Review

Wheat Production and Breeding in Israel from 1948 to 2002

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Abstract: The sown wheat acreage in Israel increased from less than 40 000 ha in 1948 to more than 100 000 ha in the seventies and has declined slightly since that time. About 3/4 of the crop are grown in the central part of the country, mostly rainfed, with precipitation of 250–500 mm. The cultivation of durum wheat, originally dominant, has declined since the sixties to a small percentage of the wheat acreage and durum wheat breeding is thus negligible. Local bread wheat breeding started around 1960 independently at three breeding organisations, one of which extensively used genetic material from international breeding programs in Mexico. Since the fifties about 25 cultivars have been released, but only a few are of economic importance now. Breeding considerably increased the yielding potential of cultivars. The recent top cultivar Galil yields about twice as much as cv. Florence Aurore, the leading cultivar in 1970. The national average grain yield rose from 900 kg/ha in 1948 to recently 2.3 t/ha. The highest on-farm yields under favourable conditions are about 9 t/ha. An increasing proportion of the wheat acreage is used for silage, reaching now more than 25%. Yearly fluctuations of yield are considerable and are closely related to rainfall. Data also show an improvement in water utilisation by the crop during the analysed period. The domestic production covered originally only about 12% of the consumption, reaching 47% in the decade 1970–1979, but declined again due to the population growth from 1.2 to 6.5 millions.

Keywords: Israel; wheat; yield; production; consumption; breeding; rainfall

The first attempts to modernise agricultural production in Palestine, the region between the Mediterranean Sea and the Jordan River, of which the State of Israel is a part, date from the beginning of Jewish settlement since the eighties of the 19th century, when the region was a part of the Ottoman Empire. The problems involved in transition from primitive to modern agriculture were already described by Elazari-Volcani (1925). Practical experience and systematic experiments from the 1880s' to World War I were described much later by Oren (1993). The first scientific experimental station was established by Aaronsohn, discoverer of *Triticum dicoccoides*, in 1910 near Athlith. This station existed till 1917, two years before the founder's death (Oppenheimer 1959, cited by Eyal & Hadas 1999).

The British Mandate Authority, succeeding the Ottoman Government during 1921–1948, established an Agricultural Experimental Station near Acre in the early twenties. At that time the World Zionist Organisation (WZO) also founded a main experimental station at Tel Aviv (moved to Rehovoth in 1933) and regional stations in a few new settlements (Geva, Ben Shemen, Gevath). The Acre station closed its activities in 1948 at the end of the British Mandate. The WZO Stations continued their existence after many reorganisations in the present Agricultural Research Organisation (ARO) and the Volcani Centre at Beth Dagan, with its three Regional Stations.

The activities of the Acre Station concerning wheat concentrated on trials with local durum landraces, individual selection from promising ones

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(Aharonowitz & Waks 1949) and multiplication of outstanding lines. A few of them became the first locally improved cultivars, maintained since the early fifties by the Cooperative Seed Company HAZERA (= "The Seed").

A comprehensive overview of Palestinian wheat production, still durum wheat only at that time, was published by Pinner (1930). Kostrinsky (1948) described Palestinian durum wheats and their agronomy in a book. Short descriptions of wheat production in the State of Israel since 1948 were published by Atsmon (1990, 1991).

The physical environment

Although a small country, Israel is very diversified in climatic and edaphic conditions. Rainfall and availability of water for irrigation are the most decisive factors. Average annual precipitation during the rainy season November–April diminishes from 900 mm in the Galilean Mountains to almost nil in Eilath, about 500 km to the South.

It also diminishes from about 700 mm in the Northern Coastal Area to about 300 mm in Beit She'an Valley, 70 km to the South-East. Yearly fluctuations are considerable. Drought years, affecting the whole country or parts of it, mostly in the South, occur frequently. Figure 1 shows the average annual rainfall for the period 1961–1990. The main areas of wheat production are marked with a dotted pattern.

About 3/4 of the wheat acreage are in the 500–250 mm precipitation zone in the central part of the country, around 31'20" latitude. The soils in this region range from alluvial in the North, mixed with loess farther to the South, to pure loess and even sandy soils in the Southern part. The remaining acreage is in the Esdraelon (Yizre'el) and Beit She'an Valleys (600–300 mm precipitation) and some fields are farther to the North in the Hulah Valley (500–700 mm precipitation). Esdraelon is alluvial, Beit She'an is on locally developed basaltic clays and Hulah is reclaimed marshland. Almost all wheat is sown in dry farming rotations, of which 10–15% have the possibility of supplemental irrigation. Of marginal importance are wheat fields in irrigated rotations. In contrast to regional differences in rainfall, the seasonal rainfall pattern is similar for the whole country.

In the wheat growing areas 353 regional field trials were performed between 1970 and 2002. Rainfall data were available from 166 of the trials. About 97%

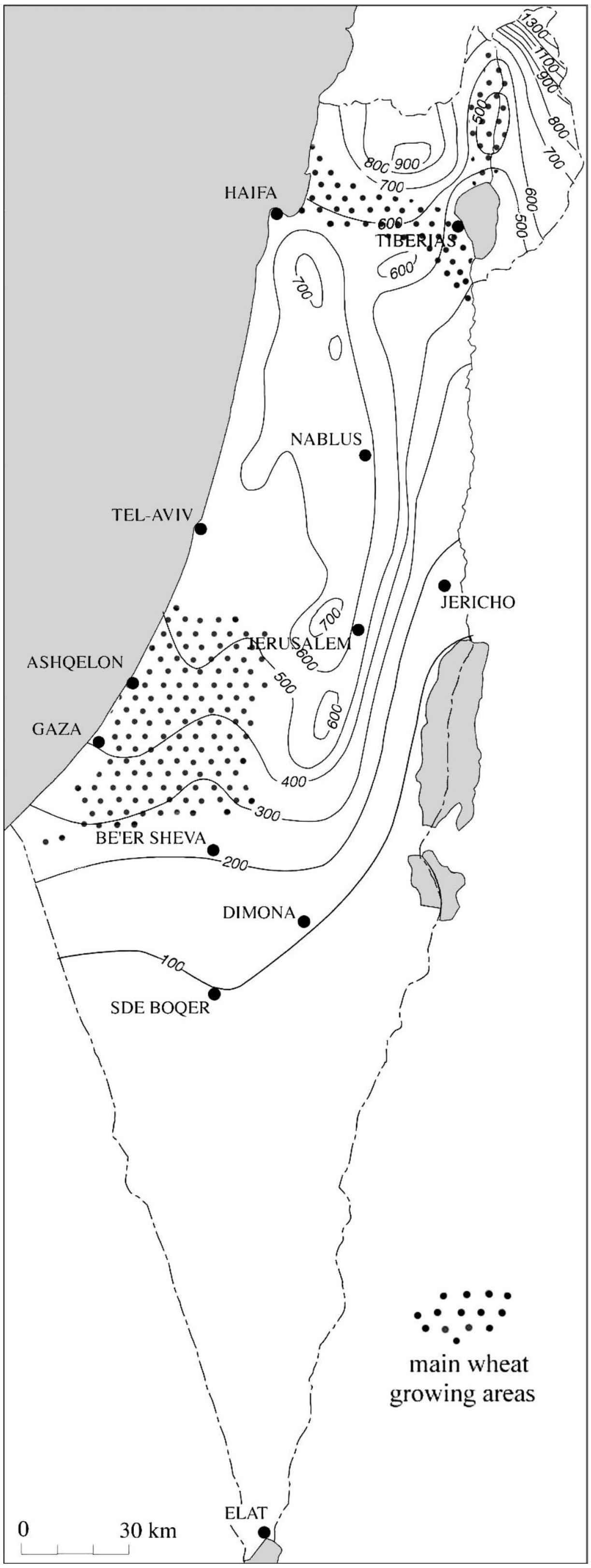

Figure 1. Precipitation map of Palestine (average 1961–1990) (adapted from Climatological Services, Israel Meteorological Service, Ministry of Transport)

Table 1. Average rainfall distribution in 166 regional field trials between 1970 and 2001

	Nov.–Dec.	Jan.–Febr.	Mar.–Apr.	Nov.–Apr.	Whole year
Average (mm)	146.6	180.1	86.1	412.8	426.8
% of total	34.3	42.2	20.2	96.7	100.0
Standard deviation of % of total	11.9	11.9	8.8	4.3	

of precipitation are restricted to the rainy period from November to April. The rainfall distribution in these trials is summarised in Table 1.

Recent meteorological studies (Ben-Gai 1998) show climatic changes in the second half of the 20th century, expressed mainly in rainfall and temperature parameters, leading to an anti-desertification process, especially in the Southern part of the country. It is probably caused by the expansion of crop production in dry farming and in irrigated fields.

Yield losses are caused by a late start of the rainy season (December or even January), prolonged dry spells in mid-season and premature end of the rainy season. Kernel shrivelling, caused by hot weather and dry winds during ripening, can also occur. Early spring frosts occur rarely. These factors and annual fluctuation of rainfall potentially cause large fluctuations of yield.

To get a deeper insight into yield fluctuation, we estimated for the main wheat growing regions the relative annual rainfall in percents of the long-term average. We used for that purpose graphical surveys, that are published yearly by the Israel Meteorological Service, Ministry of Transport. The estimates ignore the different rainfall distribution in individual years, for example a deficit in the north and a surplus in the south in 1962/1963. Even so, they were closely associated with the yearly average yield per ha, as shown in Figure 2, suggesting that regional variations in the rainfall distribution are of small importance compared with yearly variations. This confirms that water availability is the main cause of the yearly fluctuations of yield and production, while the other previously mentioned factors have smaller effects.

Figure 2 also shows a progress in the utilisation of water by the wheat crop, expressed in the

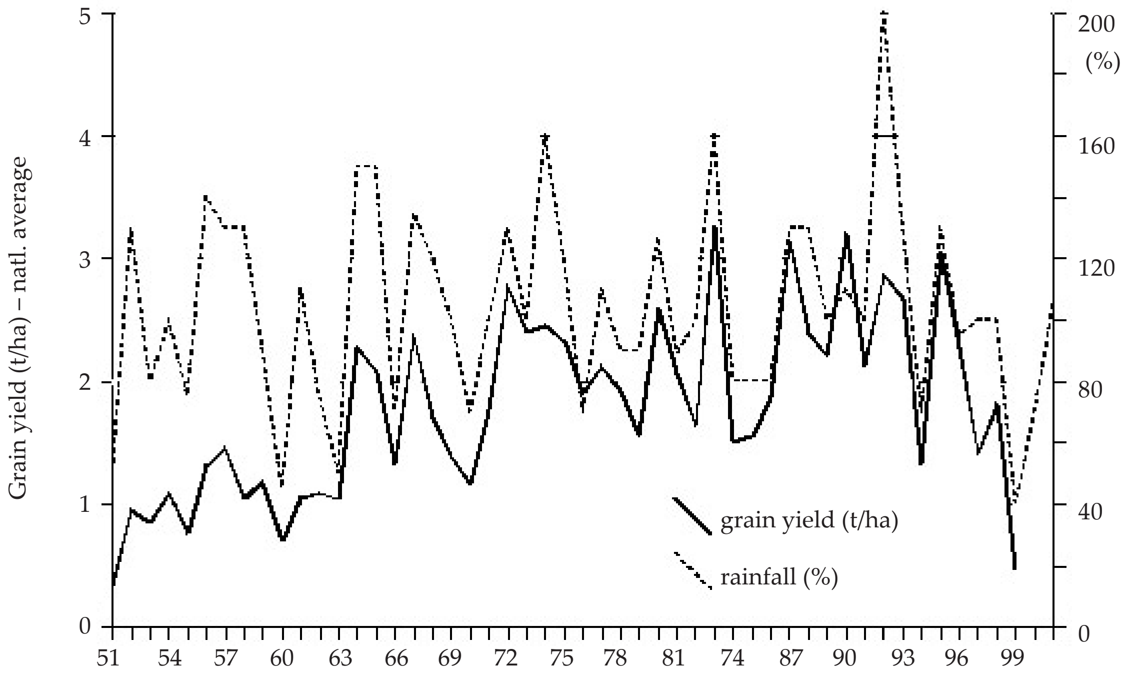

Figure 2. Relative rainfall in wheat growing areas and average national yield of bread wheat

Table 2. Statistical data averaged for 5 decades (10-year periods)

Decade	Winter grains (1000 ha)	Barley (1000 ha)	Wheat			
			total area (1000 ha)	grain area (1000 ha)	production (1000 t)	grain yield (t/ha)
1949–1958	104.8	59.8	45.0	42.7	41.2	0.92
1959–1968	129.1	57.3	71.8	68.5	106.1	1.48
1969–1978	133.8	24.6	109.2	105.8	213.3	2.02
1979–1988	126.2	20.8	105.4	92.0	201.9	2.16
1989–1998	118.3	10.9	107.4	84.5	194.5	2.29

diminishing gap between the two curves during the years, likely caused by improvements of agricultural practice and better cultivars.

Acreage, production and consumption

Wheat and barley are sown before the onset or at the beginning of the rainy period, i.e. during November and December. They are thus called winter grains, although their physiology is spring type without vernalisation need.

In the first year of Israel's Independence the acreage of winter grains was smaller than 50 000 ha, but already two years later it surpassed 100 000 ha. The acreage was largest in the late sixties: more than 140 000 ha. Since the early seventies official statistics show harvested acreage instead of sown acreage. It fluctuates around 125 000 ha, with a tendency to decline since the nineties (Table 2).

Acreage statistics distinguish between Jewish and Arab farming. This is justified by different development in both. Winter grains in the Arab farming took up 30–40% of acreage till the early eighties, and since then fluctuated between 20–25%, recently even less. The decline results from changes in many aspects of rural life, including intensification of agriculture with increasing acreage of irrigated crops at the expense of dry farming winter grains (Arnon & Raviv 1980).

Barley was the main crop in both Jewish and Arab farming till the mid-sixties. Since then the barley acreage strongly declined to about 10% of the wheat area. The decline was more dramatic in Jewish farming to less than 2000 ha since 1988. In Arab farming the barley area diminished from about 23 000 ha in1980 to approx. 12 000 ha in the next 15 years and only recently to about 4000 ha. Reasons for the decline were heavy net blotch epidemics since the early fifties, causing serious yield losses. Although breeding for net blotch resistance resulted in less susceptible experimental lines, it did not provide practical solutions to the problem (Atsmon *et al*. 1964).

Despite considerable yearly fluctuations, 10-year averages of the yearly production for the period 1949–1998, summarised in Table 2, show clear trends: increase through the third decade and decline since then, resulting from diminishing wheat acreage and increasing use of wheat for winter silage from a few percents before 1978 to more than 20% of the wheat acreage since 1988.

Similar data were published by CIMMYT (1996 – see the table on p. 61). Because of several dry seasons in the second half of the nineties large acreages were harvested early for silage or hay, or even abandoned.

The yearly average grain yields, calculated from production divided by harvested acreage, are the most inaccurate of the statistical data since the errors of both multiply. Nevertheless, a clear upward trend from about 900 kg/ha to recently 2300 kg/ha is evident.

During the first seven years of the statehood national production covered on average only 14% of consumption and there was a widespread opinion that this would remain so also in future. But statistics show that since 1956 production often covered a substantial part of consumption, eight times exceeding 50% and in 1972 even 70%. Since the yearly production varied very much, Table 3 summarises the relation of production to consumption over longer periods.

The relation of production to consumption reflects the continuous population growth from

Table 3. Relation of production to consumption in different periods

Years	Production/consumption (%)
1949–1955	14.0
1956–1959	24.1
1960–1969	33.2
1970–1979	47.0
1980–1989	39.6
1990–1999	29.7

1.1 to 6.5 millions between 1949 and 2001 and the limits of production, which has even declined in recent years.

Agronomy

The first overview of progress in field crop production and in wheat production in Jewish farming during the first two decades of the statehood was discussed by Ariel (1969). Progress in Arab farming was still slow at that time, but became accelerated later.

The first few new bread wheat cultivars were selections from introduced advanced lines. Some of them substantially outyielded durum wheat lines, selected from local landraces, and earlier introduced bread wheat cultivars. The impact of improved agronomy – tillage, crop rotation, seeding rates and dates, fertiliser application, supplemental irrigation, weed control, etc. – was much larger. Despite the occurrence of 11 drought years within two decades! – six in the whole country and five in the South only – the average bread wheat yields were estimated to be about 1.77 t/ha compared with the national average of 1.48 t/ha, mentioned in Table 2.

During these 20 years three production contests were held. The first in 1956 with the goal to reach 3 t/ha, the second a few years later with the goal of 5 t/ha and the last, during two years 1969/1970 and 1970/1971, aiming at 7 t/ha. In the first two contests the traditional cultivar Florence Aurore was the favourite. In both years of the third contest mostly the semi-dwarf cultivars Cee'on and Mivhor were chosen. In 1969/1970, a climatically unfavourable year (no rain in December and hot winds during ripening), the highest yield was 6.7 t/ha. In the next, more favourable year the highest yield was 8.9 t/ha, obtained in the low-rainfall South with supplemental irrigation. It was concluded that good husbandry with a high yielding cultivar can lead to high yield even in low-rainfall conditions under irrigation (Weiss 1970, 1971).

This conclusion is also supported by the progress in Bedouin agriculture in the last 20 years. The yield of a recently released cultivar (Galil) in an area with 250 mm rainfall and no supplemental irrigation amounted to 3.2 t/ha, in an area where 20 years ago yields were often only about 300 kg/ha (pers. commun., Abou Siam, extensionist, 2002).

The close co-operation of researchers, extension officers and farmers contributed very much to the progress in agriculture. Extensionists, in consultation with Regional Agricultural Councils or at their request, often take the initiative to conduct agronomic trials, to be planned and guided by researchers, but executed by extensionists and farmers in their own fields. Several regional field days are organised every year, and trial results are almost immediately applied and tested by farmers. Publications are almost only in Hebrew in local agricultural press and partly also in official ARO publications. Some of the exceptions are the long-term agronomic experiments at ARO's Gilat Experimental Station in the Negev with an average annual rainfall below 250 mm. They were initiated by Amir almost 20 years ago, are continued by Bonfil, and are published in international journals (Amir *et al*. 1991; Amir & Sinclair 1996; Bonfil *et al*. 1999; Sinclair & Amir 1996).

Breeding

Official cultivar statistics exist only for Jewish farming and are restricted to the harvest years 1949–1972. Since then there are only incomplete data collected by the Association of Field Crop Growers. Cultivar distribution in Arab agriculture was still more difficult to assess. Since 1966 durum wheat in Jewish farming was negligible. But in Arab farming durum landraces continued to be grown and almost all seeds were produced by the farmers. Although imported bread wheats, and later locally bred bread wheats were widely accepted by Arab farmers, their penetration was slower than in Jewish farming, but much accelerated in later years.

The oldest bread wheat introductions were probably brought from Europe by the Crusaders in the 11th century. Occasional small admixtures in no longer existing durum landraces were possibly the last remnants of those. Systematic introductions by the Acre Station and occasional introductions at the initiative of kibbutz farms started already during the British Mandate period. Most successful were a few Australian cultivars, designated as C.C.C. ("Three Seas"?) and B.I P.M. ("B.I.P."?) and Florence, obtained from Morocco and thus known as "Moroccan". Of these three, C.C.C. was the most popular, sown on considerable acreages till about 1960, but not anymore after 1965. Florence Aurore was introduced as BT 588 from Rabat, but replaced immediately by line 8193 from Maison Blanche, Algeria. It was commercially grown since 1949 and was the most popular cultivar for about 25 years, known by farmers as "Florence".

Breeding programs started at about the same time – late fifties/early sixties – at the Government Experimental Station, successor of former WZO stations, which became ARO after several reorganisations, and at HAZERA SEEDS.

The first materials, obtained in 1952, were advanced lines from the Mexican breeding program of the Rockefeller Foundation. A few lines, selected from them, became commercial in 1960. They did not yield much more than Florence Aurore and succumbed mainly to stripe rust within 10 years. A few dwarf lines became commercial in 1963. They disappeared even faster because of heavy stem rust attacks. Since then the ARO-program has been based mainly on these early introductions and Florence Aurore, resulting consecutively in the cultivars Pan and Miriam ('70), Lachish ('71), Barkaee ('77), Beth Lehem (= Betlehem) ('82), and Beth Hashita ('84), which is still in commercial use. The most recent is Goren, released in 2001.

The HAZERA-program, starting on a modest scale already in the mid-fifties, got its real push in 1962, when many advanced lines from the Rockefeller program in Colombia were received. Since then there was a steady yearly influx of genetic material first from Colombia and later from Mexico (International Wheat Improvement Program, and since 1966 CIMMYT). The program developed in a "normal" way. The first released cultivars were selections from collections of advanced lines (Cee'on in '67, Mivhor in '69, and the latest Dariel in '86). Later the cultivar Yafith was developed from an imported F_2 population and released in 1972. Finally, Hai ('71), Shafir ('76), Atir ('87), Yaniv ('93), Negev and Galil ('97) were developed from local crosses.

The third wheat breeding program, at the Department of Plant Genetics at the Weizmann Institute, replaced the original barley breeding program, abandoned because of diminished barley production. This program used sources of various origin, including also cultivars released by the former described programs. Released varieties are: Deganith ('81), Nirith ('90) and Gedera ('93).

In the ARO and HAZERA programs durum breeding was restricted to some CIMMYT-introductions and several crosses. Only three varieties became commercial cultivars, two of ARO and one of HAZERA. Their value for the local pasta-industry was small. At the Plant Genetics Department of the Weizmann Institute a separate durum breeding program headed by M. Feldman was based on the utilisation of protein-rich local dicoccoides-selections (Feldman & Millet 1991, 1993), but never produced a commercial result.

Official regional variety trials have been conducted yearly by the Extension Service of the Ministry of Agriculture since 1969/1970. Potential cultivar candidates and proven cultivars are tested on average at 12 localities in different parts of the country. The results of regional trials, accumulated over the years, reflect the progress achieved by breeding. The breeding progress was remarkable: the highest yielding recent cultivar, Galil, is yielding approx. twice as much as Florence Aurore, the most spread cultivar in 1970. A comprehensive statistical analysis of all 353 regional trials performed since 1970 and the improvements achieved by breeding are described in detail by Schwarzbach and Atsmon (2004) in this issue.

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Abstrakt

Atsmon S.Y, Schwarzbach E. (2004): **Produkce a šlechtění pšenice v Izraeli v letech 1949–2002**. Czech J. Genet. Plant Breed., **40**: 17–24.

Osevní plocha pšenice v Izraeli vzrostla z méně než 40 000 ha v roce 1948 na více než 100 000 ha v sedmdesátých letech a od té doby slabě poklesla. Přibližně 3/4 pšenice se pěstuje v centrální části země, většinou bez závlahy, s ročními srážkami 250–500 mm. Pěstování tvrdé pšenice, původně dominantní, dnes zabírá již jen nepatrný zlomek celkové výměry pšenice a šlechtění tvrdé pšenice proto bylo zanedbatelné. Šlechtění pšenice započalo v Izraeli kolem roku 1960 nezávisle ve třech šlechtitelských organizacích, z nichž jedna extenzivně využívala genetický materiál z mezinárodních šlechtitelských programů v Mexiku. Od padesátých let bylo v Izraeli uvedeno na trh kolem 25 odrůd pšenice, avšak jen některé z nich jsou v současné době ekonomicky významné. Nejvýkonnější současná odrůda Galil má zhruba dvojnásobně vyšší výnos zrna než odrůda Florence Aurore, která byla nejrozšířenější odrůdou v roce 1970. Celostátní průměrný výnos zrna vzrostl z 900 kg/ha v roce 1948 na současných 2,3 t/ha. Nejvyšší farmářské výnosy dosahují za příznivých podmínek okolo 9 t/ha. Podíl plochy pšenice využívané pro siláž vzrůstá a dosahuje nyní přes 25 %. Roční výkyvy výnosu zrna jsou značné a jsou v úzkém vztahu ke kolísání ročních srážek. Získaná data též poukazují na zlepšení využívání vody plodinou ve zkoumaném období. Domácí produkce pšenice pokrývala původně jen asi 12 % její spotřeby. Tento podíl vzrostl na 47 % v dekádě 1970 až 1979 zejména v důsledku nárůstu pěstební plochy, avšak od té doby klesá v důsledku růstu populace z původně 1,2 milionů na 6,5 milionů obyvatel v roce 2002.

Klíčová slova: Izrael; pšenice; výnos; produkce; spotřeba; šlechtění; srážky

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