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Front page photo: The wild ancestor of common buckwheat (see paper of O. Ohnishi pp. 5 - 10).

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Fagopyrum 11 (1990): 5-10

Discovery of the wild ancestor of common buckwheat

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Key words: *F. cymosum*, *F. esculentum*, *F. tataricum*, distribution, origin of buckwheat, wild species, Yunnan province

Abstract

A wild ancestor of common buckwheat, *Fagopyrum esculentum* was discovered in Yongsheng-xiang in Yunnan province in China. The ancestral species differs from common buckwheat in having a fragility of premature seeds, strong seed dormancy, longer growth period and branching at lower nodes. In other respects, the two species are similar and are intercrossable. This discovery, combined with observation of the richest distribution of wild *Fagopyrum* species in southern China, clearly indicates that the birthplace of cultivated common buckwheat is southern China, probably Yunnan province. De Candolle's theory of 1883 should be abandoned.

Odkritje divjih prednikov navadne ajde

Divji predniki navadne ajde (*Fagopyrum esculentum*) so bili odkriti v Yongsheng-xiangu, provinca Yunnan v Kitajski. Od gojene ajde se razlikujejo po tem, da odpadajo z rastlin že nezrela semena, da so močno dormantna, da rastline kasneje zorijo in da se razvejajo že pri nižjih kolencih. Glede na druge lastnosti sta si obe vrsti zelo podobni in se lahko križata med seboj. To odkritje, povezano z ugotovitvami o razporeditvi divjih vrst *Fagopyrum* v južni Kitajski, jasno kaže na to, da je južna Kitajska (verjetno provinca Yunnan) območje prvega gojenja navadne ajde. S tem je ovržena teorija De Candolla (1883).

Introduction

More than a century ago, De Candolle (1883) determined that buckwheat, *Fagopyrum esculentum* Moench, originated in Siberia or the northern part of China. New discoveries of buckwheat in cultivation and in the wild by Russian taxonomists, like Maximovicz in Siberia, in the area of the Amur river, northern China and Japan in 1860s and 1870s (see Bretschneider 1898 for the history of European botanical discoveries in those areas) led him to this conclusion. However, as already pointed out by De Candolle himself, the existence of wild common buckwheat in those areas is very suspect; no one to date has in fact confirmed its existence.

In the last two decades of the 19th century, expeditions to southern China and Tibet by European explorers clarified the existence of wild relatives of buckwheat; for example *F. urophyllum* was first collected at Tatsien-lu in Sichuan province by Prince Henri d'Orleans on his 1889-90 journey to Chinese Turkestan, Tibet and southern China, and *F. gracilipes* by E. Faber on his 1887 journey to Mt. Eimei (see Bretschneider 1898). Gross (1913) first attempted to classify oriental Polygoneae species, including *Fagopyrum*. Later, Steward (1930) did the same more accurately by examining herbariums. He took only the species of Gross's *Eufagopyrum* as the species in his section *Fagopyrum*. According to Steward (1930) there are ten *Fagopyrum* species, and all of them, except *F. suffruticosum*, are native to southern China. *F. suffruticosum* has been believed to be distributed in Sakhalin, but no one has confirmed its distribution there. Most Chinese taxonomists followed Steward's classification and have described *Fagopyrum* species in Yunnan province (e.g. Wu *et al.* 1984).

Thus, the distribution of wild relatives of buckwheat in southern China suggests that De Candolle's theory is erroneous; however, no one pointed this out until Nakao (1957) insisted that the original home of buckwheat might be southern China rather than Siberia or northern China, because of the existence of wild *Fagopyrum* species in the area. Most textbooks, however, still give De Candolle's theory and suggest *F. cymosum* as a putative ancestor of common buckwheat (e. g. Campbell 1976, Nagatomo 1984).

Discovery of the wild ancestor of common buckwheat

In 1988, I started a project to study wild relatives of buckwheat and to clarify their distribution in southern China. Here, I summarize the result of the project. Most of the wild *Fagopyrum* species, including two newly found species, have a narrow endemic distribution in southern China. *F. gracilipes* and *F. cymosum* are exceptions. *F. gracilipes*, a self-fertilizing weedy species, is distributed widely, covers almost the whole of China except Tibet. Tetraploid *F. cymosum* extends its distribution westward to Nepal and India as far as Karakoram and the Hindukush.

On October 29, 1990 in Yongsheng-xiang of Yunnan province, I found a new wild *Fagopyrum* species which is very closely related to common buckwheat, *F. esculentum*. Here I only briefly describe my discovery and the characteristics of the new species. A full taxonomic and genetic description will be given elsewhere.

The major differences of the new species from the cultivated *F. esculentum* lie in the fragility of premature seeds, strong dormancy of seeds, longer growth period and branching at lower nodes in the wild species. As shown in Figure 1, the seeds and leaves are smaller in the wild ancestral species. In other aspects, the two species are similar. The wild ancestor is also a heterostylous outbreeder as are many other *Fagopyrum* species (see Ohnishi 1989). It is crossable with common buckwheat.

I now quote my diary of the days on which I found the new species in the valley along the Liulang river, a tributary of the Jinsha river (the upper stream of the Yangtze river) in Yongsheng-xiang of Yunnan province. On the morning of October 28, I left Lijiang for Yongsheng by bus (see map on Figure 2). The bus passed a small village Longshan an hour later, then descended a steep zigzagging road on the eastern slope of the Jinsha river valley. It reached a bridge on the Jinsha river. Buses make a brief toilet stop here and there are a few small restaurants and local inns, primarily for long-distance truck drivers. I found by the roadside, by chance, a new *Fagopyrum* species which seemed to be closely related to *F. leptopodum*. *F. urophyllum* and *F. leptopodum* were also seen. The bus left soon, so I could do nothing about these *Fagopyrum* species. I decided to come back again next day from Yongsheng to collect the plants. I continued the bus trip and arrived at Yongsheng town about 2:00 PM. For the remaining hours, I botanized on a small hill located in the northwest corner of the town and obtained many samples of *F. esculentum*, *F· tataricum* and *F. leptopodum*.

Next morning, I took the earliest bus for Lijang. I got off the bus in the valley just before the bridge at 10 o'clock. The last bus for Yongsheng would pass the valley about 2 o'clock in the afternoon. So I had four hours to collect the plants. I began to collect *F. leptopodum* and the new species related to it. Then, I fortuitously found an unfamiliar wild buckwheat species similar to *F. esculentum* growing on a cliff. A glance at its morphology clearly indicated it to be the ancestral species of common buckwheat. I searched for this species along the valley. The new species was mainly distributed on rocky cliffs and roadsides. Few people live in this valley and cultivated fields are scarce. I saw more than 1000 plants in total; some had already mature seeds and some were still flowering. A farmer I met in the valley told

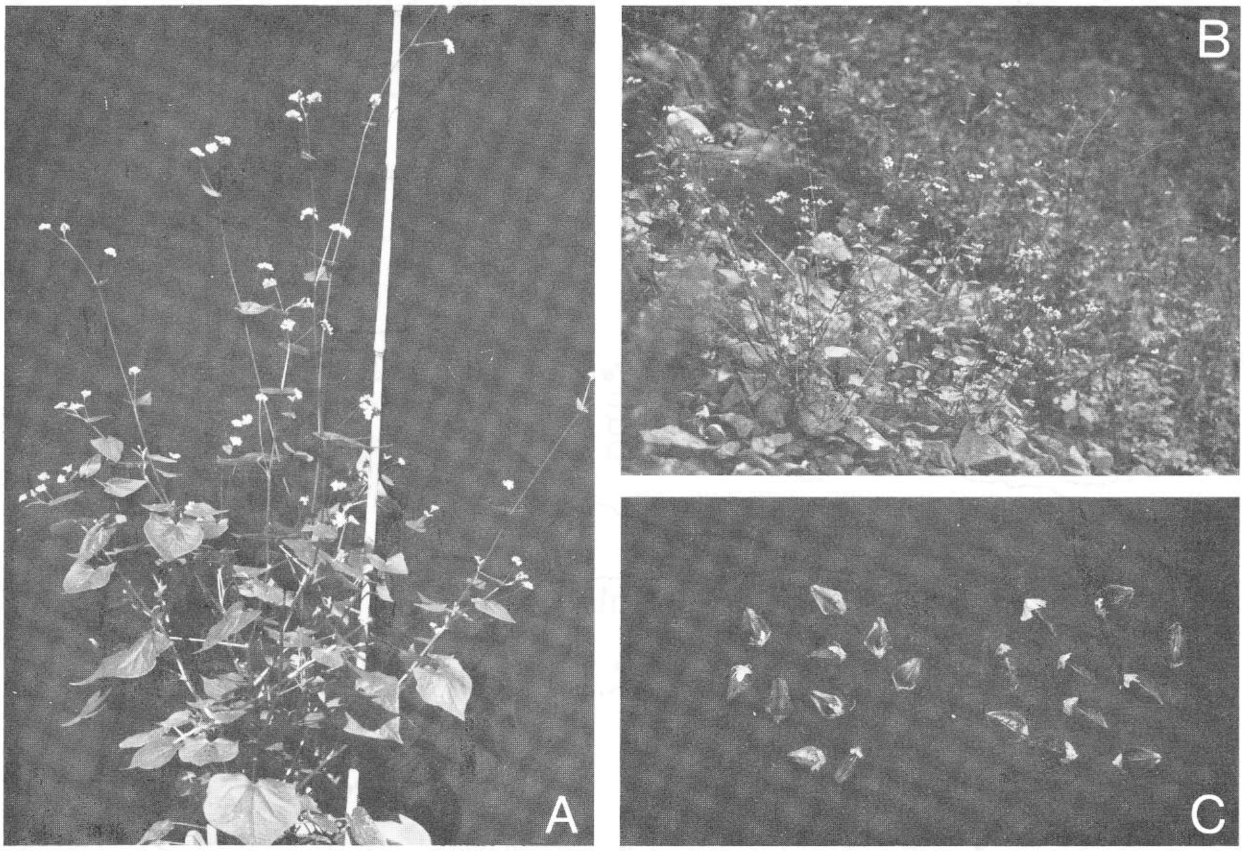

Figure 1. A: The wild ancestor of common buckwheat (ca. 70 cm high). B: The wild ancestor growing in a natural habitat in Yunnan province of China. C: Seed grains of the wild ancestor (left) and common buckwheat cultivated in Yongsheng xiang (right).

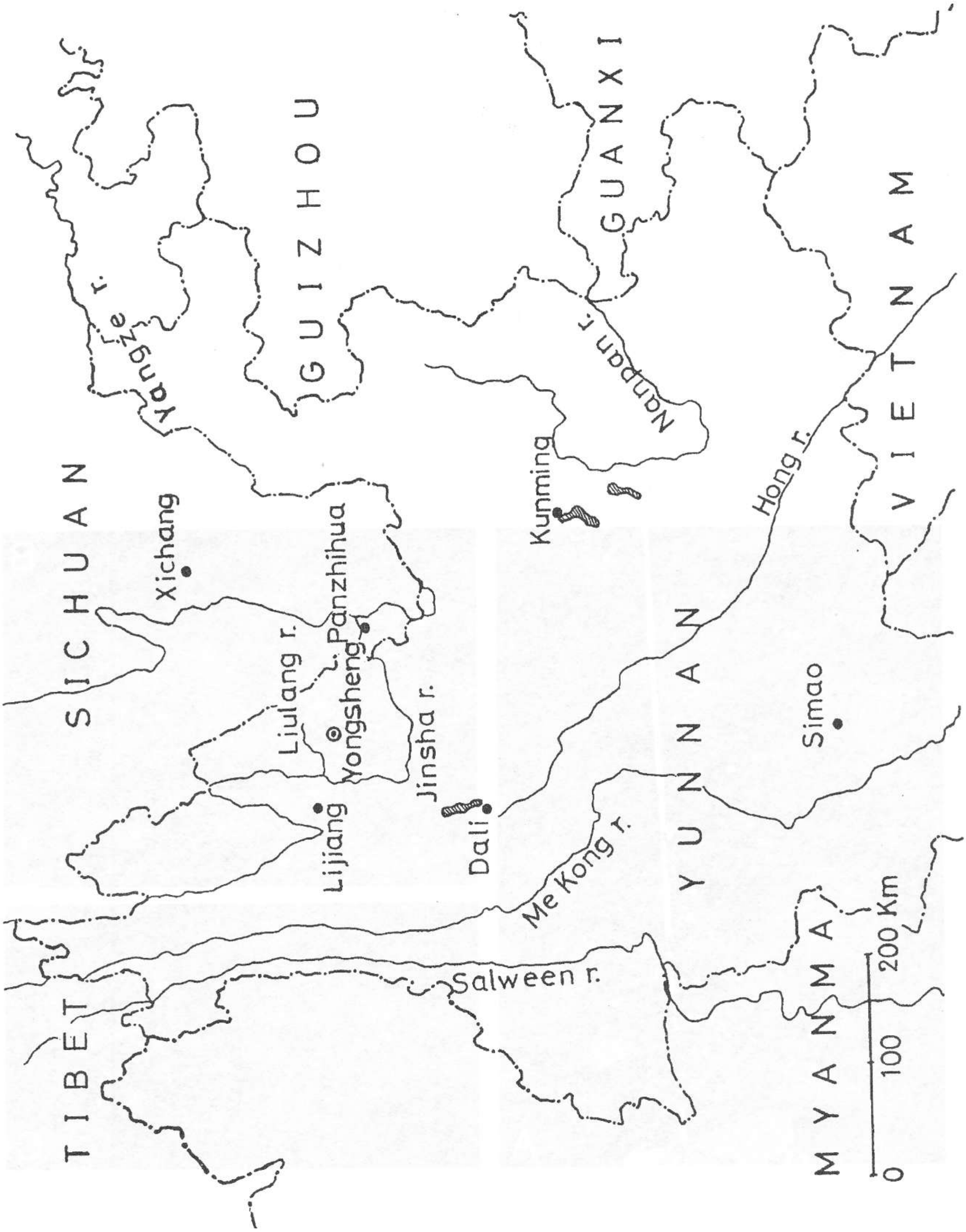

Figure 2. Map of Yunnan province

me that the plant is called "Ye hui giao" in Chinese, which implies wild Hui tribe's buckwheat. Farmers recognize that the plant is closely related to buckwheat, but it is not utilized because its seeds fall down to the ground before maturation. After collecting this new species, *F. urophyllum*, *F. leptopodum* and a new species related to *F. leptopodum*, I walked through the valley along the Liulang river and arrived at the bridge at 1:30 PM. Thirty minutes later, I was on the bus for Yongsheng.

Implication of the discovery for the problem of the origin of buckwheat

My discovery of the ancestor, together with the observation of the richest distribution of wild *Fagopyrum* species in southern China implies that the birthplace of cultivated common buckwheat is southern China rather than Siberia or northern China. The theory of De Candolle (1883) should be abandoned. More detailed information about the species' distribution is under investigation.

The discovery solves several problems about which I had previously felt difficulty. First of all, two species, *F. cymosum* and *F. esculentum* have been considered to be most closely related and the former has been believed to be a putative ancestor of the latter. However, I pointed out long ago that from the point of view of isozymes (Ohnishi 1983), *F. cymosum* is only very distantly related both to *F. esculentum* and *F· tataricum*. Now, my discovery and the existence of the wild species of Tatary buckwheat in Sichuan and Tibet (Ohnishi unpublished) completely resolves the problem of the origin of cultivated buckwheats. Hence, the search for a genetic relationship among *F. cymosum*, *F. esculentum* and *F. tataricum* is no longer the issue for the origin of common buckwheat, though it remains an issue for our understanding of the evolution of the genus *Fagopyrum*.

Allozyme analyses of common buckwheat (see for example Ohnishi 1988, Ohnishi and Nishimoto 1988) have revealed that no great allozyme differentiation has occured among local races in Asia, and the center of genetic diversity in Vavilov's sense is obscure. However, minor alleles, i.e. those alleles with low frequencies, seem to be localized in southern China. Now we know the birthplace of common buckwheat, it is easy to understand the observed geographical distribution of minor alleles. For example, only the populations in southern China have both the S and F alleles at the *Adh* locus; the S allele spread westward to Nepal and India, while the F allele was distributed to northern China with the spread of buckwheat cultivation (see Ohnishi 1988, Ohnishi and Nishimoto 1988).

The level of allozyme variability found in cultivated populations of buckwheat was relatively high; the average heterozygosity was H = 0.13 (see Ohnishi 1988). If common buckwheat suffered from a bottleneck effect when buckwheat cultivation started, this level seems too high to be explained by the neutral theory of allozymes, which says $H = 4Nu/(4Nu + 1)$ where N is the population size and u is the mutation rate (Kimura and Crow 1964). I recently observed that most allozyme variants found in common buckwheat also exist in the population of the wild ancestor (Ohnishi unpublished). This implies that common buckwheat inherited most of the allozymes from its ancestral wild species. So the gradual improvement of buckwheat from the wild ancestor is a probable evolutionary process and common buckwheat has never suffered from the bottleneck effect. The observed high level of heterozygosity can thus be reasonably explained under the neutral theory by buckwheat's own large population size and panmixis of mating due to heterostyly.

Finally, I would like to mention that my discovery may provide good hope for the utilization of the wild ancestor as a genetic source for future buckwheat breeding.

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Changes in the functional properties of buckwheat protein on heating

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Key words: *Fagopyrum esculentum*, dough, protein, texture

Abstract

Changes in the functional properties of buckwheat protein on heating were studied. Heating caused conformational changes in the buckwheat protein, especially in the globulin. Variations in the texture profile of buckwheat flour-water dough were observed during heating. Our present study suggests that the protein of buckwheat flour may be closely associated with the texture of buckwheat dough.

Vpliv segrevanja na spremembe lastnosti beljakovin ajde

Avtorji so raziskovali spremembe beljakovin po segrevanju. Segrevanje je povzročilo spremembe strukture beljakovin, zlasti pri globulinih. V zvezi s segrevanjem so ugotovili spremembe teksture testa ajde iz moke in vode. Na osnovi raziskave lahko domnevamo, da so beljakovine ajdove moke tesno povezane s teksturo testa ajde.

Introduction

Buckwheat (*Fagopyrum esculentum* Moench) is an important crop in some areas of the world. Most buckwheat seed is milled for human consumption. Noodles made from buckwheat flour-water dough have been long popular in Japan. The quality and acceptability of buckwheat products, including noodles, may depend largely on the inherent characteristics of the buckwheat constituents. Buckwheat flour exhibits relatively low cohesion. Therefore, some binders, such as wheat flour, yam, or egg, are often incorporated into buckwheat flour-water dough on making noodles. However, knowledge of the functional properties, including cohesion, of buckwheat flour, is still incomplete.

Buckwheat, as is the case with other cereals, is usually subjected to cooking or some other form of heating prior to human consumption. In general, heating enhances the availability for gastrointestinal absorption of some constituents of foods, such as protein and starch. On the other hand, heating causes changes in the functionality of foods (Cherry 1981). Such changes may be closely associated with alterations in the chemical form of the major constituents present, especially with the denaturation of protein. Alterations in the protein of buckwheat on heating might exert a profound influence upon its functionality. Detailed information regarding this problem should be resolved.

The present study was undertaken to analyze changes in the protein of buckwheat flour on heating, and to reveal the contribution of protein to the functional properties of buckwheat flour.

Materials and methods

Materials. Samples of fresh buckwheat seed were from Takii Co., Japan. Fresh buckwheat flour from a commercial mill was obtained locally and stored at -35°C until used. Enzymes used in this study were obtained from Sigma Chemicals Co.: trypsin (EC 3.4.21.4; 2 x crystalline, from bovine pancreas, 12,000 BAEE unit/mg protein); and pepsin (EC 3.4.23.1, 2 x crystalline, from porcine stomach mucosa). Superose 12 HR 10/ 30 was a product of Pharmacia Fine Chemicals. All other chemicals used were of analytical grade. Albumin and globulin of buckwheat were isolated from the seed according to the procedure of Javornik *et al.* (1981).

Peptic digestion. Peptic digestion of albumin and globulin isolated from buckwheat seed was performed by the following procedure: the isolated proteins were subjected to peptic digestion in 0.07M HCl-KCl buffer (pH 1.1). The enzyme-to-protein ratio was 1:5. After digestion, trichloroacetic acid solution was added to each digestion mixture in a final concentration of 3.4%. It was allowed to stand for 30 min, and then centrifuged at 3,000 rpm for 15 min. The supernatants obtained were assayed for peptide by the procedure with phenol reagent (Lowry *et al.* 1951)

Heating. Experiments were performed on three different samples of buckwheat commercial flour. The flour was suspended in an equal volume (v/w) of distilled water. The suspensions were heated at approximately 55°C, 65°C, and 95°C for 30 min, respectively. Another suspension was autoclaved for 20 min. After heating, the suspensions of buckwheat flour were lyophilized, and the heated flour obtained then subjected to further analysis.

Analysis of texture. About seven ml of distilled water was added to the unheated and heated buckwheat flours respectively, and then mixed. Doughs prepared from these flours were analyzed. The texture profiles, *i.e.*, hardness, adhesiveness, cohesiveness, and springiness, of the doughs were evaluated with a rheolometer (Iio Denki Co., Model RX 1600).

Other analyses. The unheated and heated buckwheat flours were each extracted with five-fold volume (v/w) of 0.1M Tris-HCl buffer (pH 8.0) for 1 hr. After centrifugation (10,000 rpm x 15 min), the supernatants obtained were analyzed. Protein concentration was estimated by the method of Bradford (1976). Protein in buckwheat solid samples (N x 6.31) was estimated by the micro-Kjeldahl method (AOAC 1984). Sulfhydryl group was determined by the procedure of Ellman (1959). Fluorescence analysis of the hydrophobicity of protein was performed by the procedure of Turner and Brand (1968). Trypsin inhibitory activity was assayed by the procedure described previously (Ikeda *et al.* 1986). One inhibitory unit (IU) is defined as the number of enzymes inhibited under the assay conditions employed. Electrophoresis with sodium dodecyl sulfate (SDS) was performed by the procedure of Laemmli (1970). Gel filtration chromatography on Superose 12 was performed with a Pharmacia fast protein liquid chromatographic apparatus. Data were subjected to analysis of variance and the significance of means was tested by t-test.

Results and discussion

Changes in buckwheat protein on heating. Table 1 shows changes in the total protein, soluble protein, free sulfhydryl group, and trypsin inhibitory activity in the aqueous extract of buckwheat flour during heating. The soluble protein gradually decreased as the heating temperature was raised. The sulfhydryl group in the aqueous extract also decreased on heating. These findings indicate that the denaturation of the protein in buckwheat flour proceeds on heating. However, it is noticeable that approximately 78% of the protein remained still soluble even on heating at 95°C. On the other hand, autoclaving caused a marked decrease in the soluble protein of the aqueous extract. Fewer changes in the total protein of the flour on heating were observed. Heating at 55°C and 65°C did not affect the trypsin inhibitory activity in buckwheat flour, whereas heating

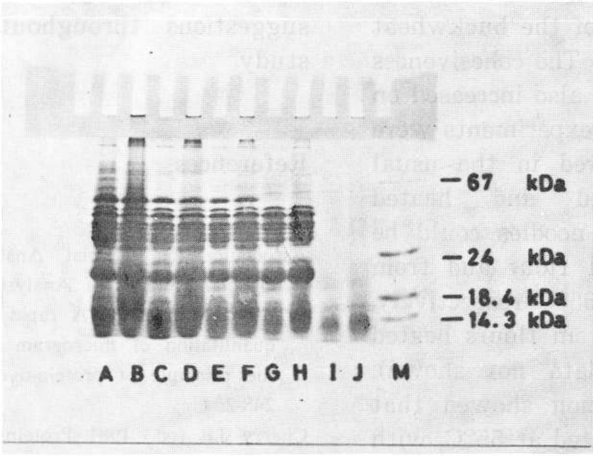

Fig. 1: Electrophoretic patterns of proteins in aqueous extracts of unheated and heated buckwheat flours. A,C,E,G, and I were extracted with 0.2M Tris buffer (pH 8.0) without 0.2% SDS; and B, D, F, H, and J were extracted with the same buffer with 0.2% SDS. A and B, unheated flour; C and D, flour heated at 55°C; E and F, flour heated at 65°C; G and H, flour heated at 95°C; and I and J, autoclaved flour. M denotes a standard reference mixture of proteins of bovine serum albumin

at 95°C and autoclaving reduced the trypsin inhibitory activity.

Table 2 shows the effect of heating on the susceptibility of buckwheat globulin and albumin to peptic action. The susceptibility of the buckwheat globulin to enzymatic action significantly decreased during heating. This finding suggests that conformational changes in the globulin molecule may occur on heating. This was also confirmed by fluorescence analysis with 1-anilinonaphthalene-8-sulfonic acid (data not shown). On the other hand, heating of buckwheat flour did not affect the susceptibility of the albumin to peptic action (Table 2).

Figure 1 shows the electrophoretic patterns of the proteins in the aqueous extracts of the unheated and heated buckwheat flours. Gel filtration chromatographic patterns of their aqueous extract on Superose 12 are presented in Fig. 2. Changes in the protein components in the aqueous extract on heating were observed. Some high-molecular-weight components, which mainly constituted the globulin, disappeared during heating (Fig. 2). This was confirmed by electrophoretic analysis (A, C, E and G in Fig. 1.). On the other hand, few changes in low-molecular-weight components, which mainly constituted the albumin, were found (A, C, E, G and I in Fig. 1 and Fig. 2). Drastic changes in the protein components were observed on autoclaving (I and J in Fig. 1 and Fig. 2). Furthermore, electrophoretic analysis indicated that SDS-soluble, high-molecular-weight components were newly formed on heating (B, D and F in Fig. 1). This finding suggests that aggregation of protein components, perhaps of the globulin components, in buckwheat flour may occur during heating.

Changes in the texture profile of buckwheat dough on heating. Table 3 shows the texture profiles of buckwheat doughs made from unheated and heated buckwheat flours. A marked rise in the hardness of the buckwheat dough was found on heating. The cohesiveness and springiness of the dough also increased on heating. On the other hand, experiments were performed on noodles prepared in the usual way from the unheated and heated buckwheat flours. Uniform noodles could be prepared from the unheated flour and from flours heated at 55°C and 65°C respectively, but could be not prepared from flours heated at 95°C and autoclaved (data not shown). Preliminary sensory evaluation showed that noodles made from flour heated at 55°C, with appropriate hardness, were acceptable, although detailed sensory evaluation should be performed.

Buckwheat is an important source of dietary protein in the world. There are a variety of buckwheat dishes, including noodles. However, the functional properties of buckwheat have still not been clarified. Although there are some reports on its functional properties (Soda *et al.* 1981, Sugiyama and Fukuba 1981-a,b, Tsuji 1984), biochemical analysis on the functionality of buckwheat flour is very incomplete. Soral-Smietana *et al.* (1984) have shown that changes in the structure and properties of buckwheat starch occur on steam hydrothermal processing. On the other hand, our preliminary study indicates that some ions, which are reactive towards the sulfhydryl group of protein, such as zinc ion and cupric ion, significantly altered the texture, including hardness, of buckwheat doughs (unpublished data). In conclusion, the present findings suggest that buckwheat protein may be closely associated with the texture of buckwheat dough. Research is currently underway in our laboratory to reveal the biochemical basis of the functionality of buckwheat dough.

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Table 1: Changes in the total protein, soluble protein, free sulfhydryl group, and trypsin inhibitory activity of buckwheat flour during heating

Heating Conditions	Total protein (mg/g flour)	Soluble protein (mg/ml extract)	Free sulfhydryl group (nmol/ml extract)	Trypsin inhibitory activity (IU/g flour)
No heating	153 ± 40	14.9 ± 0.1	212 ± 72	9.14 ± 1.20
55°C	152 ± 33	12.3 ± 0.1	111 ± 35	8.33 ± 1.80
65°C	153 ± 27	12.2 ± 0.4	28 ± 10	8.71 ± 1.56
95°C	149 ± 10	11.7 ± 0.3	9 ± 7	5.27 ± 0.19
Autoclaving	145 ± 14	3.9 ± 0.2	7 ± 3	2.28 ± 0.14

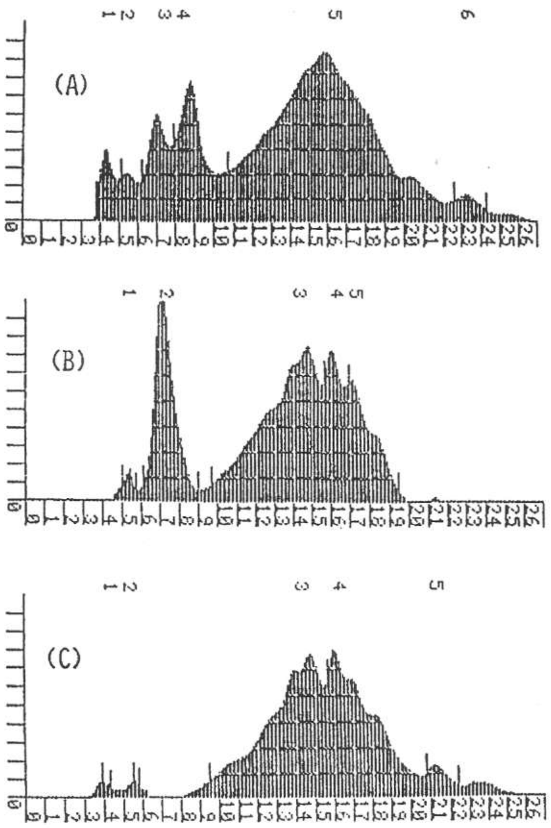

Table 2: Effect of heating on the susceptibility of buckwheat globulin and albumin to peptic action

Heating conditions	Peptic activity (mg peptide/min/ml)[1]	
	Buckwheat globulin	Buckwheat albumin
No heating	32.8 ± 1.0	15.6 ± 2.3
55°C	28.1 ± 1.2*	14.8 ± 1.2
65°C	27.9 ± 1.0*	15.3 ± 1.3
95°C	21.5 ± 1.7**	14.2 ± 1.6
Autoclaving	10.9 ± 2.0**	20.4 ± 1.3

1.* Significantly different from the no heating at $p<0.05$.
**Significantly different from the no heating at $p<0.01$.

Fig.2: Gel filtration chromatographic patterns of the aqueous extracts of unheated and heated buckwheat flours on Superose 12. A scale in vertical lines indicates 0.02 of absorbance at 280 nm. (A), unheated flour; (B), flour heated at 95°C; and (C), autoclaved flour.

Table 3: Texture profiles of buckwheat doughs made from native and heated buckwheat flours.

Heating conditions	Texture profile (texturometer units)			
	Hardness	Adhesiveness	Cohesiveness	Springiness
No heating	2.10 ± 0.44	tr.	0.24 ± 0.02	0.20 ± 0.01
55°C	2.85 ± 0.41	tr.	0.25 ± 0.01	0.23 ± 0.01
65°C	4.85 ± 0.09	tr.	0.40 ± 0.04	0.26 ± 0.02
95°C	3.67 ± 0.64	tr.	0.57 ± 0.03	0.43 ± 0.02
Autoclaving	3.64 ± 0.50	tr.	0.58 ± 0.04	0.51 ± 0.01

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Phytocenological characteristics of the buckwheat weed community in north-eastern Croatia

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Key words: buckwheat, floristic composition, life form, phytocenological characteristic, weed community

Abstract

According to phytocenological classification the buckwheat weed community in the north-eastern part of Croatia belongs to the atypical association *Panico-Galinsogetum* subass. *eragrostietosum*. This weed community is distributed in a phytogeographical area which is situated between the humid, western and wide-spread alliance *Polygono-Chenopodion* and the eastern and arid alliance of *Eragrostion*. These two alliances are linked in the order *Chenopodietalia albi* and class *Stellarietea mediae*.

Fitocenološke karakteristike korovne zajednice u heljdi na području sjeveroistočne Hrvatske

Istraživana korovna zajednica u heljdi razvija se pod utjecajem snažnog antropogenog faktora u prijelaznom fitogeografskom području između humidnije sveze *Polygono-Chenopodion* na zapadu i aridnije sveze *Eragrostion* na sjeveroistoku Hrvatske. S tim u vezi, ova korovna zajednica predstavlja prijelaznu i atipičnu asociaciju *Panico-Galinsogetum* subass. *eragrostietosum*.

Introduction

The north-eastern part of Croatia has favourable agroecological conditions for growing buckwheat and other catch crops with a short vegetation period. Parallely with the introducing of the second crop or intensifying plant production in this region, weed components are becoming more topical. In spite of this, there are very few data in the literature relating to weed flora developing in catch crops in the region of north-eastern Croatia (Knežević *et al.* 1987, 1989, 1990). Regular weed control, especially herbicide application, has made it necessary to broaden knowledge of the biology, ecology and classification of weeds and weed communities.

In this paper we present the results of several years investigation of the buckwheat weed community in the region of north-eastern Croatia according to their phytocenological characteristics.

Investigated area and methods

Between 1986 and 1990, phytocenological investigations of buckwheat weed flora was carried out in the north-eastern part of Croatia. The investigations included three types of soil: pseudogley (Feričanci), semigley (Veliškovci) and eutric brown soil (Tenja) - Fig. 1. The climate of this area is also variable, with obvious differences in humidity between the western locality of Feričanci (758.8 mm) and the eastern locality of Tenja (605.9 mm).

In comparison with other continental parts of Croatia, the investigated area has generally a more arid climate. It is especially visible during the vegetation period, from July to September, when the climate is semiarid and arid, or even perarid. As the weed flora is in full development in that period, climatic conditions have a considerable influence on vegetation growth.

The phytocenological investigations were

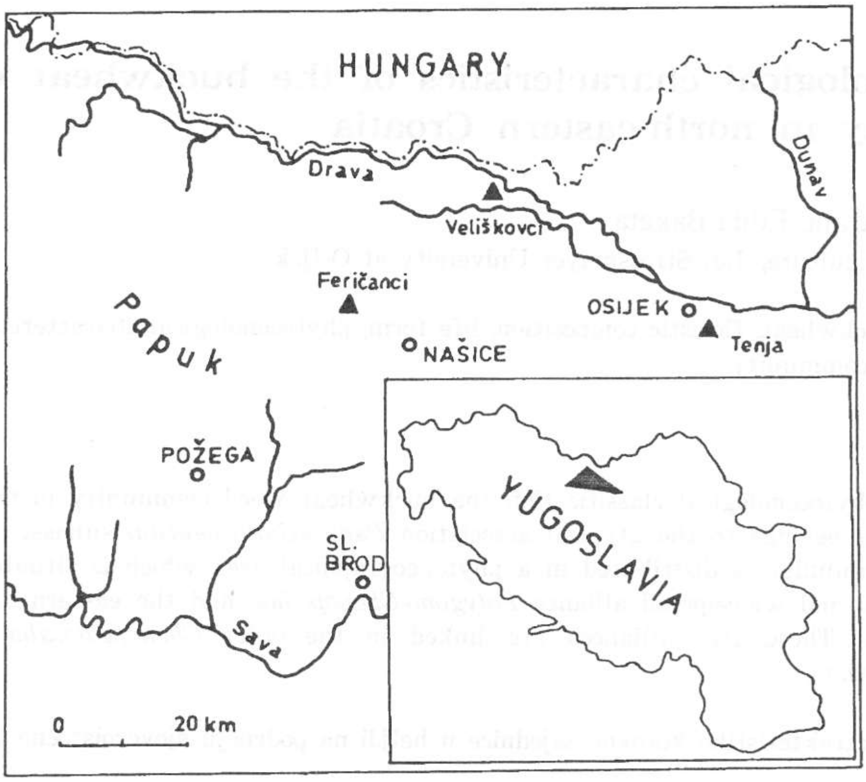

Fig. 1: Investigated area ▲ Localities

carried out according to phytocenological methods (Braun-Blanquet 1964). Vegetational records were made at non-treated plots of a size of 25 square meters. The nomenclature of plant species was made according to Ehrendorfer (1973), and life forms were listed after Ellenberg (1974).

Results and discussion

The floristic composition of the buckwheat weed community is shown in the synthetic phytocenological table according to 36 vegetational records (Tab. 1). According to phytocenological classification, this weed community can be classed into two alliances which unite the row crop weed vegetation. These communities are: *Polygono-Chenopodion polyspermy* Koch 1926 emend Sissing 1946 and *Eragrostion megastachyae* Tx. 1950 both of which belong to the order of *Chenopodietalia albi* Tx. et Lohm. 1950 and to the class of *Stellarietea mediae* (Br.-Bl. 1932) Tx., Lohm., Prsg. 1950.

In stands of the alliance *Polygono-Chenopodion*, the species *Galinsoga parviflora*, characteristic of the alliance, appears normally but in the investigated area, it was present in small quantities. In such floristically atypical stands, it was spread in the western locality (Feričanci). Stands of the alliance *Eragrostion* are characterized by the presence of thermophilous species *Eragrostis megastachya, Heliotropium europaeum* and *Hibiscus trionum* which are much more frequent in the investigated eastern part (Tenja). These stands also have an incomplete floristic structure because many species characteristic of the alliance, order and class are less frequent or completely absent. This is a result of the intensity of cultivation and herbicide application, i.e., the use of agricultural engineering which effectively controls many weed species of

Table 1. Floristic composition and syntaxonomical division of the buckwheat weed community

Life form	Investigated area	Degree of presence Western humid	 Eastern arid
	Characteristic species of the community Polygono-Chenopodion		
T	*Galinsoga parviflora* Cav.	II^{+}	.
	Characteristic species of the community Eragrostion		
T	*Heliotropium europaeum* L.	I^{+}	III^{+}
T	*Eragrostis megastachya* (Koel.) Lk.	.	II^{+-1}
T	*Hibiscus trionum* L.	I^{+}	II^{+}
	Characteristic species of the order Chenopodietalia albi		
T	*Echinochloa crus-galli* (L.) PB.	V^{1-2}	V^{1-3}
T	*Chenopodium album* L.	V^{+-2}	V^{+-1}
T	*Amaranthus retroflexus* L.	V^{+}	V^{+-1}
T	*Setaria glauca* (L.) PB.	I^{+}	V^{+-1}
T	*Digitaria sanquinalis* (L.) Scop.	.	IV^{+-2}
T	*Polygonum persicaria* L.	.	III^{+}
T	*Solanum nigrum* L. emend Miller	II^{+}	.
T	*Polygonum lapathifolium* L.	II^{+}	.
T	*Lamium purpureum* L.	II^{+}	.
T	*Capsella bursa-pastoris* (L.) Med.	I^{+}	.
T	*Amaranthus lividus* L.	I^{+}	.
T	*Diplotaxis muralis* (L.) DC.	I^{+}	.
	Characteristic species of the class Stellarietea mediae		
T	*Stellaria media* (L.) Vill.	II^{+}	I^{+}
T	*Veronica persica* Poir.	II^{+}	I^{+}
Tli	*Fallopia convolvulus* (L.) Löve	II^{+}	I^{+}
T	*Viola arvensis* Murray	I^{+}	.
T	*Stachys annua* (L.) L.	I^{+}	.
T	*Sherardia arvensis* L.	I^{+}	.
T	*Veronica arvensis* L.	I^{+}	.
	Companions		
T	*Ambrosia artemisiifolia* L.	V^{+-1}	V^{+-2}
T	*Raphanus sativus* L. var. oleifera	V^{1-2}	.
T	*Triticum vulgare* L.	IV^{+}	III^{+}
G	*Agropyron repens* (L.) PB.	II^{+}	I^{+}
T	*Helianthus annuus* L.	II^{+}	.
T	*Hordeum sativum* Jess.	II^{+}	.
G	*Convolvulus arvensis* L.	II^{+}	I^{+}
T	*Brassica nigra* (L.) Koch.	.	II^{+}
H	*Dactylis glomerata* L.	II^{+}	I^{+}
T	*Cannabis sativa* L.	.	II^{+}
T	*Matricaria chamomilla* L.	I^{+}	I^{+}
T	*Vicia sp.*	.	I^{+}
N	*Rubus caesius* L.	.	I^{+}
T	*Erigeron annuus* (L.) Pers.	.	I^{+}
G	*Cynodon dactylon* (L.) Pers.	.	I^{+}
G	*Cirsium arvense* (L.) Scop.	.	I^{+}
H	*Taraxacum officinale* Web.	I^{+}	.
T	*Datura stramonium* L.	I^{+}	.
H	*Daucus carota* L.	I^{+}	.
T	*Panicum miliaceum* L.	I^{+}	.

Dicotyledonae.

In comparison with other weed communities developing from the early spring parallel with cultivated plants, it should be pointed out that the buckwheat weed community starts its development not earlier than the summer months. Because of this, many early-spring and spring species are missing in this community. In addition to the strong anthropogenic factor, the weed community in buckwheat is influenced by the climatic conditions, and its floristic composition is modified by climazonal differences between the humid western and more arid eastern area. The established changes coincide with the phytogeographical distribution of row crop weed vegetation in the continental part of Croatia (Topić 1978a, 1978b, 1984).

Our locality of investigation, in the phytogeographical view, is located in the transfer-area between the alliance of *Polygono-Chenopodion* which is widespread in the west and the alliance of *Eragrostion* distributed in the north-eastern part of Croatia, as was earlier established by Topić (1984). Because of its specific phytogeographical position, the investigated buckwheat weed flora has not developed in a typical association of one of the mentioned alliances. So the buckwheat weed community is a transfer community between the association of *Panico-Galinsogetum* from the alliance of *Polygono-Chenopodion* widespread in the west, and the association *Hibisco-Eragrostietum megastachyae* from the alliance of *Eragrostion* which is widespread in the east. Because of this the buckwheat weed community in the investigated area could be defined as an association of *Panico-Galinsogetum* subass. *eragrostietosum*. The thermophilous species of the alliance *Eragrostion* could be defined as a differential species of the subassociation.

Table 2. Life spectrum of the buckwheat weed community in the north-eastern Croatia

Life form	No. of species	%
T (Terophytes)	35	81.4
G (Geophytes)	4	9.3
H (Hemicryptophytes)	3	7.0
N (Nanophanerophytes)	1	2.3
Total	43	100.0

According to the life form spectrum, the buckwheat weed community has a terophytic character.

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Differential distribution of different saccharides and proteins in two types of grains growing in the same ear of buckwheat (*Fagopyrum esculentum* Moench)

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Key words: *Fagopyrum*, grain yield, growth regulators, proteins, saccharides, sink

Abstract

In an effort to examine the underlying causes of variation in yielding ability, amongst grains developing in the same ear of *Fagopyrum*, the levels of mono-, di- and polysaccharides as well as total proteins were analysed at different stages of their growth and development. It was discernible that the endogenous status of these metabolites varied significantly in the two types of grains. In our earlier investigations, these grains were shown to possess differential levels of two endogenous hormones, i.e., three auxins and three cytokinins with the heavier sinks (grains) possessing higher levels per se of these (expressed as unit fresh weight). In the current investigations, these heavier grains possessed relatively more starch with a concomitant low level of total, reducing and non-reducing, sugars. In contrast their smaller counterparts possessed a low level of starch as well as a high level of non-reducing sugars. It seems that in the ontogeny of the grain's development at a particular stage (s), there was a blockage of non-reducing sugars to be transformed to starch resulting in its low levels. Further, an association was also shown between a higher level of total protein contents and heavier grains, as compared to grains which were conspicuous by low yielding ability at all stages of grain development. It was concluded from the results that the two types of grains were independent biological entities and sustained physiological parameters at variable efficacies which, in-turn, were determined by the levels of endogenous hormones contained in them.

Razporeditev različnih sladkorjev in beljakovin na dve vrsti semen pri ajdi

Avtorji so raziskovali razporeditev monosaharidov, disaharidov in polisaharidov ter beljakovin v različna semena ajde tekom rasti in razvoja semen. Različna semena se razlikujejo po vsebnosti omenjenih metabolitov. Predhodne raziskave so pokazale, da se dva tipa semen razlikujeta po vsebnosti endogenih hormonov, to je glede na vsebnost treh avksinov in treh citokininov. V težjih semenih je več hormonov na enoto mase. Avtorji sklepajo, da je bila med razvojem semen blokirana vgradnja nereducirajočih sladkorjev v škrob. Na osnovi rezultatov sklepajo tudi, da je presnova v obeh tipih semen zelo različna in da je to opredeljeno z ravnijo vsebnosti endogenih hormonov.

Introduction

One of the essential processes in the development of multicellular plants has been the evolution of means to co-ordinate the activities of the various groups of specialised cells, which subsequently reflect their total productivity potential besides unveiling the events which operated elsewhere during their ontogeny. Plant productivity is perhaps one such facet and variability with regard to the same genotype or same cultivar makes one presume sub- or supra- activity of messengers/ regulators transported to those organs, which ultimately effects the yielding ability of the plant. In our previous studies on grains of *Fagopyrum* (Dua et al. 1990) it was revealed in no uncertain terms that endogenous hormones, i.e., auxins, gibberellins and cytokinins determined the potential of individual grains to grow. However, the findings did not decipher the physiological or metabolic profile which, by virtue of the unequal distribution of these promoters, might differ among them. Working on these lines, Sugawara (1960) opined that translocation of carbohydrates to the developing grains of *Fagopyrum* might be one of the factors responsible for the poor percipitation of photosynthates in some grains, while Morton (1966) also suggested that the low grain yield in *Fagopyrum* could not be attributed to the lack of non-viable pollen or self-incompatibility and some unknown factors might govern the physiological processes conducive to a lower yield in them. In the present investigations it was considered worthwhile to look into the relative levels of saccharides (mono-, di- and poly) as well as proteins in the two types of grains (bolder and smaller) which develop in the same ear (mothershoot) but due to some key physiological reactions had their yielding ability partially impaired.

Materials and methods

Plants of *Fagopyrum esculentum* were raised in pots (40x30x30 cm) containing 30 kg of soil mixed with FYM (Farm Yard Manure) at Saproon Valley (H.P.) in the lower Himalayas. Twenty seeds per pot were sown and sixteen days later, the seedlings were thinned to eight, with the tagging of mothershoots. The plants were grown under optimum supply of water and nutrients and were given a dose of Hoagland Solution at an interval of 10 days. The date of anthesis was noted. In order to study the effect of different growth regulators on time course changes in some biochemical components during grain development, ear samples both from treated and untreated plants (control) were collected after 8, 15, 22 days after anthesis and at maturity. The labelled materials were oven dried at 50-60°C and were used for the determination of starch, total sugars, reducing and non-reducing sugars and proteins. The method of Murata et al. (1968) was followed for the estimation of starch. Total sugars were estimated by the method given by Loewis (1952) and reducing sugars by the method given by Nelson (1944). The values of non-reducing sugars were obtained by substracting the values for reducing sugars from total sugars. The conventional method of Lowry et al. (1951) was followed for the estimation of proteins. The data were analysed statistically following the analysis of variance method on a IBM Computer 1432.

Results

I. Relative levels of saccharides in the grains of *Fagopyrum* developing in the same ear.

a) Starch:

On the whole, the quantity of starch increased as the grain progressed towards maturity irrespective of the type of grain. The increase in the first three weeks was abrupt and quite substantial and was followed by a gradual increase from 22 days onwards (825 and 684 per cent in the first 15 days, 65 and 106 per cent in the 15-22 days stage and 20 and 36 per cent increase in bolder and smaller grains, respectively from 22 days to maturity. By and large, the bolder grains possessed significantly higher amounts of starch per grain than the smaller grains at all stages of grain development (Fig. 1). The maximum disparity between the two types of grain existed at the 15 day stage, when the bolder grains possessed almost double the amount of starch than their counterparts i.e., smaller grains. This narrowed to 63 per cent subsequently and at the time of harvest, the bolder grains possessed 43 per cent more starch than the smaller grains. The application of growth regulators i.e., auxin and cytokinin significantly enhanced the levels of starch in both types of grain. The increase

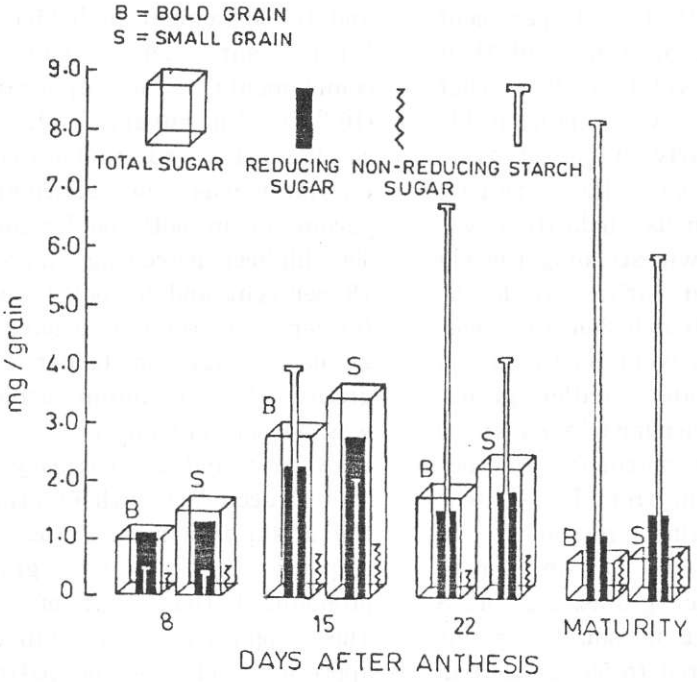

Fig. 1: Relative levels of starch, total sugars, reducing and non-reducing sugars (mg/grain) in bolder (B) and smaller (S) grains within the same ear of *Fagopyrum esculentum* at different intervals of time after anthesis.

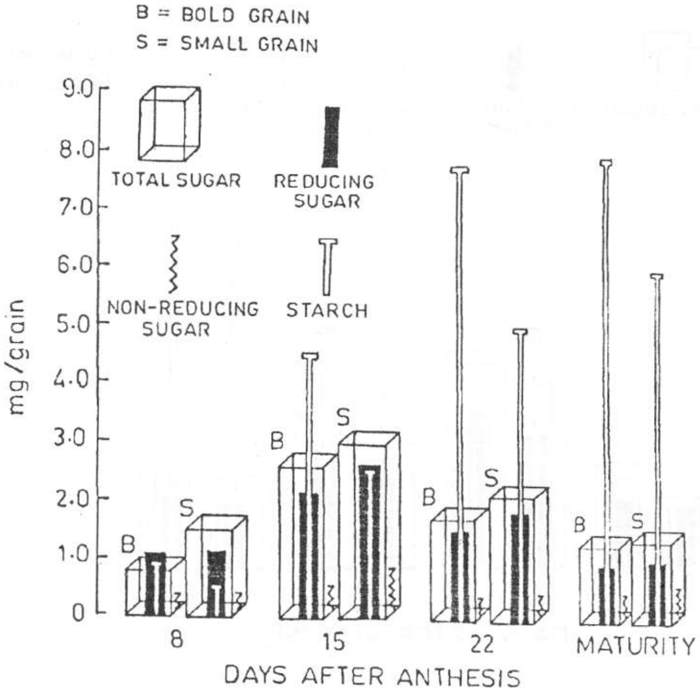

Fig. 2: Relative levels of starch, total sugars, reducing and non-reducing sugars (mg/grain) in bolder (B) and smaller (S) grains developing within the same ear of *Fagopyrum esculentum* at different intervals of time after anthesis under the influence of auxin.

was in the range of 9 to 64 per cent depending upon the type of grain and their age. The interesting revelation was that relatively more starch was precipitable through PGRs at the early stages of grain development. At harvest, the increase achievable through exogenous application was of a significant level, notwithstanding the big jump which was recorded earlier. With the application of auxin (indole-3-acetic acid, 10^{-5}M), the level of starch went up by 58 and 64 per cent in bolder and smaller grains, respectively. The figures declined to 7.7 and 9 per cent, respectively, at maturity. Another notable aspect (as apparent from Fig. 1) was that the smaller grains responded to exogenous application of auxin more vigorously than the bolder grains, e.g., at 8 days stage, the increment in smaller grains was 64 per cent as compared to 58 per cent in bolder grains over their respective placebos; at the 15 day stage, it was 16 and 9 per cent in small and bold grains respectively, while at 22 days, the data did not follow the set pattern and the increment in bolder grains was 7 and 9 per cent more than their untreated complements. The application of kinetin (10^{-6}M) also enhanced the levels of starch significantly and undoubtedly this growth regulator was more efficient in boosting this parameter in both bolder and smaller grains. The highest percentage increase recorded was 78 per cent and lowest 12 per cent, with the former recoverable at 8 days and the latter at 22 days stages in bolder grains. In smaller grains, the maximum achievable increment was 44 per cent and the minimum 13 per cent at 8 days and at maturity respectively. The overall accretion with kinetin was higher over the auxin treatment series and here, too, the response of smaller grains was more pronounced than that of the bolder grains. The application of gibberellin did not appreciably change the pattern of starch and occasionally, it tended to diminish the net levels of starch. The data has thus been precluded from the line drawings.

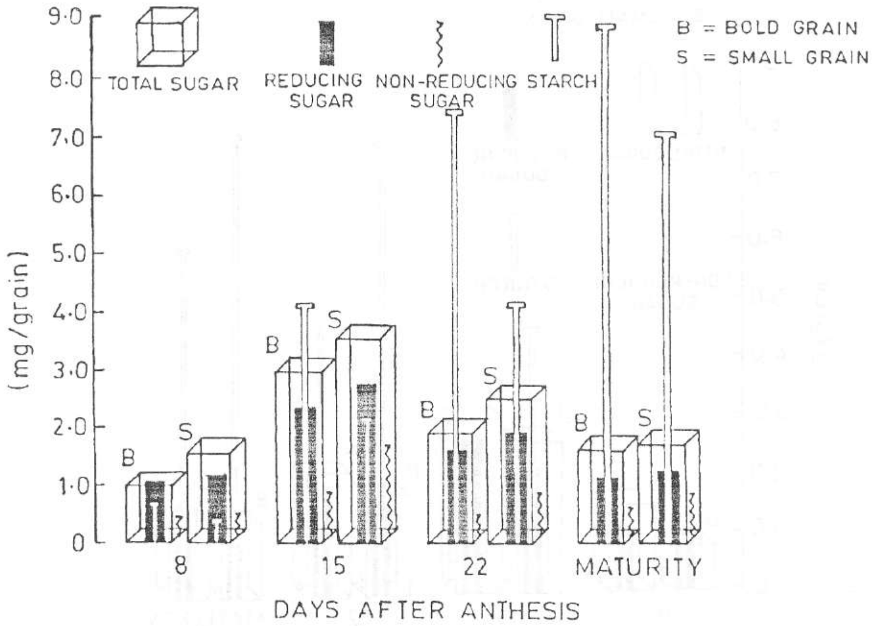

Fig. 3: Relative levels of starch, total sugars, reducing and non-reducing sugars (mg/grain) in bolder (B) and smaller (S) grains developing within the same ear of *Fagopyrum esculentum* at different intervals of time after anthesis under the influence of kinetin.

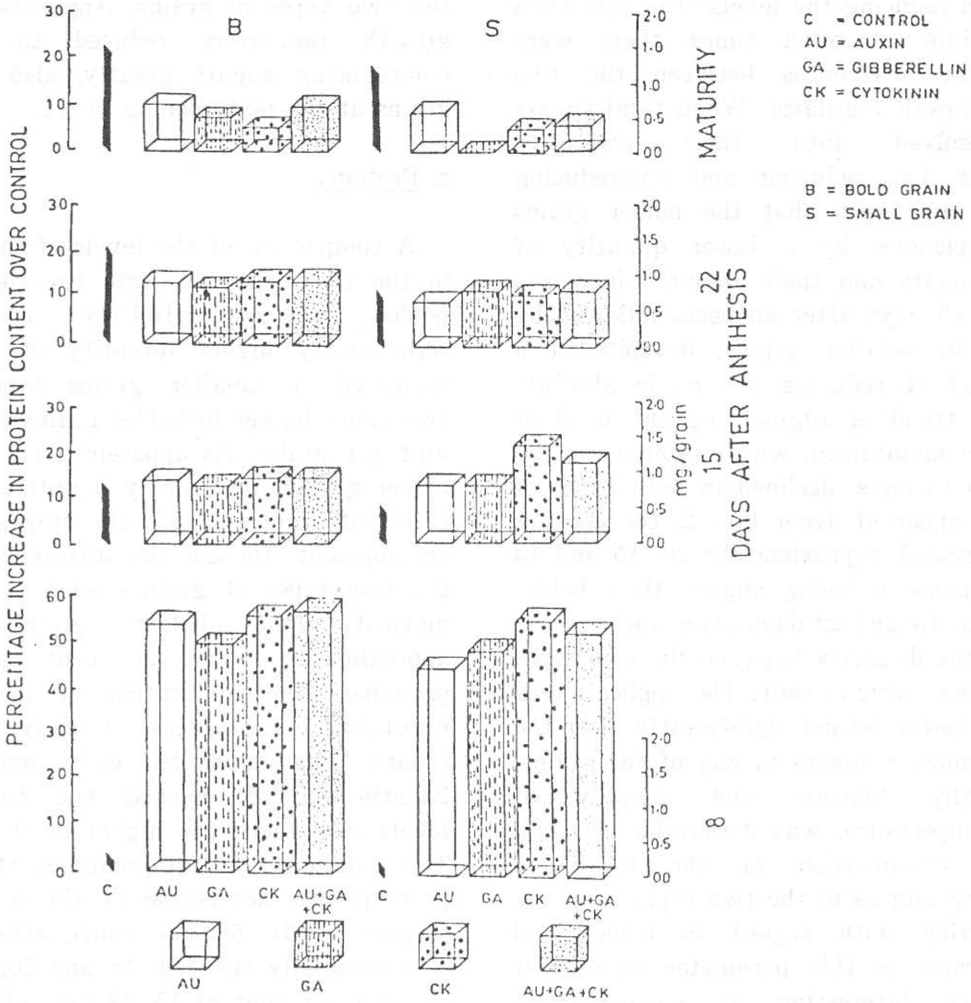

Fig. 4: Relative levels of starch, total sugars, reducing and non-reducing sugars (mg/grain) in bolder (B) and smaller (S) grains developing within the same ear of *Fagopyrum esculentum* at different intervals of time after anthesis under the influence of different growth regulators.

b) Total, reducing and non-reducing sugars:

The level of total sugars in both types of grains increased initially (up to 15 days) followed by a gradual decline and at maturity the grains were endowed with the lowest level of total sugars. The two types of grain possessed a striking disparity in the levels of total sugars (as apparent in Fig. 1, 2 and 3). The smaller grains possessed a relatively higher level of total sugars against the bolder grains at all stages of grain development. The maximum disparity between the two types of grains existed at the initial stages, when the smaller grains contained approximately 44 per cent more sugars than the bolder grains. The disparity tended to narrow around 15 days but subsequently again reflected a bigger gap around 22 days after anthesis (as evident from Fig. 1, the gaps were 14 and 29 per cent with small grains possessing more sugars at 15 and 22 days after anthesis). The two types of grains consistently showed approximately 5 per cent more sugars than bolder grains. The application of auxin (IAA, 10^{-5}M) or kinetin (10^{-6}M) significantly reduced the levels of total sugars in both types of grain. Occasionally, auxin appeared to be more effective in reducing the levels of sugars than kinetin while, at other times, there were insignifficant differences between the two types of growth regulator. When total sugars were resolved into their respective constituents i.e., reducing and non-reducing sugars, it was seen that the bolder grains were conspicuous by a lesser quantity of reducing sugars and their amounts increased from 8 to 15 days after anthesis, followed by a decline. In smaller grains, in spite of a higher level of reducing sugars, in absolute terms the trend in augmenting the level of sugars was maintained, which after an initial rise (up to 15 days) declined in both types of grain. As apparent from Fig. 2, the smaller grains possessed approximately 20, 15 and 14 per cent more reducing sugars than bolder grains at 8, 15 and 22 days after anthesis. At maturity, the disparity between the two types of grains was insignificant. The application of auxin or kinetin did not significantly alter the level of reducing sugars in any of the grains. A noteworthy feature, and possibly of immense importance, was discernible through a parallel examination of the levels of non-reducing sugars in the two types of grain. The disparity with regard to bolder and smaller grains in this parameter was great and highly interesting as compared to reducing sugars. As apparent from Fig. 3, its level was approximately 100 per cent more in smaller grains at initial stages as well as at the mid-ripening stage (22 days after anthesis). Application of auxin or kinetin significantly reduced the levels of non-reducing sugars more in the smaller grains than in the bolder grains and this was more pronounced at the mid-ripening stages. A comparison between the two types of growth regulator proved auxin to be more efficient than cytokinin. It appears that the bolder grains were conspicuous with low levels of non-reducing sugars as compared to smaller grains and this dominant component of sugars remained unused and acted as an untapped reservoir in the smaller grains, as compared to reducing sugars, whose levels offered significant but comparatively less disparity in the two types of grains. Application of plant growth regulators reduced the level of non-reducing sugars greatly, also in smaller grains at the mid-ripening stage.

c) Proteins:

A comparison of the levels of total proteins in the two types of grain revealed that the bolder grains definitely contained a significantly higher quantity of proteins as compared to smaller grains (approximately two times higher in bolder grains expressed as unit per grain). As apparent from Fig. 4, the bolder grains consistently maintained a higher level of proteins at all stages of grain development, though the differences between the two types of grain tended to narrow (at maturity the bolder grains possessed approximately 30 per cent more total proteins). The application of plant growth regulating substances, namely auxin or kinetin, augmented the endogenous proteins. Kinetin (10^{-6}M) pushed the total protein levels to a relatively higher level than auxin. The maximum enhancement in the level of proteins was detectable at the 8 days stage, (approximately 58 per cent), after which it was gradually reduced (16 and 20; 11 and 13; 7 and 7 per cent at 15, 22 days after anthesis and at maturity in bold and small grains respectively). Interestingly, the level of increment at maturity in the two types of grain was of the same order while at other stages, growth regulators elicited a better response from smaller grains.

Discussion

The harvest index precipitable in the mothershoot of a crop like buckwheat is governed by various factors, e.g. number of grains per ear as well as the single grain weight. These two factors contribute almost equally to the total build-up of the yield and a significant depreciation in the efficiency of either of these attributes diminishes the yield proportionately. In other words, any effort directed at improving the efficiency of these parameters, singly or jointly, will go a long way towards achieving a higher economic yield in *Fagopyrum*, which has gained immense economic importance since the beginning of the 20th century due to its protein rich grains and the potential of the foliage to be consumed as a green vegetable. Physiological research into cereals and related crops have been concentrated for the last fifty years or so in discovering means of isolating and improving the factors responsible for precipitating a higher grain yield. Percival (1921) mooted the idea that the differences in grain yield were attributable to numerous factors, such as leaf area duration and/or competition among the developing grains while photosynthesis as a major factor behind higher yield ability has been held responsible by other workers (Birecka & Wlodkoswaka 1966, Wellbank et al. 1966, Watson 1952, Asana and William 1965, Asana et al. 1969, Rawson and Ruwali 1972). Work done on wheat in our laboratory has unequivocally shown that the constant presence of the two types of grains in the ear, had many desirable and undesirable components supporting this malady (Dua and Bhardwaj 1979a,b; Dua 1980; Dua and Sehgal 1981; Dua et al. 1982, 1983). Briefly, it has been established that smaller sinks (grain) have a different metabolic profile compared to more efficient sinks (bolder grains) and the chain of metabolic events in the two types of grains is pre-determined and under the control of regulatory hormones (Dua and Kalsi 1991). Recent findings from our laboratory (Dua et al. 1990) have demonstrated that in addition to endogenous hormones there is an involvement of calcium ions/ calmodullin which acted as second messenger and operated at a low level in relatively poorly developing sinks. In corresponding studies, the work done on the grains of *Fagopyrum* (Dua et al. 1990) there was also a clear disparity in the different grains of *Fagopyrum* and smaller grains, developing in the vicinity of the larger grains, reflected a variation with regard to the status of endogenous promoters. The former contained fewer total auxins and cytokinins and the differences were relatively easily measured through bio- and chemical assays. Further, an exogenous application of these growth regulators at anthesis proved significantly beneficial and boosted their growth potential, especially in smaller grains. The findings in the present paper are a further step in enumerating the possible causes of smallness in grains in the ear of *Fagopyrum* with a concomitant explanation of boldness of other grains developing in the same ear. From the results in the preceding section, it is apparent that smaller grains have low levels of starch vis-a-vis a high level of total sugars and in the latter, non-reducing sugars predominate and cannot be converted into starch, with a reverse picture in the bolder grains, where a high level of starch with low level of non-reducing sugar was the major diagnostic feature. It seemed that there was a blockage in the conversion of sugars (especially non-reducing to polysaccharides), also at the post anthesis stage or at the mid-ripening stage. The blockage might be due to a lack of hormones, since an exogenous application of auxin (indole-3-acetic acid, 10^{-5} M) or kinetin (10^{-6} M) improved the level of the starch in the grains with a corresponding decrease in the activity of non-reducing sugars. The transmission might have been triggered by an increase in the level of certain synthetase enzymes which in-turn charged up the efficiency of starch returning system. Exogenously applied bio-regulators elicited a better response from the smaller grains, probably because there was a larger untapped quantity of non-reducing sugars available or due to the sub-optimal level of endogenous regulators in these grains, besides the level of these different polysaccharides; mono-, di- and polysaccharides. The results available from the exogenous application of auxins and cytokinins, show that these biochemical constituents also appreciated under the influence of these growth regulators and were conducive to an increase in the economic yield under field and pot culture experiments (Dua et al. 1990).

To conclude, the present data support the contention that poorly developed grains in ears of *Fagopyrum* are due to the lack of certain physiological parameters which operate at sub-optimal levels and the saccharide metabolism seems definitely to be one of these which determined the ultimate productivity in entirety. The blockage of non-reducing sugar transformation or the poor rate of its conversion to complex saccharides, seems to be regulated by endogenous hormones, which transmit these signals through regulatory enzymes whose levels are being studied and will be reported in our subsequent communication.

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Mutation studies in buckwheat (*Fagopyrum*) III. Effect of gamma rays on growth parameters and yield attributes.

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Key words: *F. esculentum*, *F. tataricum*, inflorescence, kernel, leaf, optimum radiation dose, yield attributes.

Abstract

Gamma rays from a cobalt-60 source were used to irradiate seeds of *F. esculentum* and *F. tataricum* at different doses. Irradiation hastened the expansion of the first true leaf up to 10 kR, whereafter there was progressive delay. Lower doses of radiations, up to 15 kR, in general increased the height of plants after which there was a regular and steep fall in plant height. The effect of radiation on induction of branching was not consistent. Radiation doses up to 15 kR hastened 50 % flowering. There was an improvement in the number of kernels per plant up to 15 kR after which a fall was noticed. Yield per plant increased up to a dose of 20 kR in *F. esculentum* and up to 15 kR in *F. tataricum*. It decreased sharply beyond these doses. Harvest indices increased up to 15 kR in both species.

Mutacije pri ajdi. III. Vpliv gama žarkov na parametre rasti in na pridelek

Z različnimi odmerki gama žarkov vira kobalt-60 smo obsevali semena navadne in tatarske ajde. Sevanje je do odmerka 10 kR pospešilo rast prvega pravega lista, pri višjih odmerkih pa je rast hitro upadla. Nižji odmerki sevanja (do 15 kR) so na splošno vplivali na višjo višino rastlin, pri še višjih odmerkih pa je višina hitro upadla. Vpliv sevanja na razvejanje ni bil značilen. Nižji odmerki sevanja (do 15 kR) so pospešili sredino cvetenja in povečali število semen na rastlino, zadnje je pri še višjih odmerkih hitro upadlo. Pridelek je bil povečan vse do 20 kR pri navadni ajdi in do 15 kR pri tatarski ajdi, pri višjih odmerkih pa je hitro upadel. Pri obeh vrstah je bil indeks žetve izboljšan pri odmerkih do 15 kR.

Material and methods

Seeds of *F. esculentum* and *F. tataricum* treated with 5, 10, 15, 20, 25, 30 and 40 kR gamma rays from cobalt-60 source along with a control (untreated), were sown in well prepared plots to raise the M1 generation. Growth parameters were recorded at an interval of 7 days. Days to flowering was recorded when the first flower appeared in approximately 50 % plants in each treatment. The harvest index was calculated by the following formula

$$\text{Harvest index} = \frac{\text{Grain yield per plant}}{\text{Biological yield per plant}} \times 100$$

Results and discussion

The number of days to the expansion of the first true leaf showed the same trend in both *F. esculentum* and *F. tataricum* (Table 1). Lower doses of gamma radiations (5, 10 and 15 kR) significantly reduced the number of days for the expansion of first true leaf, the optimum dose being 10 kR and 15 kR for *F. esculentum* and *F. tataricum* respectively. Sharma and Boyes (1962) reported that lower doses of X-rays and thermal neutron radiations significantly reduced the number of days to expansion of the first true leaf. According to them, N-10 treatment took the least time, with a very significant deviation of 1.82 days from the control. They also reported a highly significant delay in the X-40 and N-20 to N-33.5 treatments, whereas the X-30 treatment did not differ significantly from the control.

Table 2 depicts the height of plants on 80 DAS (days after sowing). It suggests that plants of *F. esculentum* were taller than those of *F. tataricum* and in general, lower doses of gamma rays caused an increase in plant height while higher doses retarded it. 15 kR was the optimum dose for plant height on 80 DAS for *F. esculentum* while it was 10 kR for *F. tataricum*.

Koblev (1981) has discussed prospects for the use of short forms in buckwheat breeding. According to him, short stature has been found to confer a number of useful characteristics viz. limited growth, better leaf and root development and high resistance to lodging. Kirilenko and Alekseeva (1983) have discussed the use of dwarf forms in breeding buckwheat. They found that a dwarf type with short internodes and a higher than normal number of inflorescence is a useful donor in breeding buckwheat for lodging resistance and high yield. Zeleznov (1970) found dwarf forms with shortened internodes in M2 of the buckwheat seeds treated with gamma ray doses of 1, 5, 10 and 15 kR. Dubey (1973) observed that 30 KR doses of gamma rays and X-rays were most effective in retarding the normal growth of bread-wheat. Different explanations have been given for the reduction in growth and vigour, some being based purely on physiological and others on cytological implications. Caldecott (1960) observed a correlation between seedling injury and genetic damage caused by X-rays and other radiations. Sparrow *et al.* (1952) attributed reduction in growth-vigour to chromosomal damage and mitotic inhibition. Inhibition in mitosis is one of the reasons for reduced growth. Marshak and Bradley (1944) observed inhibition of mitosis by X-ray in polyploid *Triticum* species. Woodstock and Justice (1967) reported that the mechanism of radiation damage is through inhibition of the respiratory system.

As regards the branching behaviour of treated plants in M_1 and M_2 generations, Table 3 indicates that there was no consistency in the number of primary branches in response to an increase in radiation dose. The effect was predominant in higher doses as against the lower ones. In some cases, especially in *F. esculentum*, the number of branches improved in M_3 as compared to M_1 and M_2. Maximum branching was at 20 kR and 15 kR in *F. esculentum* and *F. tataricum* respectively. At higher doses, the branching was markedly inhibited and a minimum number of branches was recorded at 40 kR in both species. Present findings are supported by similar reports in certain other plants. Malaviya (1984) and Sharma and Sharma (1979) have also observed that the number of branches was significantly affected in lentil at increased dose of gamma rays.

It is apparent from Table 4 that 50% flowering was hastened by lower doses (up to 15 kR of gamma rays). Higher doses produced progressive delay in 50% flowering. Malaviya (1984) has reported that the flowering was progressively delayed in lentil at higher doses. It may be mentioned It is apparent from Table 4 that 50% flowering was hastened by lower doses (up to 15 kR of gamma rays). Higher doses produced progressive delay in 50% flowering. Malaviya (1984) has reported that the flowering was progressively delayed in lentil at higher doses. It may be mentioned here that the plants of M_3 generation at almost all doses showed earlier 50% flowering than M_1 and M_2 which may be due to repair in the initial genetic damage.

Tables 5, 6 and 7 show the yield attributes (No. of kernels per plant, yield per plant and harvest indices). The number of kernels, on average, increased in both species up to a dose of 15 kR, after which there was a reduction, from 20 kR to 40 kR, 15 kR being the optimum dose (Table 5). *F. tataricum* gave a higher number of kernels in comparision to *F. esculentum.* Lower doses increased the number of kernels per plant up to a dose of 15 kR in *F. esculentum* while in *F. tataricum* the optimum dose was 10 kR.

Table 6 suggests that there was a sharp fall in the yield per plant beyond a dose of 15 kR. In X-ray and thermal neutron exposed plants of buckwheat, Sharma and Boyes (1962), have reported that the overall seed set percent was higher in the control than in any of the treatments except for X-5 where the apparent apomictics were excluded and here the difference was insignificant. Dubey (1973) working on wheat, found that higher doses i.e. 30 kR of gamma rays reduced grains per spike considerably. Roik (1979), selected an useful new mutant by combining treatments with X-ray and chemical mutagen. It was a large grained form with a 1000-seed weight of 30-45 g and single stemmed form. Alekseeva (1979) obtained a high yielding mutant by treatment with 20-40 kR gamma rays. Alekseeva (1984a) further reports that the varieties 'Aelita' and 'Lada' were bred by selection for higher yield among some of the mutants induced by gamma rays. Alekseeva (1984b) reports yet another variety (Podolyanka) bred with radiation treatment. She has obtained mutants with good grain quality bred by gamma irradiation (20-30 kR). Zeleznov (1970) obtained high yielding buckwheat forms in M2 from seeds treated with doses of 1, 5, 10 and 15 kR of gamma rays.

The harvest index, an index of the transportability of photosynthates from source to sink, was also markedly influenced by radiation treatment (Table 7). In *F. esculentum*, lower doses up to 15 kR improved the harvest index from 35.3 % in the control to as high as 39.6 % at 15 kR, the rise being about 12.5 %. Thereafter, there was a very steep fall from 39.6 % at 15 kR to a mere 12.5 % at 40 kR. In the case of *F. tataricum* the appreciation in harvest index was from 52.4 % in the control to 58.3 % at 15 kR. But under doses higher than 15 kR, a decline set, from 58.3 % at 15 kR to 27.8 % at 40 kR. In the case of *F. tataricum*, the appreciation in the harvest index was from 52.4 % in the control to 58.3 % at 15 kR. But under doses higher than 15 kR decline set in, from 58.3 % at 15 kR to 27.8 % at 40 kR. There was a marginal reduction in the harvest index (38.2 %) in M2 from M1 (40.1 %), otherwise the trend in M2 was more or less similar to that in the M1 generation. The interaction between species and radiation doses was not significant in M2 unlike that in M1. There was no further reduction in the harvest index in M3 (38.6 %) as compared to M2 (38.2 %). Both species showed an increase in harvest index from 5 kR to 15 kR, whereafter it declined markedly. However, the harvest index in *F. tataricum* continued to be higher than in *F. esculentum* at all doses of radiations.

According to Bhatia and Jagannath (1970) induced variability in the mutagen treated population has invariably yielded a higher selection response, although for certain characteristics approaching the extreme limit for the species, the selection response may be highly asymetric. Brock (1965, 66, 72) pointed out that for quantitative characters governed by polygenes, random mutation in an unselected population results in a shift in the mean away from the direction of previous selections, so the selection response in a treated population is greater in the direction opposite to that of previous selection. According to Gaul and Aastveit (1966) random mutation results in a change of the mean in a direction which is correlated with vitality reduction and the response to mutagens is largely independent of the genotype.

Table 1: Days to expansion of first leaf

Dose Rate	M_1 F.esc.	M_1 F.tat.	M_1 Mean	M_2 F.esc.	M_2 F.tat.	M_2 Mean	M_3 F.esc.	M_3 F.tat.	M_3 Mean
Control	16.6	15.2	15.9	15.0	15.0	15.0	16.0	14.5	15.2
5 kR	15.4	14.0	14.7	15.2	13.2	14.2	15.5	13.0	14.2
10 kR	13.5	13.3	13.4	12.8	13.0	12.9	14.2	12.7	13.4
15 kR	15.7	12.5	14.1	14.0	13.0	13.5	14.8	13.0	13.9
20 kR	16.2	13.0	14.6	16.4	13.5	15.0	16.8	12.8	14.8
25 kR	18.0	15.3	16.6	18.3	15.0	16.6	17.7	15.4	16.6
30 kR	24.0	19.4	21.7	22.9	19.2	21.0	21.0	18.0	19.5
40 kR	30.3	26.4	28.4	28.0	24.5	26.2	27.0	23.8	25.4
Mean	18.7	16.1	17.4	17.8	15.8	16.8	17.9	15.4	16.6
	SE(Mean)	C.Dat 5%		SE(Mean)	C.D. at 5%		SE(Mean)	C .D. at 5%	
*S	± 0.142	0.399		± 0.130	0.367		± 0.131	0.369	
T	± 0.283	0.798		± 0.261	0.735		± 0.262	0.739	
SXT	± 0.400	Not sig.		± 0.369	Not sig.		± 0.371	Not sig.	

*S = species, T = treatments, SXT = species x treatment interaction

Table 2: Plant height 80th day (cm)

DOSE RATE	M1 F.esc.	M1 F. tat.	M1 Mean	M2 F.esc.	M2 F.tat.	M2 Mean	M3 F.esc.	M3 F.tat.	M3 Mean
Control	48.2	27.8	37.6	53.0	30.7	41.8	51.7	33.0	42.3
5 kR	48.7	28.5	38.6	50.8	31.5	41.1	53.0	22.7	52.8
10 kR	54.0	34.3	44.1	52.2	37.4	44.8	55.5	39.8	47.6
15 kR	59.0	30.2	44.6	57.0	34.1	45.5	59.9	32.8	46.3
20 kR	52.0	27.9	39.9	51.0	29.3	40.1	54.0	29.5	41.7
25 kR	44.2	24.4	34.3	45.0	24.1	34.5	47.2	23.0	35.1
30 kR	39.3	20.8	30.3	36.0	21.5	28.7	38.0	19.5	28.7
40 kR	23.7	17.7	20.7	24.0	18.5	21.2	15.5	17.8	21.6
Mean	46.1	26.4	36.2	46.1	28.4	37.2	48.1	28.5	38.3
	S.E. (Mean)	C.D. at 5%		S.E. (Mean)	C.D. at 5%		S.E. (Mean)	C.D. at 5 %	
*S	± 0.163	0.458		± 0.198	0.559		± 0.201	0.566	
T	± 0.325	0.916		± 0.397	1.117		± 0.401	1.131	
SXT	± 0.460	1.296		± 0.560	1.580		± 0.567	1.510	

*S = species, T = treatments, SXT = species x treatment interaction

Table 3: No. of branches (First order)

	M1			M2			M3		
DOSE RATE	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean
Control	3.6	4.7	4.2	4.0	4.8	4.4	4.2	5.0	4.6
5 kR	3.5	4.8	4.2	4.5	4.5	4.5	5.0	5.2	5.2
10 kR	3.4	4.6	4.0	3.2	4.0	3.6	4.8	5.1	4.9
15 kR	3.1	4.8	4.0	3.4	4.7	4.0	3.8	5.0	4.4
20 kR	4.0	4.6	4.3	4.7	4.8	4.8	5.2	4.8	5.0
25 kR	3.0	3.9	3.4	3.1	3.6	3.4	3.2	4.2	3.7
30 kR	2.8	3.0	2.9	2.7	3.2	3.0	2.5	3.7	3.1
40 kR	2.3	2.4	2.4	2.5	2.8	2.6	2.4	3.0	2.7
Mean	3.2	4.1	3.6	3.5	4.0	3.8	3.9	4.5	4.2

	S.E. (Mean) C.D. at 5%	S.E. (Mean) C.D. at 5%	S.E. (Mean) C.D. at 5%
*S	± 0.045 0.126	± 0.053 0.150	± 0.041 0.123
T	± 0.089 0.252	± 0.107 0.300	± 0.088 0.246
SXT	± 0.127 0.357	± 0.151 0.425	± 0.123 0.347

*S = species, T = treatments, SXT = species x treatments

Table 4: Days to 50% flowering

	M1			M2			M3		
DOSE RATE	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean	F. esc.	F.tat.	Mean
Control	41.5	43.7	42.6	42.0	43.3	42.6	41.0	42.8	41.9
5 kR	38.4	42.0	40.2	39.0	41.7	40.4	39.6	41.0	40.3
10 kR	38.2	41.3	39.8	38.0	41.0	39.5	37.6	41.2	39.4
15 kR	37.2	41.5	39.4	37.0	41.7	39.4	36.7	41.1	38.9
20 kR	39.0	42.7	40.8	38.3	42.3	40.3	38.4	42.0	40.2
25 kR	42.7	44.5	43.6	42.0	44.0	43.0	41.0	44.2	42.6
30 kR	44.0	45.6	44.8	44.4	45.4	44.9	43.7	45.4	44.6
40 kR	51.3	54.4	52.8	51.0	53.2	52.1	50.1	49.0	49.6
Mean	41.5	44.5	43 .0	41.4	44.0	52.7	41.8	43.3	42.2

	S.E. (Mean) C.D. at 5%	S.E. (Mean) C.D. at 5%	S.E. (Mean) C.D. at 5%
*S	± 0.168 0.474	± 0.200 0.566	± 0.145 0.410
T	± 0.337 0.948	± 0.401 1.131	± 0.291 0.820
SXT	± 0.476 Not sig.	± 0.569 Not sig.	± 0.411 Not sig.

*S = species, T = treatments, SXT = species x treatment interaction.

Table 5: No. of kernels per plant

DOSE		M1			M2			M3	
RATE	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean
Control	280.8	410.3	345.6	230.3	427.5	328.9	310.9	452.4	381.6
5 kR	298.2	415.7	357.0	240.8	430.8	335.8	320.0	472.5	396.2
10 kR	346.4	468.0	407.7	370.7	475.8	423.2	345.8	487.7	416.8
15 kR	342.3	479.9	411.1	367.6	489.3	428.4	382.0	492.4	437.2
20 kR	310.0	380.3	345.2	318.3	320.1	319.2	325.4	342.9	334.2
25 kR	200.9	280.2	240.6	210.1	289.1	249.6	213.2	310.3	261.8
30 kR	117.8	189.4	153.6	123.9	200.5	162.2	150.2	213.6	181.8
40 kR	23.1	89.4	56.2	41.0	93.5	67.2	99.2	58.4	78.8
Mean	240.1	339.2	289.6	237.8	340.8	289.3	268. 3	353.8	311.0

	S.E. (Mean)	C.D. at 5%	S.E. (Mean)	C.D. at 5%	S.E. (Mean)	C.D. at 5%
*S	± 0.426	1.203	± 0.642	1.811	± 3.736	not sig.
T	± 1.702	4.810	± 1.285	3.623	± 7.472	not sig.
SXT	± 3.405	not sig.	± 1.187	5.123	± 10.566	not sig.

*S = species, T = treatments, SXT = species x treatment interaction

Table 6: Yield per plant (g)

DOSE		M1			M2			M3	
RATE	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean	F.esc.	F.tat.	Mean
Control	7.6	11.8	9.7	6.6	12.9	9.8	9.4	14.0	11.7
5 kR	8.2	12.2	10.2	7.1	13.1	10.1	9.8	14.8	12.2
10 kR	10.0	14.5	12.2	11.3	15.6	13.4	10.4	16.0	13.2
15 kR	10.2	14.3	12.2	11.8	14.9	13.4	12.2	15.2	13.7
20 kR	9.4	10.2	9.8	9.2	8.7	9.0	9.6	9.6	9.6
25 kR	5.4	7.0	6.2	5.9	7.3	6.6	6.4	8.1	7.2
30 kR	2.8	4.4	3.6	3.1	4.8	4.0	4.0	5.3	4.6
40 kR	0.5	1.9	1.2	0.9	2.0	1.4	2.2	1.3	1.8
Mean	6.8	9.5	8.2	7.0	10.0	8.4	7.0	10.5	9.3

Table 7: Harvest indices (per cent)

DOSE RATE	M1 F.esc.	M1 F.tat.	M1 Mean	M2 F.esc.	M2 F.tat.	M2 Mean	M3 F.esc.	M3 F.tat.	M3 Mean
Control	35.3 (33.4)	52.4 (62.9)	43.9 (48.1)	31.7 (27.7)	52.5 (62.9)	42.1 (45.3)	37.2 (36.9)	51.6 (61.4)	44.4 (49.2)
5 kR	35.8 (34.3)	48.6 (56.4)	42.2 (45.3)	31.8 (27.8)	47.9 (57.0)	39.8 (42.4)	36.9 (36.1)	47.6 (54.5)	42.2 (45.3)
10 kR	36.8 (35.9)	56.1 (69.1)	46.5 (52.5)	37.6 (37.2)	55.8 (68.4)	46.7 (52.8)	34.3 (30.7)	51.6 (61.5)	42.9 (46.1)
15 kR	39.6 (40.7)	58.3 (72.4)	48.9 (56.5)	41.3 (43.7)	57.4 (67.8)	49.4 (55.7)	40.7 (43.6)	51.7 (61.8)	46.2 (52.7)
20 kR	39.1 (39.9)	53.2 (64.1)	46.1 (52.0)	37.4 (37.0)	42.8 (46.1)	40.1 (41.6)	39.7 (40.9)	43 .5 (43.8)	41.6 (42.3)
25 kR	32.7 (29.2)	46.0 (51.8)	39.4 (40.5)	32.2 (28.0)	41.7 (44.4)	37.0 (36.2)	33.4 (30.3)	42.2 (45.2)	37.8 (37.8)
30 kR	25.3 (18.3)	41.7 (44.3)	33.5 (31.3)	25.8 (19.0)	38.0 (38.0)	31.9 (28.5)	29.1 (23.8)	35.2 (33.3)	32.2 (28.6)
40 kR	12.5 (4.7)	27.8 (21.9)	20.1 (13.3)	16.1 (7.7)	21.0 (20.2)	18.5 (14.0)	(23.7) (16.2)	18.7 (10.3)	31.2 (13.1)
Mean	32.2 (29.6)	48.0 (55.4)	40.1 (42.5)	31.8 (29.6)	44.6 (50.6)	38.2 (40.1)	34.4 (32.4)	42.8 (46.0)	38.6 (39.5)
	S.E. (Mean) C.D. at 5%			S.E.(Mean) C.D. at 5%			S.E.(Mean) C.D. at 5 %		
*S	± 0.176 0.497			± 0.537 1.515			± 0. 317 0.893		
T	± 0.352 0.992			± 1.075 3.030			± 0.634 1.787		
SXT	± 0.498 1.23 8			± 1.520 Not sig.			± 0.896 2.527		

Note: Figures in paranthesis denote transformed back values in percentage.

*S = species, T = treatments, SXT = species x treatment interaction

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Pollination biology and reproductive ecology for improving genetics and breeding of common buckwheat, *Fagopyrum esculentum* (2)

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Key words: breeding system, competition, environment, evolution, floral traits, foraging behavior, pollination, pollinator, seed production, self-incompatibility, self-compatibility

Abstract

Common buckwheat (*Fagopyrum esculentum* Moench) is one of the most typical cultivated plants with flowers displaying dimorphic heterostylous self-incompatibility and outcrossing, i.e., legitimate pollination between different flower types, pin and thrum. The present paper briefly reviews the development of knowledge of the following two topics as elements of the pollination biology and reproductive ecology of buckwheat, in order to improve techniques of breeding, seed growing and cultivation of buckwheat on the basis of the nature of the breeding system and its evolutionary significance, and which has resulted in increasing the adaptability as well as the grain yield and quality: (a) Foraging behavior of pollinators and adaptive nature of floral traits, (b) Evolution, maintenance, and loss of self-incompatibility. The importance of rapid development of pollination biology and/or reproductive ecology in all plant species, especially outcrossing cultivated ones, is especially stressed.

Biologija oprašitve in ekologija razmnoževanja za požlahtnitev ajde

Ajda ima med poljščinami najbolj značilen dimorfizem cvetov in samoinkompatibilnost. Legitimna je le oprašitev med cvetovi različnega tipa. V prispevku je kratek pregled razvoja znanja na področjih biologije oprašitve in ekologije razmnoževanja ajde, da bi tako izboljšali žlahtnjenje, semenarstvo in pridelovanje ajde. To mora biti ustrezno zasnovano na razvojno pogojenem načinu razmnoževanja. Način razmnoževanja omogoča široko prilagodljivost, kot tudi višino pridelka in njegovo kakovost. Pomemben je: (a) način prehranjevanja opraševalcev in temu prilagojene lastnosti cvetov, (b) nastanek, ohranjevanje in izguba samoinkompatibilnosti. Poudarjen je tudi pomen razvoja biologije opraševanja in ekologije razmnoževanja pri vseh vrstah rastlin, zlasti pa še pri gojenih tujeprašnicah.

6. Foraging behavior of pollinators and the adaptive nature of floral traits in buckwheat

As mentioned in section 3 of a previous paper (Namai 1990), the pollinator-flower system has served us well in the quest for establishing general concepts in animal foraging behavior. Information on pollinator foraging behavior may also be important in studies of floral structure population and community structure. Foraging behavior is a result of intrinsic factors, including the animal's evolutionary history and its own experiences, and extrinsic factors, which must also be known to predict an animal's behavior in a novel floral array (Waddington 1983). From such a point of view, the followings are the main problems in studying the adaptive nature of floral traits (Waser 1983): (1) what species visit a plant, and where do they come from? (2) how do flower visitors behave once at the plant? (3) what do flower visitors do after leaving the plant?

Honeybees can discriminate about 5% differences in sucrose concentration within the normal range of nectar concentration (Waller 1972), and they detect solutions as low as 2-4% of sugar (von Frish 1967). Bumblebees leaving these inflorescences with high rewards flew short distances (about 20 cm in flight distance after visiting nectar-rich inflorescences with more than 1.2 µl in nectar volume), whereas relatively long flights were made after visits to nectar-poor inflorescences (about 40-50 cm in flight distance after visiting nectar-poor inflorescences with less than 0.6 µl in nectar volume) (Waddington 1981).

In buckwheat plants, Sugawara (1958) described a strong correlation between the incidence of retarded pistil development, giving rise to female sterility and unfavourable photoperiodic conditions (long-day). Under long-day conditions, most varieties produced frequent abnormal stigmas. Pausheva (1965) noted a succession in opening of the flowers, the short-styled flowers remaining open for a shorter period than the long and considerable differences between individual plants. Her observations coincide well with my own data, shown in Tables 3 to 6, which indicate that a short-styled thrum flower tends to be well pollinated and produces many mature seeds. It is a well known phenomenon that flowers of many plant species do not remain constant in form or color when legitimate pollination or fertilization occurs; following pollination or fertilization, they fade and become unattractive to pollinators. It is also shown that with legitimate pollination of long-styled flowers effected at different times of the day, the best set is obtained with pollen collected and applied immediately after dehiscence of the anthers. Naumova (1976) observed that the ratio of long-styled (L) to short-styled (S) plants in varieties varied between 1:0.88 and 1:1.37, and L and S plants differed in their grain yield, namely a shortage of legitimate pollen led to poor fruiting in both forms and especially poorer in the case of L plants. I believe that under the condition of a lack of pollinators, the long period of opening and poorer seed fruiting in the long-styled pin flowers is quite reasonable on the basis of data mentioned in section 5 of the previous paper (Namai 1990).

Gorina and Anokhina (1978) clearly reported that there were great intervarietal differences in nectar production of buckwheat, and environmental conditions, especially low temperature, had a greater effect on nectar production in early varieties than in mid-season and late ones. Kopeljkievskii *et al.* (1978) described that nectar production was correlated with grain yield (r=0.92), number of fruits per plant (r=0.83) and the frequency with which bees visited the flowers (r=0.64), and Kopeljkievskii et al. (1979) also described that nectar production proved to be correlated with leaf area (r=0.79) and yield (r= 0.67). Progenies better able to withstand cold and drought and containing 15-40% more sugar in the nectar were obtained by selecting for high nectar production. Chepik (1979) described that the sugar content in the nectar of 100 florets was 13.2 mg in short-styled and 11.4 mg in long-styled forms, the coefficient of variation in sugar content of the nectar was 53.0% in the long-styled and 20.2% in the short-styled form, and nectar production was correlated with yield (r=0.91) and with number of florets per plant (r=0.77). Chepik (1981a) described that forms obtained by selecting seedlings with a well-developed root system were found to have a higher nectar production rate and nectar content than normal forms under low temperatures and under drought conditions. Chepik (1981b) also noted that tetraploids contained more sugar in the nectar than diploids and the nectar content, as the amount of sugar/100 flowers was about 20 mg in tetraploid varieties and 10 mg in diploid ones. Jablonski *et al.* (1986) reported that the quality of the homostylous variety for beekeeping is similar to that of heterostylous one.

Komenda *et al.* (1986) studied 120 varieties from different countries and noted that pistil length differed among plants of the same variety, and that perianth size in pin types was generally smaller than in thrum types, but 1000-seed weight tended to be greater in the latter. Ren *et al.* (1986) reported that the mean flower number per plant differed among the varieties, from 700 to 1070, and this figure varied with locality; the percentage fruit set varied from 5.3 to 9.0% and was in general inversely related to the number of flowers.

In spite of the general description that buckwheat is a typical dimorphic heterostylous plant, long-styled pin type with short stamens and short-styled thrum type with long stamens, there are actually wide inter- and intra-varietal variations in length of pistil and stamen in each flower. Sobolev (1988), therefore, recommended a new system for exactly classifying pistils and stamens in buckwheat flowers, as for example, very short (b), short (B), long (l) and very long (L), and combining these classes gives 16 types of hermaphroditic flower so that the symbol for pistil length is followed by that for stamen length; hermaphroditic flowers are divided into two major groups, heteromorphic and homomorphic, with the former further divided into 3 subgroups (heteromorphic, subheteromorphic, and semiheteromorphic) and the latter into 4 (homomorphic, subhomomorphic, semihomomorphic and intermediate) according to similarities in pistil and stamen length. In each subgroup there are 2 types (long-styled and short-styled) irrespective of whether the pistils or stamens are longer.

Samborska-Ciania *et al.* (1989) studied buckwheat flowers just after opening, over a 24-day period, in connection with the flower position on the raceme and stage of flowering, and concluded that the first 3 flowers on the raceme and the size of their flower components were largest in the opening sequence, and pistil length and stigma cell size were greater while filament length and pollen grain size were less for pin than thrum flowers; in general, pistil and filament length, stigma cell size and pollen grain size decreased with each successive flower in the raceme; pollen grain cell size decreased as flowering progressed in pin type flowers while in thrum type flowers it reached a peak at full flowering and had the same, lower, value at the beginning and end of flowering; stigma cell size decreased as flowering progressed but it tended to level off towards the end of flowering; pistil and filament length were relatively constant as flowering progressed except for pistil length which decreased in thrum flowers after full flowering.

Signifficant correlation is found between nectar production and grain yield as already mentioned. Nectar production is correlated with leaf surface area (r=0.96) and a threefold increase in nectar production in the selected plants attracted a greater number of insect pollinators and resulted in a 58% increase in yield compared with the unselected control (Kopeljkievskii and Chepik 1978).

On the basis of results from experiments of hybrid buckwheat seed production, Elagin (1961) reported that the best results were obtained when using a high-yielding local variety as seed parent and one from some other locality as pollen parent, and emphasized the need for growing the parental plants in fertile soil with a good supply of bees for pollinating. Elagin (1968) also reported that seed set in cv. 'Hero' reached 86.8% when pollen supply was adequate but was as low as 7.6% when it was not; age of pollen, position of flowers in the inflorescence, various environmental factors and heterostyly also affected the sets, although this last factor was eliminated by selecting homostylous lines among hybrids from legitimate pollinations. According to his results, in legitimate pollinations within heterostylous forms, those with long styled flowers give the best yields owing to the greater vigour of the pollen tubes from the larger pollen grains of the short-styled individuals. However, in illegitimately pollinated homostylous forms, those with short styled flowers give the highest yields, since the pollen grains reach their embryo sacs more rapidly.

As mentioned above, critical correlations between frequency of pollinator visits, volume of nectar and grain yield of buckwheat are well known. It has also been observed in general that the main dominant pollinator of buckwheat fields is the honey bee (Free 1970). Ren and Liu (1986) reported that there were two orders, ten families, seventeen genera and thirty-four species in the pollinators of a common buckwheat field in Inner Mongolia, China; the dominant pollinators, 65% in all, were *Apidea*, including honeybees, *Syrphidae*, including a variety of drone flies, etc.; *Diptera*, including a variety of wasp-bellied syrphid flies also included a number of species groups of buckwheat pollinators, and *Hymenoptera*, including other varieties of bees in *Sphecidae*. Munshi (1989) described that honeybees visited an average of 10-15 flowers/min., and worked on buckwheat for 4-5 hours a day, during which time they made an average of about 5 trips.

The author has described a technique using an artificially reared insect pollinator (*Eristalis cerealis*) in isolation cages for conserving genetic resources, as well as the kinds and number of visiting insect pollinators and related pollination mechanisms, and the correlations among frequency of visiting insect pollinators and the number of flowers, climatic conditions, number of compatible pollen grains deposited on a stigma lobe, and % seed set (Namai 1986, 1990). He has also observed annually insect visitors to an inflorescence of common buckwheat flowering in a field at Tsukuba, by continuous monitoring with an 8-mm cinecamera at 2-sec intervals from 9:00 to 11:00 during the few days at the peak of flowering in October. The cinefilms were then analysed for frequencies and durations of insect visits with a memory motion analyzing system in the laboratory. It was found that the frequency of insects visiting, especially honeybees, was very changeable (Table 7) and it seemed to be caused by weather and neighboring nectar-source conditions. This phenomenon of honeybees was also observed in a previous year (Table 8).

Table 7. The kind and mean number of visitors onto an inflorescence of buckwheat per day, recorded during mornings in two successive years

Year	Species name	9:00-9.30	9:30-10:00	10:00-10:30	10:30-11:00	Total
1977	*Apis mellifera*					0.00
	Eristalis cerealis	1.50			1.50	3.00
	Eristalomyia tenax			4.00	2.50	6.50
	Muscidae, Calliphoridae		2.50			2.50
	Others	0.50				0.50
	Total	2.00	2.50	4.00	4.00	12.50
1978	*Apis mellifera*	1.00	1.50	2.25	0.75	5.50
	Eristalis cerealis	0.25		0.25		0.50
	Eristalomyia tenax	0.25	1.50	0.25	0.75	2.75
	Muscidae, Calliphoridae	0.50	0.25		0.50	1.25
	Others		0.25	0.25		0.50
	Total	2.00	3.50	3.00	2.00	10.50

Table 8. Daily change in frequencies of insect visitors to a buckwheat field per 1 m^2, at hourly intervals from 9:00 to 13:00, during the flowering period (Namai 1986)

Kind of visitors	Sept.29	30	Oct.1	2	3	4	5	6	7	Total	Freq.(%)
Apis mellifera	5	6	0	17	0	4	0	0	1	33	5.2
Eristalis cerealis	11	7	0	12	4	11	12	20	7	84	13.3
Eristomyia tenax	9	15	0	23	18	36	25	36	33	195	30.9
Megaspis zonata	0	4	0	9	4	4	1	9	6	37	5.9
House flies	18	17	0	18	8	25	23	28	27	164	26.0
Others	16	20	0	24	25	9	2	11	11	118	18.7
Total	59	69	0	103	59	89	63	85	85	631	100.0

Some plants began to bloom on Sept. 24, and almost all by Sept. 28.

Table 9. Duration and number of flowers visited on an inflorescence of buckwheat

Species name	Duration(sec).	No. of flowers
Apis mellifera	4.0±0.7	3.1±0.1
Eristalis cerealis	14.1±6.3	4.6±3.3
Eristomyia tenax	9.8±3.2	3.8±1.4
Rhingia leavigta	7.8±5.2	2.3±0.4

The author, therefore, revealed that honeybees are not as useful a pollinator for buckwheat fields when there are a lot of better neighboring nectar sources. In these cases, *Eristalis cerealis*, some flower flies, etc. are valuable pollinators, even under such conditions. The mean durations of main insect visits onto an inflorescence varied from 4.0 sec. in honeybees (*Apis mellifera*) to 14.1 sec. in shimahanaabu (*Eristalis cerealis*) (Table 9).

Naumkin (1986) described that a considerable variation among selected accessions was observed for the frequency of bee visits: under different weather conditions, the most frequently visited by bees were early forms from the northern ecological group, midseason forms from the southern group and a midseason form from the Baltic group; using these forms as donors of high nectar production in breeding would not only increase buckwheat yields, it was suggested, but also increase honey yields from the bees.

Molchan (1986) reported that average style length was the only difference between short-styled (1.62 mm) and long-styled (3.01 mm) flowers in 4800 flowers analized, and polymorphism of flower structure allowed the results of pollination to be accounted for in homomorphic long- or short-styled populations, where pollination was between flowers of the same styly group but different pistil and stamen lengths. Molchan (1987) also noted that, in common buckwheat populations, long-styled and short-styled flowers differed in mean pistil length, but the variation was so wide in both floral types that the boundary between flowers of different style length was blurred; in homomorphic long-styled populations, as well as dimorphic populations, cross pollination of plants with different flower structure occurred under natural conditions; homostylous long-styled flowers with long stamens and large pollen grains and homostylous short-styled flowers with short stamens and small pollen grains showed fairly high compatibility and floral structure occurred not only between plants in a population but also between flowers within a plant.

In terms of the relationship between floral traits and seed productivity of diploid and tetraploid buckwheat, Dorofeeva (1988) recommended recently that plants with large flowers and fused petals in both short-styled and long-styled forms should be eliminated due to low yielding, often with a grain set of 0. 0-2.1% vs. 7.0-15.9% for the population as a whole. She also described that plants with short-styled flowers exceeded plants with long-styled ones in grain number under a high crop density regime, whereas under a low crop density regime, plants with long-styled showed superiority.

As mentioned in section 4, sexual selection has been suggested as a possible factor in the evolution of various plants species, including buckwheat. It has also been suggested that sexual selection is a possible important factor in the evolution of sexual polymorphism in plants, particularly where competition for pollinators gives disproportionaly high paternity to plants capable of reallocating female reproductive resources to male functions (Willson 1979, 1982). Since, as mentioned in previous sections, pollen carryover in which only a fraction of the pollen present on an animal is deposited on a flower and subsequent flower visits get some pollen picked up from several flowers, not just from the last flower visited, must be common, pollinator movement and deposition patterns are more complexly related (Lertzman and Gass 1983). It seems certain that there will be many subtle ways in which pollen flow patterns influence the quality and quantity of pollen transfer from and to a plant, and that some optimal pollen flow pattern will therefore exist for a plant (Waser 1983). Waser (1983) also suggested that measuring the value of the seeds produced as vehicles of eventual gene transfer had to be more challenged, in terms of their germination and survival to maturity under natural conditions, with special reference to plant fitness.

7. Evolution, maintenance, and loss of self-incompatibility in buckwheat

Sexual selection, the optimal allocation of resources to maternal and paternal functions, and strategies for coping with environmental uncertainly have all been invoked to explain the evolution of different reproductive modes (Barrett 1988). In this regard, several new hypotheses have been proposed to explain the selective forces involved in the evolution and maintenance of plant breeding systems (Charnov 1982, Willson and Burley 1983).

Regarding heteromorphic incompatibility, Muenchow (1981, 1982) developed a theoretical model for the evolution of distyly by loss of alleles from an existing multiallelic sporophytic system, following the view of a unitary, strictly conserved *S*-locus in flowering plants. His model suggested that selection for maximal cross-incompatibility could remove, under rather restricted conditions, incompatibility alleles in such a way that the remaining alleles displayed the pattern of dominance and recessiveness found in distylous species populations. Since the recognition factors normally associated with the tapetum in homomorphic systems have no role to play in the incompatibility systems of heterostylous plants, and since physiological differences between pollen tubes and the pistil mediate incompatibility (Stevens and Murray 1982), it should be worth noting that inhibition sites in heterostylous plant species can involve the stigma, style, or ovary (Shivanna *et al.* 1981, Anderson and Barrett 1986). In this connection, Charlesworth (1982) suggested that if the general properties of heteromorphic incompatibility turn out to be fundamentally different from homomorphic incompatibility systems, the conventional use of the term *S* gene should probably not be applied to the incompatibility locus in heterostylous plant species.

The frequency of long- and short-styled morphs is almost equal in most distylous populations, except for certain species. In tristylous *Lythrum salicaria* on Finnish Islands, Halkka and Halkka (1974) discovered that gene flow between the islands had to be frequent in order for the populations to remain tristylous. Heuch (1980) also showed theoretically that loss of style morphs of *L.*

salicaria occurs with regularity in populations below 20 plants, and the short-styled morph governed by the dominant *S* allele is lost more frequently. Dulberger (1973) and Richards and Barrett (1984) have described the developmental relationships between floral polymorphisms and incompatibility in heterostylous plant species.

Charlesworth and Charlesworth (1979) and Ganders (1979) documented the breakdown of genetic polymorphisms in many heterostylous species, in the direction of increased self-fertilization by the formation of homostylous population systems. Barrett and Shore (1987) reported on the breeding system evolution in the dimorphous *Turnera ulmifolia* complex; this complex is composed of diploid and tetraploid varieties which exhibit typical dimorphic incompatibility, and self-compatible homostylous hexaploid ones; breeding system evolution from disassortative mating of dimorph to selfing of homomorph must occur through crossing-over within the supergene that controls heterostyly. Many monomorphic relatives of heterostylous species are known to possess large flowers and outcrossing adaptions. Whether homostyles maintain selfing or redevelop outcrossing adaptions may depend in part on the capacity of other components of the genetic system to influence recombination, and local selection pressures favoring outcrossing (Barrett 1988). Variants display differing degrees of self-compatibility as a result of either aberrent style or pollen behavior and the genetic control of compatibility behavior is of polygenic nature in *T. ulmifolia* (Shore and Barrett 1986).

In generally dimorphic common buckwheat populations, not a few monomorphic relatives are also evident as follows:

Saharov *et al.* (1944) described that autotetraploid forms of buckwheat induced by colchicine treatment were evidently capable of self-fertilization, in contrast to diploid forms, in which self-fertilization was rare or absent, though Frolova *et al.* (1946) reported that homostyly of the flowers of buckwheat was a morphological manifestation of sterility. Saharov (1946), then suggested that in diploid buckwheat, cross-pollination is maintained by heterostyly, a character depending upon a single gene pair *Ss*; because the heterozygotes of the constitution *Ss* have short-styled plants, and recessive homozygotes (*ss*) long-styled plants, a 1:1 ratio of the two forms is preserved from generation to generation; in the first generation, plants obtained by the cross-pollination of tetraploid forms, the ratio shifted to a marked preponderance of short-styled plants, since the *S* factor was completely dominant to three *s* factors and thus the short-styled character was expressed in tetraploids of either the genotype *SSss* or *Ssss*; the normal ratio of 1:1 was, however, restored towards the third, fourth and fifth generations, since crossing could only occur between short-styled and long-styled flowers, as in the diploid; thus the proportion of short-styled plants falls rapidly with succeeding generations, and plants of the original constitution *SSss* are replaced by *Ssss* plants.

Tatebe (1953) reported that there were some self-fertile, long-styled plants with 100% large pollen grains in the anthers, and self-fertility was inherited. Tatebe (1954) also reported that the starch content of the pollen grains of short-styled plants was higher than in long-styled plants and that the styles of short-styled plants contain less amylytic enzyme. On the other hand, Modilevsjkii (1954) described that the percentage of short-styled plants in the offsprings of illegitimately-pollinated buckwheat was increased when the plants were sprayed with boron before the flower opened, while the grains were setting and after they had set; the number of short-styled plants from hybrids between short-styled and long-styled forms was more than doubled and in the offspring of the reciprocal cross, it was nine times greater than in the controls. Alekseeva (1967) also reported that the ratio of long-styled to short-styled flowers was determined by environment; crosses in which the female parent was long-styled produced the highest-yielding hybrids. Marshall (1968, 1970) first described that a new homostyled cultivar 'Pennline 10' had been released as breeding material, having been selected for self fertility, and the flowers have anthers and stigmas of similar length.

Astafjev (1972) described the possibilities of obtaining heterotic hybrids by cross pollinating homozygous short-styled forms, produced by inbreeding and maintained in subsequent generations by illegitimate pollination involving forms identical in style length. Lezzova (1975) reported that in long-styled plants, female sex expression is more marked and in short-styled plants, male sex expression, and also in 1973 three rare homomorphic forms, having both long styles and long stamens, were found in a population of the buckwheat variety 'Bolshevik'. In terms of the differences between self-incompatibilities of short-styled and long-styled plants in buckwheat, Tyukavin (1974) reported that both plants in the diploid differed in the extent of their self-incompatibility, but no marked differences in this respect were found in the tetraploid, since the self-incompatibility of its short-styled plants fell markedly whereas that of its long-styled ones changed very little compared with diploid.

Gorina (1971) noted that pollen grains from the lower flowers on the various branches were larger and more fertile; using such flowers for pollination gave sets of 29-36% compared with 3-4% in pollination of short-styled x short-styled flowers or long x long flowers. Gorina (1974) also described that the inflorescences studied consisted of short stems containing 7-9 flowers; with legitimate pollination between forms differing in style length, a high fruit set was obtained from the first four flowers per stem (44-59%) and a low set from flowers 7-8 (3-21%), whereas with illegitimate pollination between forms identical in style length, the first flowers gave a low set (1-2%) and the last a higher set (up to 18%); with self pollination, the first flowers set no fruit, while the last ones gave a low set (3.5-6.5%). Pausheva and Grishina (1971) described that high temperature during pollination, e.g., 35 to 40°C resulted in a sharp fall in compatibility regardless of the type of pollination, viz. legitimate, illegitimate crossing and selfing in long-styled and short-styled forms; the largest fruit set was obtained from diploid forms using legitimate pollination at normal temperature, 18-24°C; lower temperatures, such as 12-15°, increased compatibility with illegitimate pollination in both diploid and tetraploid forms.

Gorina and Anokhina (1975) described that a homostylous form, with short stamens and pistils on the same level, had greater variation in habit and yield components compared with the initial variety 'Yubileinaya 2' (Jubilee 2); the homomorphic long-styled form was inferior to the initial variety in height and yield, but exceeded it in number if inflorescence per plant and number of flowers per inflorescence; the homostylous and homomorphic forms differed from each other little in habit, but the latter exceeded the former in yield. Anokhina (1975) also reported that in a homostylous form with short-styles and stamens and a homomorphic form with long-styles and stamens, selection for self fertility against a background of repeated inbreeding led to a marked reduction in plant height, number of inflorescences per plant and inflorescence length; the homostylous form developed normally and set the amount of fruit expected of a plant with poor vigour; it did not differ from its initial form as regards variation in morphological characters. Anokhina and Palilov (1977) later reported that highly self incompatible genotypes were found in all monomorphic forms and F_1 hybrids and the heterozygous condition of alleles and modifiers of the SI gene. Therefore, even though 3 new monomorphic populations were obtained after 5 cycles of selection, the % fruit set was low (Gorina and Anokhina 1986). Adachi *et al.* (1981) suggested that the breakdown of self incompatibility in autotetraploid buckwheat is caused by changes in the pistil rather than the pollen reaction.

Sobolev and Fesenko (1976) described that in denoting style and stigma length it is suggested that "s" be used for short and "l" for long, style length being recorded first and stamen length next, so that "sl" denotes a short-styled long-stamened flower (ordinary standard short-styled flower), "ls" a long-styled short-stamened one (ordinary standard long-styled flower), "ss" a homostylous form with short styles and stamens, "ll" a homostylous form with long styles and long stamens and "LL" a homostylous form with very long styles and stamens; the homozygosity of the "ss" and "ll" forms was confirmed, the "LL" form was found to be heterozygous, and the order of dominance was "ll">"ls">"ss". Kovalenko and Laptev (1979) reported that a study revealed the presence, in the *S* locus, of four genes controlling dimorphism of the florets; a new homostylous form, with high seed set after selfing, was obtained; prolonged inbreeding on the basis of homostyly revealed the presence of extensive polymorphism in 1000-seed weight, facilitating the selection of lines with high seed yield. Ruszkowski (1980) also concluded that the difference in fruit set between *F. tataricum* which is self fertile, and up to 50% of the flowers set fruit, and *F. esculentum* which is self sterile and less than 10% of the flowers set fruit, reflects the difference in self compatibility alone. He also noted that homomorphy was controlled by two recessive genes and that self fertility occurs only in double recessive homozygotes. Anokhina (1980) also reported that prolonged inbreeding of homostylous buckwheat tended to cause inbreeding depression in some characters, but not in fertility, whereas the use of cross pollination in the early stages of breeding homostylous forms increased the proportion of underdeveloped fruits. The long-styled component with homozygous *S* is more mutable than the short-styled (Anokhina and Gorina 1981).

Fesenko (1985) reported that the floral characteristics of the self-incompatible and homostylous long-styled form were dominant over those of a normal long-styled form, and recessive to those of a normal short-styled form. As an analogue of the normal short-styled forms in terms of pollen/pistil compatibility, it can be used in legitimate crosses between forms of different style length. Fesenko (1986) also reported that the heterostyly locus in buckwheat, controlling the flower type, was shown to consist of subgenes *G* (pistil length), *P* (pollen grain size) and *A* (stamen length), and when the dominant alleles *G* and *A* combined, the flower had a short pistil and long stamens (short-styled), whereas when the alleles were recessive (*ga*), the pistil was long and the stamens short (long-styled); the genotype *Ga* gave homostylous short-styled (HSS) flowers, and *gA* gave homostylous long-styled (HLS) flowers; an analysis of crosses between forms differing in flower type indicated that *G* and *A* were not linked and short-styled forms were predominant; the free combination of *G* and *A* in hybrids involving HSS form 5 indicated that the dominant *G* allele in this form was located outside the heterostyly locus and probably on another chromosome.

Molchan (1987) described that in common buckwheat populations, long-styled and short-styled flowers differed in mean pistil length, but the variation was so wide in both floral types that the boundary between flowers of difference style length was blurred as already mentioned in this paper. Molchan and Leszova (1989) concluded that polymorphism in degree of self-incompatibility and flower structure is linked not only with the effect of cross-pollination, but also with the cenotic effect of interaction of the sex types of buckwheat plant with each other and with insect pollinations.

Fesenko (1989) explained clearly three types of inheritance for flower homostyly in buckwheat: (1) Dominant homomorphic forms controlled by the "switch" locus ("switch" supergene) consisting of three subgenes, *G*, *P* and *A* as mentioned above. The genetic determination of heterostyly in buckwheat seems to be clearly explained, i.e., homostylous genotypes are *gPA* (Long-pistil, large-pollen, long-stamens), *gpA* (L, small-pollen, L), *GPa* (Short-pistil, large-pollen,short-stamens), *Gpa* (not yet obtained, but S, s, S), as like as in *Primula* (Bateson and Gregory 1905, Dahlgren

1922); (2) Transdominant homomorphic forms controlled by the free dominant subgene *G* outside the heterostyly locus, probably in another chromosome, whose homostylous genotypes are *G,--a/gpa* (S, -,S) and *g,--A/gpa* (L,-,L) (Fesenko 1985, 1986); (3) Recessive homomorphic forms controlled by modifier genes (*ls* for pin, and *sl* for thrum) or polygenes. He also speculated that mutant alleles of the modifier genes should lead to the destruction of heterostyly and result in releasing homomorphic forms (Mather 1950). In addition, since the concentration of such mutant alleles is very low in ordinary cross-pollinated buckwheat populations, these genes seem to experience a constant selection pressure for maintaining heterostyly in buckwheat.

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Effect of selected growth stimulators on biometric features and on crop yield of buckwheat (*Fagopyrum esculentum* Moench)

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Key words: *Fagopyrum esculentum*, buckwheat, germination, grain yield, cv. Hruszowska, regulation of development, regulation of growth

Abstract

An investigation of the effect of certain synthetic growth regulators on biometric features and crop yields of buckwheat cv. Hruszowska was carried out. The growth regulators did not affect the course of the growth phases of the buckwheat. Statistical analysis of the results of biometric measurements of the buckwheat indicated that the best results were obtained after the application of Betokson. The highest crop yields were observed in combination with Betokson. Mival also had a favourable effect, at doses of 200 and 500 mg/dm^3, on the grain yield. The harvest index was related significantly to the weather conditions in the course of vegetation, and especially to the level of precipitation.

Vpliv izbranih stimulatorjev rasti na biometrijske lastnosti in na pridelek ajde.

Avtorji so raziskovali vpliv sintetičnih stimulatorjev rasti na lastnosti ajde in na pridelek pri ajdi cv. Hruszowska. Regulatorji rasti niso vplivali na potek faz rasti ajde. Statistična analiza rezultatov merjenj rastlin ajde kaže, da so najboljši rezultati doseženi po uporabi betoksona. Najvišji pridelki so bili pri kombinaciji z betoksonom. Tudi mival je imel pri odmerkih 200 in 500 mg/dm^3 koristen vpliv na pridelek zrnja ajde. Žetveni indeks je bil značilno povezan z vremenskimi razmerami, zlasti s količino padavin med rastjo ajde.

Introduction

The great possibilities of the application of plant growth regulators in agriculture have been described in many papers (1, 2, 3). Application of growth substances may generate yield extension (4, 5, 6), improve the structure or extend the quality of agricultural products (6, 7).

The use of plant growth regulators brings advantageous results due to different effects on the plant and its environment (8,9). Many preparations are now used in the cultivation of the four main cereals (1, 5, 10), but there are no regulators for buckwheat, which is cultivated on a smaller acreage but is a valuable plant. Investigations are being carried out in this direction in countries which are interested in the cultivation of buckwheat (11, 12), and our work is a part of this.

We wanted to designate the changes which were caused by the application of three growth regulators - Mival, Krezacyna (Soviet Union) and Betokson (Polish) on buckwheat cv. Hruszowska.

Material and methods

Field experiments were performed in 1987 and 1988 at Felin Agricultural Experimental

Station of the Agricultural Academy in Lublin with buckwheat cv. Hruszowska. The experiment scheme was the following:

1. Control (dry grain).
2. Grain soaked in water.
3. Mival - used in concentration 200 mg/dm^3.
4. Mival - 500 mg/dm^3.
5. Mival - 1000 mg/dm^3.
6. Krezacyna - 10 mg/dm^3.
7. Krezacyna - 25 mg/dm^3.
8. Krezacyna - 50 mg/dm^3.
9. Betokson - 5 cm^3/dm^3

Grain was soaked in Mival and Krezacyna for 3 hours. Afterwards the grain was dried and sown. Betokson was applied as a spray in the flowering stage.

In the vegetation period, the following development phases were observed. Biometric measurements (plant length, number of internodes, number of racemes, general number of flowers, number of formed and unformed grains, mass of grains from one plant) were taken. After harvest of the mature plants, the yield of grain and straw and mass of thousand and hectolitre grains were estimated. In addition, germination of grain after 3 - 7 days was investigated.

Results and discussion

In 1987, when the buckwheat was sown, the mean temperature was 10°C and the soil was wet (in the second ten days of May, sum of precipitation was 36.5 mm). The thermal factor was practically in optimum in the final vegetation months - the average summer months temperature often exceeded 18°C and the maximum was 24°C. The amount of precipitation was: May - 43.3, June - 43.9, and July - 43.9 mm. Precipitation increased in the second ten days of August (56.9mm), which generated partial lodging of buckwheat. A considerable number of days with precipitation caused a high relative humidity, which was beneficial in the plant fructification period.

Weather conditions were different in vegetative periods in 1988 and in 1987. Low air temperatures in the germination period and in the first and third ten day periods of August unfavourably affected buckwheat fruiting, and the greater number of days with precipitation caused plant lodging and considerable grain losses.

Application of plant growth regulators did not have a significant effect on the course of the growth phases of the buckwheat. The appointed times of germination, appearance of flowers, setting and maturity of grains were very similar for plants of all combinations. The length of vegetation period was 104 days in 1987 and 105 days in 1988.

Statistic analysis of biometric measurement results showed a significant influence of plant growth regulators used in the experiment (Tab. 1). Betokson had the best influence - increased height of plants, number of racemes and formed grains and mass of formed grains. The changes which Mival and Krezacyna caused, were less beneficial.

Yield of grain depended significantly on meteorological conditions and on experiment variants (Tab. 2). The yield was higher in 1987. The greatest yield was obtained after application of Betokson, independent of the year. Mival (dose 200 and 500 mg/dm^3) and Krezacyna (50 mg/dm^3) also increased the yield. Average straw yield oscillated from 5.22 t/ha (control) to 7.3 t/ha (Betokson) - Tab. 2. Both meteorological conditions and plant growth regulators influenced its quantity. Betokson caused the greatest rise of straw yield followed by Mival (200 mg/dm^3) and Krezacyna (50 mg/dm^3). Changes of mass of 1000 grains caused by the growth regulators under study, were analogous.

The harvest index was significantly different in the two years, whereas differences causes by growth regulators were within the range of experimental error (Tab. 2). Mival and Krezacyna (in smaller doses) increased significantly grain germination but Betokson did not have this effect (Tab. 3).

Conclusions

1. The growth regulators which were tested -

Mival, Krezacyna and Betokson did not affect the course of the growth phases of the buckwheat.

2. Results of biometric measurements indicate that only Betokson has a stimulating effect on buckwheat.

3. Grain and straw yield depended on both meteorological conditions and on experimental

Table 1. Biometric measurements of buckwheat plants (two-year means)

Combination	plant height (cm)	number of internodes	number of racemes	number of formed grains	number of unformed grains	mass of formed grains	percent of formed grains
1	76.1	7.6	7.2	49.3	42.5	1.30	53.7
2	75.0	7.2	7.0	61.2	45.3	1.62	57.5
3	76.2	7.8	7.9	55.3	49.2	1.49	52.9
4	74.5	7.2	6.9	52.1	47.8	1.39	52.2
5	72.2	7.1	7.7	45.6	50.0	1.18	47.7
6	77.1	7.8	7.8	52.1	44.4	1.36	54.0
7	74.5	7.9	6.8	48.6	39.7	1.27	55.0
8	77.7	7.7	7.1	52.8	44.3	1.39	54.4
9	80.9	8.1	8.5	69.9	50.1	1.76	58.2
Mean	76.0	7.6	7.4	54.1	45.9	1.42	54.0
LSD$_{0.05}$	2.0	-	1.0	15.2	3.9	0.25	7.0

Table 2. Yield of grain and straw, mass of 1000 grain and harvest index

combination	YIELD (t/ha) grain			straw			mass of 1000 grains (g)			harvest index		
	1987	1988	mean	1987	1988	mean	1987	1988	mean	1987	1988	mean
1	1.62	1.25	1.44	4.70	5.75	5.22	27.7	24.9	26.3	0.26	0.18	0.22
2	1.80	1.55	1.68	5.97	6.40	6.18	27.9	25.1	26.5	0.23	0.19	0.21
3	1.86	1.45	1.66	5.82	6.60	6.21	28.2	25.9	27.0	0.24	0.18	0.21
4	1.79	1.40	1.60	5.41	6.55	5.98	28.0	25.4	26.7	0.25	0.18	0.22
5	1.78	1.00	1.39	5.59	5.45	5.52	26.2	25.3	25.8	0.24	0.16	0.20
6	1.94	1.20	1.57	5.49	5.65	5.57	27.4	25.1	26.2	0.26	0.18	0.22
7	1.73	1.10	1.42	5.52	5.50	5.51	26.9	25.6	26.2	0.24	0.17	0.20
8	1.70	1.50	1.60	5.37	6.55	5.96	26.0	26.7	26.4	0.24	0.19	0.22
9	2.12	1.90	2.01	6.01	8.70	7.36	28.4	27.0	27.7	0.26	0.18	0.22
mean	1.82	1.37	1.60	5.54	6.35	5.94	27.4	25.7	26.5	0.25	0.18	0.21
LSD$_{0.05}$ for												
years			0.29			0.80			1.4			0.06
combination			0.08			0.36			0.4			-

Table 3. Effect of growth regulators on buckwheat seed germination (two-year means)

combination	days after sowing				
	3	4	5	6	7
1	91	91	92	92	92
2	84	84	88	89	90
3	93	94	97	99	99
4	92	94	94	94	94
5	83	85	87	87	88
6	93	93	94	95	96
7	85	86	87	89	89
8	89	89	92	92	92
9	89	87	91	92	92
mean	88	89	91	92	92
$LSD_{0.05}$	3.6	3.4	3.5	3.2	3.7

variants. Application of Betokson caused the greatest yields. Mival used in concentrations of 200 and 500 mg/dm^3 improved grain yield.

4. The harvest index was significantly dependent on the weather conditions during the vegetation period only.
5. Mass of 1000 grains was higher in the dry, warm year and of the regulators tested, only Betokson increased it.
6. Of the investigated preparations, Betokson used in the form of a spray during the flowering phase is most profitable. This preparation has great possibilities in buckwheat cultivation.
7. Soaking of buckwheat grain in clear water has a beneficial effect on the number and mass of grain, which, consequently, increases grain yield.

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Effect of preservatives on the chemical composition of buckwheat juice obtained in the process of mechanical extraction of plants

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Key words: *Fagopyrum esculentum*, chlorophylls, proteins, proteolytic enzymes

Abstract

The effect of the following preservatives: sodium sulphate, propionic acid, benzoic acid, citric acid and sodium hydroxide (added in the quantity of 10 g per 1 kg of the pulp) on the chemical composition of juice extracted from the pulp of buckwheat plants was investigated. All these preservatives when added to the pulp decreased the concentration of chlorophylls and protein proper to the juice and increased its dry matter. The activity of proteolytic enzymes was decreased under the influence of citric acid, sodium hydroxide and benzoic acid. The time from the moment of cutting the plant to that of extracted the juice from it, had a significant influence on the chemical composition of the juice.

Vpliv konzervansov na kemično sestavo soka ajde dobljenega z mehanično ekstrakcijo soka iz rastlin.

Avtorji so raziskovali učinek konzervansov natrijevega sulfita, propionske kisline, benzenske kisline, citronske kisline in natrijevega hidroksida na kemično sestavo soka dobljenega iz rastlin ajde. Vsi omenjeni konzervansi so znižali koncentracijo vsebnosti klorofila in beljakovin v soku ter povečali vsebnost sušine. Aktivnost proteolitskih encimov je bila zmanjšana pod vplivom propionske kisline, natrijevega hidroksida in benzenske kisline. Čas, ki je pretekel od spravila rastlin do ekstrakcije pomembno vpliva na kemično sestavo soka.

Introduction

Buckwheat is a plant grown mainly for seeds, but fresh plant mass can be used in feeding monogastric animals by extracting the juice and then coagulating the proteins contained in it.

Mechanical extraction of juice from the plants depends on the manner and degree of maceration of the plant, on the acidity of the comminuted material, on the presence of phenol compounds as well as the activity of hydrolytic and oxydizing enzymes (2, 4, 5, 6).

The distribution of proteins between juice and foots is also influenced by the time passing from cutting the plants to extracting the juice, as well as by the addition of chemical compounds as preservatives. The aim of the present paper was therefore to establish the influence of preservatives present in buckwheat pulp on the chemical composition of juice obtained from it.

Materials and methods

The material for the study was green fodder of buckwheat harvested before flowering from the experimental fields of RZD at Felin. The plants were preliminarily ground in a screw press. The following preservatives (in a quantity of 10g per 1kg of pulp) were added to the plant pulp thus obtained: sodium sulphite, citric acid, propionic acid, benzoic acid and sodium hydroxide.

The true protein content was determined using Orange-G (9), and the chlorophyll content by the Arnon method (1). Total proteolytic activity was measured in 0.5 ml of juice by adding 4 ml of 5% casein in 0.1M phospate buffer (pH = 5.5) and incubating for 18 hours at 40°C. The unhydrolysed protein was then precipitated with 4 ml of 24% TCA and left in 4°C for 20 hours. The sediment was filtered off and the amount of protein in the obtained filtrate was determined by the Lowry method (6). Extraction was measured against the control, in which hydrolysis was stopped with 24% TCA immediately after adding casein. The amount of protein was calculated from an analytical curve determined for various concentrations of tyrosine. Enzymatic activity was expressed in micromoles of tyrosine released by 1 ml of juice in 1 hour.

Results

The efficiency of the mechanical process of extraction was calculated on the basis of the relation of the mass of juice extracted by means of the expeller to the initial mass of the plant pulp obtained by comminuting the green fodder in the screw press, accepting the green fodder mass as 100%. The obtained values (Fig. 1) were high - they ranged from 64 to 76%. Addition of sodium sulphite, propionic acid and citric acid to the pulp increased the yield of juice as compared to the control (pulp without preservatives). The presence of electrolytes in the pulp caused an increase in mineral salts content, which consequently caused an increase in the osmotic pressure of the juice. Changes in the osmotic pressure upset the equilibrium in the diffusion process - the outer electrolyte is absorbed by the pulp, causing its spontaneous reextraction. This process probably causes an increase in the efficiency of extraction. The reduction of this value in the case of benzoic acid and sodium hydroxide may be due to the interaction between the preservative and buckwheat components. On the other hand, the time passing from the moment of cutting the plant to the process of extraction caused a decrease in the juice yield (Fig. 2).

Both time and adding preservatives produced an increase in the density of juice obtained from buckwheat pulp (Figs. 1 and 2). This is proved by the increase of the dry matter of the juice - greatest in the case of benzoic acid, least under the influence of propionic acid.

All the added preservatives (except sodium hydroxide) caused a decrease in the protein content of the pulp (Tab. 1) - so they accelerated its hydrolysis. The biggest protein losses occured under the influence of benzoic acid. The quantity of protein also decreased during storage of the plant (Tab. 2). In investigations carried out by Ostrowski-Meisner (8) a decrease was demonstrated in the protein yield from plants stored for 3 hours at a temperature of 22°C as compared to plants processed immediately after cutting. This process was accompanied by an increase of the amount of soluble nitrogen in the plant.

In investigations which were carried out, storing a plant at a temperature of 4° for 52 hours caused a very unfavourable distribution of protein between juice and foots (Tab. 2). After this time, only 14.2% of the protein of the plant was obtained in the juice. When preservatives were applied, on the whole this distribution was better than in the juice obtained without their presence (Tab. 1). Only propionic acid and benzoic acid decreased the percentage of plant protein obtained in the juice. However, the number of grams of protein proper obtained in the juice from 1 kg of pulp was smaller for all samples treated with preservatives (as compared to the control). So the presence of chemicals causes increased proteolysis of proteins present in buckwheat comminuted mechanically. It also caused a change in the pulp's colour. The amount of chlorophyll in juices obtained from pulps with added preservatives was therefore investigated.

The total chlorophyll content decreased a

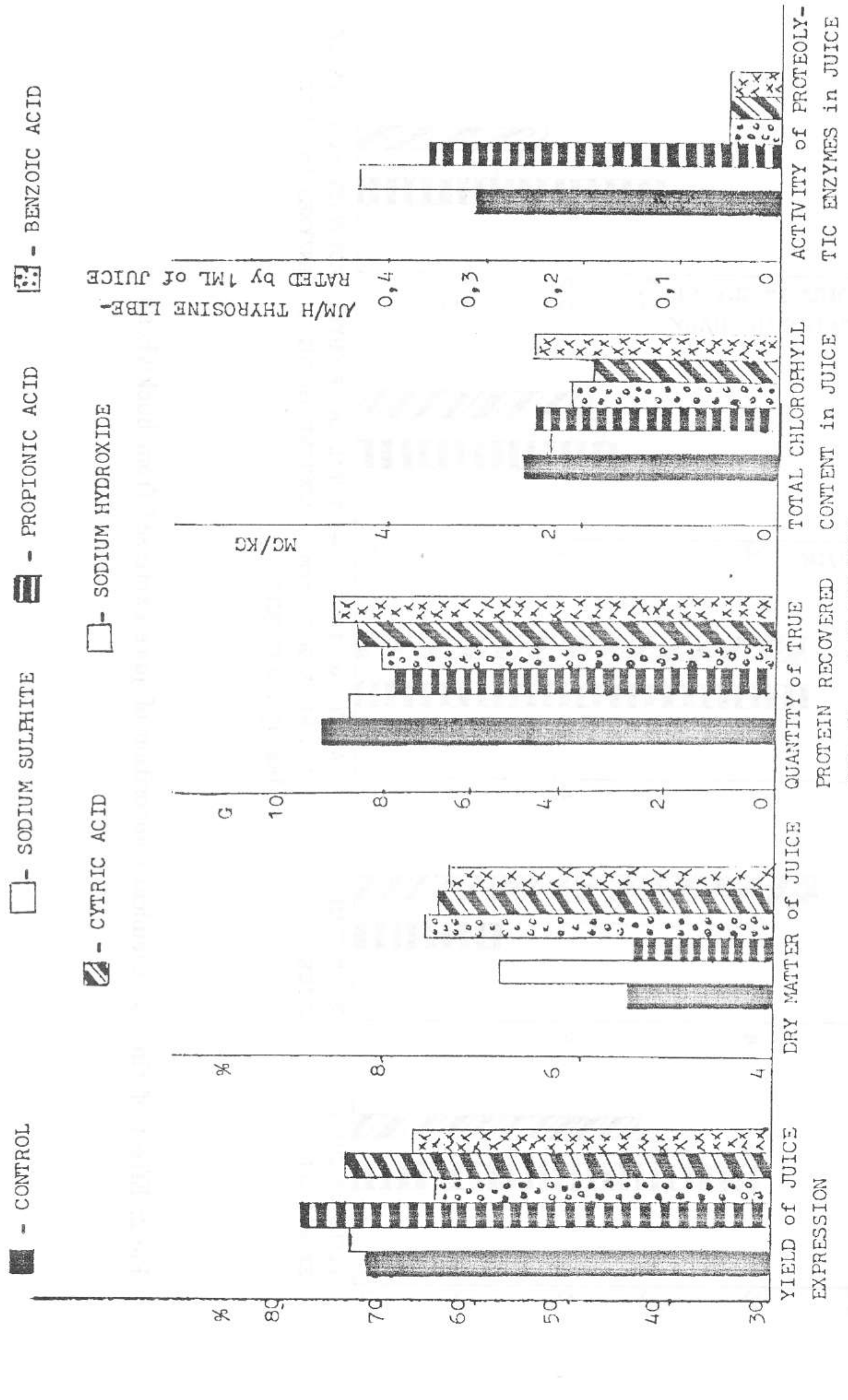

Fig. 1: Effect of preservatives on chemical composition of juice expressed from buckwheat

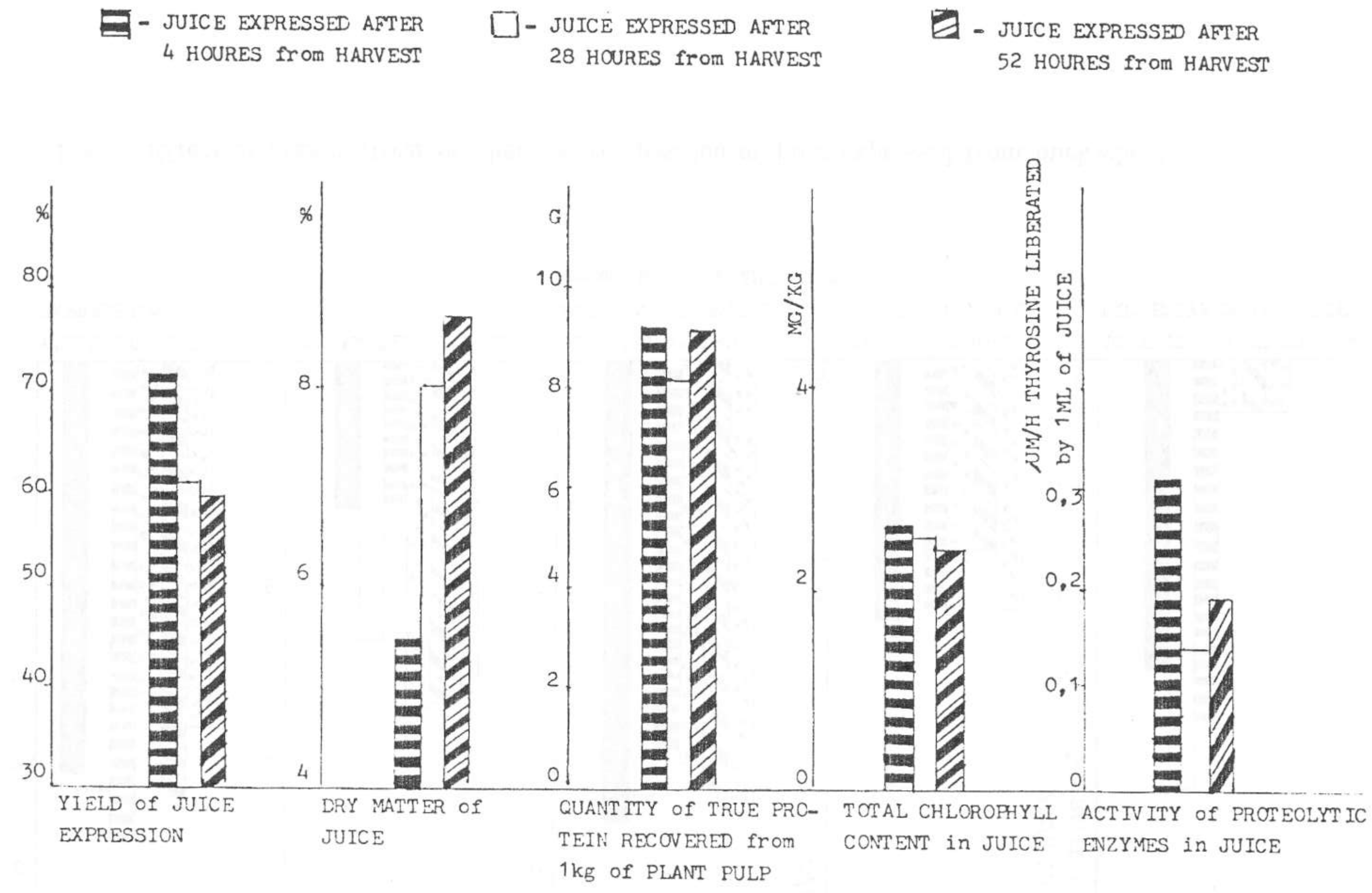

Fig.2: Effect of time on chemical composition of juice expressed from buckwheat

Table 1: Effect of preservatives on changes in chosen parameters characteristic of the process of mechanical extraction of juice from buckwheat

pulp from buckwheat plants	total protein (% d.m.)	distribution of protein between juice and foots (values expressed as % of the plant's protein)		chlorophyll "a" and "b" content of the juice (mg/kg d.m.)		percent of chlorophyll "a" and "b" in total amount of chlorophylls (%)		activity of proteolytic enzymes in the juice (%)
		juice	foots	a	b	a	b	
with no preservatives	12.81	32.8	62.2	1.85	0.74	71	29	100
with Na_2SO_3	11.03	39.5	60.5	1.76	0.59	75	25	136.2
with propionic acid	11.70	35.0	65.0	1.67	0.74	69	31	115.1
with benzoic acid	10.63	35.8	64.2	1.73	0.40	81	19	15.1
with citric acid	12.51	38.7	61.3	1.49	0.41	78	22	15.1
with sodium hydroxide	13.30	40.5	59.5	1.78	0.68	72	28	15.1

Table 2: Effect of time on changes in chosen parameters characteristic of the process of mechanical extraction of juice from buckwheat

time from cutting the plant to receiving juice	total protein (% d.m.)	distribution of protein between juice and foots (values expressed as % of the plant's protein)		chlorophyll "a" and "b" content of the juice (mg/kg d.m.)		percent of chlorophyll "a" and "b" in total amount of chlorophylls (%)		activity of proteolytic enzymes in the juice (%)
		juice	foots	a	b	a	b	
4 hours	12.81	37.8	62.2	1.85	0.74	71	29	100
28 hours	12.17	41.2	58.2	1.75	0.75	70	30	45.5
52 hours	11.54	14.2	87.8	1.72	0.69	71	29	60.6

little under the influence of the introduced chemicals (Fig. 1). Greater changes were found in the amount of chlorophyll "b", which is a characteristic feature only of higher green plants. Its content decreased by 54% as compared to the control when benzoic and citric acids were used. These preservatives also lowered the percentage of chlorophyll "b" in the total chlorophyll content. On the other hand, time passing from the moment of cutting the plant to extracting the juice caused little change either in the total chlorophyll content or in its particular content (Fig. 2, Tab. 2).

The process of protein biosynthesis in the plant is stopped at the moment it is cut, whereas proteolysis goes on both in the plant material and in the juice obtained from the plant (3, 8). The protein losses caused by this process can be as high as 50% (3). This is why determining the activity of proteolytic enzymes in the juice and defining the factors inhibiting proteolysis is of great significance in the process of obtaining the maximum quantity of proteins from plant juice.

Buckwheat was characterized by a low activity of enzymes amounting to 0.31 µmol of tyrosine released by 1 ml of juice during 1 hour. The added preservatives significantly changed this value. Under the influence of sodium sulphite and propionic acid, activity increased, whereas benzoic acid, citric acid and sodium hydroxide reduced this value to 0.05, that is by as much as 85% (Tab. 1).

The activity of enzymes is influenced by various kinetic factors, such as pH, concentration of cooperating coenzymes, feedback connected with the influence of reaction products as allosferic effectors, and finally, the presence of other substances. The addition of preservatives to buckwheat pulp changes the activity of enzymes by changing the pH of the pulp as well as by reacting with the components of the plant. Besides the manifold influence of the preservatives, also various effects of time were found on the activity of proteolytic enzymes (Fig. 2). In juice obtained 28 hours after cutting the plant, the activity of the enzymes decreased by 55%, whereas in juice obtained after 52 hours - by 40% (Tab. 2).

The decrease, and the small increase in enzyme activity, can be explained by proliferating microorganisms capable of producing and secreting peptides and proteolytic enzymes to the environment.

The green fodder of buckwheat cannot therefore be stored for too long before extracting the juice, even at low temperatures.

Conclusions

1. All the preservatives added to the buckwheat pulp changed (as compared to the control) the chemical composition of the juice extracted from these pulps.
2. The character and proportions of these changes depended on the type of introduced chemical.
3. The total chlorophyll content in the juice decreased under the influence of all the preservatives introduced into the buckwheat pulp.
4. Benzoic acid, citric acid and sodium hydroxide caused an increase in the dry matter of the juice and a significant decrease in the activity of proteolytic enzymes.
5. Citric acid proved to have the most favourable influence on the process of mechanical extraction of buckwheat juice, since it decreased the chlorophyll content and the activity of proteolytic enzymes in the juice and increased the efficiency of extraction and the dry matter of the juice.

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Ideotype, canopy and field architecture in buckwheat productivity

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Key words: branching, competition, dominance, flowers fertility, nitrogen fertilization, plant density, plant distribution

Abstract

Obtaining a profitable buckwheat ideotype and field architecture as a consequence of proper plant distribution per m^2, time of seeding and level of nitrogen fertilizer was studied. A relatively profitable plant ideotype (low branching - limitation of dominance and competition phenomena) and the highest yield was obtained when the seeding time was between May 10 and 15, with nitrogen fertilizer 60 kg/ha and distribution of plant 33 x 1 or 22 x 2 cm.

Ideotip, sestoj in arhitektura rastlin ajde ter vpliv na rodovitnost

Raziskovana je bila možnost rodovitnega ideotipa ajde in ustrezna arhitektura rastlin v povezavi z gostoto posevka, časom setve in nivojem gnojenja z dušikom. Relativno rodoviten ideotip rastlin z nizko stopnjo razvejanja, z omejeno dominanco in tekmovalnostjo in z visokim pridelkom je dosežen, če sejemo ajdo med 10. in 15. majem pri gnojenju z dušikom 60 kg/ha in razporeditvijo rastlin 33 x 1 cm ali 22 x 2 cm.

Sinopsis

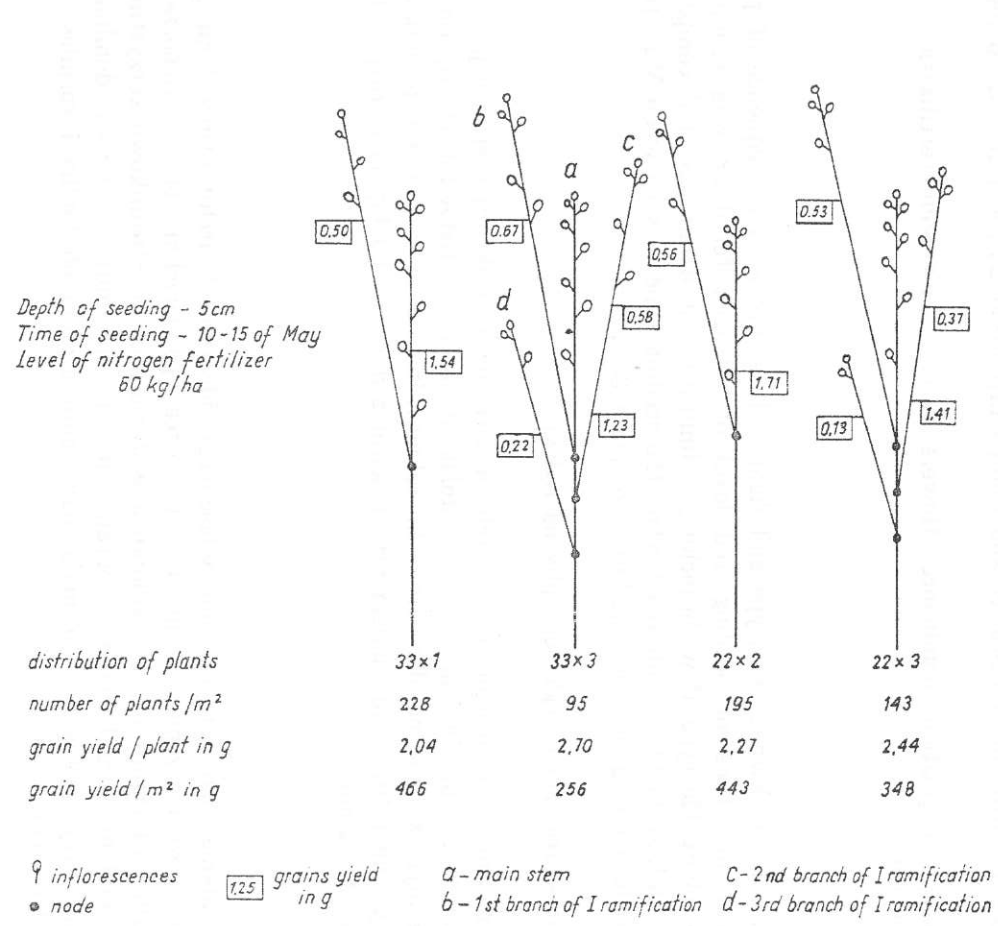
Przeprowadzone badania nad otrzymaniem właściwego ideotypu i architektury łanu gryki poprzez odpowiednie rozmieszczenie roślin na jednostce powierzchni przy równoczesnym zastosowaniu optymalnego terminu siewu i poziomu nawożenia azotem. Stosunkowo korzystniejszy ideotyp rośliny (o małym rozgałęzieniu - ograniczone do minimum zjawisko dominacji i konkurencji) uzyskano przy siewie 10 -15 maja, nawożeniu azotem 60 kg/ha i rozmieszczeniu roślin: 33 x 1 albo 22 x 2 cm.

Introduction

The main factor which influences buckwheat productivity is low flower fertility connected with heterostylity and branching of individual plants (Kreft 1986, Listowski 1979, 1985; Ruszkowska 1965, Ruszkowski 1965, 1983, 1990, 1991a, 1991b, 1991c). The high branching which can be observed results in a higher nutrient uptake used for vegetative growth, and only a small amount being utilized for the accumulation of photosynthetic products needed for seed establishment (Kreft 1986, Listowski 1985, Ruszkowski 1990, 1991). The phenomena occur of dominancy and competition within inflorescences, between inflorescences and between main stem and branches of different orders (Ruszkowski 1990, 1991).

The variability of buckwheat productivity connected with changes in ideotype, canopy and field architecture has been studied (Ruszkowski 1965, 1990, 1991, 1991c). The results of these studies have shown that the monotype (only main stem) ideotype of buckwheat plant with high amount of inflorescences and large leaves assimilate surface is probably optimal. To support this

Fig. 1. The habits and yield of buckwheat depending on sowing density



hypothesis experiments with various plant distribution/m^2 of buckwheat, in order to limit plant branching were conducted in 1989 - 1990.

Material and methods

The study was carried out at Puławy on microplots (1 m^2) in 1989 -1990. Cultivar Emka. Mineral fertilization: N 60, P_2O_5 54, K_2O 72 kg/ha. Time of sowing 10 of May, depth of seeding 5 cm, distribution of plants per m^2: 1) 33 x 1, 2) 33 x 3, 3) 22 x 2, 4) 22 x 3 cm. After harvest, the habits and yield structure of individual plant and grain yield/m^2 was determined (Fig. 1).

Results

An increase of plant density reduces the number of branches on individual plants. Under such conditions the plants create only main and 1st branch of I ramification (Fig. 1), only occasionally was the appearance of 2nd branch of I ramification was observed. The plants distributed at 33 x 3 and 22 x 3 cm, formed three branches of I ramification (Fig. 1).

The individual plant grain weight was lower at high plant density. Nevertheless, as a result of greater plant density at a distribution of 33 x 1 and 22 x 2 cm, the grain yield per m^2 was much higher.

Many years of microplot experiments have supported the hypothesis, introduced on the basis of studies on the ideotype canopy and field architecture (Aufhammer 1987, Kreft 1986, Ruszkowska 1965, Ruszkowski 1965, 1990, 1991a, 1991b, 1991c), of higher productivity of nonbranching buckwheat plants. As a result of the decrease of dominance and competition between main stem and branches of I ramification, an increase of the grain mass of the main stem was observed. In effect a higher yield/m^2 was obtained.

In various production technologies, it is possible in defined soil and climatic conditions, to obtain a higher yield with appropriate plant density.

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Fagopyrum 11 (1990): 60 - 62

Simulation of growth rate in buckwheats (*Fagopyrum* spp.) grown in Kashmir

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Key words: buckwheat species, dry mass, growth rate constant (K), height, leaf area

Abstract

Growth rate constant (K) was simulated for each of dry mass, leaf area and height in four species of *Fagopyrum* viz. *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. and *F. kashmirianum* Munshi. The K values were appreciably higher in *F. esculentum* as compared to the other three species. In each of the four species the K values for leaf area corresponded to those for dry mass; the rate of extension growth, however, seems to be independent of dry mass and leaf area. The differences in rate constants highlight the inherent differences between *F. esculentum* as compared to the other three species.

Simulacija količnikov rasti štirih vrst iz rodu *Fagopyrum* v Kašmirju

Konstanta hitrosti rasti (K) je bila simulirana posebej za suho snov, listno površino in višino rastlin pri štirih vrstah iz rodu *Fagopyrum* in sicer *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. in *F. kashmirianum* Munshi. K vrednosti so bile znatno višje pri *F. esculentum* v primerjavi z ostalimi tremi vrstami. Pri vseh štirih vrstah so K vrednosti površine listov odgovarjale vrednostim suhe snovi; nivo rasti pa je bil kot kaže neodvisen od suhe teže in listne površine. Razlike v rastnih konstantah kažejo svojstvene razlike med *F. esculentum* in ostalimi tremi vrstami.

Introduction

Four species of *Fagopyrum*, viz. *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. and *F. kashmirianum* Munshi have been reported in populations from various high altitude areas of Kashmir (Tahir and Farooq 1983). The various aspects of botany, cultivation and uses of buckwheats have been reviewed by Tahir and Farooq (1988). In recent years, growth analytical parameters have been profoundly used in the simulation of growth of various crops (Causton and Venus 1981; Hunt 1982). Knowledge of the physiological aspects of growth in buckwheats is still incomplete. The present study is focussed on the simulation of growth rates in the four buckwheats.

Materials and methods

Seeds of the four buckwheats were sown in beds (3 x 1 m) randomised into three blocks for two successive trials during two successive summer seasons (May-September) under optimum conditions of growth and yield (Farooq and Tahir 1987a). At weekly intervals, 5 plants were sampled at random from each block. During trial I, dry mass was recorded for individual plants. However, during trial II, dry mass values for individual plants were found as a mean of 5 pooled plants (from each block) for simplicity of experimental design. Plant height was recorded for individual plants in both trials. Leaf area was estimated gravimetrically (Šesták *et al.* 1971) only for trial I, due to the complexity of the procedure.

The plant material was dried in a forced draught oven for 48 hours at 70°C. The growth rate (Kt) for dry mass, leaf area and height was determined at weekly intervals by the formula:

$$Kt = l_n \frac{X}{X_{max} - X}$$

where X represents the value of the growth parameter at a given time and X_{max} represents the maximum value attained by the growth parameter over a period of time. The growth rate constant (K) was later simulated graphically (Ting 1982). The data have been presented in figures only. The Kt values for dry mass and height represent mean values of the two trials; however, values for leaf area represent only trial I.

Results and discussion

The rate constant (K) summarises the behaviour of a plant in relation to the growth parameters and considerable importance has been attached to its practical utility in evaluating growth potential (Hunt 1978), in addition being a function of the environment and the plant's genetic composition (Ting 1982). Since the buckwheat species were subject to the same environmental conditions, the difference in K values could be genetic in nature. The rate constants for each of dry mass, leaf area and height exhibited a more or less linear relationship with time (Figs. 1-3). The K value for each of dry mass, leaf area and height in *F. esculentum* was higher, being 1.103, 1.018 and 0.714 respectively compared to the other three species, where it ranged between 1.005 - 0.994 for dry mass, 0.933 - 0.880 for leaf area and 0.576 - 0.500 for plant height. The K values for leaf area seem to correspond closely to those for dry matter, suggesting an intimate relationship between leaf area and dry matter production, the rate of extension growth, however, appears to be independent of both dry mass and leaf area. The inherent differences between *F. esculentum* and the other three species are substantiated by studies on grain composition, electrophoretic patterns and breeding systems of the four buckwheats (Tahir and Farooq 1985, 1987; Farooq and Tahir 1987b).

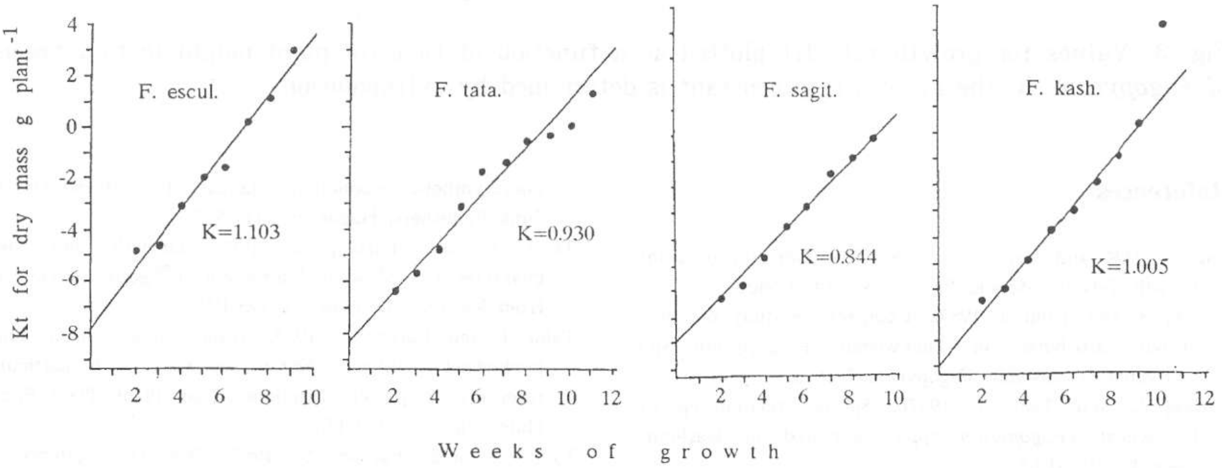

Fig. 1: Values for growth rate Kt plotted as a function of time for plant dry mass in four species of *Fagopyrum*. K, the growth rate constant is determined by extrapolation.

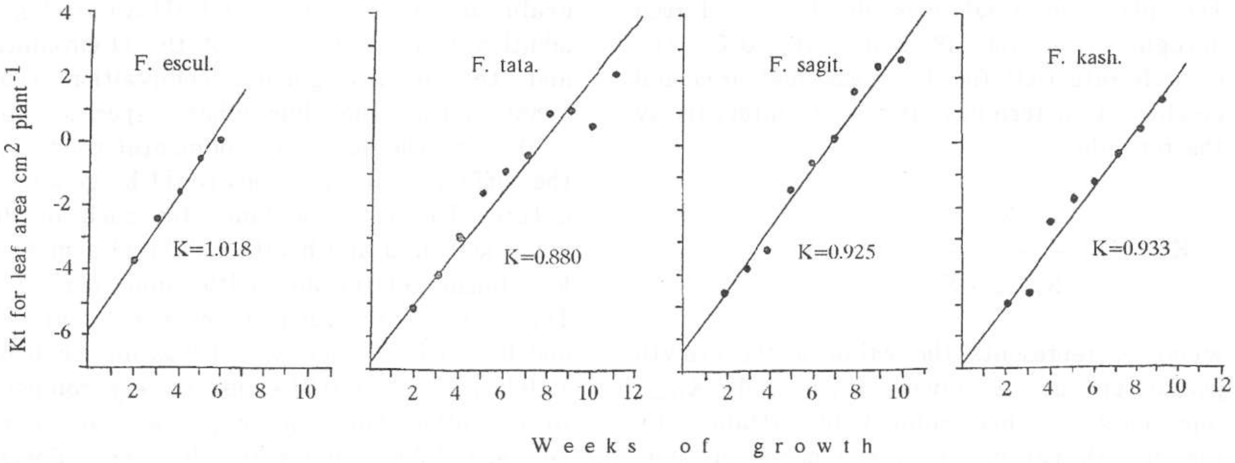

Fig. 2: Values for growth rate Kt plotted as a function of time for leaf area in four species of *Fagopyrum*. K, the growth rate constant is determined by extrapolation.

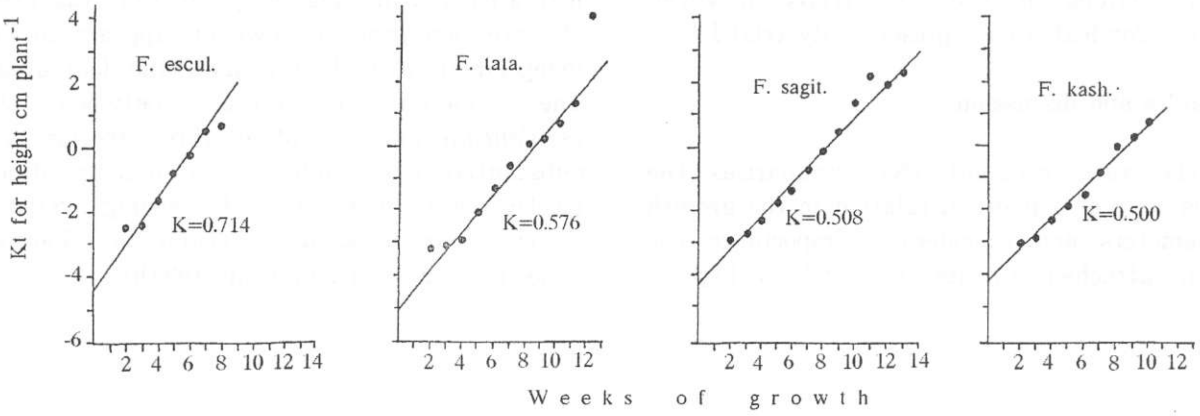

Fig. 3: Values for growth rate Kt plotted as a function of time for plant height in four species of *Fagopyrum*. K, the growth rate constant is determined by extrapolation.

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Fagopyrum 11 (1990): 63 - 67

Growth patterns in buckwheats (*Fagopyrum* spp.) grown in Kashmir

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Key words: F. esculentum, *F. kashmirianum*, *F. sagittatum*, *F. tataricum*, dry mass, growth patterns, height, leaf area

Abstract

The patterns of some important growth parameters (i.e. dry matter accumulation, leaf area, height) were studied in four species of *Fagopyrum* viz. *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. and *F. kashmirianum* Munshi. Maximum values for growth parameters were attained relatively earlier in *F. esculentum* and later in *F. tataricum*. While a major portion of dry mass was partitioned into branches, only a small fraction represented the roots. The pattern of leaf dry mass showed an initial phase of slower and later phase of faster dry matter accumulation. *F. tataricum* possesses a higher productivity potential since it maintains an increasing trend in its biomass and leaf area for a longer duration.

Način rasti ajde v Kašmirju

Akumuliranje sušine, naraščanje listne površine in rast rastlin v višino so avtorji raziskovali pri štirih vrstah iz rodu *Fagopyrum* in sicer pri *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. in *F. kashmirianum* Munshi. Parametri rasti so dosegli največje vrednosti razmeroma zgodaj pri navadni ajdi in pozno pri tatarski ajdi. Razmeroma velik del sušine se je razporedil v veje in le majhen del v korenine. V liste se je sušina v začetku razporejala le počasi in kasneje hitreje. Pri tatarski ajdi je večji potencialni pridelek saj traja pospešena prirast mase in listne površine daljše obdobje.

Introduction

In Kashmir, the genus *Fagopyrum* is represented by four cultivated species viz. *F. esculentum* Moench, *F. sagittatum* Gilib., *F. tataricum* Gaertn. and *F. kashmirianum* Munshi (Munshi 1986); farmers, however, seem to be aware of only two types of buckwheats i.e. common buckwheat (*F. esculentum*) and coarse buckwheat (*F. sagittatum*). The importance of buckwheat has stressed the need to study the physiological aspects of growth in these plant species. However, work on this aspect is meagre (Kajfež-Bogataj and Orešnik 1989). In the present study, the patterns of some important growth parameters were studied in the four buckwheat species.

Materials and methods

Seeds of the four species of *Fagopyrum* were separately sown in beds (3 x 1m) randomised into three blocks for two succesive trials during two succesive summer seasons (May - September) under standard conditions of growth and yield (Farooq and Tahir 1987). At weekly intervals, 5 plants were sampled at random from each block. During trial I, values for individual plants were recorded. During trial II, mean values of the 5 pooled plants (from each block) were considered for simplicity of experimental design; plant height, however, was recorded for each individual plant in both trials. During trial I, leaf area was estimated gravimetrically by the method described by Šesták et al. (1971). For trial II, leaf dry mass and dry mass of branches was recorded. Dry mass was recorded after drying the fresh material in a forced draught oven for 48 hours at 70°C. Growth patterns are presented in Figs. I - VI.

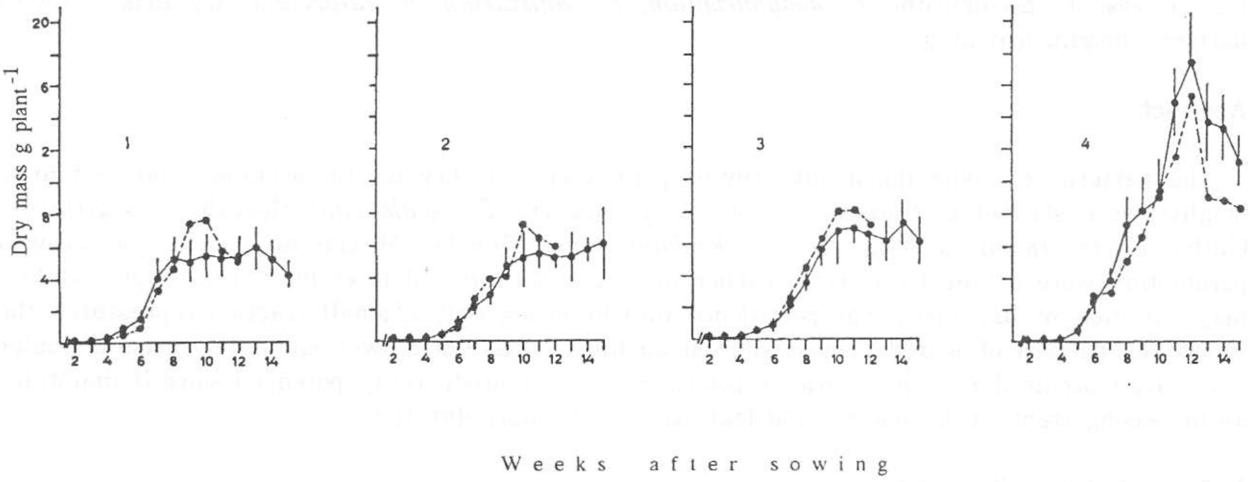

Fig. I. Time course of dry mass for trial I (·——·) and trial II (· - - - ·) in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

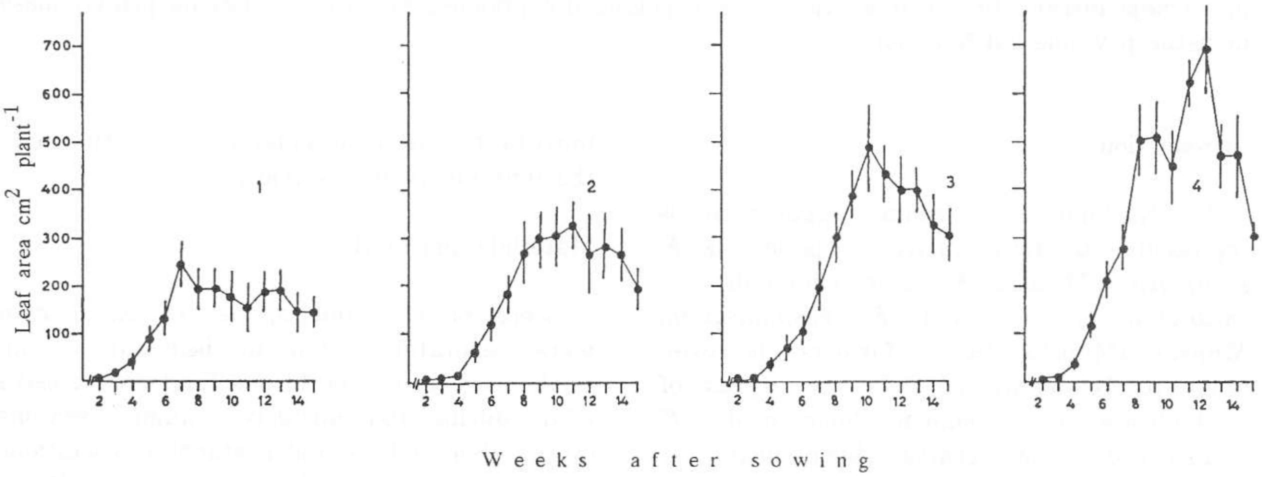

Fig. II. Time course of leaf area for trial I in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

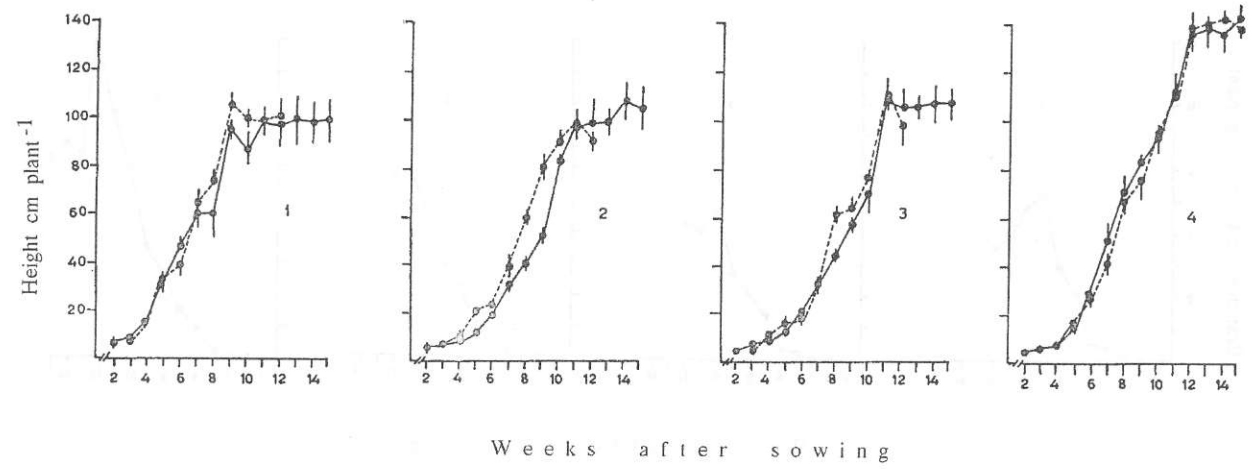

Fig. III. Time course of plant height for trial I (·———·) and trial II (· - - - ·) in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

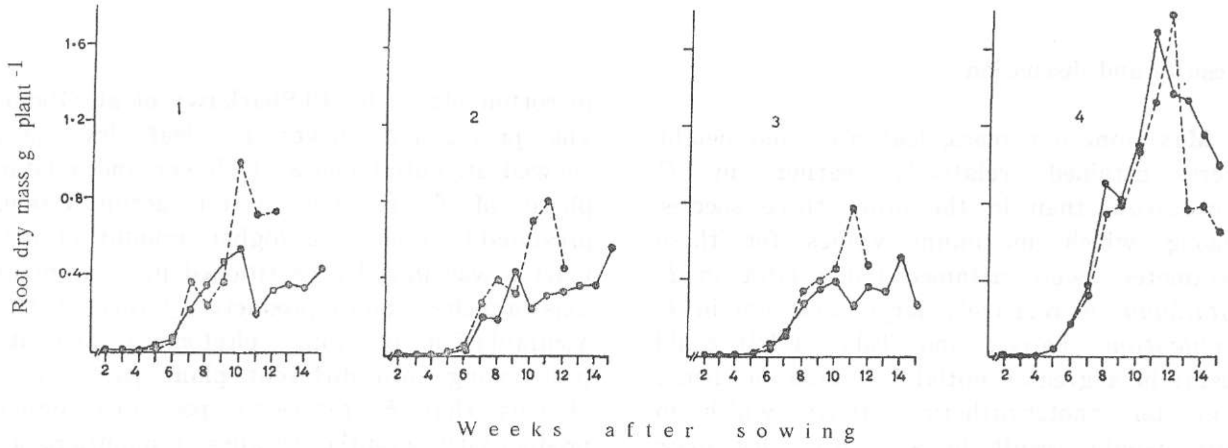

Fig. IV. Time course of root dry mass for trial I (·———·) and trial II (· - - - ·) in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

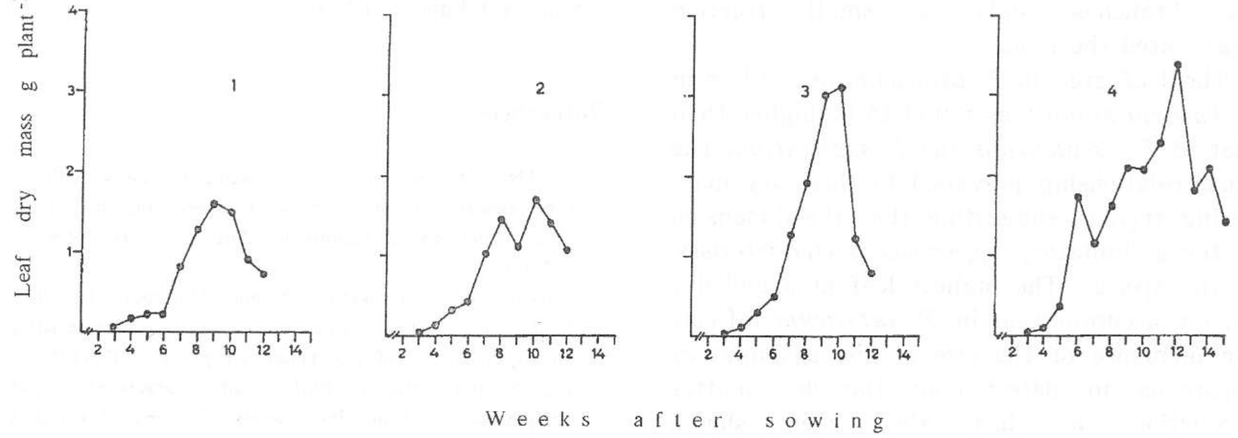

Fig. V. Time course of leaf dry mass for trial II in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

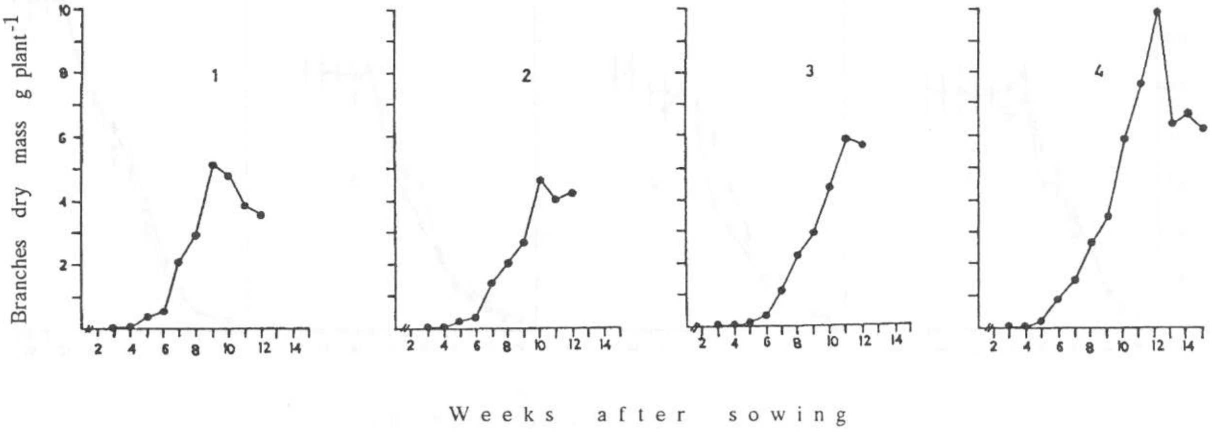

Fig. VI. Time course of dry mass of branches for trial II in four species of *Fagopyrum* viz. *F. esculentum* 1, *F. sagittatum* 2, *F. kashmirianum* 3 and *F. tataricum* 4.

Results and discussion

Maximum dry mass, leaf area and height were attained relatively earlier in *F. esculentum* than in the other three species, among which maximum values for these parameters were attained much later in *F. tataricum*. A relatively large seed size in *F. esculentum* (Farooq and Tahir 1982) could result in a greater initial leaf area and hence a greater photosynthetic activity which in turn would result in a greater dry mass increase at initial stages in this species. This accords with the findings of Black (1957) for *Trifolium subterraneum*. While a major portion of the dry mass was partitioned into the branches, only a small fraction represented the roots.

The leaf area in *F. tataricum* as well as in *F. kashmirianum* was found to be higher than that of *F. esculentum* and *F. sagittatum*. The same relationship prevailed for leaf dry mass during trial II, suggesting that the dimension of the assimilatory apparatus is characteristic of the species. The highest leaf area and dry matter accumulation in *F. tataricum* reflects the influence of the size of the assimilatory apparatus in determining the dry matter production, as has also been shown in cotton plants by El-Sharkawy et al. (1965). The progressive curves for leaf dry mass showed an initial phase of slower and a later phase of faster dry matter accumulation, presumably because a higher amount of dry matter was initially partitioned into the main axis/branches. Since productivity reflects the accumulation of total phytomass and its partitioning into different plant parts, it is obvious that *F. tataricum* possesses higher productivity potential because it maintains an increasing trend in its biomass and leaf area for a longer duration. Further, the maximum yield efficiency has been recorded in this buckwheat species in pot culture experiments (Tahir and Farooq 1989).

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5th International Symposium on Buckwheat

Organized under the auspices of The International Buckwheat Research Association

First circular

Taiyuan, The people's Republic of China, 20-26 August 1992

Objectives:

To discuss biology, genetics and breeding, germplasm management and utilization of buckwheat.

Language:

The official language of the Symposium will be English.

Invitations:

Scientists who wish to receive a personal invitation to present a communication to the Symposium should let know by 31 July 1991 to:

Prof. Lin Rufa , Head of Small Grain Programme
Shanxi Academy of Agricultural Sciences, Taiyuan, 030031, Shanxi Province
People's Republic of China
Tel. 774804-3012, Cable adress Taiyuan 1759, FAX 0351-740092

Details will be given in the second circular.

Scientists who wish to publish their reports in the symposium's collection materials should send 4 copies in English by 1 November, 1991.

Commentary

When the Socialist Federal Republic of Yugoslavia was created after the second world war, the six individual republics of which it was composed retained the constitutional right to self-determination. The current constitution, dating from 1974, is quite clear in this respect.

Even prior to the recent dramatic events in Eastern Europe, when the previous political system collapsed, there had been major democratic changes in Yugoslavia, primarily in the two most westerly republics of Slovenia and Croatia. Since the growth of democracy was less pronounced in other parts, and on the level of the Federation, this added to the historical, linguistic, cultural, religious and other differences among the republics and caused many problems, constant tension and even armed conflict.

To avoid further difficulties and conflict, at the end of 1990, the inhabitants of Slovenia and Croatia voted by overwhelming majorities for independence. The plebiscites were based on the Constitution of Yugoslavia and held in the presence of international observers. The two republics, Slovenia and Croatia, simultaneously offered the other republics negotiations on some looser form of association.

Slovenia and Croatia, supported by Bosnia-Herzegovina and Macedonia, sought a peaceful dissolution of Federal Yugoslavia. Every effort in this direction was consistently blocked, most notably by the still hardline communist regime of Serbia and by unreformed federal structures, including the army. In May, 1991, Serbia and Montenegro prevented the election of a new President of the Presidency of Yugoslavia and thus created a situation in which there was no constitutional Commander-in-Chief of the federal army. On June 26th, after the Republics of Croatia and Slovenia declared their independence, the army, acting without the authority of the Federal government, used tanks to try to seal off Slovenia's access to the outside world. During the brief war which took place, Ljubljana airport, TV and radio transmitters, and several population centres, were bombed by the federal army. Many civilians, including 10 foreigners, as well as young conscripts of about 19 years old belonging to the federal army and members of the territorial defence forces of Slovenia, died in the fighting. The material damage is immense.

An uneasy truce is now in place in Slovenia, under international observation. The war has moved to Croatia, where Serbian militias, implicitly supported by the federal army, are wreaking havoc throughout the republic.

Understandably, the war created a number of organisational problems in preparing and printing Fagopyrum. We apologise for the delay.

We pray for mutual understanding, friendship, democracy and peace throughout the world.

The Editor

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