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**FAGOPYRUM (Buckwheat Newsletter)** is open to everyone interested in buckwheat and will cover all aspects of buckwheat research: genetics, cytology, breeding, cultivation, nutrition, utilization, biochemistry and other. No special priority is given to any language. Scientific papers, reviews, research notes on work in progress or on results not yet published: comments and speculations related to buckwheat; list of stock materials wanted or available; lists of names, addresses and field of work of scientists who have expressed the desire to receive the Newsletter; lists of publications which are related to buckwheat and which have appeared during preceding years; announcements concerning the promotion of research on buckwheat (workshop, symposia, and so on); abstracts and/or contents of published papers/books on buckwheat; bibliographies and other information related to buckwheat or buckwheat research will be published. In order to facilitate the elaboration of the bibliography scientists are asked to send reprints of their own publications to the editor of Fagopyrum.

**Front page photo:** Farmer and her children who harwest buckwheat at Chumey. (See paper of O. Ohnishi, pp. 5-13)

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# Buckwheat in Bhutan

Ohmi Ohnishi
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**Key words:** *F. cymosum*, *F. gracilipes*, common buckwheat (Jare), tartary buckwheat (Bjo), utilization of buckwheat

**Abstract**

Two wild species, *Fagopyrum cymosum* Meissn. and *F. gracilipes* Hemsl. grow in Bhutan. They are weeds and have never been utilized. This is the first report on the distribution of *F. gracilipes* in the Himalaya; Bhutan is the western limit of the distribution of *F. gracilipes*. Common buckwheat (called Jare or Gare in Bhutan) and Tatary buckwheat (called Bjo) are both cultivated frequently on mountain slopes throughout Bhutan, in particular in eastern Bhutan. Flour of both species is used to make tsampa-like food, chapati-like pancake and buckwheat noodles. The Bhutanese use a special tool called a putta to make buckwheat noodles.

Allozym assays of common and Tartary buckwheat suggest that both species probably came from southern China, the original birth place, through northern Myanmar and the Naga hills and diffused farther west to Nepal and the Indian Himalaya.

**Ajda v Butanu**

V Butanu rasteta dve divji vrsti ajde *Fagopyrum cymosum* in *F. gracilipes*. To sta plevelni rastlini, ki ju nikoli niso gojili ali uporabljali. Ta članek je prvo poročilo o razširjenosti *F. gracilipes* na območju Himalaje. Butan je zahodna meja razširjenosti te rastline. Navadno ajdo (v Butanu imenovano jare ali gare) in tatarsko ajdo (imenovano bjo) pogosto gojijo na gorskih pobočjih, posebej v vzhodnem delu. Moko obeh vrst uporabljajo za hrano (tsampa, čapati in ajdovi rezanci). V Butanu uporabljajo posebno napravo (imenovano putta) za pripravo ajdovih rezancev. Alozimske raziskave navadne in tatarske ajde nakazujejo da sta obe vrsti verjetno prišli iz južne Kitajske, kjer sta nastali; od tu pa sta se razširili dalje na zahod proti Nepalu in Indijski Himalaji.

## Introduction

My discovery of the wild ancestor of common buckwheat in Yunnan province of China (Ohnishi 1991) clarified that common buckwheat was born in southern China rather than northern China or Siberia as proposed by De Candolle (1883). Buckwheat cultivation probably spread from there to northern China in one direction and to the Himalayan regions in the other direction. Tartary buckwheat, the other cultivated buckwheat, also originated in Sichuan province of China and has diffused like common buckwheat (Ohnishi unpublished).

Both common and Tartary buckwheat are very popular crops in the Himalayan regions, and to some extent also in Tarai, cultivated mostly in the hills. Common buckwheat is called "ogal" in India, "mite phapar" in Nepal and "jare" in Bhutan, while Tatary buckwheat is called "phapar" in India, "tite phapar" in Nepal and "bjo" in

Bhutan. Buckwheat in the Himalayan regions has been studied to some extent (see Gohil *et al.* 1983, Ohnishi 1985, Ohnishi and Nishimoto 1988, Baniya 1990). Common buckwheat in this region does not differ so much in morphology from that in southern China as vegetatively being very vigorous and sensitive in photoperiodism and also in allozyme variability (see Ohnishi 1988). The samples used in those studies mostly came from Nepal, Garwal, Kumaun and Kashmir. At present, we completely lack information on buckwheat from the areas of northern Myanmar, Naga hills, Assam and Bhutan.

Recently I had an opportunity to visit Bhutan and collect buckwheat samples (see Table 1 and Fig.2) as a member of the scientific expedition team conducted by Prof. Ichiro Fukuda, Tokyo Woman' Christian University. In this article, I briefly describe wild buckwheat species in Bhutan, buckwheat cultivation and its utilization in Bhutan and provide a brief summary of allozyme assay of common and Tartary buckwheat in Bhutan, and discuss the issue of transmission of buckwheat species in the Himalayan regions.


Figure 2. Route of the expedition in Bhutan

## Buckwheat species in Bhutan

1. Wild species

Only two species grow in Bhutan. One is a perennial buckwheat *F. cymosum* Meissn. This species is commonly found around habitation on farms in the Paro, Thimphu and Tongsa valleys (see Fig. 1C and Fig. 2), but is never found in the Punaka valley. The species is tetraploid as in Nepal and India; this was first noticed by Ujihara and Matano (1982). Both pin and thrum plants grow together and plants set many seeds in late September to October, in contrast with the adjacent Darjeeling area in India where only thrum plants grow. Although this species grows very vigorously everywhere, it has never been utilized in Bhutan. In Nepal, in Grung, it

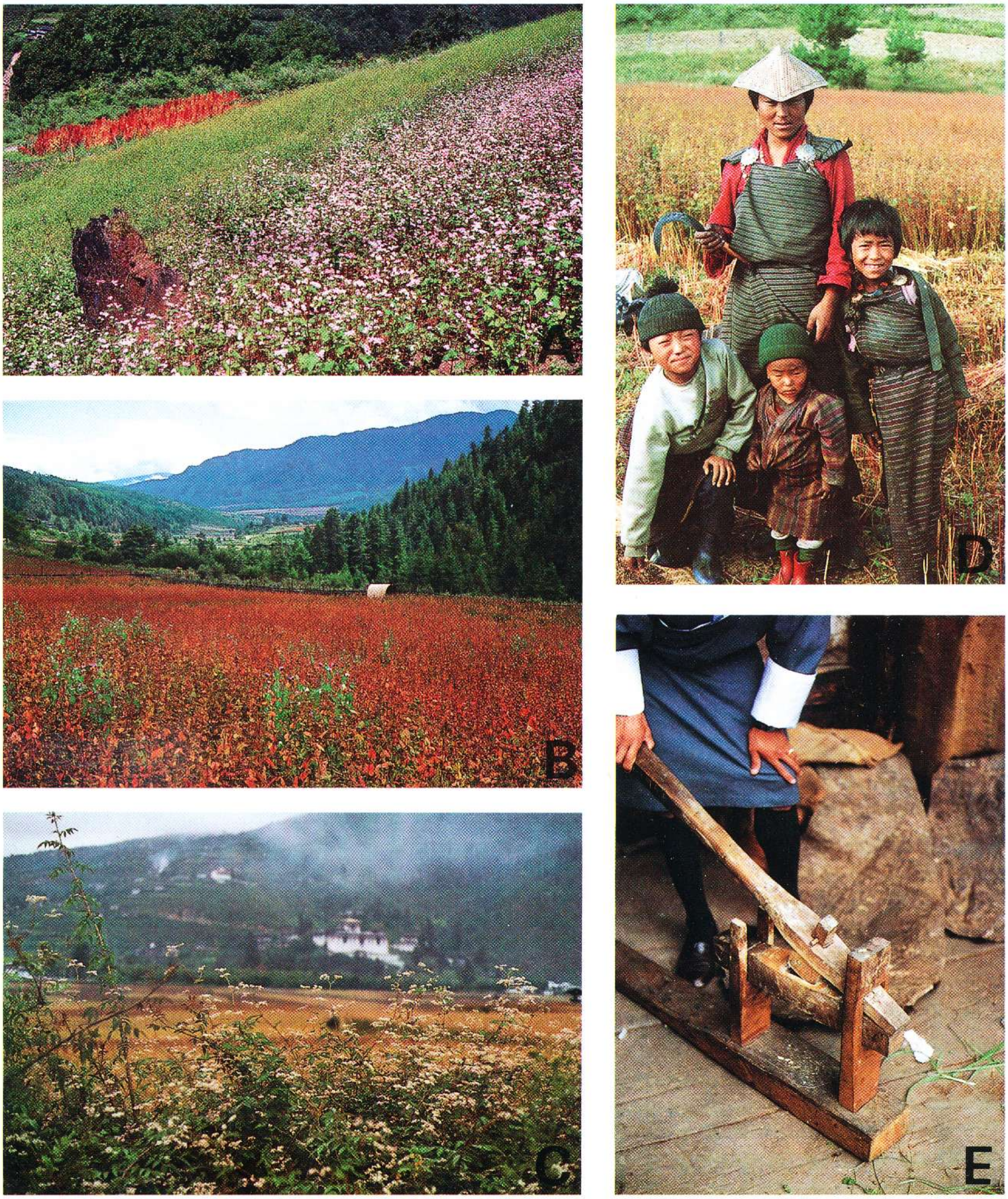


Figure 1.
A. Common buckwheat (white) and tartary buckwheat (green) cultivation at Khelakha
B. Common buckwheat field mixed with tartary buckwheat at Gyetsa
C. *F. cymosum* at Paro
D. A farmer and her children who harvest buckwheat at Chumey
E. A buckwheat noodle making equipment, putta, at Gyetsa

is called "Barmare" and it is utilized as forage for cattle and goats. Its young leaves can even be used for human consumption (see also Regmi 1982). This species is a medicinal plant in Nepal (Mall and Shakya 1984), as in China and northern Thailand.

The second wild species in Bhutan is *F. gracilipe* Hemsl., a weedy species in farmer's fields. This species has never been reported from Tibet (see, for example, Wu 1985) or Nepal (Hara 1966) and I could not find it in Nepal and Tibet in 1986 and 1990, respectively. This species was seen in Paro, Thimphu and Chandebji as a weed in farmer's fields, as well as on road sides (see Fig. 2 and Table 1). This species is the most successful colonizer and has the widest distribution in China amongst *Fagopyrum* species. Bhutan is the western limit of the distribution of the species, which is also tetraploid.

2. Cultivated species

Both common and Tartary buckwheat are cultivated commonly on mountain slopes higher than 2000 m above sea level throughout Bhutan, in particular in eastern Bhutan, such as Bumthan (see Fig. 1A,B,D). Common buckwheat is called "Jare", or not uncommonly "Gare" and Tartary buckwheat is called "Bjo" in the Bhutanese language, Dzonkar. Both species are sown in July to August and harvested in late September to October. They are used to make flour and consumed as a tsampa-like food (just add water to flour and make dough, then eat with some seasoning) or thin chapati-like pancake (this is called "phapar" in India) or thick pancake. Buckwheat flour is also used to make noodle, like the Japanese soba (buckwheat) noodle. After making dough of buckwheat flour, Bhutanese use a noodle-making machine (see Fig. 1E). The dough is pressed through a hole in the equipment, then the noodle comes through narrow channels (2-3 mm in diameter). The noodle is boiled and eaten. The principle of the equipment is the same as the Chinese "he lou chuan". However, I do not know the geographical distribution of this kind of buckwheat-noodle maker. Common and Tartary buckwheat are not distinguished critically when they are consumed nor in cultivation. The two species are thus frequently grown mixed together in fields.

## Allozyme variability in buckwheat in Bhutan

The procedure for allozyme assay is the same as was described in Ohnishi (1985) and Ohnishi and Nishimoto (1988). 200 individuals were assayed for each population of common buckwheat, and 10 individuals for each Tartary buckwheat population.

1. Common buckwheat

It has been shown that buckwheat populations from different parts of Eurasia have a similar genetic construction so far as enzyme loci are concerned; no critical differentiation has occurred among different localities (see Ohnishi 1988). Table 2 shows the allele frequency at polymorphic loci in five Bhutanmese populations. Among the populations studied, the Drukyal population is not a properly cultivated population; rather it is a population of contaminative plants in cultivated Tartary buckwheat. The population size is very small, several hundreds plants. Hence, this population lost variability by random drift at the *6-Pdh-1* and *Pgm-2* loci, while, it increased the frequency of the S allele at *Dia-2*. The other four populations have a more or less similar gene frequency at each locus both to southern China and eastern Nepal populations, having a frequency which lies between the Chinese and Nepalese populations.

Table 1. Buckwheat samples collected in Bhutan

| Line number | Species | Name of village | Altitude | Date of Sampling |
|---|---|---|---|---|
| B9110 | F. esculentum | Drukyal Dzong | 2600 | Sept. 24 |
| 11 | " | Khelakha | 1930 | 28 |
| 12 | " | Gyetsa | 2900 | 28 |
| 13 | " | Jakar | 2580 | 29 |
| 14 | " | Chumey east | 2700 | 29 |
| 15 | " | Chumey | 2680 | 29 |
| 16 | " | Serpuchen | 2200 | 30 |
| B9121 | F. tataricum | Drukyal Dzong | 2600 | 24 |
| 22 | " | Thimphu | 2350 | 24 |
| 23 | " | Thimphu(market) | " | 26 |
| 24 | " | Khelakha | 1930 | 28 |
| 25 | " | Nobding | 2530 | 28 |
| 26 | " | Longtola | 3070 | 28 |
| 27 | " | Nikkachu | 2750 | 28 |
| 28 | " | Sherubling | 2200 | 29 |
| 29 | " | Tongsa | 2070 | 30 |
| 30 | " | Gyetsa west | 2900 | 29 |
| 31 | " | Gyetsa | 2860 | 29 |
| 32 | " | Jakar | 2550 | 29 |
| 33 | " | Chumey east | 2700 | 29 |
| 34 | " | Chumey | 2680 | 29 |
| 35 | " | Serpuchen | 2200 | 30 |
| 36 | " | Chandebji | 2320 | 30 |
| 37 | " | Chandebji (field) | " | 30 |
| 38 | " | Rukubji | 2740 | 30 |
| 39 | " | Hongtsho | 2680 | Oct. 1 |
| B9101 | F. cymosum | Paro | 2300 | Sept. 24 |
| 02 | " | Memju | 2360 | 24 |
| 03 | " | Thimphu | 2350 | 26 |
| 04 | " | Olakha | 2300 | 26 |
| B9105 | F. gracilipes | Paro | 2300 | 24 |
| 06 | " | Thimphu | 2350 | 26 |
| 07 | " | Memju | 2360 | 24 |
| 08 | " | Chandebji | 2320 | 30 |
| 09 | " | Hongtsho | 2680 | Oct. 1 |

2. Tartary buckwheat

Tartary buckwheat has only a few allozyme variants within a species in spite of its high morphological variability (Ohnishi 1986). In the Himalayan regions, the F allele at the *Lap* locus is a unique variant. In Figure 3. variability at this locus for the samples from Nepal and Bhutan is plotted on a map. Two facts should be noticed from the figure. (1) The variant F allele can be seen in Bhutan, Kalimpong and eastern Nepal, but it completely disappears from western Nepal. (2) This allele can not be seen in deeper parts of valleys in Nepal, i.e. Dudh kosi, Tamur river and Trisuli river. These insist that buckwheat cultivation once diffused throughout the Himalayan regions; at that time Tatary buckwheat had the normal non-variant allele at the *Lap* locus. Later a mutation occurred, probably in Bhutan, then cultivars with the variant F allele spread along the main trading roads from east to west, Bhutan to Kathmandu valley.

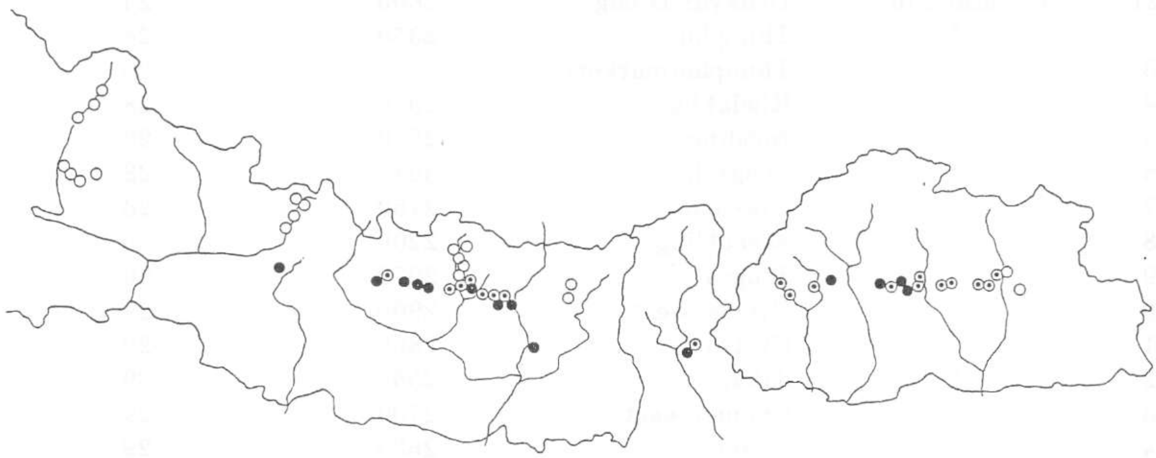

Figure 3. Distribution of the F and N alleles at the Lap locus in Nepal and Bhutan (○ monomorphic of N, ⊙ polymorphic of N and F, ● monomorphic of F )

**Discussion**

From the point of view of the study of the origin and subsequent spreading processes of buckwheat cultivation, a survey of buckwheat species in Bhutan gives a clue to understanding east-west movement of buckwheat cultivation. Diffusion of buckwheat along the south slope of the Himalayas was first noticed by Nakao (1957) and it was he who first pointed out that southern China may be the centre of buckwheat cultivation. I later confirmed it in finding the wild ancestor of common buckwheat in Yonsheng xian of Yunnan province (Ohnishi 1991).

*F. cymosum* successfully colonized as a major weed around habitation and farming areas in Bhutan, Nepal and India, and it is utilized as forage for cattle in Nepal. *F. graciliepes*, which is the most successful colonizer of *Fagopyrum* species in China, has extended its distribution up to Bhutan. Although it has never been found in Nepal (Hara 1966), it has the potential to spread farther west in future.

Wild, weedy, tartary buckwheat is quite common in Sichuan, Tibet and Karakoram, but it has not been found in Nepal and Bhutan. Furthermore, I have never found any sign of movement of buckwheat species across the great Himalayas, from Tibet to

Table 2. Allele frequency at polymorphic loci of common buckwheat populations in Bhutan

| Locus | 6-Pdh-1 | | | Pgm-2 | | | Adh | | | Mdh-1 | | Gdh | | Sdh-1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allele | S | F | N | S | F | N | S | F | N | F | N | F | N | S | F |
| Population | | | | | | | | | | | | | | | |
| Sichuan* | 2.8 | 0.6 | 96.6 | 13.6 | 8.6 | 77.8 | 0.1 | 2.7 | 97.2 | 42.5 | 57.5 | 0.5 | 99.5 | 47.7 | 52.3 |
| Yunnan** | 5.0 | 0.5 | 94.5 | 12.9 | 8.8 | 78.3 | 0.4 | 2.2 | 97.4 | 35.9 | 63.1 | 0.3 | 99.7 | 52.8 | 46.2 |
| Bhutan | | | | | | | | | | | | | | | |
| Jakar | 1.8 | 0.0 | 98.2 | 11.3 | 6.5 | 82.2 | 0.5 | 1.0 | 98.5 | 44.8 | 55.2 | 1.5 | 98.5 | 56.7 | 43.3 |
| Chumey | 3.5 | 0.3 | 96.2 | 10.8 | 4.3 | 84.9 | 0.5 | 1.3 | 98.2 | 41.4 | 58.6 | 0.8 | 99.2 | 58.3 | 41.7 |
| Gyetsa | 3.8 | 0.0 | 96.2 | 12.0 | 3.3 | 84.7 | 0.3 | 1.3 | 98.4 | 49.8 | 50.2 | 1.5 | 98.5 | 50.8 | 49.2 |
| Khelakha | 5.0 | 0.0 | 95.0 | 10.3 | 5.0 | 84.7 | 0.0 | 0.5 | 99.5 | 32.5 | 67.5 | 1.5 | 98.5 | 59.1 | 40.9 |
| Drukyal | 0.0 | 0.0 | 100.0 | 0.8 | 0.5 | 98.7 | 0.0 | 3.8 | 96.2 | 34.3 | 65.7 | 0.8 | 99.2 | 48.0 | 52.0 |
| Kalimpong | 7.9 | 0.0 | 92.1 | 13.1 | 6.1 | 80.8 | 0.9 | 0.2 | 98.9 | 26.5 | 73.5 | 0.2 | 99.8 | 58.8 | 41.2 |
| East Nepal*** | 5.3 | 0.3 | 94.4 | 11.5 | 7.5 | 81.0 | 0.6 | 0.0 | 99.4 | 30.5 | 69.5 | 0.0 | 100.0 | 59.8 | 40.2 |

| Locus | Got-2 | | | Mdh-3 | | | | Dia-2 | | | Pgm-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allele | U | S | N | U | S | F | N | S | F | N | S | F | N |
| Population | | | | | | | | | | | | | |
| Sichuan* | 10.0 | 47.6 | 42.4 | 1.0 | 22.7 | 14.5 | 61.8 | 5.3 | 0.4 | 94.3 | 12.5 | 0.1 | 87.4 |
| Yunnan** | 10.2 | 54.2 | 35.6 | 1.3 | 24.0 | 12.0 | 62.7 | 4.8 | 0.6 | 94.6 | 12.6 | 0.1 | 87.3 |
| Bhutan | | | | | | | | | | | | | |
| Jakar | 16.7 | 53.6 | 29.7 | 3.8 | 26.0 | 24.0 | 46.2 | 1.9 | 0.0 | 98.1 | 8.8 | 2.0 | 89.2 |
| Chumey | 12.3 | 46.2 | 41.5 | 0.8 | 13.5 | 23.0 | 62.7 | 7.6 | 0.0 | 92.4 | 10.4 | 0.0 | 89.6 |
| Gyetsa | 15.6 | 50.8 | 33.6 | 0.0 | 20.5 | 20.5 | 59.0 | 4.1 | 0.0 | 95.9 | 8.3 | 0.0 | 91.7 |
| Khelakha | 10.4 | 51.7 | 37.9 | 0.5 | 17.4 | 15.7 | 66.4 | 5.6 | 0.0 | 94.4 | 13.5 | 1.0 | 85.5 |
| Drukyal | 8.2 | 32.8 | 59.0 | 0.0 | 10.5 | 14.5 | 75.0 | 30.3 | 0.0 | 69.7 | 5.9 | 0.0 | 94.1 |
| Kalimpong | 6.3 | 47.8 | 45.9 | 0.5 | 18.8 | 15.8 | 64.9 | 7.3 | 0.8 | 91.9 | | | |
| East Nepal*** | 8.2 | 46.4 | 45.4 | 0.0 | 19.2 | 12.6 | 68.2 | 4.3 | 3.2 | 92.5 | | | |

* Average of 6 populations (Ohnishi unpublished)

** Average of 5 populations (Ohnishi unpublished)

*** Average of 3 populations (after Ohnishi and Nishimoto 1988)

Nepal or Bhutan. Wild tartary buckwheat was, thus, not accompanied by other *Fagopyrum* species. I assume, judging from the present growing habits of wild tartary buckwheat in Tibet, it diffused across the Tibetan plateau, Nakao's Tibetan arc, from east to west accompanying barley. Barley, emmer wheat and yumai are believed to have passed through this arc from west to east (Nakao 1957).

All the evidence we now have, i.e., the geographical distribution of *Fagopyrum* species, allozyme variability between southern Chine and the Himalayan region, suggests that not only common buckwheat but also tartary buckwheat and two wild species, *F. cymosum* and *F. gracilipes* diffused along the south slope of the Himalayas, i.e., Nakao's Himalayan arc. For common buckwheat, which is relatively resistant to humid high temperature, it was not difficult to have passed northern Myanmar and crossed the Brahmaputra river and arrived at the lower part of eastern Bhutan, where we now see slash/burn (swidden) cultivation of buckwheat and rice plant. Similar buckwheat cultivation is also seen in the Assam hills (K. Nishioka, Dept. of Agr. of Bhutan, personal communication). An ethnobotanical survey in Meghalaya, northeastern India (Neogi *et al.* 1989) reports that buckwheat is called "Jarain" in Khasi, while it is called "Jare" in Bhutan; this suggests that buckwheat in Bhutan and Assam hills probably have common roots in Nagaland (see chap. 1 of Alemchiba 1970 for migration of peoples in Nagaland). Tartary buckwheat might have taken a northern route. From Sichuan, the birth place of tartary buckwheat, crossing Jinjang, Mekon and Salween rivers and entering the eastern corner of Tibet, then taking the route southwest and arriving at the Brahmaputra river, proceeding like common buckwheat to east Bhutan.

A study of the geographical distribution of buckwheat noodle may add to our understanding of buckwheat diffusion in this area. The noodle making machine, putta, in Bhutan has its origin either in "he lou chuan" of northern China or in similar equipment for making rice flour noodle in southern China. However, the exact distribution of the equipment has not been studied.

In conclusion, common and tartary buckwheat and two wild species, were all born in southern China, diffused along the southern slope of the Himalayas, as first noticed by Nakao (1957), while wild tartary buckwheat took Nakao's Tibetan route and extended its distribution to northern Pakistan.

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# Response of buckwheat to phosphorus rate and placement

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**Key words:** *Fagopyrum esculentum* Moench, seedling establishment, yield

**Abstract**

Field studies were conducted at the Morden Research Station to determine the maximum levels of P that can be placed with or near the seed. In 1982 - 1984, the cultivar Manor was grown with four levels of P (0, 50, 100, 150 kg $ha^{-1}$ $P_2O_5$) as triple superphosphate (0-46-0) with five band placement methods using hoe openers and a 30 cm row spacing. The 50 kg $ha^{-1}$ $P_2O_5$ rate had no detrimental effect on seedling stands or seed yields. However, the highest levels of P (100 and 150 kg $ha^{-1}$ $P_2O_5$) applied with the seed caused reductions in seedling stands in one of the three years, but did not decrease seed yields.

**Vpliv odmerka in razporeditve fosforja na pridelek in na gostoto posevka ajde**

Na Morden Research Station v Kanadi so izvedli poljski poskus, da bi ugotovili najvišje možne odmerke fosforja, ki se lahko razporedijo v bližini semen. Poskusi so potekali v letih 1982 do 1984. Kultivar 'manor' so pognojili s štirimi različnimi odmerki fosforja (0, 50, 100, 150 kg/ha $P_2O_5$) kot trojnega superfosfata (0-46-0) razporejenega na 5 različnih načinov v trakovih in pri 30 cm razdalji med vrsticami. Tudi odmerek 50 kg/ha $P_2O_5$ ni negativno vplival na gostoto posevka ali na pridelek zrnja. Najvišja odmerka P 100 in 150 kg/ha $P_2O_5$ sta povzročila zmanjšanje gostote posevka v enem od treh let, čeprav se pridelek ni znižal.

## Introduction

Buckwheat has an indeterminate flowering habit and produces many flowers, of which often only a small percentage develop into normal mature seed. Low seed set can be caused by several factors. Krotov (1963) reported that flowering of buckwheat at temperatures above 30 °C was accompanied by desiccation of the fruit and a lowering of yield. Low soil moisture levels during periods of high temperature can aggravate the situation (Krotov 1963; Marshall 1969; Veremeichik 1972). Phosphorus (P) is generally known to promote seed formation and the application of P fertilizer results in increased seed yield when P is limiting in the soil.

This study was conducted to determine the maximum levels of phosphorus that can be placed with or near the seed.

## Materials and methods

Field experiments were conducted at the Agriculture Canada Research Station, Morden, Manitoba, from 1982 to 1984. Plots consisted of four rows 6 m long with 0.3 m between rows and 1.5 m between plots. The seeding rate was adjusted according to germination tests to provide 125 viable seeds per 6 m row. After seedling emergence, rows were trimmed to 5 m. All four rows of each plot were used for data collection.

Treatments included five methods of placement and four rates of P fertilizer. The treatments were replicated four times and were arranged in a split-plot design with placement method as main plot treatments and P rate as subplot treatments. Placement treatments included: (1) narrow and (2) wide bands in which hoe openers placed the seed and fertilizer together in 1.5- and 5-cm wide bands, respectively; (3) separate bands in which hoe openers placed the seed and fertilizer in separate bands 1.5 cm wide and 4.5 cm apart, both at the same depth; (4) 4.5 cm x 3 cm placement, fertilizer placed 4.5 cm to the side and 3 cm below the seed; and (5) fertilizer was placed 3 cm below the seed. The four rates of P were 0, 50, 100, 150 kg $ha^{-1}$ $P_2O_5$. The triple superphosphate (0-46-0) formulation of P was used. The tests were grown on barley stubble in 1982 and on summerfallow in the other two years. The soil was a clay loam with 149, 188 and 198 kg $ha^{-1}$ $NO_3$, 25, 64 and 38 kg $ha^{-1}$ P and 630, 889 and 725 kg $ha^{-1}$ K in 1982, 1983 and 1984, respectively, at 0-60 cm depth for $NO_3$, and 0-15 cm for P and K. Seeding dates were 21, 6 and 16 June in 1982, 1983 and 1984, respectively. Data were recorded on seedling stands, plant height at maturity, seed yield, volume weight and seed weight. Standard multi-year analyses of variance were conducted, as well as linear and quadratic analyses to determine the effects of fertilizer rates.

## Results and discussion

Seedling stand counts recorded soon after seedling establishment were not affected by triple superphosphate applied separate from the seed. However, stands were reduced at the high rates of P where the fertilizer was placed with the seed. In the narrow band treatment, seedling counts averaged over the 3 yr were 19, 19, 18 and 17 seedlings $m^{-1}$ of row for the 0, 50, 100 and 150 kg $ha^{-1}$ $P_2O_5$ rates, respectively. Corresponding values for the wide band treatment were 21, 20, 18 and 17 seedlings $m^{-1}$ of row. These reductions were largest in 1984, when the average for all plots without added P was 18 seedlings $m^{-1}$ of row compared to 13 and 14 for the narrow and wide bands, respectively, at the 150 kg $ha^{-1}$ $P_2O_5$ rate. Plant height at maturity decreased slightly with increase in P rate from 118 to 115 cm from lowest to highest P rate. Although there were small differences from year to year and from one placement method to another, there were no marked yield responses from the addition of P. Volume weights were not markedly affected by placement method or P rate. Seed weight decreased linearly with increase in P rate from 30.5 to 30.0 g $1000^{-1}$.

Racz (1980) reported that response to P applied with or near the seed is obtained in about 25 to 30% of instances with annual crops even if the soil has high or very high levels of available P. However, no response was achieved in these tests as P levels were probably adequate. Strong and Soper (1974, I and II) found that buckwheat had a high capacity to utilize P from a fertilizer band, but P recovery from the band was greatly reduced as the P level in the soil surrounding the band was increased. McClachlan (1976) also reported on the high efficiency of use of P by buckwheat.

High rates of triple superphosphate fertilizer reduced seedling stands only when applied in the same band as the seed. These reductions were evident only at the highest P rates in only one of the three years (1984). There was no consistent relationship between seedling stands and seed yield. Other research (Gubbels and Campbell 1986) has shown that buckwheat has a great capacity to compensate for reduced stands. Undoubtedly, if there had been a large increase in yield due to P application, as could be expected in soils low in P, then those increases could more than compensate for reduced stands. Ukrainetz et al. (1975) stated that in soils low in fertility, a moderate decrease in plant stands due to fertilizer may not result in decreased yields if growing conditions favor a strong response to fertilizer.

The absence of large reductions in seedling stands and seed yields by high rates of P applied with the seed may be due to the lower concentration associated with application by hoe openers as compared to higher concentration in a small band by double disc openers. The Manitoba recommendation that no more than 20 kg $ha^{-1}$ $P_2O_5$ should be placed with the seed (Anonymous 1988) is based on the use of double disc openers. Also, the triple superphosphate formulation used is generally considered to have less effect on emergence than formulations that contain ammonium ions or release ammonia. The advantages of applying fertilizer with the seed rather than in a separate band are that no additional equipment or attachments are required and the soil below the seed is not disturbed. The row spacing used in these experiments was 30 cm. Narrower row spacings would have proportionally lower rates of fertilizer in each linear m of row for any stated rate $ha^{-1}$. From these tests, it was concluded that the 50 kg $ha^{-1}$ $P_2O_5$ rate applied with the seed did not reduce stands or yield. The highest levels of P added with the seed reduced seedling stands in one of the three years, but did not decrease seed yields. Thus, the use of hoe openers and the triple superphosphate formulation may permit the application of moderate to high levels of P with the seed while maintaining a firm seedbed and minimizing seedling injury.

## Acknowledgements

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# Analysis of Texture of Doughs from Buckwheat Flours

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

**Abstract**

The textures of doughs made from various buckwheat flour fractions were analyzed. Doughs made from inner-layer flour fractions of buckwheat exhibited significantly higher hardness and chewiness as compared to those made from whole straight flour or from outer-layer flour fractions. The present findings suggest that the protein in buckwheat may be closely associated with the texture of buckwheat dough. On the other hand, incorporation of wheat flour into buckwheat dough altered the texture, including the hardness and springiness, of the buckwheat dough. Factors responsible for the palatability of buckwheat products are discussed.

**Analiza teksture testa iz ajdove moke**

Avtorji so proučili teksturo testa iz različnih ajdovih mok. Testo iz moke, ki izvira iz notranjosti ajdovega zrnja je bilo trdnejše v primerjavi s testom iz moke celotnega zrnja ali iz moke, ki je izvirala pretežno iz zunanjih plasti zrnja. Ugotovitve tega dela nakazujejo, da so beljakovine ajde tesno povezane s teksturo testa ajde. Hkrati pa je pomemben tudi vpliv primesi pšenične moke. Omenjeni so možni vplivi dejavnikov, ki lahko vplivajo na okusnost izdelkov iz ajde.

## Introduction

The seed of buckwheat (*Fagopyrum esculentum* Moench) contains relatively high levels of certain nutrients such as protein and vitamins, and serves as a valuable source of nutrients in some areas of the world. There are a variety of buckwheat dishes around the world (Kreft 1983). Noodles made from buckwheat flour-water dough have long been popular in Japan (Shiratori and Nagata 1986). Buckwheat seed is usually milled for human consumption. Various different kinds of buckwheat flours, such as whole flour and inner-layer flour, are utilized for preparation into products; and various types of buckwheat noodles are found in Japan, including those made from the whole flour of buckwheat and those made from the inner-layer flour. On the other hand, buckwheat flour exhibits relatively low viscoelasticity. Therefore, some binders, such as wheat flour, are often incorporated into buckwheat flour-water doughs on making noodles.

In general, an important quality factor of food is palatability. Considerable attention has been paid to the science of the palatability and acceptability of food in recent years (Sinki 1988, Szczesniak 1990). The attainment of good palatability in buckwheat products, including noodles, depends largely on the texture of the products. However, a theory regarding the texture of buckwheat products is still not established. The textures of products made from various available buckwheat flours have been not fully analyzed. Furthermore, the question of how well processing, including incorporation of such a binder as wheat flour, of the raw material into products may lead to desirable sensory texture remains unanswered. On the other hand, it appears that the texture of buckwheat may be associated with the inherent characteristics of its constituents such as protein (Ikeda *et al.* 1991a). Analysis of endogenous factors responsible for the palatability of buckwheat products is the subject of intensive investigation.

The present study was undertaken to analyze the texture of doughs made from various available buckwheat flours, including whole flour and inner-layer flour, and to clarify the effect on texture of incorporation of wheat flour into buckwheat flour.

## Materials and methods

**Materials.** Fresh buckwheat seeds were obtained locally, stored at 4°C and milled with a Brabender Quadrumat Junior roller mill prior to analysis. Four different kinds of buckwheat flour fractions from a commercial mill were kindly provided by Masuda-ya Milling Co. (Kobe, Japan) and stored at -80°C until used. On milling of buckwheat seeds, the inner endosperm is easily ground into flour, whereas the periphery is more difficult to grind. Thus, on milling, flour fractions are successively obtained from the inner to outer layers: the first fraction is superior flour (SF) (extraction yield approximately 16%); second 1F (40%); third 2F (40%); and the last 3F (3%) (Ikeda *et al.* 1991b). The contents of protein per 100 g flour, as determined by the micro-Kjeldahl method (AOAC 1984), were 4.5 ± 0.2 g (means ± S.D., n=4) for SF; 3.7 ± 0.2 g for 1F; 5.6 ± 0.5 g for 2F; and 17.3 ± 0.4 g for 3F. Wheat medium flour examined was a fresh commercial product. All other chemicals used were of analytical grade.

**Analyses.** All determinations were performed four times with different samples. Approximately 5 g of buckwheat flour was mixed with approximately 4.0 ml of distilled water, and then column forms (approximately 2 cm height x 2 cm diameter) of doughs were prepared. The texture of the doughs prepared were analyzed with a rheolometer at 20° C (Iio Denki Co., Model RX 1600) (Sherman 1970, Ikeda 1991a). In case of heated doughs, raw prepared doughs were heated in boiling water for 3 min, then cooled, and analyzed for texture. Protein (N X 6.31) was estimated by the micro-Kjeldahl method (AOAC 1984). Data were subjected to analysis of variance and the significance of means was tested by t-test.

## Results and discussion

Texture profiles of doughs made from various buckwheat flour fractions.

Table 1 shows the texture profiles of various doughs made from buckwheat whole flour and made from four buckwheat flour fractions. There were significant differences in texture among various buckwheat doughs examined. Doughs made from inner-layer flour fractions, i.e. superior flour and first flour, exhibited significantly ($p<0.05$) higher hardness and chewiness as compared with those made from outer-layer flour fractions, i.e. third flour and made from the whole flour. The two doughs made from the inner-layer flours also exhibited significantly ($p<0.05$) higher cohesiveness and springiness than those made from the outer-layer flour and made from the whole flour. On the other hand, estimated correlation coefficients ($\nu$) of each texture value to the total protein content of each buckwheat flour were: $\nu$= -0.90 for hardness; $\nu$= -0.89 for cohesiveness; $\nu$= 0.55 for adhesiveness; $\nu$= -0.91 for springiness; and $\nu$= -0.93 for chewiness. There was thus a high negative

Table 1: Texture profiles of doughs made from various buckwheat flours

| Flours | Texture profile (texturometer units)[1] | | | | |
|---|---|---|---|---|---|
| | Hardness | Cohesiveness | Adhesiveness | Springiness | Chewiness |
| Whole flour | 12.2$^{C}$ | 0.527$^{C}$ | 0.315$^{C}$ | 0.841$^{B}$ | 5.38$^{C}$ |
| Superior flour | 13.4$^{A}$ | 0.586$^{A}$ | 0.501$^{B}$ | 0.872$^{A}$ | 6.83$^{A}$ |
| First flour | 13.1$^{B}$ | 0.551$^{B}$ | 0.458$^{B}$ | 0.875$^{A}$ | 6.29$^{B}$ |
| Second flour | 12.5$^{C}$ | 0.547$^{B\ C}$ | 0.199$^{C}$ | 0.863$^{A\ B}$ | 5.91$^{B}$ |
| Third flour | 7.2$^{D}$ | 0.499$^{C}$ | 0.757$^{A}$ | 0.685$^{C}$ | 2.45$^{D}$ |

1. Heated doughs were analyzed. Values are means (n=4). Means within the same column that are not followed by the same letter are significantly different at $p<0.05$.

Table 2. Effect of incorporating wheat flour into buckwheat flour on the texture of buckwheat dough[1]

| Buckwheat dough | Texture profile (texturometer units)[2] | | | | |
|---|---|---|---|---|---|
| | Hardness | Cohesiveness | Adhesiveness | Springiness | Chewiness |
| Without wheat flour | 0.432 | 0.099 | 0.230 | 0.292 | 0.012 |
| With wheat flour[3] | 0.197* | 0.420* | 0.018* | 0.929* | 0.076* |

1. Buckwheat whole flour was used.
2. Raw doughs were analyzed. Values are means (n=4). Means with asterisk are significantly different from those of "without wheat flour" at $p<0.05$.
3. Wheat flour was incorporated into buckwheat flour with a buckwheat-to-wheat ratio of 8:2, and dough was prepared with its flour mixture.

correlation between each texture value of buckwheat doughs, except for adhesiveness, and the total protein content. These findings suggest that the protein in buckwheat flour may be closely associated with the texture of its dough. This suggestion was also confirmed in our other studies with various commercial buckwheat noodles (Ikeda *et al.* 1992). On the other hand, we have shown that there are a marked differences in protein components between buckwheat whole flour and its inner-layer flour (Ikeda *et al.* 1991b). The relationship of the texture of buckwheat dough to the protein components is a very interesting subject.

Effect on the texture of buckwheat dough of incorporating wheat flour into buckwheat flour

Table 2 shows the effect on the texture of the dough of incorporating wheat flour into buckwheat flour. Incorporation of wheat flour into buckwheat dough led to significantly ($p<0.05$) lower hardness and adhesiveness of the dough, and to significantly ($p<0.05$) higher cohesiveness, springiness and chewiness. A similar result was also found with heated doughs but with a partial difference in texture profile (data not shown). There was a more pronounced difference in texture between the two doughs, i.e., buckwheat dough with or without wheat flour, with raw doughs (Table 2).

On the other hand, we have recently performed sensory comparison with our students as panel members, with various commercial noodles (Ikeda *et al.* 1992). The sensory evaluation indicated that noodles made from a mixture of buckwheat flour and wheat flour was significantly ($p<0.05$) more palatable than noodle made from buckwheat flour alone. In addition, since the texture was assayed under essentially the same conditions as for Table 2, there was a high positive correlation of springiness of buckwheat noodles to sensory palatability, while there was a high negative correlation of hardness of the noodles to sensory palatability. These findings suggest that buckwheat noodles with appropriately low hardness and high springiness (Table 2) might be palatable and acceptable.

Buckwheat seed is a valuable source of some essential nutrients around the world. There are a variety of buckwheat dishes including flour dishes and groat dishes (Kreft 1983). On the other hand, factors responsible for the palatability of buckwheat products still remain uncertain, although there are some reports on the functional properties of buckwheat (Soda *et al.* 1981, Sugiyama and Fukuba 1981, Soral-Smietana *et al.* 1984). In addition, biochemical analysis of the texture of buckwheat is largely incomplete. Further analysis is in progress in our laboratory to establish a biochemical basis of palatability of buckwheat products.

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# Tannin-carbohydrate complex in buckwheat seeds (*Fagopyrum esculentum* Moench)

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**Key words:** fructose, glucose, HPLC, hydrolysis, polyphenols - tannin

**Abstract**

Using 72% $H_2SO_4$, the following substances were determined in hydrolysed polyphenol percolates of buckwheat seeds (Siva, Darja, Petra and Bednja 4n): carbohydrates by the Molisch test, polyphenols by a phenol test and monosaccharides (glucose and fructose) bound with tannin by high performance liquid chromatography (HPLC). The procedure was founded on ion-exchange chromatography and after-column reaction derivation with copper 2,2'-bicinchoninate and detected by using a UV-VIS spectrophotometer.

**Povezava tanina z ogljikovimi hidrati v semenih ajde (*Fagopyrum esculentum* Moench)**

V hidroliziranih (72% $H_2SO_4$) polifenolnih perkolatih semen ajde (Siva, Darja, Petra in Bednja 4n) so bili z Molischevim testom določeni ogljikovi hidrati, s testom na fenole polifenoli in s tekočinsko kromatografijo (HPLC) monosaharidi (glukoza in fruktoza), ki so vezani s taninom. Postopek je temeljil na ionsko-izmenjevalni kromatografiji s pokolonsko derivatizacijo z bakrovim 2,2'-bicinkoninatom in detekcijo z UV-VIS spektrofotometrom.

## Introduction

Tannin is an aromatic compound containing the phenol group, and characterised by an astringent taste. It is located in all plant parts (seeds, fruit, flower, tree bark, wood, leaves and occasionally in roots) but very rarely in monomer form. Tannin forms complexes with specific proteins and sugars, which renders isolation more difficult (Cai *et al.*, 1989; Hagerman, 1989).

Biosynthesis of tannin and other polyphenols is effected through the process of secondary metabolism regulated by an enzyme system whose functioning is highly complex and has not yet been fully explained (Saijo, 1980; Santappa, 1982; Koch, 1985).

The secondary metabolism process runs from glucose through shikimic acid. Aromatic compounds are transformed into lignin and other important phenol substances such as hydrolising tannins, lignans, koumarins, stilbenes, flavonoids and into final products - condensed tannins (Rice, 1984; Koch, 1985; Lewis *et al.*, 1989). It is possible with certain plant species that a C-C bond is formed between the hydrolysing and the condensed components and such substances constitute a third group of tannins - complex tannins (Nishimura *et al.*, 1986; Nonaka, 1989).

Tannins have a flavonoid $C_6$-$C_3$-$C_6$ core with attached flavan-3-ols (catechin and epicatechin) and flavan-3,4-diols (leucoanthocyanidin), or they are constituted of esters of phenol carboxyl acids (gallic acid, ellagic acid) and hexose molecules, usually glucose.

Considering tannins' high tendency to oxidation and their colloid properties, it is very difficult to define their structure and composition.

Modern research of tannins is based mainly on their structural features rather than on their chemical properties. The basis for defining the structural features are NMR spectrum interpretations of $^1H$, $^{13}C$ and chromatographic detections which enable easier study of tannins and their bonds with proteins and sugars (Kashiwada *et al.*, 1986).

## Material and methods

### Material

Two diploid buckwheat cultivars, Siva nad Darja, and two tetraploid cultivars, Petra and Bednja 4n were used for the analysis. The cultivars were grown in 1990. A UDY Tecator mill was used to mill the ripe seeds of each cultivar.

### Methods

1 Percolation (liquid-liquid extraction)

40 g of buckwheat flour (particle size 0.4 mm) was mixed with 300 ml deionised water. Percolation was performed by ethylacetate in a Kutschen-Stendel percolator. Percolation was carried out at room temperature for 7 hours. The percolate thus obtained was then concentrated using a vacuum pump.

2 Hydrolysis

200 mg of absolutely dry sample (polyphenol percolate of buckwheat flour) was hydrolysed with 2 ml of 72% sulphuric acid ($H_2SO_4$) for 1 hour at 30 $^oC$. The post-hydrolysis thus obtained was diluted with 30 ml of water and autoclaved for 1 hour at 120 $^oC$ and pressure 1.1 bar and filtered through glass filters (G-3 crucible) (Körner *et al.*, 1984).

The Molisch test was used to determine the carbohydrates in the filtrate, a phenol test was used for polyphenols, and HPLC for monosaccharides that were bound in a tannin-carbohydrate complex. The percentage of precipitate was also determined according to 200 mg of absolutely dry sample (percolate).

3 Molisch test

We added to the filtrate a 5% ethanol solution of α-naphtol to qualify those carbohydrates which are dehydrated to furfural when 72% $H_2SO_4$ is present. Furfural condenses with α-naphtol and gives a reddish-violet colour. A negative reaction shows there are no carbohydrates in the solution (Browning, 1967).

4 Phenol test

The 1% methanol solution $FeCl_3$ reacts with mono-, di- and trihydroxy phenols. A complex dark blue substance is formed which indicates the presence of polyphenols in the sample (Browning, 1967).

5 HPLC

Sugar analysis was done by high performance liquid chromatography (HPLC). Sugars in the polyphenol hydrolysate were qualified and quantified by borate ion-exchange chromatography and after-column reaction with copper 2,2'-bicinchoninate reagent (Merck).

A Biotronik Carbohydrate Analyzer LC 5001 was used. Detection was effected by UV-VIS spectrofotometer BT 0310 at wavelength 570 nm. The results were presented by integrator Shimadzu Chromatopac C-R6A. Each sample analysis took 67 minutes.

The mobile phase consisted of 5 borate buffers (Merck) of different pH and molarity values (buffer A: pH = 8.50 ± 0.05, M = 0.15; buffer B: pH = 9.00 ± 0.05, M = 0.20; buffer C: pH = 9.00 ± 0.05, M = 0.45; buffer D: pH = 9.50 ± 0.05, M = 0.80).

Prewash column dimension: 6 mm x 85 mm, pitch type: VWS - pitch ZA and maximal pore size: 10 - 16 µm; column dimension: 4 mm x 385 mm, pitch type: BTA 2118 and maximal pore size: 10 - 16 µm; postcolumn dimension: 0.5 mm x 2 mm x 30 mm.

## Results and discussion

Table 1: Test of flour hydrolysate and polyphenol percolates using the Molisch test, phenol test, pH value and precipitate quantity measurement

| hydrolysate | Molisch test | Phenol test | pH | precipitate % |
|---|---|---|---|---|
| flour: | | | | |
| Siva | ++ | - | 0.39 | 7.15 |
| Darja | ++ | - | 0.55 | 9.30 |
| Petra | ++ | - | 0.53 | 7.95 |
| Bednja 4n | ++ | - | 0.52 | 7.05 |
| polyphenol percolate: | | | | |
| Siva | -+ | ++ | 0.28 | 69.45 |
| Darja | -+ | ++ | 0.30 | 71.55 |
| Petra | -+ | ++ | 0.29 | 70.20 |
| Bednja 4n | -+ | ++ | 0.29 | 69.00 |

- negative test
-+ slightly positive test
++ higly positive test

The flour hydrolysates (Table 1) were highly positive to the Molisch test (carbohydrates test) and negative to the phenol test. This resulted in a low precipitate percentage ($\bar{x}$ = 8.17%).

Hydrolysed polyphenol extracts had a slightly positive Molisch test. It is probable that remainders of sugar were present bound with tannin. The phenol test was highly positive, which also resulted in a high precipitate percentage ($\bar{x}$ = 70.27%) containing the previously extracted polyphenols.

In the polyphenol hydrolysates of buckwheat flour we established (in comparison with the standard chromatogram Fig. 1) the presence of the monosaccharides, fructose and glucose (Fig. 2).

The cultivars analysed all contained the same monosaccharides but differed in individual monosaccharide content (Fig. 3). The diploid cultivars contained a higher amount of fructose while the tetraploid cultivars Petra and Bednja 4n contained a similar fructose and glucose percentage.

The central endosperm (starch - glucose) does not contain fructose. Therefore tannin bound to fructose is probably located in those parts of the seeds which do not contain only glucose.

## Conclusions

The tannin in buckwheat seeds is bound with monosaccharides, fructose and glucose into tannin-carbohydrate complex. The presence of fructose in the complex demonstrates that buckwheat tannin is not located in those parts of the buckwheat seed that contain glucose only (the central endosperm).

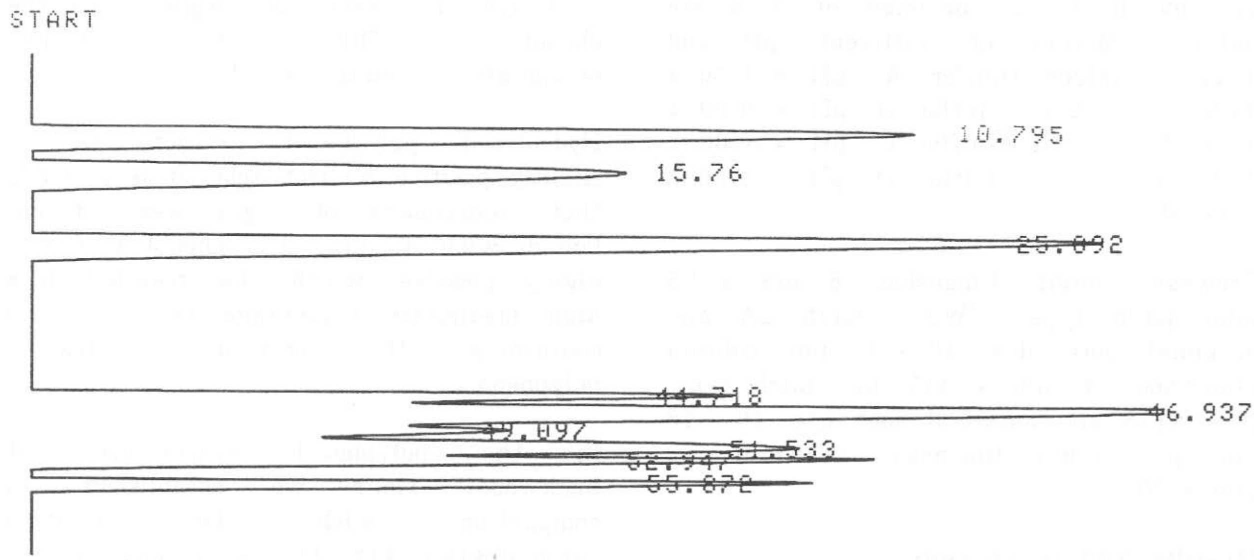


Figure 1: Monosaccharide standard chromatogram and retention times Rt = 10.79 - cellobiose, Rt = 15.76 - maltose, Rt = 25.09 - rhamnose, Rt = 44.71 - mannose, Rt = 46.93 - fructose, Rt = 49.09 - arabinose, Rt = 51.53 - galactose, Rt = 52.94 - xylose, Rt = 55.87 - glucose.

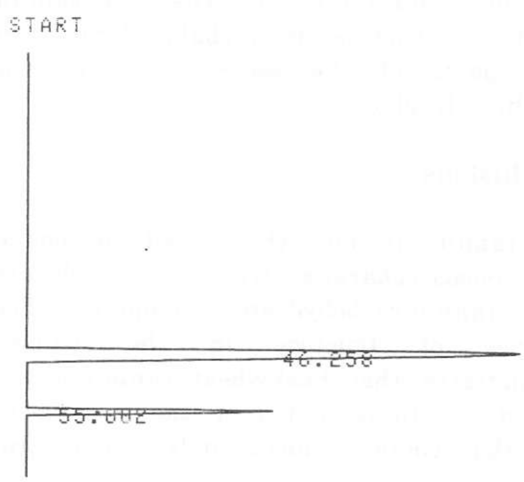


Figure 2a

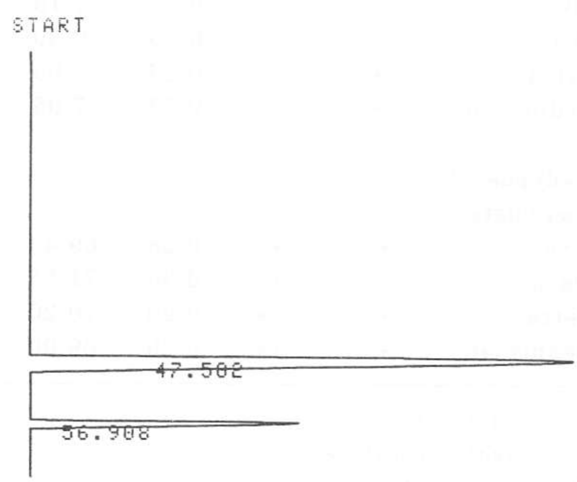


Figure 2b

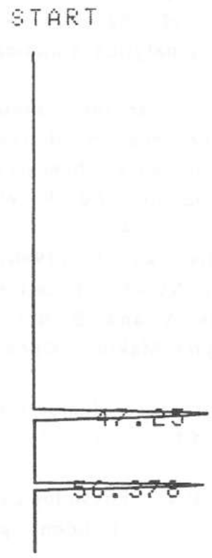


Figure 2c

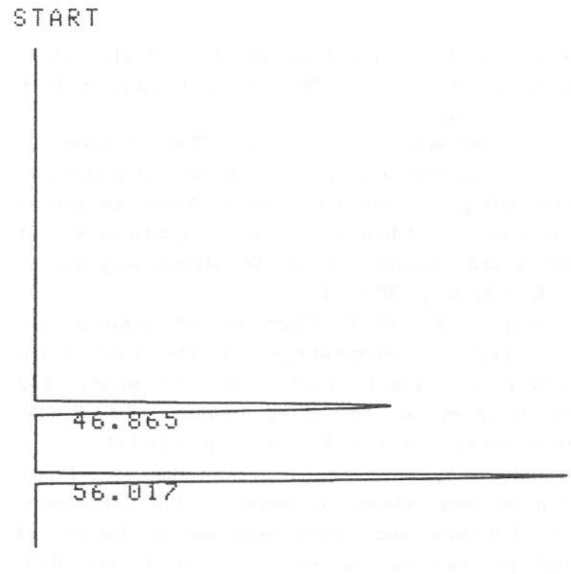


Figure 2d

Figure 2: Polyphenol hydrolysate chromatograms of the 4 buckwheat seed cultivars: 2a Siva, 2b Darja, 2c Petra, 2d Bednja 4n and retention times Rt = from 46.23 to 47.50 - fructose, Rt = from 55.02 to 56.91 - glucose.

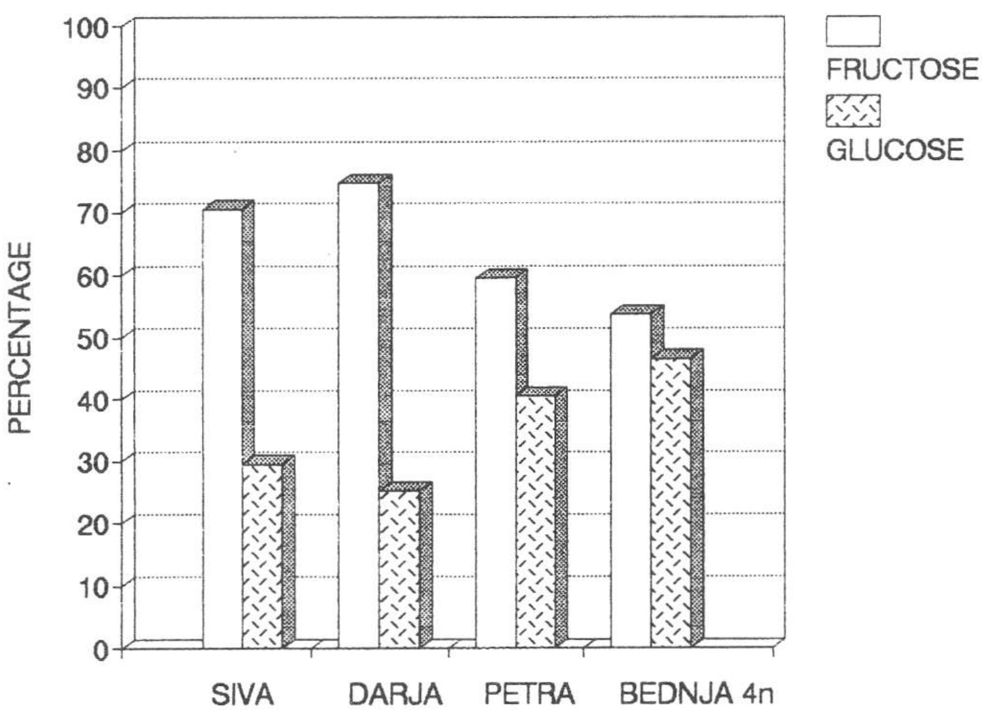


Figure 3: Fructose and glucose percentage in polyphenol hydrolysate of buckwheat flour of Siva, Darja, Petra and Bednja 4n.

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# Chemical characteristics and biological functions of phenolic acids of buckwheat and lentil seeds

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**Key words:** tannins, chemical activity, pests, natural resistance.

**Abstract**

The work presents the results of studies on phenolic compounds in buckwheat and lentil seeds. Phenolic acids, both in a free and bound form occurring in seeds and hull, were identified. The chemical and biological activities of phenolic compound extracts were determined, as well as the relation between the presence of tannins in buckwheat and resistance to storage pests growth.

**Synopsis**

W pracy przedstawiono wyniki badań związków fenolowych w nasionach gryki i soczewicy. Dokonano identyfikacji kwasów fenolowych występujących zarówno w formie wolnej, jak i związanej w nasionach i okrywie nasiennej. Określono aktywność chemiczną i biologiczną wyciągów związków fenolowych oraz zależność między obecnością tanin w gryce, a jej odpornością na rozwój szkodników magazynowych.

**Kemijske značilnosti in biološke funkcije fenolnih kislin semen ajde in leče**

V delu so prikazani rezultati raziskave fenolnih snovi v semenih ajde in leče. Fenolne kisline so bile ugotovljene v semenih in v luskah. Ugotovljena je bila kemijska in biološka aktivnost ekstraktov s fenolnimi snovmi, posebej z vidika vsebnosti taninov v ajdi in odpornosti proti škodljivcem.

## Introduction

Buckwheat and lentil are very common in the world of edible plants. Their seeds contain relatively low amounts of antinutritional substances and are low in flatulence (Durkee 1977). In recent years there has been an observable increase in both buckwheat and lentil cultivation and in the use of their seeds for producing valuable food (Bhatty 1988, Elkowicz and Sosulski 1982, Fornal and Soral-Smietana 1989, Javornik 1986). Most investigations have been aimed at broadening knowledge of the chemical composition and technological properties of these seeds. Only a few works have dealt with undesirable substances which may reduce the nutritional value of seeds, polyphenols among them (Ikeda et. al. 1989). Phenolic compounds, being biologically active, have many different functions during the formation, growth and storage of seeds (Ribereau - Gayon 1972). However, their presence in seeds ready for consumption affects the organoleptic and nutritional value of the food produced.

The aim of the study was to identify

phenolic compounds occurring in a free and bound form in buckwheat and lentil seeds, as well as to determine their antioxidative properties and those impeding the growth of microorganisms and storage pests.

## Material and methods

Buckwheat grain and groats, buckwheat hull and lentil seeds were examined. Commercialy available buckwheat groats produced by steam treatment before dehulling were used. Reagents used for analyses were of a purity required for chromatographic investigations and were also of commercial origin.

### Methods

The total amount of phenolic compounds was determined by the colorimetric method

Fig. 1: Scheme of extraction and separation of phenolic compounds.

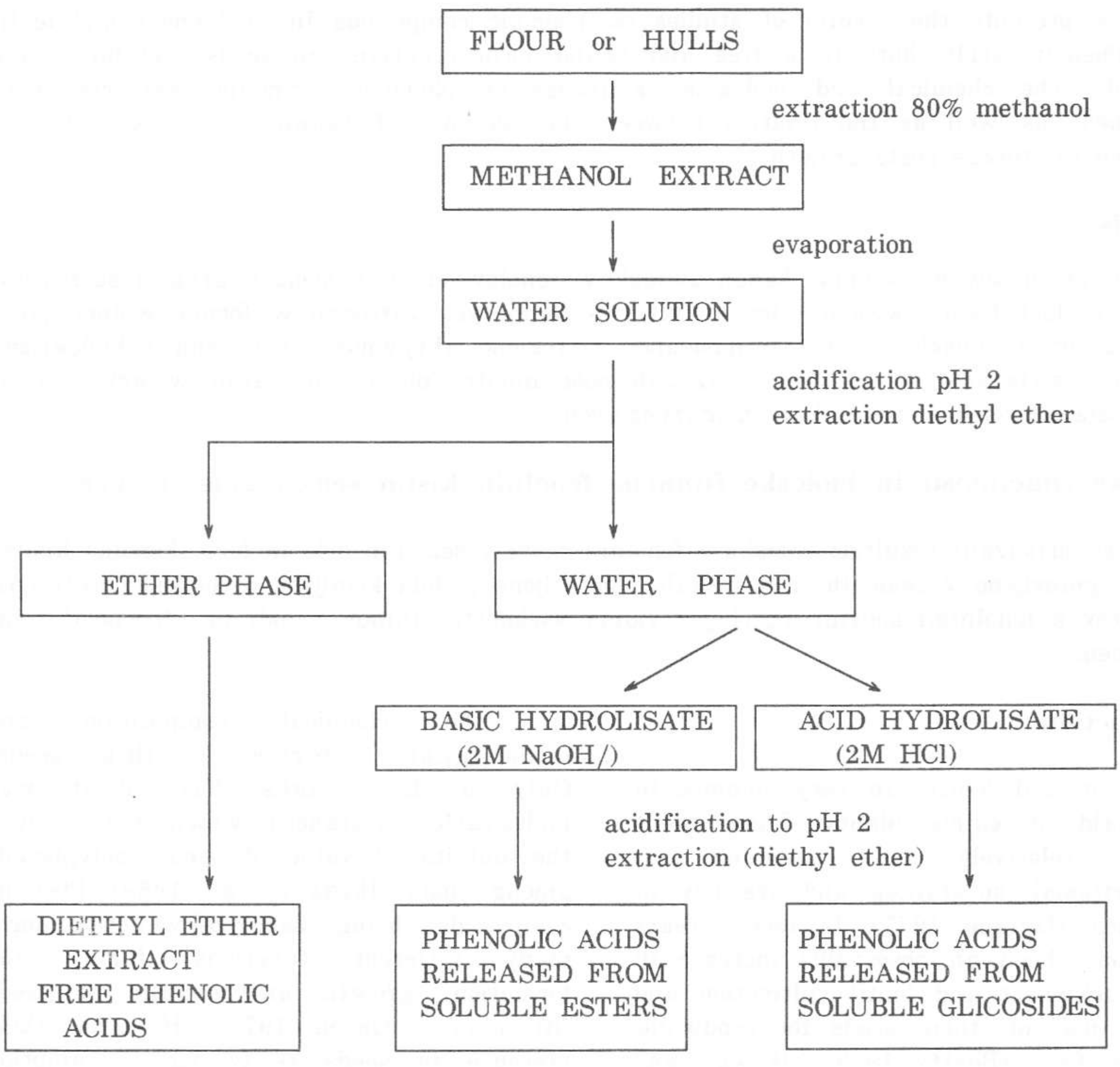
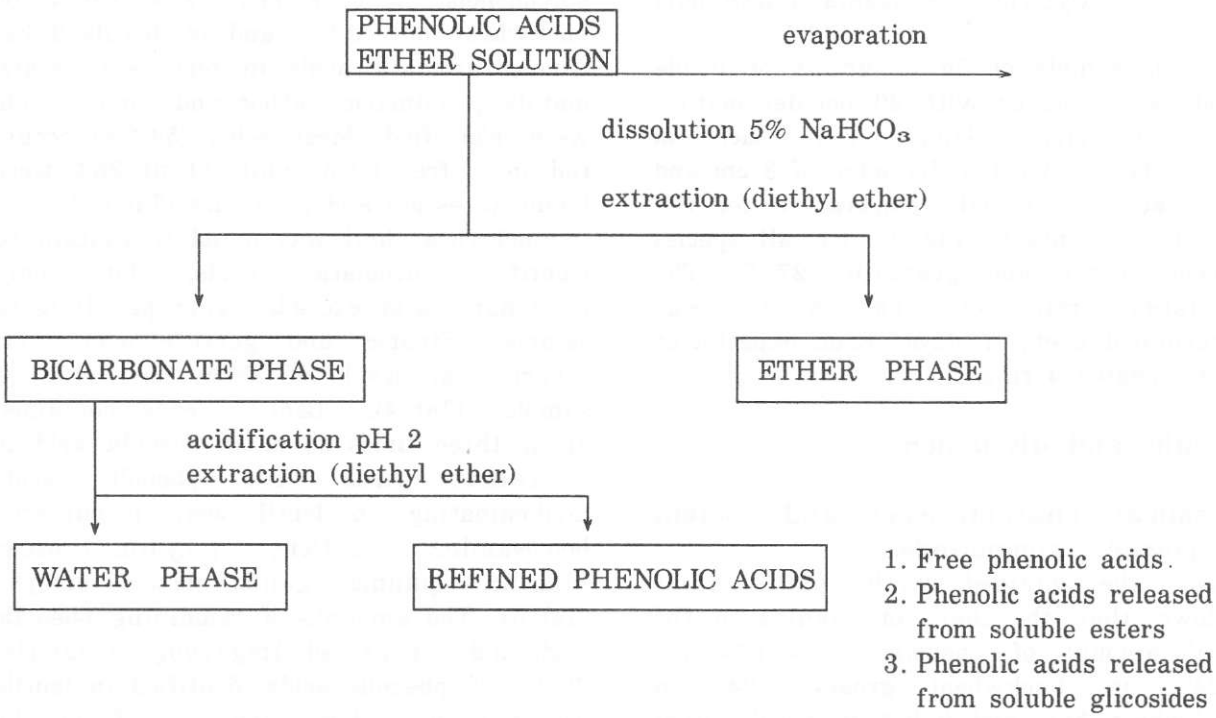


Fig. 2: Scheme of purification of isolated phenolic acids.




using Folin-Denis reagent (Ribereau - Gayon 1972).

Tannins were determined according to the method described by Burns (1971) with modifications proposed by Price and Butler (1978). The content of total phenolic compounds and tannins was calculated as a catechin equivalent.

Free and bound acids were isolated according to the scheme in Fig. 1,2. Isolated phenolic acids were sililated with N, O - bis- (Trimethylsilyl) acetamide (BSA). Sililated derivatives were analyzed by gas chromatography, applying conditions according to Zadernowski (1987). N-tetracosane was used as an internal standard for the quantitative interpretation of results.

**Antioxidative and antibacterial properties**

The biological and chemical activity of the substances isolated from the examined material was determined for ethanol extracts. The latter were studied by the method described by Tag et al. (1984). Estimation of the influence of the obtained extracts on selected bacteria strains was made by the plate method using blot papers saturated with the substance under examination.

**Influence on storage pests**

The susceptibility of the seeds to storage pests was checked in stable, controlled conditions. Both whole and dehulled seeds were infested with nine insect species:

Sitophilus oryzae L., Rhizopertha dominica F., Oryzaephilus surinamensis L., Acanthoscelides obtectus Say., Cryptolestes ferrugineus Steph., Sitophilus granarius L., Tribolium confusum Duv., Tribolium destructor Uyttenb., Anagasta kuechniella Zell.

Each sample of 5g of groats or whole seeds was infested with 20, one-day mature insect individuals. Samples were placed on Petri platters with a diameter of 8 cm and kept at an optimal temperature for the growth of insects (32 C for all species except oryzae and granarius 27 C). The mortality rate of the insects was determined every 7 days. Each experiment was repeated 4 times.

## Results and discussion

### Chemical characteristics and content of phenolic compounds.

From the obtained results (Table 1) it follows that the share of tannins in the total amount of phenolic compounds was 0.24% in buckwheat groats, 1.04% in buckwheat hull and 0.36% in lentil. Other than tannins, derivatives of phenolic compounds also made up a significant proportion of total polyphenols. They occurred in the investigated material in a free form as aromatic acids and in a bound form as esters or glycosides (Table 2). The share of phenolic acids in the total polyphenols of buckwheat was 1.07%, of buckwheat hull 0.5%, and of lentils 3.2%. Among aromatic acids in buckweat groats, mainly p-coumaric, caffeic and sinapic acids were identified. Most acids (54.2%) occurred in a free form, while about 28% were bound to esters and glycosides (Table 3).

Buckwheat hull was found to contain 16 identified aromatic acids, but only p-coumaric acid exceeded 1mg per 100g of sample. Sinapic and gentisic acids also occurred at levels of about 1mg/100g of sample (Tab.4). Lentil seeds contained about three times as much phenolic acid as buckwheat seeds. The phenolic acids predominating in lentil were p-coumaric, homovanillic, caffeic, p-hydroxybenzoic, salicylic, quinnic, gallic, ferulic, sinapic. (Tab.5). The amounts of remaining phenolic acids did not exceed 1mg/100g of sample. 23.3% of phenolic acids identified in lentils occurred in a free form; 42.0% of the phenolic acids made esters and 34.7% - glycosides.

Table 1.Total amount of phenolic compounds, tannins and derivatives of phenolic acids.

| | Total poliphenols (%) | Tannins (mg/100g) | Derivatives of (mg/100g) |
|---|---|---|---|
| Buckwheat groats | 1.33 | 3.23 | 14.25 |
| Buckwheat hull | 1.87 | 19.64 | 8.72 |
| Lentil seeds | 1.11 | 4.03 | 34.19 |

Table 2. The content of free phenolic acids and liberated from soluble glicosides, esters in buckwheat groats, hull and lentil seeds.

| | Phenolic acids (mg/100g) | | |
|---|---|---|---|
| | Free | liberated from: glicosides | esters |
| Buckwheat groats | 8.32 | 4.55 | 14.25 |
| Buckwheat hull | 3.93 | 4.51 | 8.72 |
| Lentil seeds | 7.64 | 18.18 | 34.19 |

Table 3. Phenolic acids separated from buckwheat groats.

| | Phenolic acids (mg/100g) | | |
|---|---|---|---|
| Name of acid | Free | liberated from: glicosides | esters |
| 1. benzoic | 0.350 | 0.167 | - |
| 2. mandelic | trace | trace | - |
| 3. salicylic | 0.115 | 0.079 | - |
| 4. cinnamic | 0.050 | - | - |
| 5. pyrogallic | 0.065 | - | - |
| 6. m-OH-benzoic | 0.225 | - | - |
| 7. piperonylic | 0.034 | - | - |
| 8. p-OH-benzoic | 0.659 | 0.512 | - |
| 9. p-OH-phenyloacetic | 0.207 | 0.256 | - |
| 10. veratic | 0.200 | 0.100 | 0.215 |
| 11. homovanilic and | | - | - |
| 12. vanilic | 1.035 | 0.644 | - |
| 13. gentisic | | - | - |
| 14. protocatechuic | trace | - | - |
| 15. homogentisic | 0.223 | 0.698 | - |
| 16. syringic | 0.078 | - | - |
| 17. p-cumaric | 1.989 | 1.829 | 0.810 |
| 18. gallic | 0,789 | - | 0.450 |
| 19. izo-ferulic | 0.200 | trace | - |
| 20. ferulic | trace | trace | - |
| 21. caffeic | 1.333 | trace | - |
| 22. sinapic | 0.770 | 0.170 | - |

**Antioxidative activity**
Studies of the antioxidative activity of the polyphenolic extracts isolated from buckwheat and lentil revealed that antioxidative substances occurred mainly in buckwheat hull and lentil seeds. No antioxidative substances were found in buckwheat groats (Tab.3). The antioxidative activity of lentil seeds was the highest and clearly exceeded the activity of such antioxidative standards as tocopherol and Tevox-2. Buckwheat hull inhibited linoleic acid oxidation in a similar way to applied antioxidant standards. The diverse antioxidative activity of lentil may result from a clearly higher content of phenolic acid derivatives.

**Biological activity**
An inhibitory effect on gram-negative bacteria was revealed in the extracts from lentil seeds and buckwheat hull (Table 6). The obtained extracts did not, with one exception, inhibit the growth of gram-positive bacteria. The exception was the extract from buckwheat hull, which limited the growth of Streptococcus lactis.

Table 4. Phenolic acids separated from buckwheat hull.

| Name of acid | Phenolic acids (mg/100g) | | |
|---|---|---|---|
| | Free | liberated from: glicosides | esters |
| 1. benzoic | trace | trace | trace |
| 2. mandelic | - | - | - |
| 3. salicylic | 0.200 | trace | - |
| 4. cinnamic | - | - | - |
| 5. pyrogallic | - | - | - |
| 6. m-OH-benzoic | - | - | - |
| 7. piperonylic | 0.098 | 0.095 | - |
| 8. p-OH-benzoic | 0.364 | trace | - |
| 9. p-OH-phenyloacetic | 0.098 | trace | - |
| 10. veratic | 0.213 | 0.056 | - |
| 11. homovanilic and | | | - |
| 12. vanilic | 0.645 | 1.000 | - |
| 13. gentisic | 0.083 | 0.967 | - |
| 14. protocatechuic | 0.110 | - | - |
| 15. homogentisic | - | - | - |
| 16. syringic | - | - | - |
| 17. p-cumaric | 1.619 | 1.995 | - |
| 18. gallic | 0.075 | - | - |
| 19. izo-ferulic | - | 0.135 | 0.250 |
| 20. ferulic | trace | 0.118 | - |
| 21. caffeic | 0.150 | 0.050 | - |
| 22. sinapic | 0.275 | 0.990 | 0.030 |

Table 5. Phenolic acids separated from lentil seeds.

| Name of acid | Phenolic acids (mg/100g) | | |
|---|---|---|---|
| | Free | liberated from: glicosides | esters |
| 1. benzoic | 0.386 | 0.441 | 0.707 |
| 2. mandelic | 0.163 | 0.125 | 0.100 |
| 3. salicylic | 0.117 | 0.566 | 0.352 |
| 4. cinnamic | trace | 0.364 | 0.057 |
| 5. pyrogallic | 0.085 | trace | 0.242 |
| 6. m-OH-benzoic | trace | | |
| 7. piperonylic | 0.076 | 0.356 | trace |
| 8. p-OH-benzoic | 0.552 | 1.466 | 0.630 |
| 9. p-OH-phenyloacetic | 0.230 | 1.466 | 0.179 |
| 10. veratic | 0.283 | 0.438 | 0.175 |
| 11. homovanilic and | | | |
| 12. vanilic | 0.913 | 1.546 | 0.185 |
| 13. gentisic | 0.530 | 1.067 | 0.605 |
| 14. protocatechuic | 0.090 | 0.366 | 0.190 |
| 15. homogentisic | 0.180 | 1.546 | 0.095 |
| 16. syringic | 0.284 | trace | trace |
| 17. p-cumaric | 1.599 | 1.550 | 1.864 |
| 18. gallic | 0.582 | 0.540 | 0.641 |
| 19. izo-ferulic | 0.230 | trace | 0.392 |
| 20. ferulic | 0.165 | 1.306 | |
| 21. caffeic | 0.923 | 1.441 | 0.364 |
| 22. sinapic | 0.258 | 0.053 | 1.588 |

The entomological studies demonstrated that all the infested pests except A. obtecus lived longer than 3 weeks on whole or dehulled seeds. Four of them, T. confusum, T. destructor, A. kuehniella and R. dominica, lived over 11 weeks and reproduced on dehulled seeds while two, R. dominica and A. kuehniella, did so on whole buckwheat seeds. Some species were not able to reproduce but they fed on both whole and dehulled seeds for over 10 (C.ferrugineus) and 15 weeks (S. granarius) (Table 7). A greater ability to reproduce was found on dehulled buckwheat seeds - in 4 species. The most sensitive to the presence of hull were T. confusum and T. destructor. Buckwhet hull contained six times as much tannin as dehulled seeds. So it can be assumed that tannins may be a factor inhibiting the reproductive abilities of these two species.

Polyphenolic compounds in buckwheat differe considerably from the composition of polyphenols in other kinds of cereals. Cereals contain mainly ferulic and other hydrocinnamic acids but they usually do not contain tannins. Among cereals, small amounts of tannins are found in barley and millet, and more in sorgo varieties. Buckwheat contains condensed tannins

Table 6. The influence of methanolic extracts on selected bacteria strains.

| Investigated bacteria | B.G. | B.H. | L.S. |
|---|---|---|---|
| Gram - negative: | | | |
| Escherichia coli 204 | - | - | - |
| Escherichia coli 205 | + | - | + |
| Enterobacter aerogenes T | + | - | + |
| Enterobacter aerogenes T | + | - | - |
| Pseudomonas fluorescens | + | - | - |
| Gram positive: | | | |
| Streptococcus lactis | - | - | + |
| Streptococcus cremoris | - | - | - |
| Bacillus cereus | - | - | - |

B.G.-buckwheat grouts B.H.-buckwheat hulls L.S.-lentil seeds

Table 7. Death rate of insects growing on whole and dehulled seeds of buckwheat.

| Kinds of insects | 100% death rate of insects (weeks) | |
|---|---|---|
| | dehulled seeds | whole seeds |
| Sitophilus oryzae | 4 | 4 |
| Rhizopertha dominica | 30 x,* | 30 x,* |
| Oryzaephilus surynamensis | 5 | 5 |
| Acanthoscelides obtectus | 3 | 4 |
| Cryptolestes ferrugineus | 10 x | 10 x |
| Sitophilus granarius | 15 x | 15 x |
| Tribolium confusum | 11 x,* | 11 x |
| Tribolium destructor | 11 x,* | 11 x |
| Anagasta kuehniella | 11 x,* | 11 x,* |

x - continuing to live; * - reproducing;

mainly in the hull, while phenolic acids occur there only in small quantities. The biological and chemical activity of buckwheat hull extracts may result from the presence of tannins and phenolic acids. However, Ikeda (1986) found the content of tannin as the catechin equivalent in buckwheat flour to be approximately 1.3 g in dry matter. Differences could be the effect of variety and other factors, such as the condition of heat treatment of grains before dehulling.

A similar influence of the buckwheat hull was also observed towards storage pests of cereals. Buckwheat hull tannins are part of a natural immunological mechanism against microbiological contamination or growth of storage pests; tannins and phenolic compounds have a similar significance. Their possible influence on a reduction of the protein availability of these seeds is not of importance since the removal of the hull is one of the basic conditions of processing.

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# Polyphenol classification and tannin content of buckwheat seeds (*Fagopyrum esculentum* Moench)

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**Key words:** complex tannins, condensed tannins, diploid, flavonoids, hydrolysable tannins, tetraploid, vanillin-HCl method

**Abstract**

Aromatic compounds consisting of phenol or polyphenol components are divided into flavonoids and tannins. Some polyphenolic components are also found in buckwheat seeds.

The quantity of tannin in buckwheat seeds in diploid and tetraloid buckwheat cultivars was studied by the vanillin-HCl method. Buckwheat seeds contain from 0.5 to 4.5% of tannin. The content depends on the cultivar differences (genetic factors) and on ecological influences.

**Razdelitev polifenolov in vsebnost tanina v semenih ajde (*Fagopyrum esculentum* Moench)**

Aromatske spojine, ki so sestavljene iz fenolnih ali polifenolnih komponent se delijo v flavonoide in tanine. Nekatere od teh komponent so prisotne tudi v semenih ajde.

Količina tanina v ajdovih semenih je bila določena z vanilin-HCl metodo pri diploidnih in tetraploidnih kultivarjih. V ajdovih semenih je od 0.5 do 4.5% tanina. Vsebnost tanina je odvisna od kultivarja (genetskih dejavnikov) in ekoloških vplivov.

## Introduction

Polyphenols are aromatic compounds. They are secondary plant metabolites. Plants synthesize different polyphenolic substances, some of which may contribute to the formation of tannins.

Of all the aromatic compounds, flavonoids and tannins are the most common in plant organs. They not only have a major functional role in the plants, but are also commercially significant in pharmacology, the food industry and in ornamental plants.

Synoptic Table 1: Division of aromatic compounds - polyphenols

Polyphenols: A) flavonoids and B) tannins

A) FLAVONOIDS
1 flavones and flavonols
a) flavones (apigenin, apiin, cosmosiin, vitexin, luteolin, orientin, baicalein and baicalin)
b) flavonols (kaempferol, quercetin, quercitrin, rutin, myricetin and myricitrin)
2 flavanones (hesperetin, naringenin, hesperidin, naringin, fustin and aromadendrin)
3 chalcones (butein, carthamin, dihydrochalcone, phloretin and phlorizin)
4 isoflavones (3-phenylchromone, genistein, genistin, daidzein, daidzin and puerarin)
5 anthocyanidins (anthocyanin, pelargonidin, cyanidin and delphinidin)

6 aurones (aureusidin)
7 biflavones (amenthoflavone and hinokiflavone)
8 neoflavonoids, flavonolignan

B) TANNINS
1 hydrolysable tannins
- gallotannins
  (gallic acid, quinic acid, tannic acid)
- ellagitannins
  (ellagic acid, castalagin, vescalagin, etc.)
- hydrolysable tannin oligomers
  (agrimoniin, rugosin D)
- caffeic acid derivatives
  (chlorogenic acid, caffeetannin, dicaffeoylquinic acid, rosmarinic acid)

2 condensed tannin
- flavan-3-ol
  (catechin, epicatechin)
- flavan-3,4-diol
  (leucoanthocyanidin)

3 complex tannin
(stenophyllanin A, acutissimin B, mongolicain A, stenophynin A, etc.).

Synoptic table 1 shows the division of those aromatic compounds which are built of phenol or polyphenol components, i.e. flavonoids and tannins (Rice, 1984; Okuda, 1988).

Buckwheat contains tannins and flavonoids (anthocyanidins - anthocyanins and flavonols - rutin, quercetin). Condensed tannins and flavonoids (anthocyanidins and flavonols) all share a similar structure of the $C_{15}$ skeleton.

## Flavonoids as plant pigments

Flower colour and the colour of other plant parts is mainly due to three types of natural pigments: flavonoids, corotenoids and betalains. These three types of pigments are entirely different chemically.

Flavonoids as flower pigments consist of two aromatic rings (A and B) and a heterocycle (C) with oxygen.

Based on the configuration and state of oxidation of the central $C_3$ unit in the molecule, flavonoids are divided into eight groups (synoptic table 1).

The first to suggest this flavonoid structure was Robinson (1936). This hypothesis was further confirmed by the formation and biosynthesis of quercetin in tartary buckwheat (Underhill *et al.*, 1957; Watkin *et al.*, 1960).

The most important flavonoid classes with regard to flower colour are anthocyanins, flavonols and flavones, and, in addition, the chalcones and aurones which are biosynthetically closely related to the flavonoids (Forkmann, 1991).

Flavan-3,4-diols, also known as leucoanthocyanidins, are the direct substrates in catechin (condensed tannin) and proanthocyanidin formation. Leucoanthocyanidin is the trivial name used to refer to flavan-3,4-diol. Moreover, they are precursors for the synthesis of anthocyanins.

Despite the high structural variation found in nature, there are four main anthocyanidins: anthocyanin, pelargonidin, cyanidin and delphinidin. They differ only in their B-ring hydroxyl groups.

## Tannins

Tannins have specific properties which promote their use as natural substances in medicine, the leather industry, wood industry, beer brewing, wine industry, petroleum oil industry, etc.

Tannins' specific properties are: antibacterial function (Mori *et al.*, 1987), and antitumor, antivirus and antimutagenic functions. Tannins are active components of natural tanning agents, are antioxydants, natural conserving agents, cleaning and aseptic agents, natural wood preservatives - biocides (Laks *et al.*, 1988; Laks, 1989). Tannins' unwanted properties are: they inhibit enzymes (α-amylase), in larger quantities they have a negative influence on amino acid digestibility, and they are strongly astringent in taste.

In the past few years, much research has been done on tannins in different plant species. The result are new discoveries about the chemical structure, biosyntheses and practical applications.

An older division of tannins was based on their reaction with iron salts (Gnamm, 1949).

1. tannins which give a green colour when iron salts are present,

2. tannins which give a blue colour when iron salts are present.

This division criterion is no longer much in use, since several organic substances exist in nature which obtain colour in contact with iron salts, bur do not pertain to tannins.

Freudenberg (1938) classified plant tannins according to their chemical nature and structural characteristics into hydrolysable tannins and condensed (flavonoid) tannins.

While hydrolysable tannins undergo hydrolysis with mineral acids or enzymes, condensed tannins, which are non-hydrolysable, produce coloured solutions and precipitates known as phlobaphenes or tannin reds with these reagents.

Modern research and NMR specter interpretations of $^{1}H$ and $^{13}C$ have made possible the following division of tannins:

### Hydrolysable tannins

These are based on esters of phenol carboxylic acids (gallic acid) with a central carbohydrate core. Zenk (1966), Haslam (1966) and several others workers studied the biosynthesis of gallic acid. Depending on the polyphenolic acids that are obtained as products of hydrolysis, these are again sub-divided into: gallotannins and ellagitannins.

Gallotannins yield gallic acid and glucose on hydrolysis.

Ellagitannins are different from gallotannins in that they deposit on standing (hydrolysis) ellagic acid in addition to gallic acid and glucose from their tannin influsions. They show the characteristic phenomenon of the formation of sludge or bloom on leathers.

### Condensed tannins

Structurally related to flavonoids, these tannins are distributed widely in nature and constitute a heterogeneous group. The $C_{15}$ skeleton of the flavonoids is made up of two distinct units, A ring (consisting of a $C_6$ unit) and B ring (made up of $C_6$-$C_3$ unit).

Condensed tannins are chemically oligomers of hydroxyflavan-3-ol (catechin, epicatechin) and polyhydroxyflavan-3,4-diols (leucoanthocyanidin) or oligomers of a combination of those two compounds. The basic flavonoid structure in condensed tannins is flavan (Santappa *et al.*, 1982).

### Complex tannins

The complex tannins are a series of compounds first isolated from the bark of *Quercus stenophylla* Makino (*Fagaceae*) and now found to occur widely in plants containing both hydrolysable and non-hydrolysable or condensed tannins (Hishimura *et al.*, 1986).

Complex tannins are shown to contain a hydrolysable tannin moiety in their molecules connected through a carbon-carbon linkage to flavan-3-ol (flavano-ellagitannin), procyanidin (procyanidino-ellagitannin) and flavonoid glucoside (flavono-ellagitannin) moieties. Typical examples of complex tannins are stenophyllanin, acutissimin, mongolicain and stenophynin. More than 30 different kinds of complex tannins are known (Nonaka, 1989).

The most commonly occurring is flavano-ellagitannin, which possesses a flavan-3-ol in the molecule, the component unit of condensed tannins, connected to a hydrolysable tannin moiety through a carbon-carbon linkage.

## Polyphenols (tannin) in buckwheat

Buckwheat pigments (anthocyanins - flavonoids), have been studied by Margna *et al.* (1973).

The mechanism of buckwheat pigment formation was studied by Ali and Kagan (1974), Saito (1974), Margna *et al.* (1978 a, 1978 b).

Flavonol compounds (quercetin, quercitin, hyperin and rutin) in buckwheat seeds were investigated by Sato *et al.* (1975).

In a study of some polyphenols in the bran-aleuron layer of buckwheat, it was shown that syringic acid, p-hydroxybezoic acid, vanillic acid and p-coumaric acid occured in a bound form and were liberated by either alkaline or acid hydrolysis, indicating the possibility of both ester and glycosidic linkages. There were flavan-3,4-diols and soluble condensed tannins, but no flavone or flavonol glycosides were present (Durkee, 1977).

A study on flavonoids in buckwheat was made by Kiselev *et al.* (1985). They state that the genus *Fagopyrum* has good prospects for rutin extraction because of its high flavonol content. Most of the rutin is located on the flower (approximately 10%), in the leaves (cca. 9%) and the least in the stalk (cca. 1%). It is also traceable in the roots. Rutin content varies throughout the growth period of buckwheat. Maximum quantities are found in the buds and blooming phase. The content decreases after the flowering period and in the phase formation of seeds. Fully grown plants contain rutin, quercetin, quercitrin and a group of yet undefined phenolic components. These components are mostly found in the reproductive organs (buds and flowers).

During the formation and development of seeds, not only the quantity but also the quality of phenol components changes.

Tahir and Farooq determined (1985) the content of phenolics of hull and groats in four buckwheat species. *Fagopyrum esculentum* contained 0.73% and 0.79%, *F. sagittatum* 1.57% and 1.61%, *F. tataricum* 1.87% and 1.52%, *F. kashmirianum* 1.42% and 1.68% of phenolics in hulls and groats, respectively.

Dietrych-Szostak and Ploszynski (1986) determined by use of the vanillin-HCl method, 7.03% hull and 0.87% groat tannin content in *F. esculentum* cultivar Hruszowska.

Tannin inhibits enzymes and lessens amino acid digestibility in buckwheat pasta and groats (Ikeda, 1987; Ikeda *et al.*, 1991).

The digestibility of groats amino acids is cca. 10% higher than that of the whole seeds (cca. 80%), which is due to the low tannin and raw fibre content in groats. Amino acid digestibility in buckwheat is in negative correlation with the tannin and raw fibre content (Eggum *et al.*, 1981; Javornik *et al.*, 1981).

Polyphenol components in ripe buckwheat seeds have been less elucidated than those located in the other parts of the plant (leaves, flowers and unripe seeds). Much research has also been done on other species of the *Fagopyrum* genus, since their polyphenol contents are greater and more varied than that of common buckwheat.

## Material and methods

We analysed 63 diploid and 4 tetraploid cultivars. The samples were from different growth regions (Slovenian and foreign cultivars), and differed in age and polyploidy. Only the ripe seeds of each cultivar were milled.

Vanillin-HCl method

Samples (0.4 g, particle size 4 mm) of ground grain were extracted with 10 ml of methanol for 20 min at room temperature. One millilitre of the resulting extract was reacted with 5 ml of vanillin reagent (50 : 50 mixture of 1% vanillin/8% HCl in methanol) for 20 min at 28 °C and absorbance was read at 500 nm. For blanks, 4% HCl instead of vanillin reagent was added to the extract and absorbance was also read at 500 nm. Blank values were subtracted from experimental values to give an adjusted rate. A catechin standard curve from 0.0-2.0 mg/ml in 0.2 mg increments was used in calculating tannin levels (Earp *et al.*, 1981; Hallgren, 1987).

## Results and discussion

The difference in the tannin content of cultivars was statistically significant ($p = 0.05$). Buckwheat seeds contain from 0.5 to 4.5% tannin, depending on the genotype, polyploidy, seed age and ecological factors (Table 1). Samples aged 10 years or more contained less tannin than new samples (recently multiplied). The same genotypes grown on different areas often had different tannin contents. A temperature of cca. 25 °C had a negative effect on tannin synthesis and deposition in the seeds.

Table 1: Tannin content in buckwheat seeds

| buckweat | % tannin min. | % tannin max. | % tannin $\bar{x}$ | number of samples |
|---|---|---|---|---|
| diploid 2n = 16 | 0.50 | 4.50 | 2.46 | 63 |
| tetraploid 2n = 32 | 1.06 | 3.18 | 2.08 | 4 |

Tetraploid cultivars showed a lower tannin content. This might be attributed to the small number of analysed samples, which did not include the complete variability. Unfortunately, we only had 4 tetraploid cultivars at our disposal. Fewer tetraploid cultivars exist and they are also not as widespread as diploid ones.

## Conclusions

Flavonols (quercetin, quercitrin, rutin) and anthocyanidins (anthocyanin), which are plant pigments, are frequently found sub-groups of flavonoids in buckwheat seeds. In addition to flavonoids buckwheat also contains tannins.

Plant tannins known to date may be classified into three groups based mainly on structural features rather than on chemical properties.

Buckwheat seeds contain from 0.5 to 4.5% tannin, depending on the genotype and on ecological factors.

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# Efficacy of some herbicides in agrophytocenosis of buckwheat in the Slavonia region

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**Key words**: weed species, efficacy coefficients

**Abstract**

The efficacy of some herbicides in buckwheat was examined in the locality of Feričanci in Slavonia from 1988 to 1990. Among herbicides, fluorochloridone had good effects on Dicotyledonae weeds, as had acetochlor on Monocotyledonae weeds. However, in the applied doses these preparations were phytotoxic on buckwheat. The most effective herbicidal results in weed extermination and in crop selection were achieved with the combination metolachlor + MCPA (EC=93.70%).

**Efikasnost nekih herbicida u agrofitocenozi heljde na području Slavonije**

U heljdi, na području Slavonije ispitano je u razdoblju od 1988. do 1990. godine, 10 herbicidnih varijanata. Najveću djelotvornost na korove i dobru selektivnost na usjev pokazala je kombinacija herbicida metolachlor + MCPA (KE: 93.70%).

## Introduction

In comparison with other crops in Slavonia, buchwheat is still relatively unexplored, particularly as to its protection from weeds. Owing to the recent increased production of buckwheat, more intensive studies of weed components of agrophytocenosis of buckwheat have recently been performed (Knežević *et al.* 1987, 1989; Knežević and Baketa 1989, 1990).

This paper describes the results of a three-year study of weed flora in buckwheat and the possibility of eliminating them by means of chemicals in the agroecological conditions found in Slavonia.

## Material and methods

The efficacy of weed control in buckwheat by means of chemicals was investigated in the areas of the Agricultural Firm of Feričanci in Slavonia during the period 1988 to 1990. Buckwheat "Siva" was sown each year after wheat, in a pseudogley type of soil. Sowing was done from the 10th to 12th of July with the use of adequate agrotechnics.

Testing with herbicides was carried out by the block method in plots of 25 square meters with four repetitions. All the herbicides were applied on the same day, following sowing, and their variants and doses are shown in Table 1. The average number of weed plants in crops and the efficacy of herbicides were determined for each variant by counting the weed shoots in one square meter as compared with the control. Floristic examinations were done 15, 30 and 60 days following the application of herbicides and, at the same time, the phytotoxic influence of herbicides on buckwheat was determined according to EWRC. The dry mass of weeds per square meter was determined at the end of October each year in the same plots on which buckwheat was harvested by hand. The grain yield with 14% humidity is

Table 1. Herbicidal treatments of buckwheat

| Treatment | Chemical | Herbicide | | Rate l/ha |
|---|---|---|---|---|
| 1. | Bravo | 48% | alachlor | 5 |
| 2. | Bravo+Dicofluid | 48% | alachlor+ | |
| | MP Combi | 43% | mekoprop+ | 5+2.5 |
| | | 13% | 2,4-D | |
| 3. | Dual 500 | 50% | metolachlor | 3 |
| 4. | Dual 500 + | 50% | metolachlor | |
| | Banvel M | 30% | MCPA+ | 3+3 |
| | | 2,25% | dicamba | |
| 5. | Racer | 25% | fluorochloridone | 0.5 |
| 6. | Racer | | " | 1 |
| 7. | Racer | | " | 1.5 |
| 8. | Racer | | " | 2 |
| 9. | Wenner EC | 84% | acetochlor | 1 |
| 10. | Wenner EC | | " | 1.5 |
| 11. | Control | | | |

expressed in kg/ha.

Climatic data for the buckwheat vegetation period during the investigations are shown in Table 2.

Nomenclature of plant species used here is according to Ehrendorfer (1973). The data processing was done by the usual statistical methods (Snidicor and Kohren 1971).

Table 2. Climatic conditions through the growth period of buckwheat for the Feričanci region

| Investigated period 1988-1990 | Months VII | VIII | IX | X |
|---|---|---|---|---|
| Rainfall (mm) | 48.8 | 52.8 | 56.2 | 52.0 |
| Mean air temp. (°C) | 21.5 | 20.8 | 15.9 | 11.2 |
| Monthly rainfall factor | <u>2.3</u> | <u>2.5</u> | 3.5 | 4.6 |

_____ months with arid climate (after Gračanin and Ilijanić, 1977)

## Results and discussion

Composition of weed species in buckwheat in control plots is shown in Table 3.

Herbicides fluorochloridone and acetochlor in a Racer preparation (1, 1.5 and 2 l/ha) and Wenner preparation (1, 1.5 l/ha) had a phytotoxic influence on buckwheat in the initial stage. Phytotoxicity was particularly pronounced in the humid growing season of the year of 1989 when only 98 buckwheat plants were found per square meter in the plots treated with Racer (2 l/ha), 42.8% less than in the control.

The results also show that Racer in doses of 1.5 and 2 l/ha showed good herbicidal effects on Dicotyledonae weeds such as:

*Ambrosia artemisiifolia, Chenopodium album, Polygonum lapathifolium, Amaranthus retroflexus* and *Raphanus sativus* var. oleifera. Similar results were obtained by the use of fluorochloridone in buckwheat in test fields in Manitoba in Canada (Friesen et al. 1985). In spite of its considerable success in exterminating the weeds, Racer cannot be recommended for the protection of buckwheat in the investigated agroecological conditions. Neither can Wenner be recommended in the applied doses owing to its toxic effect on the crop, though this same preparation showed a very good herbicidal effect in controlling Monocotyledon weed species *Echinochloa crus-galli* and *Setaria glauca* (Tab. 4 and 5).

Table 3. Average number of weed shoots per square meter in untreated plots of buckwheat through the period of investigation

| Weed species | Investigated years 1988 | 1989 | 1990 | Average number of weed shoots |
|---|---|---|---|---|
| *Echinochloa crus-galli* (L.)PB. | 72.0 | 3.7 | 69.8 | 48.5 |
| *Setaria glauca* (L.) PB. | 1.5 | 15.6 | 10.3 | 9.1 |
| *Triticum vulgare* L. | 0.5 | 3.8 | 42.8 | 15.7 |
| *Agropyron repens* L. | - | 8.2 | 6.1 | 4.8 |
| *Digitaria sanguinalis* (L.) Scop. | 0.9 | 0.8 | - | 0.6 |
| Total of Monocotyledonae | 74.9 | 32.1 | 1 29.0 | 78.7 |
| *Chenopodium album* L. | 21.0 | 0.7 | 5.4 | 9.0 |
| *Raphanus sativus* L.var. oleifera | 8.5 | 7.3 | 2.0 | 5.9 |
| *Ambrosia artemisiifolia* L. | 0.3 | 8.2 | 1.2 | 3.2 |
| *Stellaria media* (L:) Vill. | 2.0 | - | 2.8 | 1.6 |
| *Amaranthus retroflexus* L. | 2.8 | 0.6 | - | 1.1 |
| *Polygonum lapathifolium* L. | 2.0 | 1.0 | - | 1.0 |
| *Chenopodium polyspermum* L. | - | 0.3 | 1.1 | 0.5 |
| *Solanum nigrum* L. | 1.0 | 0.2 | - | 0.4 |
| *Convolvulus arvensis* L. | - | 0.5 | 0.1 | 0.2 |
| *Plantago major* L. | - | 0.8 | - | 0.3 |
| *Veronica persica* Poir. | 0.5 | - | - | 0.2 |
| *Hibiscus trionum* L. | 0.5 | - | - | 0.2 |
| *Anagallis arvensis* L. | - | 0.5 | - | 0.2 |
| *Cirsium arvense* (L.) Scop. | - | 0.2 | 0.1 | 0.1 |
| *Ranunculus repens* L. | - | 0.3 | - | 0.1 |
| *Rumex acetosa* L. | - | 0.3 | - | 0.1 |
| *Hypericum humifusum* L. | - | 0.3 | - | 0.1 |
| *Erigeron annuus* (L.) Pers. | - | 0.3 | - | 0.1 |
| *Gnaphalium uliginosum* L. | - | 0.4 | - | 0.1 |
| *Diplotaxis muralis* (L.) DC. | 0.3 | - | - | 0.1 |
| Total of Dicotyledonae | 38.9 | 21.9 | 12.7 | 24.5 |
| Total number of weed plants | 113.8 | 54.0 | 41.7 | 103.2 |

Table 4. Average number of weed plants per square meter in buckwheat through the investigated variants (1988-1990)

| Treatment | Rate l/ha | Number of weed plants per $m^2$ Monocotyledonae | Dicotyledonae | Total |
|---|---|---|---|---|
| 1. Bravo | 5 | 5.9 | 10.6 | 16.5 |
| 2. Bravo + Dicofluid MP Combi | 5+2.5 | 7.2 | 4.1 | 11.3 |
| 3. Dual 500 | 3 | 2.4 | 15.1 | 16.2 |
| 4. Dual 500 + Banvel M | 3+3 | 3.2 | 3.3 | 6.5 |
| 5. Racer | 0.5 | 19.4 | 7.0 | 26.4 |
| 6. Racer | 1 | 13.0 | 3.6 | 16.6 |
| 7. Racer | 1.5 | 15.0 | 1.5 | 16.5 |
| 8. Racer | 2 | 11.0 | 1.1 | 12.1 |
| 9. Wenner | 1 | 2.4 | 5.8 | 8.2 |
| 10. Wenner | 1.5 | 1.4 | 4.0 | 5.4 |
| 11. Control | - | 78.7 | 24.5 | 103.2 |

Table 5. Average efficacy coefficients of herbicides (%) and buckwheat grain yields (kg/ha) in 1988-1990.

| Treatment | Rate l/ha | Efficacy coefficients (%) Monocotyledonae | Dicotyledonae | Total | Grain yield kg/ha |
|---|---|---|---|---|---|
| 1. Bravo | 5 | 92.50 | 56.73 | 84.01 | 1310 |
| 2. Bravo + Dicofluid MP Combi | 5+2.5 | 90.85 | 83.26 | 89.05 | 1717 |
| 3. Dual 500 | 3 | 96.95 | 38.37 | 84.30 | 1204 |
| 4. Dual 500 + Banvel M | 3+3 | 95.93 | 86.53 | 93.70 | 1786 |
| 5. Racer | 0.5 | 75.35 | 71.43 | 74.42 | 1048 |
| 6. Racer | 1 | 83.48 | 85.31 | 83.91 | 1236 |
| 7. Racer | 1.5 | 80.94 | 93.88 | 84.01 | 1088 |
| 8. Racer | 2 | 86.02 | 95.51 | 88.28 | 1208 |
| 9. Wenner | 1 | 96.95 | 76.33 | 92.05 | 1011 |
| 10. Wenner | 1.5 | 98.22 | 83.67 | 94.77 | 1174 |
| 11. Control | - | - | - | - | 936 |

Herbicides metolachlor and alachlor in preparations of Dual 500 (3 l/ha) and Bravo (5 l/ha) showed a satisfactory crop selectivity and great efficacy in controlling Monocotyledon weeds. However, these herbicides showed poor results in controlling Dicotyledon weed species (Table 5). The best results were achieved in variant 4, that is by the combination of herbicides metolachlor and MCPA with the preparations of Dual 500 + Banvel M (3 + 3 l/ha). All this is supported by significant differences between variants in the yields of buckwheat grain. Highly significant differences appeared between variant 4 and variants 5,6,7,8,9 and 10, as well as significant differences between variant 4 and the variants 1 and 3 (Lsd 0.05=435.3, 0.01=593.7).

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# Preliminary division of cultural and ecological regions of Chinese buckwheat

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**Key words:** *Fagopyrum esculentum*, accumulated temperature, altitude, China, species, varieties

**Abstract**

Buckwheat growing is discussed on the basis of the geographic location of China's natural regions, ecological factors of light, temperature and water, actual growth periods of species and varieties, agronomic and economic characters, planting methods and cultivating systems. China's cultivated buckwheat can be divided into 4 ecological regions: northern spring buckwheat region, northern summer buckwheat region, southern autumn and winter buckwheat region and southwestern spring and autumn buckwheat region.

**Predhodna razdelitev področij pridelovanja ajde na Kitajskem**

Področja pridelovanja ajde na Kitajskem so razdeljena v štiri ekološke skupine: severno področje pridelovanja spomladanske ajde, severno področje pridelovanja poletne ajde, južno področje jesenske in zimske ajde, ter jugozahodno področje s pomladanskim in jesenskim pridelovajem ajde. Opisane so ekološke razmere in agrotehnika pridelovanja ajde v teh področjih.

Buckwheat has a long history of cultivation in China. It has been cultivated over a wide area, and is a rich resource of germplasm, with characteristics such as short growth period, wide adaptation and integration of food with medicine. At present, its area of cultivation is 1.5 - 2 million hectares. Although it is not a staple crop, it is an important crop in remote mountainous regions, as well as for multiple cropping and for providing disaster relief.

The division of cultural and ecological region of China's buckwheat is made on the basis of the catalog of the germplasm of China's buckwheat, a nation-wide regional test on superior varieties of buckwheat, China's buckwheat production and variety evolution, and with reference to partial data of 1989-1991 nation-wide experiments on the ecological type and adaptation of buckwheat varieties, in view of actual sowing dates in China's buckwheat production, and considering both types of buckwheat (common and tartary).

## The position of buckwheat in the cultural and ecological regions of Chinese crops

I. The geographical location of buckwheat production areas

Though buckwheat is not a staple crop in China, it has a long history of cultivation and has a wide area of distribution.

It is particular suitable for growing in areas of high latitude and high altitude. Its vertical distribution extends to the mountainous region of Kanbazong in Tibet with an altitude of over 4000 meters above sea level. It has an obvious production advantage in dry and remote mountainous areas of high altitude in North China, Northwest China and Southwest China, and in areas inhabited by minority nationalities.

Buckwheat culture in China is of two kinds: common buckwheat (*Fagopyrum esculentum*) and tartary buckwheat (*Fagopyrum tataricum*). Common buckwheat is widely distributed, ranging from the mid-tropical zone of 20 north latitude to the mid-temperate zone of 50° north latitude. a total of 30 degrees. Tartary buckwheat is often grown in succession in the mountains and hills in Sichuan Province, where common buckwheat occupies a smaller area, which is determined by the biological characteristics of buckwheat and by the natural conditions and farming system of that region.

II. The position of buckwheat growing districts in agricultural division.

Northeast China, North China, and Northwest China belong to the mid-temperate and north-temperate zones, where the weather is cold and rainfall is limited, so farming conditions are rather bad. The cold highlands west of Da Xing-an Ling, Inner Mongolia, and in the north of Ying Shan Mountain, are subject to drought and dust storm and unsuitable for farming. It is a mainly a pastoral area, on the border of which crop production and animal production are intermingled. In the mountains around the forest region in Northeast China, mixed arable and stock farming are also preserved. It is only in the Nanjiang River area of Heilongjiang Province and at the east foot of Xing-anling Mountain in northeast inner Mongolia that people begin to grow buckwheat.

In addition to pastoral and forest areas in North China, the natural agricultural boundaries which are closely related with buckwheat are the Great Wall, Qin Mountain-Huai River, and Bashan Mountain in Yunnan-Guizhou Plateau. Buckwheat is grown from Aksu and Hetian in Xinjiang at longitude 80° east, to Fujing in Heilongjiang at longitude 132° east, stretching for 52 degrees altogether. Its distribution increases with altitude. Major areas of buckwheat can be found in Inner Mongolia, Shaanxi, Shanxi, Gansu, Ningxia, and Hubei provinces, mostly on loessial plateaux. Tartary buckwheat is not so widely distributed as common buckwheat. It is distributed from Wenshan in Yunnan Province at latitude 23° 30' north to Keshiketeng of Inner Mongolia Autonomous Region at latitude 43° north; and from Zada in Tibet at longitude 80° east to Jiujiang in Jiangxi Province at longitude 116° east, extending to 20 degrees of latitude and 36 degrees of longitude. It is concentrated in Yunnan, Guizhou, Sichuan, Hunan, Hubei Province, and in the mountainous region on loessial plateaux, including Shanxi, Shaanxi and Hebei provinces. The line of the Huai River, Qin Mountain and Ba Mountain (conventionally called the Qin-Huai Line) is the border between common buckwheat and tartary buckwheat cultivation. The region beyond the Qin-Ba mountain range is the main growing district of China's common buckwheat, where tartary is only sparsely cultivated, especially along the Great Wall, while China's tartary buckwheat is grown mainly in the south of the Qin-Ba Mountain Range, particularly in Yunnan and Guizhou Provinces.

The Great Wall is an important climatic boundary in China, which influences not only the constitution of crops and farming systems but also the sowing of winter and spring wheat. China's common buckwheat is mainly cultivated along both sides of the Great Wall.

The Qin-Huai Line is the demarcation line of annual mean rainfall of 750 mm. North of this line is the main growing district of rainfed grain crops, where buckwheat is used as a relay crop after the wheat has been harvested. South of this line is the paddy rice region, where buckwheat is grown after the rice has been harvested.

III. The distribution relationship between buckwheat and other crops.

Buckwheat is of secondary importance among China's grain crops in comparison to rice, wheat and corn (maize), and to millet, sorghum, sweet potato and soybean. It is even less important than barley and potato. It is a non-staple crop like oats and broomcorn millet.

In different areas in China, the disposition of crops is restricted by local natural and production conditions, and overall economic effect. South of the Qin-Huai Line, rainfall is plentiful, air temperature is high, water and heat resources are rich, the soil is fertile, and where there are too many people for too little land, peasants are engaged in intensive cultivation of rice. They grow a little buckwheat only on the hills or after the rice crop. North of the Qin-Huai Line, wheat has a higher economic value, and can be grown in winter, so it is a staple crop. Corn (maize) has potential in increasing yield, and is also a staple crop. Soybean, sorghum and sweet potato have their advantages. Millet is drought-tolerant, barrenness-tolerant, early maturing, and can grow well on dry hills with higher latitude. Buckwheat has the advantage of a specially short growth period of only 60-70 days. It is usually grown after main crops or after drought or water-logging. Of course, due to its short period, stress-tolerant trait, buckwheat can grow well under poorer conditions, such as in the northeast parts of Inner Mongolia, on the plains of Zhangjiakou in Hebei Province, in North Shanxi Province, and the plains in Yulin Country in Shaanxi province, that is, in dry and windy areas along both sides of the Great Wall as well in the highland in Southwest China.

## Cultural and ecological regions of China's buckwheat

I. Basis for division

1. The cultural division of buckwheat should be in agreement with the comprehensive division of agriculture and crop. There are four fundamental bases for the comprehensive division of China's agriculture: (1) relative agreement of the natural conditions for the development of agriculture with the social economic conditions; (2) relative agreement of the fundamental characteristics of agricultural production with the orientation of further development; (3) relative agreement of the key problems in agricultural production with the ways of construction; (4) essentially maintaining the integration of the administrative division of countries. On the basis of these principles, China's buckwheat production can be divided into 10 primary regions and 38 secondary regions. Since China's buckwheat cultivation is widely scattered, its growing districts are essentially covered.

The division of a crop is made on the basis of natural conditions and period of maturity of the crop. Being in a subordinate position in the farming system compared to the cultivation of staple crops seriously affects the growing of buckwheat. Buckwheat is mainly sown in spring and summer, although a number of places practice autumn and winter sowing. The growth periods of the varieties range from over 50 days to over 100 days, leading to a distinction between extra-early-maturing, early-maturing, medium-maturing and late-maturing varieties. All these problems should be considered in the division of cultural regions of buckwheat.

2. The characteristics of buckwheat species, varieties, and cultivation should also be fully considered. Buckwheat has a rather short growing period and is widely adaptable, but there is a great difference between the common buckwheat species and tartary buckwheat species. Common buckwheat is more widely adaptable than tartary buckwheat, and has a wider ecological range; while tartary buckwheat is limited in adaptation, and hence a smaller ecological range. The latitude of the original growing districts of buckwheat varieties affects their adaptability and sensitivity to environments. Varieties introduced to the south from the north show buds and flowers in advance, while varieties introduced from the south to the north are retarded in showing buds and flowers, and their growth periods are prolonged. Very few buckwheat varieties are adapted to spring, summer, and autumn sowing at the same time. Generally, the distinction between spring sowing and summer sowing is more obvious. Autumn buckwheat when sown in the spring will yield something at least, but spring buckwheat sown in the summer will yield nothing at all.

3. The cultural division of buckwheat should take the local farming system into consideration. Although buckwheat is not a staple crop in China, it is grown somwhere in the country throughout the year. Except along the Great Wall, it is a complementary crop to grain crops, and its cultural position is greatly influenced by staple crops.

II. An outline of cultural and ecological regions of China's buckwheat.

1. Spring buckwheat region in northern China

(1) Geographic scope and natural boundaries. The geographic scope of buckwheat includes both sides of the Great Wall, and the highlands and mountains beyond. The northern belt consists of pastoral areas and forest lands, starting from the northwest of Heilongjiang Province (including Xinganling Mountain, Bei-an and Kabai hills), and embracing Baicheng District of Jilin Province, Fuxing, Chaoyang, and Tieling of Liaoning Province, the southeast part of Inner Mongolia, Chengde, Bashang of Hebei Province, Yanbei of Shanxi Province, Yulin of Shaanxi Province, Kuyuan, Yanzi of Ningxia Province, and the east part of Qinghai Province.

(2) Natural conditions. This region consists mainly of high latitudes and high altitudes, mostly 1000 meters above the sea level, with a frost-free period of 100-130 days. It is cold in the winter, dry and windy in the spring. The summer is mild but short, while the autumn has fine weather and large temperature differences between day and night. During the growing period, the temperature rises rapidly. The accumulated temperature is low, in most parts, the annual > 10 $^{o}$C accumulated temperature is less than 3000 $^{o}$C. Rainfall is scarce, with annual precipitation of 300-400 mm. It is especially low in the spring, but fairly heavy in the summer. During the buckwheat growing period, the climate is warm and humid, and its needs for light, heat and water can be met.

(3) General situation of buckwheat cultivation. This region is characterized by extensive cultivation since the land is thinly populated. The principal crops are buckwheat, oats and potato, all of which are cold-tolerant. This is China's main growing district of common buckwheat. The planting area of buckwheat in this region accounts for 50-60% of the whole area of buckwheat in China. Only one crop can be grown in a year. Sowing is from late May to early June. In Northeast China and in Southeast Inner Mongolia, peasants are accustomed to using wide ridges, while

in West China, they prefer to drill seeds in wide rows.

(4) Differences within the region. There is significant difference in latitude between north and south of the region, and there is also a difference in topography between the east and the west. The eastern part of Inner Mongolia is similar in topography to the western part of Liaoning, while the western part of Inner Mongolia is similar to Zhangjiakou, Hebei, Yanbei, Shanxi and Yulin, Shaanxi. In the north, the weather is cold, the growing period is short, hence cold-tolerant and early-maturing varieties are needed. In the south, the weather is mild, the growing period is a little bit longer, so medium or late-maturing varieties are needed.

(5) Trend of development and problems. This region is the main growing district of China's common buckwheat. In most cases, it is grown on sandy, dry wastelands, where production conditions are very poor, and farming is quite extensive. Buckwheat is sown in the spring and harvested in the autumn. Yield is relatively low, and the grade of product is also low. It is necessary to practise crop rotation, to raise soil fertility, to increase farm mechanization, and to intensify management.

2. Summer buckwheat region in Northern China

(1) Geographic scope and natural boundaries. This region is centred around the Yellow River Valley and located within the belt of wheat with sowing-to-maturing periods of 225-275 days, starting in the north from Yanshan Mountains along the Great Wall, bordering the spring buckwheat growing region, and ending in the south at the border of the Qin Mountain-Huai River-Ba Mountain. This region reaches the west side of the Loess Plateau in the west and reaches the sea coast in the east. Its range coincides with that of winter wheat in North China, including Huanghai, Huaihai, and southern Shanxi, central Shaanxi and Liaodong Peninsula.

(2) Natural conditions. This region is located in the middle part of our country, consisting mainly of plains with low altitudes,from several meters to several hundred meters above sea level, with a frost-free period of 170-225 days. There are cold currents in the spring and there is frost in autumn. The summer temperature is rather high. The $>10\ ^{o}C$ annual accumulated temperature reaches $3600\ ^{o}C$ to $4000\ ^{o}C$. The annual rainfall ranges from 500 to 900 mm, concentrated in July and August, usually causing floods. Soil fertility is moderate.

(3) General situation of buckwheat cultivation. This region is densely populated, with too many peasants engaged in intensive farming, and is the main growing district of China's winter wheat. Buckwheat is a catch crop after the wheat is harvested. Here, the planting area accounts for 15-20% of the total buckwheat area in China. In the region of the Huang, Huai and Hai Rivers, the practice of growing 3 crops in 2 years has consistently prevailed. On irrigated land and in the south of the Yellow River, 2 crops can be grown in one year, while on the plateau and in the mountains, a system of one crop a year can sometimes be found. On the plain, common buckwheat is multiple-sown in July or August, while in the high altitude mountains, tartary buckwheat is sown in May or June. Peasants in this region are accustomed to drill-seeding in narrow rows.

(4) Differences within the region. In the west of this region, the difference between north and south is less than $1^{o}$, while in the east, the difference is $7^{o}$. The difference between east and west is $19^{o}$,

thus forming a right triangle. With major differences in altitudes, differences in climate and planting conditions are very great indeed. So varieties in the south and in the north, and in the east and in the west are not interchangeable. However, due to the lack of natural barriers, differences change gradually. It is difficult to make a further division. Generally speaking, the Beijing-Tainjing-Tangshan Region in the east of the Taihang Mountains and north of the Shi-Tai Railway is considered the northern region, while the region from the Shi-Tai Railway to the Long-Hai Railway is classified as the southern region. The area to the west of Taihang Mountains, poor in water, but rich in light and heat resources, is regarded as the western region.

(5) Trend of development and problems. This region, called 'the south and the north of the Milky Way' in ancient times, is the multiple-cropping area of China's buckwheat. In recent years, as a result of the development of irrigation and water conservancy, and of the reform of agricultural systems, the plains to the east of the Taihang Mountains, originally used to multiple-crop buckwheat is used now to grow corn (maize) and beans. The planting area of buckwheat has thus been greatly reduced. Only on the hills and mountains west of the Taihang Mountains, where irrigation is impossible, is buckwheat still grown. It is advisable here to use varieties with a growth period of about 70 days. There is a need to change the habit of extensive cultivation, to intensify farming and management, and to prevent lodging and hence increase yield.

3. Growing areas of autumn and winter buckwheat in South China

(1) Geographic scope and natural boundaries. This region is located roughly in the vast area to the south of the 0 $^{o}C$ mean temperature and 5000 $^{o}C$ accumulated temperature, including Jiangsu, Zhejiang, Anhui, Jiangxi to the south of Huai River and the middle and lower reaches of the Yangtse River, and the plains and hilly paddies in Hubei and Hunan, and Lingnan Ridges, as well as most parts of Fujian, Guangdong, Guanxi, Taiwan, and the south plateau of Yuannan and Hainan.

(2) Natural conditions. This region lies in South China and along the sea coast, with low altitudes. To the south of the Yangtse River, the yearly mean temperature is 16-18 $^{o}C$, the annual > 10 $^{o}C$ accumulated temperature is 5000-6000 $^{o}C$, with a frost-free period of 240-330 days, and annual rainfall of 1000-1800mm. The region is rich in water and heat resources, but short of land, about one mu cultivated land per person. The soil is mainly hilly red loam.

(3) General situation of buckwheat cultivation. This region covers a wide area, enjoys a warm climate, a long frost-free period and abundant rainfall. The staple crop is rice, buckwheat is a catch crop between two crops of rice. It is grown in a scattered fashion. Its planting area is very small, less than 5% of the total buckwheat area in China. Hill-sowing is preferred by peasants in this region.

(4) Difference within the region. The system of two or three crops a year on the plains, hills and paddies in the Yangtse River's middle and lower reaches is different from that in South China, where buckwheat is usually grown as a relay crop between 2 crops of rice.

(5) Trend of development and problems. Buckwheat formerly had a certain importance in the agricultural production of this region, but with the improvement of irrigation and water conservancy facilities, buckwheat has been replaced by high-yielding crops such as corn (maize).

Today, on hillsides, where light, heat and irrigation are insufficient, buckwheat is still grown. Hereafter, in order to maintain a proper position for buckwheat in agricultural production, it is necessary to select a proper crop succession, such as to utilize the gap of the 60 days from early September to early November, to change the rotation of "spring grain crop-hybrid rice" to that of "spring grain crop-hybrid rice-buckwheat".

4. Spring, autumn buckwheat region on the Southwest Plateau

(1) Geographic scope and natural boundaries. This region includes Tibet-Qinghai Plateau, South Gansu, Yunnan-Guizhou-Sichuan Plateau, Sichuan-Hubei-Hunan-Guizhou border hills, and the southern foot of the Qing-Ba Mountains.

(2) Natural conditions. This region is at low latitudes and high altitude, ranging from 800 to 3000 m, covering hills, basins and plains, characterized by vertical farming. Annual mean temperature ranges from 7 to 18 $^{o}C$ and yearly > 10 $^{o}C$ accumulated temperature ranges from 2700 to 4300 $^{o}C$. Rainfall ranges between 900 and 1300 mm annually. On the flatlands along the river below an altitude of 400 m, the yearly > 10 $^{o}C$ accumulated temperature exceeds 5500 $^{o}C$, with a frost-free period of over 300 days.

(3) General situation of buckwheat cultivation. This region is thinly populated and extensively cultivated. Cultivated crops mainly consist of cryophilic crops such as buckwheat, oats, and potato, being supplemented with other cold-tolerant nonstaple beans. Due to the long duration of the active accumulated temperature and the low intensity of temperature, in addition to the abundance of fog and cloud, insufficiency of sunlight, and small temperature difference between day and night, this region is suitable for the growing of cryophilic tartary buckwheat, and has become the main growing district of this kind of buckwheat. The cultivated area comprises 25-35% of total area of China's tartary buckwheat. Only one crop of tartary buckwheat can be grown in a year. It is sown in the spring. On river plains at low altitudes, 3 crops of tartary buckwheat can grow in 2 years.

(4) Differences within the region. These are mainly caused by high altitude. In the Tibet highlands, mainly cold-tolerant and cryophilic crops are grown. Annual > 10 $^{o}C$ accumulated temperature is 2300 $^{o}C$. Peasants here practise a one-crop-one-year fallow system, with a fallow period from as short as 1-2 years to as long as 3-5 years. On dry land at the southern foot of the Qin-Ba Mountain Range, the annual > 10 $^{o}C$ accumulated temperature ranges between 4500 and 5400 $^{o}C$, and annual rainfall from 800 to 1400 mm. Here, the one-crop-one-year system prevails. On the border between Hunan and Hubei, arable land is limited and scattered. Here, crop yield is low. In the high-altitude area, only-one crop can be grown in a year. Below an altitude of 400 m, two crops can be grown, one of which is autumn buckwheat. The Yunnan-Guizhou-Sichuan Plateau has an altitude of 1500-2000 m, with a gentle undulation, a mean temperature of 13-16 $^{o}C$ and a > 10 $^{o}C$ yearly accumulated temperature of 3600-5000 $^{o}C$.

(5) Trend of development and problems. This region is the main growing district of tartary buckwheat in China and also the main area inhabited by minority nationalities. Here, farming is extensive, production lags behind, and the economy is undeveloped. Attention should be paid to the cultivation of tartary buckwheat, the selection of superior varieties, an increase of yield and the rapid development of the overall economy.

**Summary**

The cultural and ecological regions of China's buckwheat are divided on the basis of the geographic location of China's natural regions, ecological factors such as light, temperature and water, the actual growth periods of species and varieties, agronomic and economic character, planting methods and farming systems, into four cultural and ecological regions: the spring buckwheat region in North China, the summer buckwheat region in North China, the autumn and winter buckwheat region in South China, and the spring and autumn buckwheat region on China's southwest highland.

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