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Variability of *Caltha palustris* L. populations in garden culture

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Abstract

On the basis of studies performed in the experimental garden the character of the variability of *Caltha palustris* L. populations is described. Individuals were bred under uniform conditions from diaspores of meadow, springwood, flood-plain forest and alder forest populations. The results obtained allow to evaluate the hypothesis concerning the ecological preference of cytotypes (Smit 1967, 1968) and the somewhat different ecological requirements of two subspecies: *C. palustris ssp. palustris* and *C. palustris ssp. cornuta.* It was found that each population includes individuals with different cytotypes. The situation is similar as far as subspecies are concerned, distinguished on the basis of fruit morphology (Fig. 1). It should be stressed, however, that, investigations of many years duration raised serious doubts as to the diagnostic value of fruit morphology (Figs. 2, 3). On the basis of the preserved differences between the populations in shoot habitus, reproduction and phenology in garden culture, a springwood and an alder forest ecotype were distinguished. Meadow and flood-plain populations exhibited a transitional character with certain similarities both to the alder forest and to the springwood populations.

INTRODUCTION

Caltha palustris L., a species with a high genetic and ecological variability, raises many serious taxonomic problems (Penigrahi 1955). Each diagnostic trait indicating the diversity of relationships of the distinguished taxons proves, after studies in more detail, not sufficiently precise for revealing the true differences or similarities of the given taxons. Consequently, the classification of *C. palustris* is based on the morphological variability of the generative organs, that is the shape of mature follicles (Rothmaler 1963). In the Białowieża Forest two subspecies were distinguished: *Caltha palustris ssp. palustris* and *C. palustris ssp. cornuta* (Fig. 1).

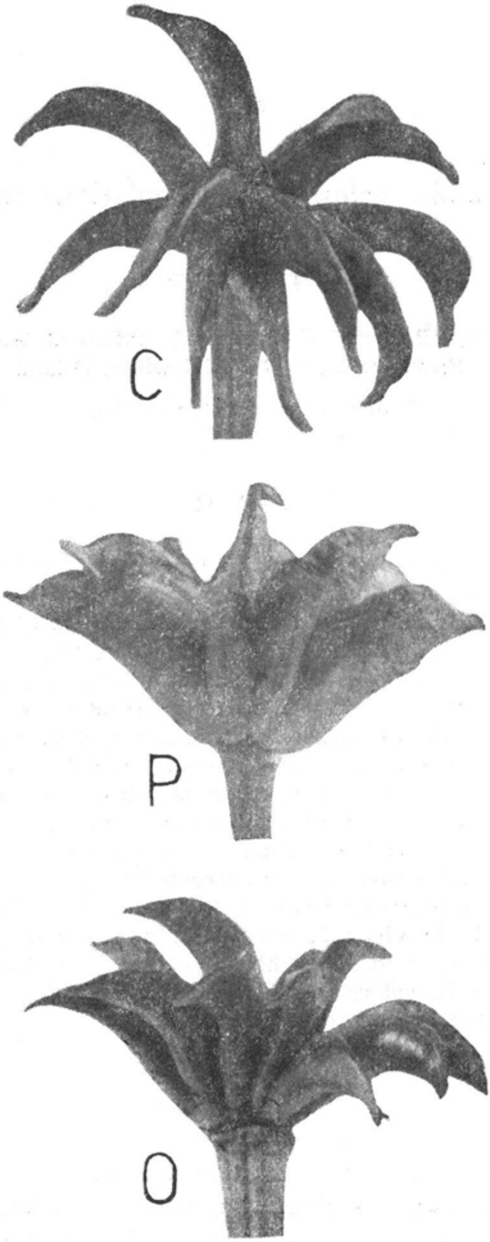

Fig. 1. Fruit types in *Caltha palustris* L. (*s.l.*), populations C — *ssp. cornuta*, P — *ssp. palustris*, O — indefinite (photo by L. Wilczek)

C. palustris ssp. palustris has erect follicles tapering into a beak 1.5 mm long, whereas *C. palustris ssp. cornuta* has follicles opening almost horizontally with an s-like bent beak (Rothmaler 1963, Hegi 1975). It should be noted that fruits of such perfect shape as those in the photograph (Fig. 1) are seldom seen under natural conditions (Fig. 2). They were selected from several thousand fruits of individuals growing in the garden.

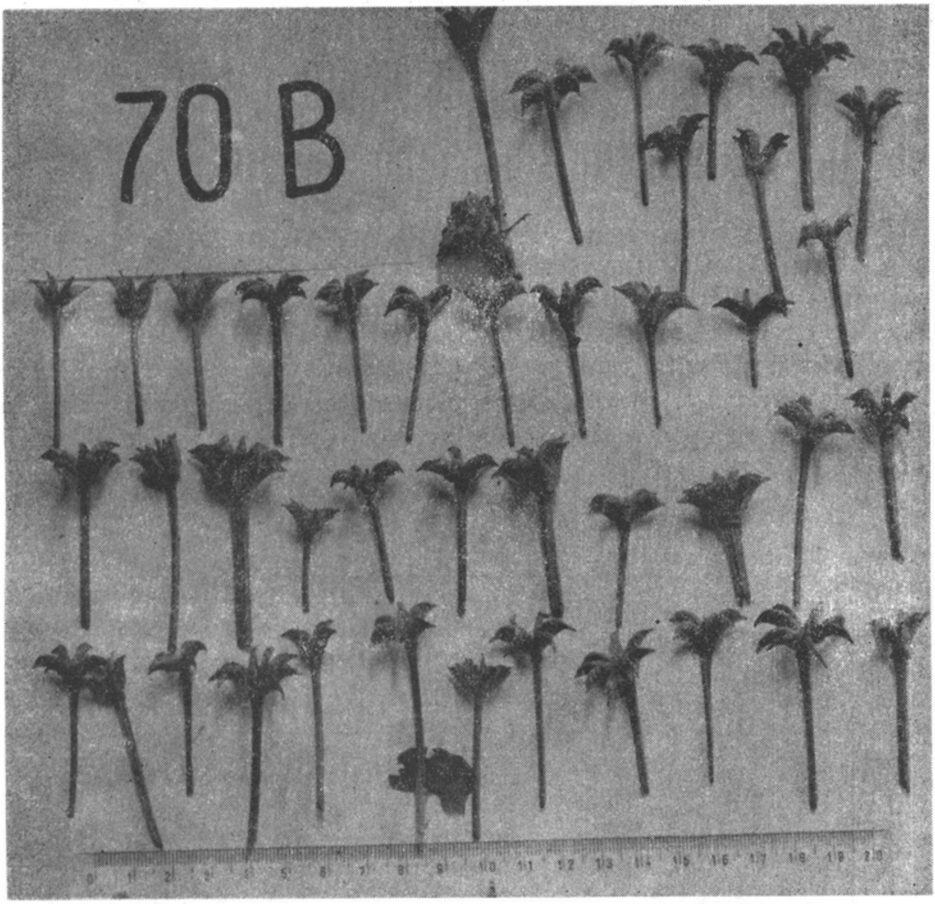

Fig. 2. Morphological differences between fruits of flood-plain forest population
Photo by L. Wilczek

It resulted from earlier investigations (Falińska 1978, 1979) that the differences in the populations are of the character of continuous variability, and most traits exhibit a sustained rise of their values in the order: meadow — springwood — flood-plain forest — alder forest. The degree of modification of the traits indicated a strong relation with the degree of differentiation of the life conditions, particularly ground water level and soil fertility. Individuals in the alder forest developing up to the fruiting phase at a high stagnant water level had erect shoots with numerous flowers and later infructescences. The plants growing in springwood with unceasing flow in and run off of water exhibited a trailing habitus with intensively rooting shoots.

The individuality of each population was manifested above all in the habitus and size of the plants and the course of reproduction. It was supposed that the variability of some features may be not only of the character of an environmental modification, but of an adaptation to the different conditions of life. In order to establish the character of the variability observed, further studies were conducted in the experimental garden and in a vegetation house.

METHODS

Experimental plots were chosen in the experimental garden in 1975 in a natural depression filled with fertile soil from an alder forest. The plots 1×2.6 m were surrounded by channels filled with water (Fig. 3). On each plot 26 vegetative diaspores were sown, separately from individuals with fruit type *P* (*C. palustris ssp. palustris*) and type *C* (*C. palustris ssp. cornuta*). The plan of the experimental plots and the distribution of the individuals on them are shown diagramatically (Fig. 4).

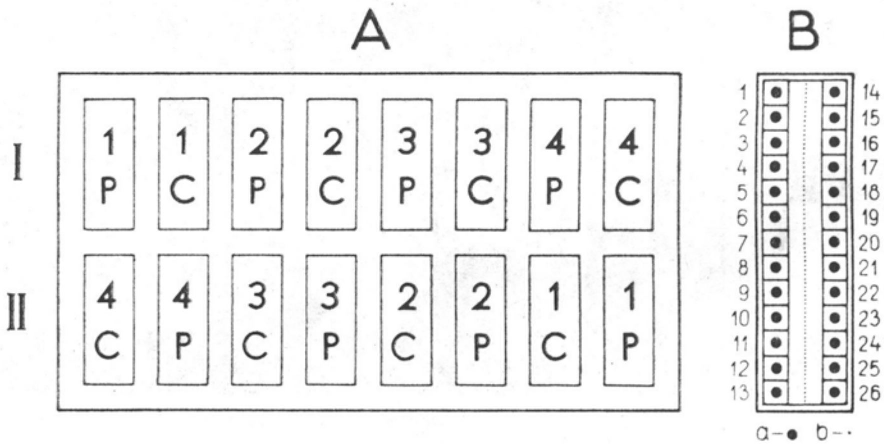

Fig. 4. Scheme of experiment in garden culture (A) and distribution of individuals on plots (B)
I-II — replications, a — vegetative diaspores, b — seeds, P — *C. palustris ssp. palustris*, C — *C. palustris ssp. cornuta*, 1 — meadow population, 2 — springwood population, 3 — flood-plain forest population, 4 — alder forest population

In order to avoid in garden culture the observation of individuals from one clone, plants were randomly chosen on 4 different areas in each community: meadow, springwood, flood-plain forest and alder forest. Vegetative diaspores were collected before their rooting. Moreover, on the same areas seeds were collected from the plants in order to check their germination capacity. An experiment was performed for each natural population according to the scheme:

Fig. 3. Part of experimental garden plot in the period of maximal bloom of *Caltha palustris* L.
Photo by J. B. Faliński

— 6×100 in Petri dishes,
— 10×100 in pots with soil in the vegetation house,
— 1000 seeds in the garden, 500 on one plot (Fig. 4).

The germination capacity of seeds was tested once in the garden. When the plants reached the fruiting phase on the plots, the experiment could not be continued because seeds of plants developing in the garden started intruding on the same plots. All newly appearing individuals were removed.

The development of the tagged plants was observed for 3 years, note was taken of: seedlings with cotyledones, seedlings with 1-2 leaves, seedlings with 3-5 leaves. In the case of plants developing from vegetative diaspores the following records were made: the first leaves, generative shoots, flower buds and flowers, infructescences, vegetative diaspores on the shoots and rooting vegetative diaspores.

Collection of material. In the third year the plants developing from vegetative diaspores were collected in the order of fruit maturation: 1) from the springwood population, 2) the meadow and flood-plain forest populations, 3) the alder forest population. The material is listed in Table 1.

Table 1

Traits and amount of material

Populations		Number of				
		individuals	shoots	leaves	infructescences	seeds
1	*P*	61	402	610	342	23070
	C	30	236	300	152	17175
2	*P*	28	127	280	124	7597
	C	70	275	700	327	13845
3	*P*	62	410	620	635	46484
	C	32	275	320	518	37230
4	*P*	47	390	470	894	66500
	C	61	698	610	1091	179937

1—meadow population, 2—springwood population, 3—flood-plain forest population, 4—alder forest population, *P*—*Caltha palustris ssp. palustris*, *C*—*Caltha palustris ssp. cornuta.*

Traits to be analysed. Measurements were taken of: shoot length and petiole length of basal leaves. Shoots, leaves, infructescences and follicles in the infructescence were counted. Infructescences and seeds previously dried at 85°C were weighed.

Determination of cytotypes. The growth apexes of roots were incubated in colchicin, fixed in Carnoy's solution and stained with orcein.

The results were statistically elaborated and compared graphically as the "shape curve" of Jentys-Szaferowa (1959). For all traits confidence intervals of mean values were established at the confidence level 0.95 (Perkal 1963) and analysis of variance was performed. The significance of differences between the populations was checked by Duncan's test (Oktaba 1966).

The variability of *Caltha palustris* L. populations was elaborated on the basis of individuals developing from vegetative diaspores in garden culture. The germination capacity of seeds from natural populations and the survival of seedlings were evaluated in the laboratory and in the garden.

RESULTS

The plants developing in garden culture from vegetative diaspores of meadow, springwood and forest populations were found to partly preserve their primary differences in morphology and intensity of reproduction.

SIZE AND SHAPE OF PLANTS

Length and habitus of shoots. Differences are statistically significant between the traits of the flood-plain population and those of the remaining ones (Fig. 5). Most individuals of the meadow, springwood and alder forest populations fell to the size class 35-50 cm, those of the flood-plain population to the class 30-40 cm. The individual variability of the latter population is markedly lower than in the remaining ones (Fig. 6). It is noteworthy that individuals with fruit types *P* and *C* differed in shoot length, but the difference was only significant as regards the springwood population (Fig. 5). Moreover, in this population more than 90 per cent individuals exhibited trailing shoots taking root at 2 or 3 points. In the alder forest population 90 per cent of the shoots are erect and only few trailing. Meadow and flood-plain forest populations hold an intermediate position as regards "shoot habit". Some individuals have erect shoots (30-40%) and others trailing ones (60-70%). It appears, therefore, that, as regards the length and habitus of the shoot, the populations form two groupings: the first — the flood-plain forest, meadow, springwood and alder forest populations and the second — springwood, flood-plain forest, meadow and alder forest populations.

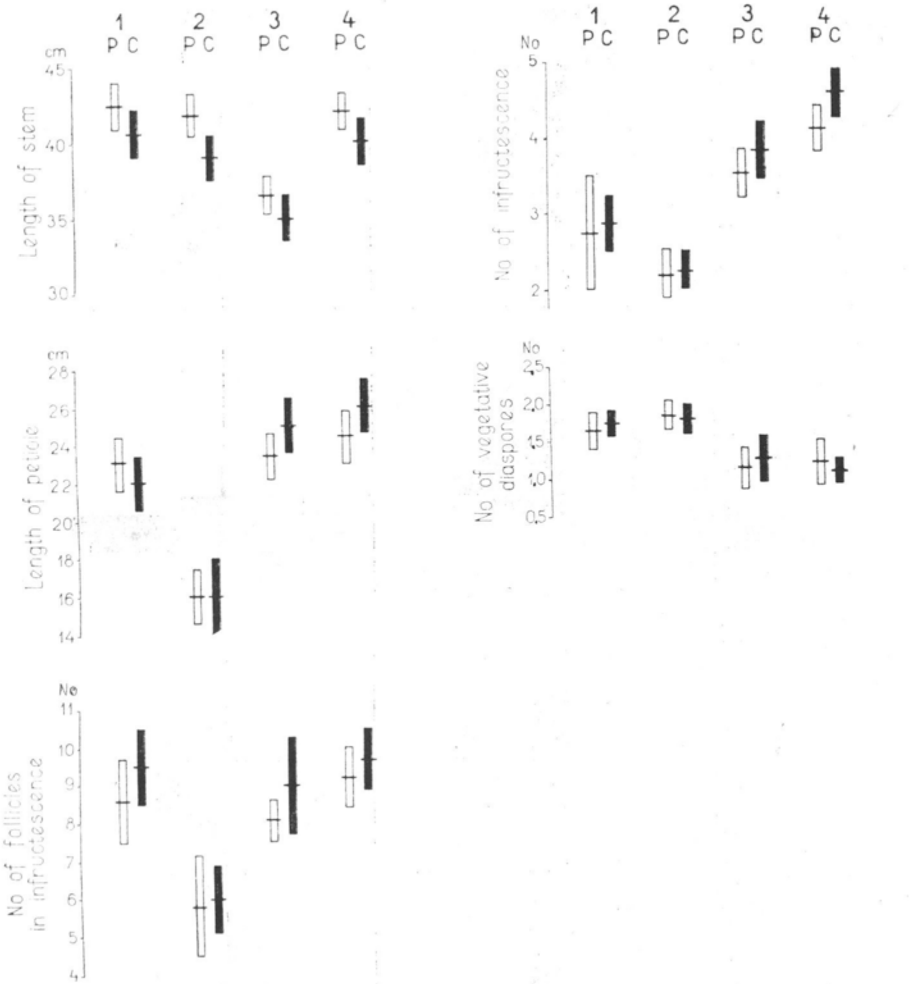

Fig. 5. Confidence intervals of traits (at confidence level 0.95) of individuals in garden culture

Populations: meadow (1), springwood (2), flood-plain forest (3), and alder forest (4). P — *ssp. palustris,* C — *ssp. cornuta*

Length of petioles of basal leaves. Individuals of the springwood population with the shortest petioles in natural conditions (F a l i ń s k a 1979) preserved this trait throughout the garden experiment. Most individuals as regards this trait may be classified to the 10-20 cm size, with an average value of 16 cm (Fig. 5). In the remaining populations the plants have longer petioles (average 25 cm). Moreover, in this group the proportion of plants with 30-15 cm petioles is larger (Fig. 6).

Number of infructescences. Plants of the meadow and springwood populations produce in the garden on the average 1-3 infructescences

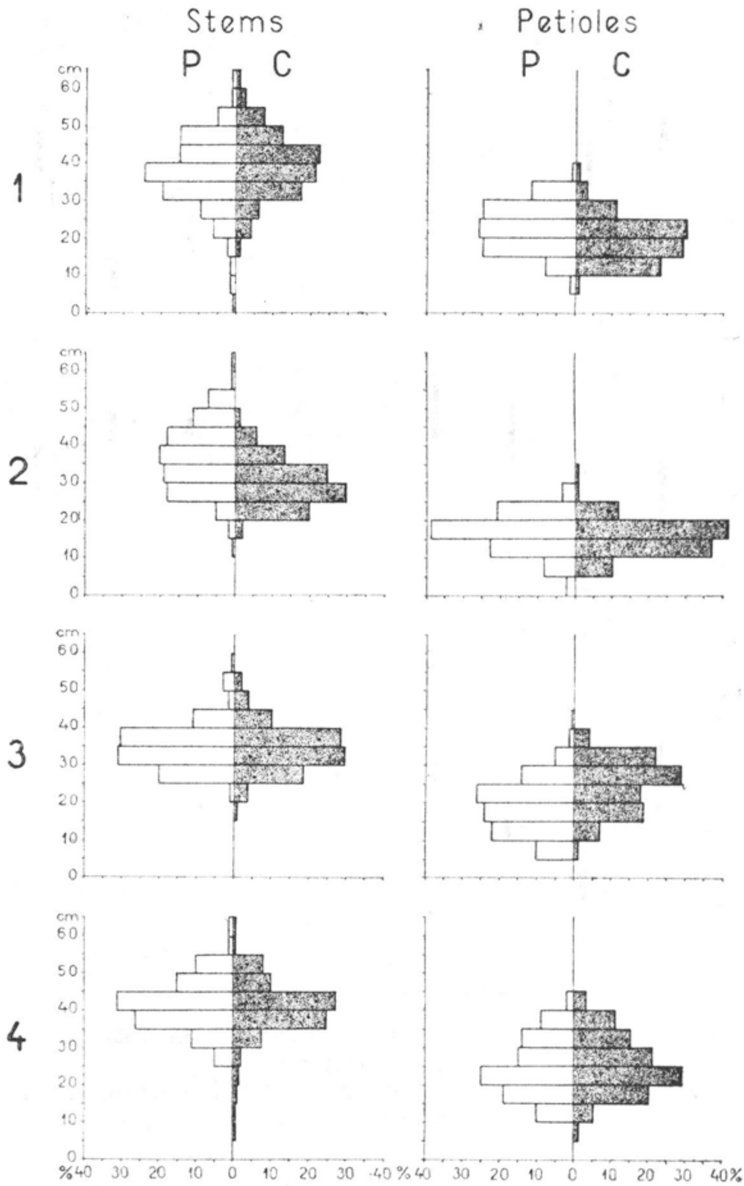

Fig. 6. Diagram of frequency classes of shoot and petiole length from basal leaves in *Caltha polustris L.* population in garden culture
Legend as in Fig. 5

on one shoot, whereas on the plants of the flood-plain and alder forest four to five. The observed differences in natural conditions are still more pronounced in garden culture. In the forest populations the proportion of individuals producing 4-10 infructescences on one shoot doubled in the garden, while in natural conditions only a negligible per cent of plants showed such values. Statistically significant differences of this trait were noted between the meadow and springwood populations and the forest ones (Figs. 5, 7).

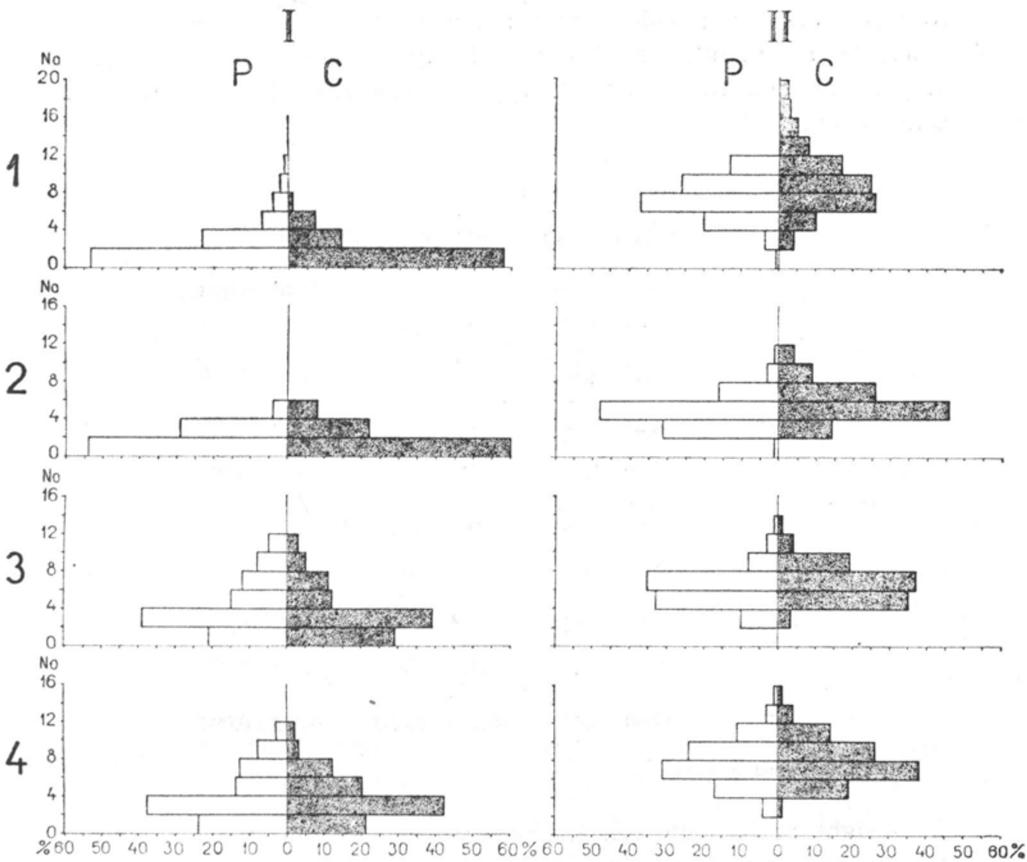

Fig. 7. Diagrams of infructescence number on shoots (I) and follicle number in infructescence (II)
Legend as in Fig. 5

The difference between these two groups appears as early as the flowering phase. The number of flowers at the moment of maximal bloom on the plots with plants from flood-plain and alder forests reached 800-1000 (while on the remaining plots it was 300-600 with the same number of individuals). This results both from the unequal number of flowers on the shoots and the different number of generative shoots on the particular plots. In forest populations the number of shoots on one plant is 16.5 ± 5.90 and in the springwood and meadow populations it is 8.9 ± 5.1. The number of flowers on the shoot in the former populations ranges from 2 to 10, whereas in the latter from 2 to 5. The smallest infructescences are seen in the springwood population (Table 2).

1) Number of follicles. The infructescences in the springwood population are formed of 2-7 follicles. Larger ones are very rare. As compared with other populations relatively frequent are infructescences with 6 follicles, and in meadow and alder forest populations with 6-10 follicles. In all populations the variability in the number of follicles in dependence on the *P* and *C* type of the fruit is statistically not significant (Fig. 5).

Table 2

Characteristic of fruits and seeds

Populations		Number of follicles	Weight of infructescence, g	Seed weight mg
1	*P*	8.63±1.10	0.088±0.014	0.701±0.090
	C	9.45±0.98	0.105±0.013	0.705±0.113
2	*P*	5.79±1.37	0.057±0.011	0.660±0.50
	C	5.98±0.46	0.067±0.025	0.630±0.114
3	*P*	8.18±0.50	0.098±0.019	0.692±0.138
	C	8.96±1.32	0.082±0.025	0.644±0.159
4	*P*	9.20±0.78	0.138±0.044	0.693±0.070
	C	9.60±0.80	0.116±0.020	0.783±0.094

Legend as in Table 1.

2) Weight of infructescence. The differences concerning the weight of the infructescence are similar. The lowest values were noted in the springwood population where its weight ranges from 40 to 90 mg dry weight. Next came the infructescences of the meadow population and flood-plain forest with weight from 60 to 120 mg (Table 2). The largest and heaviest infructescences (100-180 mg) were characteristic for plants of the alder forest population. It should be added that the infructescence weight under the conditions of the experimental garden increased almost twofold in all populations as compared with those produced by the plants in natural conditions.

REPRODUCTION

The fraction of individuals reproducing generatively and vegetatively was determined and so was the number of vegetative and generative diaspores per individual and per shoot and the germination capacity of seeds, the survival and development of seedlings.

In natural populations the plants were characterised by a more intensive vegetative than generative reproduction (F a l i ń s k a 1978). In garden culture the fraction of individuals forming seeds reached in all populations 90-100 per cent. As regards vegetative reproduction, differences appeared between the individuals of the particular populations. Plants of the springwood and meadow populations multiplied vegetatively more intensively in the garden. The fraction of plants and shoots with vegetative diaspores reached here 80-90 per cent, whereas in forest populations it varied within the limits of 30-60 per cent.

Number of vegetative diaspores. Statistically significant differences in this trait were noted between the forest populations and those of meadow and springwood (Fig. 5). In the forest populations there seldom remains more than one vegetative diaspore on the shoot, while on the springwood and meadow plants more than 50 per cent of the shoots produce 2-3 diaspores.

It should be noted that vegetative reproduction shows a high correlation with the shoot habit. This feature distinguished on the plots individuals of forest, meadow and springwood populations. The shoots of the latter particularly were characterised by a large number of rootings and the fraction with trailing shoots reached 90 per cent.

Number and weight of seeds. The number of seeds in the follicle proved to be a relatively stable trait. In all populations this number varied within 10-15 seeds. There were, however, marked differences between the populations as regards the number of seeds in the infructescence. This number was largest (70-100) in the infructescences of alder forest populations, whereas in the remaining ones it was 40-80 seeds. The seed number is strongly correlated with the number of follicles in the infructescence. The differences are still more distinct when these data are compared within the whole population (Table 1).

Under the experimental garden conditions the statistically significant differences in seed weight between the alder forest population and the remaining ones (Table 2) did not persist. In natural conditions the seeds from the alder forest are almost two times heavier than those of other populations (F a l i ń s k a 1979).

Germination capacity of seeds and seedling development.

1) Seeds germinate on Petri dishes after 15-20 days. The germination period lasts 30-40 days. The seeds of the alder forest population germinate best and those from the springwood show the poorest capacity (Table 3).

2) Germination of seeds in pots with flood-plain forest soil starts after 20-30 days. The fraction of germinating seeds (40-60%) is much

Table 3

Germination capacity of seeds

Populations		Replications	Petri dishes			Pots			Garden		
			N	N_1	%	N	N_1	%	N	N_1	%
1	*P*	6	600	422	70	1000	414	41	1000	280	28
	C	6	600	470	78	1000	521	52	1000	190	19
2	*P*	6	600	372	62	1000	272	27	1000	210	21
	C	6	600	336	56	1000	251	25	1000	230	23
3	*P*	6	600	450	75	1000	499	50	1000	301	30
	C	6	600	511	85	1000	563	56	1000	312	31
4	*P*	6	600	522	87	1000	587	59	1000	317	32
	C	6	600	538	90	1000	629	63	1000	368	37

Legend as in Table 1. N—number of seeds, N_1—number of germinating seeds.

lower than on the Petri dishes. Only the springwood population seeds showed a low germination capacity (25-27%) in the soil.

3) On the garden plots a still lower fraction of germinating seeds was recorded (19-37%). In this experiment two groupings could be distinguished: one including the springwood and meadow plants and the other — the forest populations (Table 3).

4) In the development of seedlings the date of cotyledone appearance and of the first leaves was noted. Under natural conditions wide differences were observed: the leaves appeared earlier on the meadow and the flood-plain forest plants and latest in the springwood and alder forest. This retardation was ascribed to the long standing of water on the ground surface (Falińska 1979).

In the vegetation house certain differences between the alder forest and the meadow populations remained. Seedlings developing from meadow seeds reached the first leaf phase earlier than those from the alder forest population seeds (Fig. 8).

These differences persisted to the end of November when the seedlings attain the phase of winter rest. Survival of the seedlings during winter is largely dependent on the degree of advancement of development of the seedlings of the given population. Seedlings with several leaves and a well developed root system usually survive through the winter, whereas others die (Falińska 1979). It is interesting that even in the vegetation house where such factors as ground frost, snow and low temperature were excluded this dependence remained. The fraction of surviving seedlings was 20-50 per cent and it was the higher the more seedlings had developed 3-5 leaves.

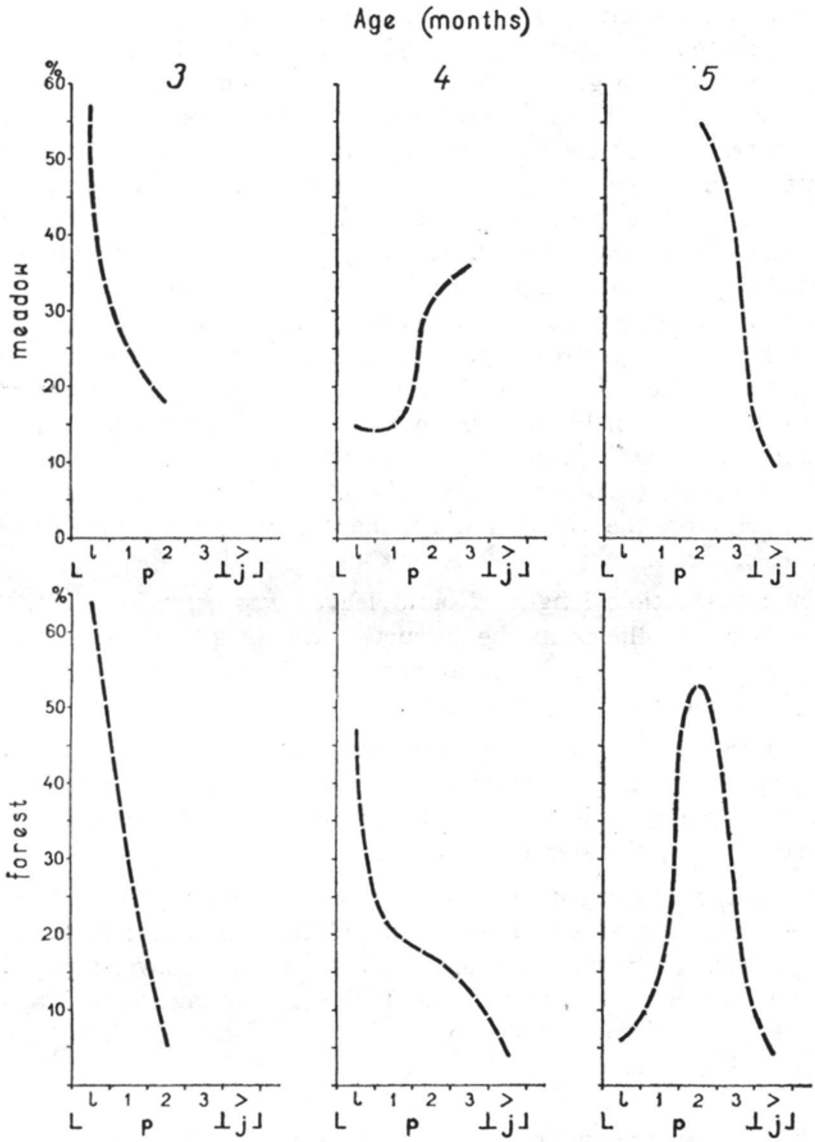

Fig. 8. Seedling development under controlled conditions from seeds of natural meadow and alder forest populations
On horizontal axis: l — cotyledones; 1, 2, 3, — number of leaves; p — seedling; j — juvenile individual

COMPARATIVE ANALYSIS OF THE TRAITS

The variability of traits in individuals from various populations noted in the garden reveals its more complicated character, than was observed in natural conditions. In this case comparative analysis of the traits does not always lead to a nonequivocal classification into three groupings: meadow, springwood and forest ones (Falińska 1978). Most frequently the groupings of populations can be ordered according to similar life conditions. It appeared that the diversity of populations is the more pronounced the wider the difference between the ecosystems from which the given populations are derived, among these differences are the ground water level, the structure of the phytocenosis or the seasonal dynamics. Comparison of the individuals from the studied populations in respect to the particular traits gave as result varying groupings. In several cases alder forest and springwood populations occupied two extreme positions (Fig. 5). Frequently, in the case of five traits the populations formed two groups: a) springwood and meadow populations, b) flood-plain and alder forest ones. This type of ordering was obtained when the shoot habitus (erect, trailing), type of shoot branching (number of branches), number of flowers and infructescences on the shoot and number of vegetative diaspores were taken as criterion.

When the petiole length of basal leaves was compared (Fig. 9) and the number of follicles in the infructescence (Fig. 10), the populations could be ordered as follows: a) springwood populations, b) meadow, flood-plain, alder forest populations.

When the individuals were compared in respect to the number of seeds produced and their germination capacity, thus their reproductive potential, three groupings were singled out: a) springwood populations, b) meadow ones, c) alder forest ones.

As regards morphological traits, most frequently two groupings are observed: springwood and meadow populations in one and forest ones in the other. There are also situations where springwood populations form an independent grouping and the remaining ones a common grouping.

VARIABILITY OF *CALTHA PALUSTRIS* L. POPULATIONS

The most prominent feature in the variability observed in the garden is the difference between populations according to their origin. A slight variability was observed when comparing individuals with different cytotypes derived from one ecosystem (Fig. 11).

In spite of the varying combinations of population groupings in dependence on the traits compared, the widest diversity was noted in springwood and alder forest populations which as a rule occupied extreme positions when mean values of the traits were compared

Plate II

Fig. 9. Petiole length of basal leaves most frequently noted in springwood population (above) and alder forest population (below)
Photo by L. Wilczek

Fig. 10. Morphological differentiation of fruits in springwood (69A) and alder forest populations (71B)
Photo by L. Wilczek

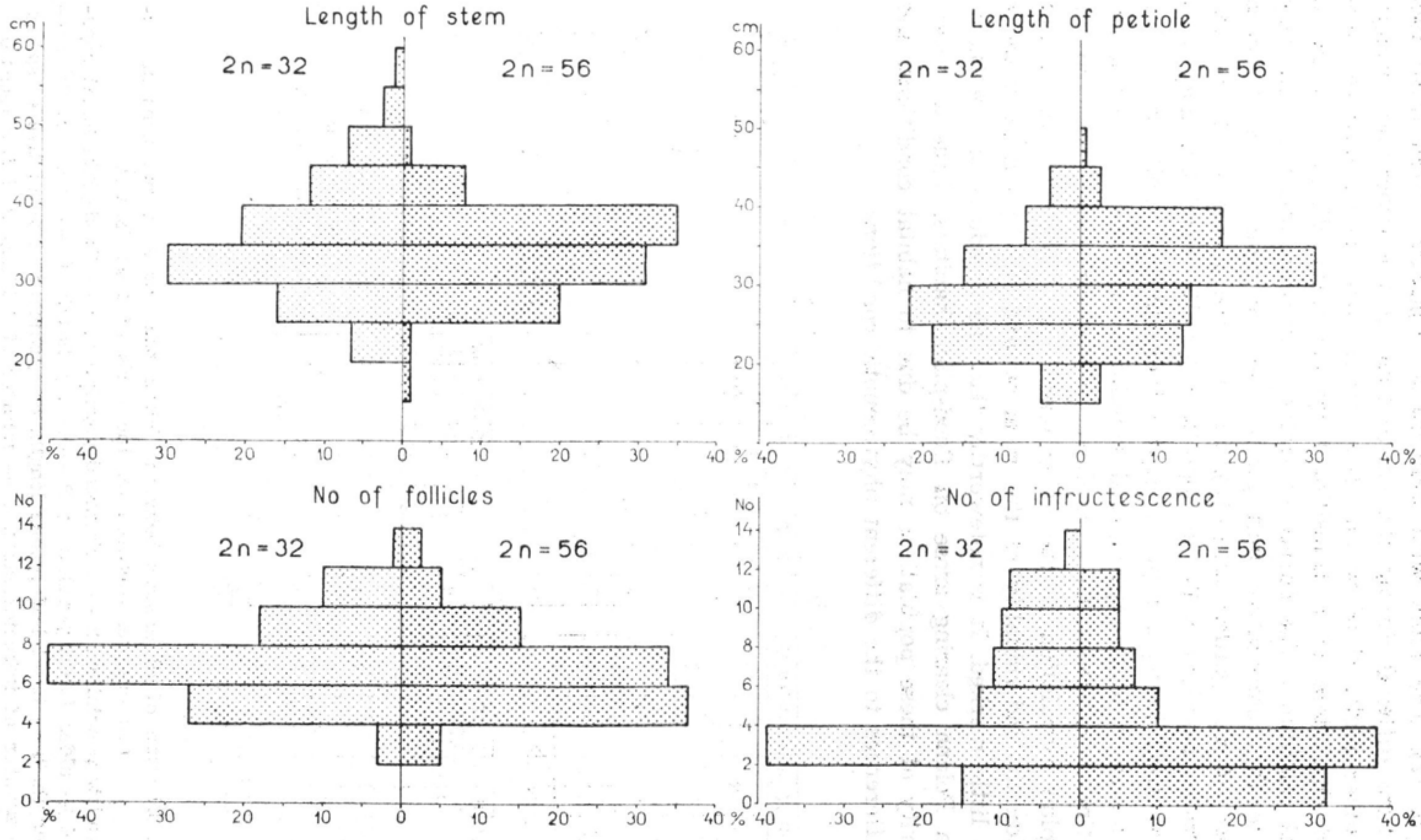

Fig. 11. Variability of traits in dependence on cytotype of individuals in flood--plain forest population

(Figs. 5, 12). The plots with individuals originating from these two ecosystems differed during the entire time of the experiment widely from other plots. Meadow and flood-plain populations, however, exhibited characters of a transitional system more distinctly than in natural conditions. The curves of traits of these populations run very close to the comparative unit plotted on the basis of all the data obtained in the garden (Fig. 13). In this case the alder forest and springwood populations lie on opposite sides. It should be added that meadow and flood-plain populations either show a similarity to the alder forest or to the springwood population, the meadow population exhibiting more frequently a similarity to the springwood one, and the flood-plain population to the alder forest one (Figs. 12, 13). In this situation the individuality of the meadow and flood-plain populations is but little marked. It is noteworthy that the meadows on the Biało-wieska Polana clearing arose on flood-plain habitats. Thus a certain similarity of these populations may be due to habitat conditions, and the differences to the different phytocenotic conditions.

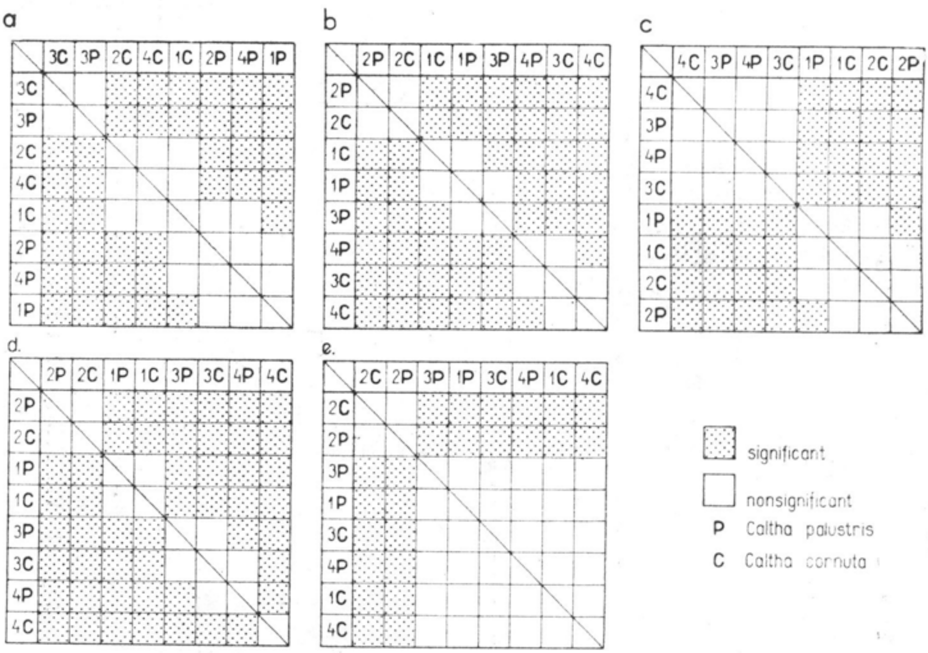

Fig. 12. Diagram of differences between *Caltha palustris* L. populations in garden culture, prepared on the basis of Ducan's test

1 — meadow population, 2 — springwood population, 3 — flood-plain forest population, 4 — alder forest population; P — *ssp. palustris,* C — *ssp. cornuta,* a — shoot length, b — basal leaf petiole length, c — number of vegetative diaspores, d — number of infructescences, e — number of follicles in infructescence

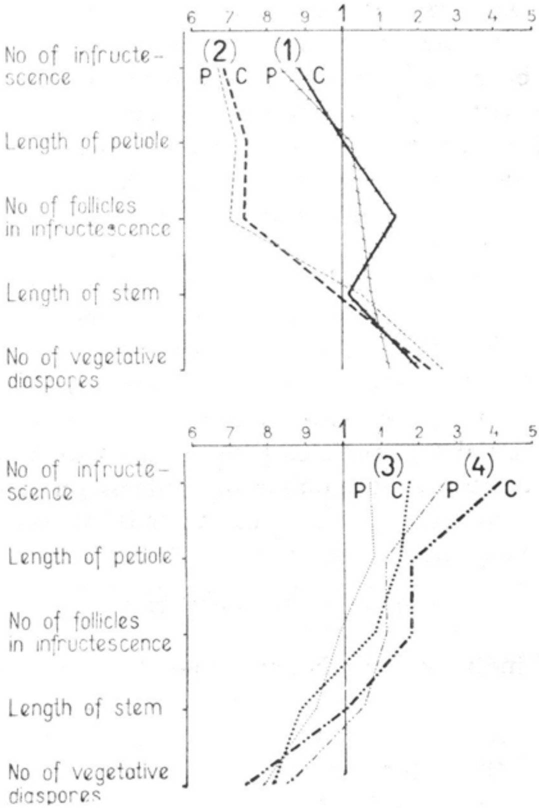

Fig. 13. Comparison of *C. palustris* L. populations in garden culture by the method of the "shape curve" of Jentys-Szaferowa (1959)
Legend as in Fig. 12

SPRINGWOOD POPULATION

Individuals of this population exhibit various cytotypes (Table 4) and various fruit types, *P* and *C* (Figs. 1, 10). From among all populations this one had most frequently follicles which according to their

Table 4

Proportion of individuals with different cytotypes and fruit types (see Fig. 1) in garden culture

Populations	Fruit type %			*P*: *C*	Cytotype %			C_{56}: C_{32}
	P	*C*	*O*		C_{56}	C_{32}	*O*	
Meadow	39	35	26	1: 0.90	62	24	14	1: 0.40
Springwood	25	12	63	1: 0.50	18	71	11	1: 4
Flood-plain	39	26	35	1: 0.70	46	34	20	1: 0.70
Alder forest	42	48	10	1: 1	39	46	15	1: 1

P—Caltha palustris ssp. palustris, C—Caltha palustris ssp. cornuta, O—indefinite.

shape could not be classified either to type *P* or *C* (Figs. 1, 10). Most individuals have trailing shoots rooting in 2 or 3 places. The poorly branched shoots bear 1-2 infructescences consisting of 5-8 follicles.

For the diversity of this population above all the small number of generative shoots produced (1-3) is decisive as well as the short petioles of the basal leaves (Fig. 9). The seeds have a lower germination capacity than those of the remaining populations (Table 3). On the other hand, they form much more vegetative diaspores which take root readily. Most of the springwood individuals produce shoots with 1-2 diaspores. Thus, this population may be considered as having a higher potential of vegetative than of generative reproduction.

From among the distinctive properties of this population in natural conditions the following persisted in the garden: the trailing habit of the shoots, short basal leaf petioles (Fig. 9), a small number of flowers on the shoot and the lowest number of follicles on the infructescence (Fig. 5).

ALDER FOREST POPULATION

It consists of individuals with fruit type *P* and *C* (Fig. 1) and cytotype 2n=32 and 2n=56 (Fig. 4). In this group follicles other than of type *P* or *C* are very rare. They are larger and morphologically better developed than in the other populations (Fig. 10).

Individuals of this populations exhibit erect shoots strongly branched at the top. Each individual produces several or a dozen or so generative shoots. Numerous inflorescences grow out of the shoots consisting mainly of 8-12 follicles. Their number is thus almost twice that in the springwood population. Seed production was highest here both in reference to the infructescence and individual or population (Table 1). The seeds from the alder forest germinate best (Table 3). Only a small number of shoots, however, produce vegetative diaspores which seldom take root.

The individuals of this population are characterised by a high generative reproduction potential and a low vegetative one. All these traits distinguished the individuals from the alder forest also in natural conditions (F a l i ń s k a 1978), the differences being more pronounced in the garden.

DISCUSSION

The results of investigations on the variability of *Caltha palustris* L., a species with a wide ecological amplitude and a wide morphological differentiation, may be considered from at least two aspects: the taxonomic and the ecologic one. In various studies (S m i t 1967, 1968, W c i s ł o 1967, 1968) the small differences between the distinguished subspecies were stressed. It was found earlier that the differences in the *Caltha palustris* L. populations are dependent on the ecosystem type (F a l i ń s k a 1978). This prompted the author to consider the hypothesis of ecotypes. Observation of the character of variability of the populations under the uniform conditions of the experimental garden confirmed this hypothesis, particularly when the habit and size of the plants were taken into account. When the number of flowers and fruits, however, on the shoots was compared between the alder forest and the springwood populations (Figs. 5, 7, 10), it was not easy to explain these differences by ecological conditions. The variability of the populations in respect to this trait was as rule interpreted as an environmental modification. This trait, however, distinguished still more these populations in garden culture than under natural conditions. All this seems to indicate that in the alder forest and springwood the populations may differ genetically. In the present study the ecosystem was considered as the source of population variability. It results from the data here presented that the examined populations are heterogenous, including various cytotypes and plants belonging to various subspecies. Of course only as far as it may be admitted that establishment of subspecies on the basis of one trait, and a so highly variable one, is correct. It also seems to result from the cytotaxonomic and morphologic analysis (W c i s ł o 1967, 1968, S m i t 1967, 1968) that this problem is still open to discussion.

In taxonomic practice morphological traits are most highly valued which distinguish one species from another. These traits are required to be moderately stable. In the light of ecological studies involving *Caltha palustris* (*s.l.*) within the entire ecological amplitude, the diagnostic value of the morphological traits of the fruit arouses some doubts. In the course of six years 400 tagged individuals of *Caltha palustris* were observed in the experimental garden. Only in one third of the material no major difficulties were encountered in the identification. In 80 per cent this concerned individuals of the alder, forest population. On the other hand, individuals of the flood-plain population, and particularly the springwood ones, exhibited follicles which could not be classified either to type *P* or type *C*, neither could a different type of fruit be distinguished (Fig. 1). Such "perfect" fruit shapes of the follicles as those shown in the photograph are extremely rare in natural populations and they are generally found in alder forest populations.

The diversity of individual reaction of each trait to ecological (and perhaps other) conditions leads finally to a complicated picture of the intrapopulation and interpopulation variability of *Caltha palustris* L.

The differentiation in garden culture is not simple and cannot be unequivocally interpreted. Many traits indicate, however, a rather significant relation with the ecological conditions. The springwood and alder forest populations preserved their diversity in garden culture. The variability of some traits is distinctly of adaptive character to the conditions prevailing in springwood, as for instance the trailing shoots and short petioles of the basal leaves. The affluence and effluence of the springwood waters probably eliminated the individuals with erect shoots and long petioles of the basal leaves. The conditions are different in the alder forest. Here the individuals develop with a high stagnant water level (30-50 cm). Most of the alder forest individuals have tall erect shoots with several or a dozen or so inflorescences and later infructescences. In the garden the differences between these populations were even more marked than in natural conditions.

The hypothesis of Smit (1968) that there is an ecological preference of cytotypes has not been confirmed, in the present investigations neither has the suggestion of the different ecological requirements of the *Caltha palustris* subspecies (Hegi 1975). In all populations, even when they developed in quite different conditions, for instance in the alder forest and on meadows, various cytotypes and plants with various types of fruits were noted.

The author of the present paper rather favours the view of Smit (1968) that the observed variability of the *Caltha palustris* L. populations is of ecotypic character.

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REFERENCES

Falińska K., 1978. Behaviour of *Caltha palustris* L. populations in forest and meadow ecosystems of the Białowieża National Park. Ekol. Pol. 26: 85-109.

Falińska K., 1979. Modifications of plant populations in forest ecosystems and their ecotones. Pol. ecol. Stud. 5: 89-150.

Hegi G., 1975. Illustrierte Flora von Mitteleuropa. Bd. 3. t. 3: 77-81, Carl Hanser, München.

Jentys-Szaferowa J., 1959. Graficzna metoda porównywania kształtów roślinnych. Nauka Polska 7: 79-110.

Oktaba W., 1966. Elementy statystyki matematycznej i metodyka doświadczalnictwa. PWN, Warszawa, pp. 310.

Panigrahi C., 1955. *Caltha* in the British flora. In: British flora. Ed. J. E. Lousley, T. Buncle and Co. Ltd., London, pp. 107-110.

Perkal J., 1963. Matematyka dla przyrodników i rolników. PWN, Warszawa, vol. 2: pp. 314, vol. 3: pp. 359.

Rothmaler W., 1963. Exkursions Flora von Deutschland. 4. Kritischer Erganzungsband Gefasspflanzen. Volk und Wiessen Volkseigner Verlag Berlin, vol. 22: pp. 622.

Smit P. C., 1967. Taxonomical and ecological studies in *Caltha palustris* L. Proc. R. Neth. Acad. Sci. Ser. C. 70: 500-510.

Smit P. C., 1968. Taxonomical and ecological studies in *Caltha palustris* L. Meded. bot. Mus. Herb. Rijks. Univ. Utrecht. No. 300: 280-292.

Wcisło H., 1967. Karyological studies in *Caltha palustris* L. Acta biol. cracov. Ser. bot. 10: 501-511.

Wcisło H., 1968. Further studies on experimental hybrides in *Caltha palustris* L. Acta biol. cracov. Ser. bot. 11: 206-212.

Zmienność populacji Caltha palustris L. w kulturze ogrodowej

Streszczenie

Na podstawie prowadzonych badań w ogrodzie doświadczalnym określono charakter zmienności populacji *Caltha palustris* L. W wyrównanych warunkach siedliskowych obserwowano rozwój osobników z diaspor populacji łąkowej, źródliskowej, łęgowej i olsowej. Uzyskane wyniki pozwoliły na ustosunkowanie się do hipotezy o preferencji ekologicznej cytotypów (Smit 1967, 1968) oraz o innych wymaganiach ekologicznych dwu podgatunków: *C. palustris ssp. palustris* i *C. palustris ssp. cornuta*. Stwierdzono, że w każdej populacji występują osobniki o różnych cytotypach. Podobnie rzecz ma się z podgatunkami, wyróżnionymi na podstawie morfologii owoców (Fig. 1). Jednak warto podkreślić, że w świetle wieloletnich badań, wartość diagnostyczna morfologii owocu budzi poważne wątpliwości (Figs. 2, 10). Na podstawie utrzymującego się zróżnicowania populacji w kulturze ogrodowej — pod względem fenologii, reprodukcji oraz wielkości i pokroju roślin — wyróżniono ekotyp olsowy i źródliskowy. Populacje łąkowe i łęgowe ujawniły charakter układów przejściowych, wykazując pewne podobieństwo z populacjami olsowymi, jak i źródliskowymi.