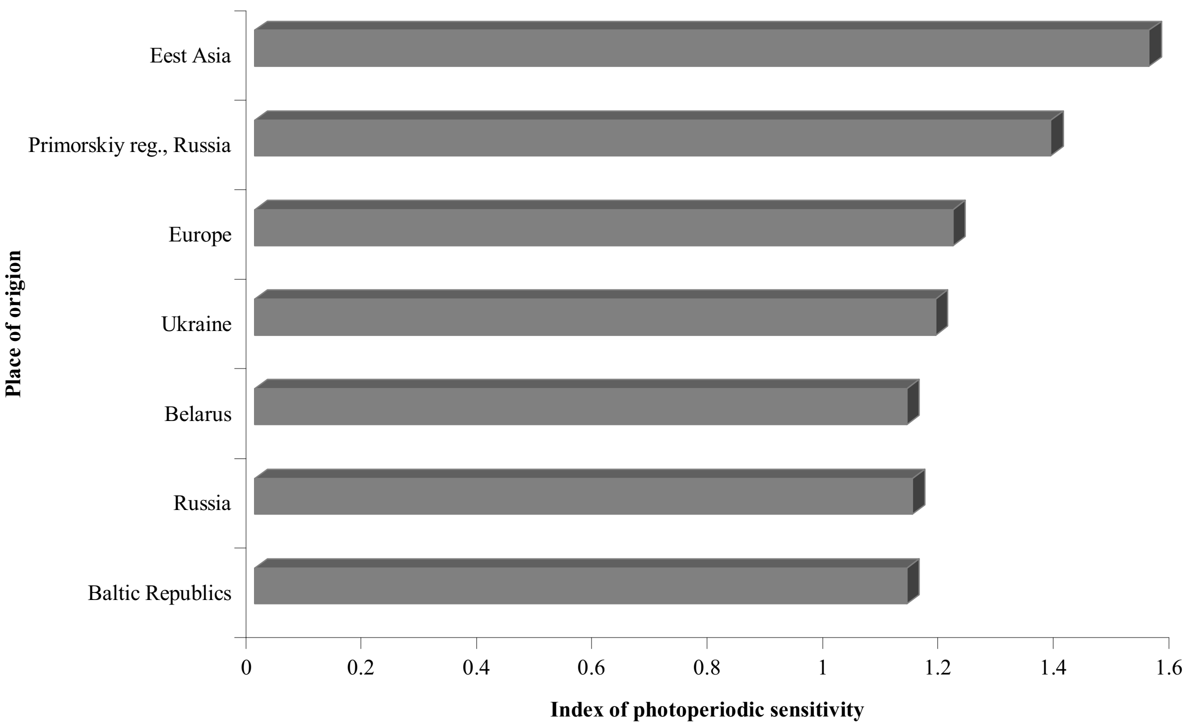

Fig. 3 Photoperiodic Sensitivity Index (I_{PhS}) of common buckwheat accessions from Western Europe and Republics of the former USSR.

we can not confirm that photoperiodic sensitivity and duration of the vegetative period are closely connected.

Our observation that the improved buckwheat varieties from Russia seemed to be less sensitive to day length than landraces has to be checked. To sum up, it can be stated that the accessions with the highest degree of sensitivity to LD conditions originate from East Asia and Canada, those with a high degree of sensitivity from the Primorsky Region of Russia, the medium-sensitive ones originate from Western Europe and Ukraine, and the least sensitive accessions are from Russia, Belarus and Baltic Republics.

The eastern part of the European continent is the secondary area of common buckwheat cultivation that evolved by Slavonic tribes during their expansion from the territory of modern Ukraine northeastwards (Klyuchevsky 1992). Expansion was accompanied by substantial changes in soil and climatic conditions and stimulated natural selection of local populations. According to the duration of the vegetation period furthermore water, temperature and light requirements of plants, all the buckwheat diversities from the territory of the former USSR (Russia, Ukraine, Belarus, Baltic Republics) has been subdivided by Krotov (1975) into 4 production zone groups: Northern early ripening, Southern mid-ripening, Baikal Lake mid-ripening, and Primorsky late ripening. Representatives of each of these groups possess characteristic traits of their own, which clearly differentiate them from each other and especially from buckwheat forms from East Asia. Having carried out field observations of a

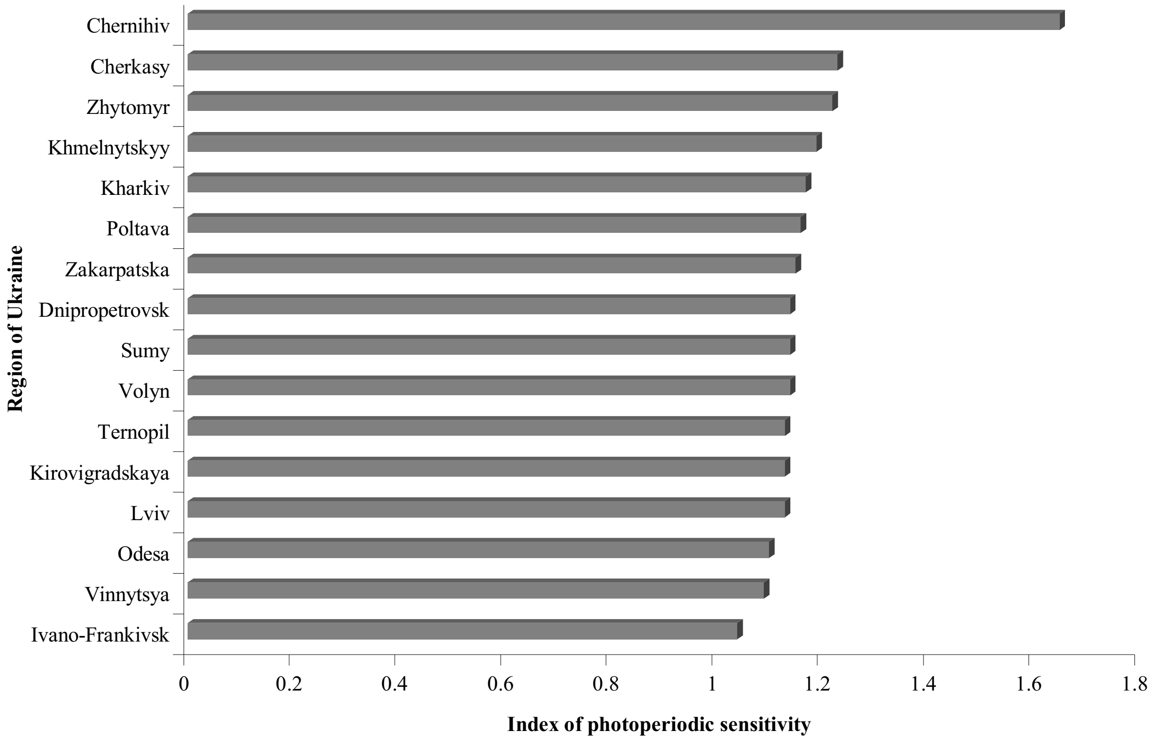

Fig. 4 Photoperiodic Sensitivity Index (I_{PhS}) of common buckwheat accessions from different regions of Ukraine.

Table 1 Common buckwheat accessions with the lowest photoperiodic sensitivity.

VIR cat.[a]	Cultivar name	Cultivar origin	T_1[b] (days) (±SEM)	T^{2c} (days) (±SEM)	T_1-T_2 (days)	I_{PhS}[d]
1690	Local	Orel Region, Russia	29.4 ± 0.51	28.6 ± 0.69	0.8	1.03
1947	Local	Moscow Region, Russia	28.9 ± 0.50	27.4 ± 0.50	1.5	1.05
3482	Local	Leningrad Region, Russia	30.0 ± 1.00	28.8 ± 0.62	1.2	1.04
2430	Local	Vladimir Region, Russia	32.7 ± 0.53	31.1 ± 0.57	1.6	1.05
3436	Local	Brest Region, Byelorussia	30.5 ± 0.99	29.1 ± 0.71	1.4	1.05
4273	Local	Ivano-Frankivsk Region, Ukraine	31.7 ± 0.33	30.6 ± 0.50	1.1	1.04
3943	Local	Lithuania	28.7 ± 0.41	27.5 ± 0.57	1.2	1.04
2720	Local	Vinnytsya Region, Ukraine	30.6 ± 0.62	29.6 ± 0.50	1.0	1.03
1252	Local	Kharkiv Region, Ukraine	33.1 ± 0.50	31.7 ± 0.50	1.4	1.04
1243	Local	Kharkiv Region, Ukraine	32.4 ± 0.30	31.0 ± 0.33	1.4	1.05
4500	Skorospelaya 86	Orel Region, Russia	22.0 ± 0.00	20.9 ± 0.23	1.1	1.05
4511	Molva	Orel Region, Russia	27.9 ± 1.01	26.7 ± 0.47	1.2	1.04
4542	Natasha	Novosibirsk Region, Russia	31.5 ± 0.56	30.7 ± 0.37	0.8	1.03

[a]catalog number
[b] duration of the 'seedling emergence to flowering' period (days) under the long day conditions
[c] duration of the 'seedling emergence to flowering' period (days) under the short day conditions
[d] Index of Photoperiodic Sensitivity

wide range of accessions with different geographical origin in the Orel Region, Fesenko *et al*. (2006) concluded that a peculiar secondary centre of genetic diversity of buckwheat has formed at latitudes 50-60° N after the disappearance of photosensitive genotypes. The results obtained during the present research illustrated and confirmed the above statement.

CONCLUSION

The study demonstrated that the strongest photoperiodic response could be observed when the buckwheat genotypes adapted to cultivation at low latitudes are moved to higher latitudes. This response is expressed in an increased late-maturity up to absolute incapability to produce seeds under LD conditions. A lower photoperiodic response is typical of the East European buckwheat landraces, particularly of many Russian ones. The secondary centre of genetic diversity of buckwheat which exists at 50-60° N differs from the primary center (Southern China) by a wide range of forms with a reduced photoperiodic response.

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