RESPONSE OF CERTAIN MALTING BARLEY VARIETIES TO NITROGEN FERTILIZATION

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Abstract. The Barley Committee of the Laboratory of Brewing in Helsinki, carried out a series of field trials from 1967 to 1969 to investigate the effect of the timing and the quantity of nitrogen fertilization on properties of malting barleys grown in Finland. This paper deals with a part of this project. The varieties were the two-rowed brewing barleys Ingrid, Arvo and Karri and the six-rowed enzyme barley Pirkka. As a basic fertilizing 59 kg phosphorus and 99 kg potassium per hectare were administered. Varying nitrogen levels (30 or 60 kg N per hectare) were given as saltpetre at harrowing (early) or on the sprouts (late). The nitrogen given early increased the yield in all varieties more than the late spreading. The treatment on sprouts increased the protein content of the yield. The difference in protein contents between the two spreading times was as big as the difference between the two nitrogen doses given at the same point of time. Ingrid and Pirkka reacted very sensitively to the late nitrogen fertilizing. Karri was least sensitive to the changes in nitrogen supply. The yearly fluctuations of the protein contents were bigger than the differences between varieties in each year. The order of varieties in regard to the protein content was the same in all trial years: Pirkka, Ingrid, Arvo and Karri. Besides the cultivation technique, e.g. placement of fertilizers, attention must be paid to the sensitivity of the varieties in increasing their protein content under changeable conditions.

High yields of malting barley presuppose a sufficiency of all the necessary nutritives even nitrogen in the soil. In the other hand, barley intended for brewing must not have too high a protein content (the upper limit in Finland is 12 per cent crude protein). The nitrogen fertilization should therefore be such that this nutritive element is used up by the plants early during the vegetative phase of growth, so that there is not too much of it left in the soil when the plants start heading and taking nutritives to the developing kernels. Finland is the most northerly country aiming systematically at self-sufficiency in the production of malting barley. According to an EBC Barley Committee study, the protein content of barley rises most sensitively under the conditions prevailing in the fast-rhythmic northern summer (Lang 1966). Under these circumstances, therefore, one of the main problems of growing barley for brewing is the rapid increase of its protein content above the critical limit for malting.

This paper deals with some of the results of a study begun in 1967 by the Barley Committee of the Laboratory of Brewing in Helsinki, to investigate the effect of the timing and quantity of nitrogen fertilization on the protein content and certain other properties

of malting barley varieties officially approved in Finland (KIVI 1971). The reason for the study was that domestic production of malting barley was due shortly to be raised owing to the limitation of imports, and to the expectable growth of beer consumption following the lifting of restrictions on the sale of beer in Finland.

Performance of trials

Field trials were carried out from 1967 to 1969 on the Tammisto Experimental Farm (60°N) of the Hankkija Plant Breeding Institute. The soil was typical South Finnish clay with an acid subsoil of a kind commonly used for the cultivation of malting barley. In the same fields ordinarily one of the Finnish EBC Barley trials takes place.

The method used was split plots with three replicates. Each plot measured 8 sq.m. The varieties grown were the two-rowed brewing barleys Ingrid, Arvo and Karri, and the six-rowed Pirkka which is used for other purposes in the malting industry thanks to its high enzyme activity (KIVI 1968).

The plots were fertilized with a mixed phosphor-potassium fertilizer (P 7.4 % and K 12.4 %) as the basic nutrient in all the replicates. This was supplemented with a saltpetre-nitrogen fertilizer (N 15.5 %). Three levels of nitrogen fertilization were used: 0, 30, and 60 kg of nitrogen per hectare. The following amounts of main nutrients were given at the three nitrogen levels:

Nitrogen level	Main nutrients kg per ha		
kg/ha	N	P	K
0	0	59	99
30	30	59	99
60	60	59	99

To vary the time at which nitrogen became available to the plants, it was spread at two different times:

1) at harrowing, simultaneously with the phosphor-potassium fertilizer,
2) on the sprouts, approximately two weeks after their emergence.

In the second case the nitrogen fertilizer was spread by hand as was customary formerly.

The crude protein content was analyzed by the Kjelldal method at the Peat Research Institute in Hyrylä. Statistical analyses were made by SNEDECOR's (1956) method and treated at Hankkija's computer centre.

Grain yield

Nitrogen increased the yields of all the varieties. Their reactions to the increased levels of nitrogen fertilizing were fairly similar: the later nitrogen application raised the yield less than the earlier treatment.

On the plots grown without nitrogen, the yields of all the two-rowed varieties were almost equal, the order being Karri, Arvo and Ingrid (Table 1). Throughout the trial, the covariance of both the varieties and the fertilizing with the year of cultivation was significant, revealing the close dependence of the two first mentioned factors on the weather conditions prevailing in each growing season.

Table 1. Grain yields per variety and nitrogen treatment 1967—69.

		Nitrogen fertilization Relative yields (zero-nitrogen yield = 100)			
	Zero-nitrogen yield kg/ha	30 kg/ha early	30 kg/ha late	60 kg/ha early	60 kg/ha late
Arvo	3510	119	120	145	137
Ingrid	3430	118	122	141	128
Karri	3600	124	121	148	130
Pirkka	2140	119	115	158	115

	F value	LSD (0.05) yield kg/ha 1967—69
Nitrogen treatment	65.5***	268
Variety	461.8***	138
Year	10.7*	503
Treatment × variety	3.3*	—
Treatment × year	5.0*	—
Variety × year	12.9**	—

The six-rowed, early ripening Pirkka was largely outyielded by the two-rowed ones: during the whole trial the Pirkka yields were only 62 % of those of Ingrid. Pirkka has not been a profitable variety under the conditions prevailing on South Finnish clay soils. The relative poorness of its yields is aggravated by dry weather of the sort experienced during all three years of the trial.

The effectiveness of the early nitrogen treatment was highest at the higher nitrogen level (60 kg of N per ha). All the varieties yielded an average of 14 per cent more when the nitrogen was given early than when an equal amount was added at the later time. The difference in grain yields between the two spreading times was thus almost similar to the difference between the two nitrogen levels (30 and 60 kg of N per ha) given at the same stage of development, which averaged 15 per cent. At the lower nitrogen level, the timing of fertilization did not have a noticeable effect on the grain yield. The amount of nitrogen was probably so limited that existing differences of soil fertility eliminated the differences in fertilization.

At the higher nitrogen level the advantage of early treatment became particularly noticeable in the Pirkka. This variety also displayed the same trend at the lower nitrogen level, in which it differed from the two-rowed barleys. The covariance between variety and nitrogen level was significant. Contrary to the Pirkka, the two-rowed Karri also made good use of the nitrogen spread later: its grain yields decreased the least with later fertilization.

The average yields fell off from 1967 to 1969, owing to differences in the weather in those years.

Crude protein content

The use of nitrogen increased the crude protein content in all the varieties, but the timing of the treatment had a greater effect on the protein content than the amount of nitrogen used. In all treatment pairs, the later spreading yielded grains with a higher protein content than the earlier treatment. The differences varied from 0.3 to 1.9 percentage units (Table 2).

Table 2. Crude protein content per variety and nitrogen treatment 1967—69.

	Crude protein content				
		Difference from zero nitrogen Percentage units			
	Percentage, zero nitrogen	30 kg/ha early	30 kg/ha late	60 kg/ha early	60 kg/ha late
Arvo	10.9	+ 0.2	+ 0.6	+ 0.3	+ 1.6
Ingrid	11.0	+ 0.1	+ 1.0	+ 0.6	+ 3.1
Karri	10.6	+ 0.1	+ 0.4	+ 0.6	+ 1.3
Pirkka	11.9	+ 1.9	+ 3.0	+ 2.3	+ 4.2
		F value		LSD (0.05) %	
Nitrogen treatment		3.2		3.5	
Variety		18.9***		1.5	
Treatment × variety		< 1			

The protein content of the varieties differed significantly even on the zero-nitrogen plots. The greatest difference of all was between Pirkka and the low-protein variety Karri: 1.3 percentage units. The differences between the two-rowed varieties were much smaller — only 0.4 percentage units between the two most divergent ones, Karri and Ingrid.

The varieties tested differed much more in their reactions to nitrogen fertilization, especially to the later timing of the treatment. Pirkka differed from the other varieties in that the lower nitrogen dose (30N) raised its crude protein content significantly.

In the two-rowed varieties, the differences in protein content were bigger between the two treatment times than between the two nitrogen doses. Ingrid differed from both Arvo and Karri, because it reacted very sensitively to the late nitrogen treatment. The increase of its crude protein content from zero nitrogen to the late-treatment 60N level was 3.3 percentage units, which was about twice that of Arvo (1.6 percentage units) or Karri (1.3 percentage units). Karri was the least sensitive to changes in nitrogen supply.

The annual fluctuations in the protein content were large (Table 3). In 1967 all the varieties displayed high protein contents, averaging over 12 per cent, which was above the approved upper limit for brewing barley. Arvo exceeded this limit in all the fertilizer treatments. Ingrid was below the limit only in the zero-nitrogen plots, Karri also in the plots treated earlier with the lower nitrogen quantity.

Table 3. Annual fluctuations of crude protein content, averages and limit values.

	1967		1968		1969	
	average	range	average	range	average	range
Arvo	13.1	12.1—14.4	12.3	11.6—13.8	9.1	8.7— 9.4
Ingrid	13.8	11.8—19.5	12.8	11.7—14.8	9.4	8.9— 9.8
Karri	12.2	11.1—13.7	12.0	11.7—12.7	9.1	8.9— 9.2
Pirkka	14.0	8.6—15.6	15.6	14.3—17.6	12.9	11.9—13.8

In 1969, all the two-rowed varieties yielded crops with protein contents of less than 10 per cent, regardless of their fertilization. However, the average protein content of the Pirkka variety was almost 13 per cent and even its minimum was 11.9 per cent.

Certain growth characteristics

G r o w i n g t i m e . It is obvious that at the Northern limits of cereal cultivation, as in Finland, any method of fertilization that prolongs growing times is unsuitable. The general opinion is that nitrogen may be one of these factors. In fact, the earlier nitrogen treatment in our trials accelerated the heading of barley compared with both zero nitrogen and the later treatment (Table 4). On the generative stage of growth, nitrogen treatment had little or no retarding effect.

Table 4. Duration of vegetative and generative stages for two-rowed Ingrid and six-rowed Pirkka. Zero nitrogen: averages for whole trial in days; other nitrogen treatments: differences from zero nitrogen.

Nitrogen	Ingrid		Pirkka	
kg/ha	Veg.	Gen.	Veg.	Gen.
0	61.3	38.7	53.7	35.3
30 early	— 0.6	— 0.4	— 1.0	+ 0.5
30 late	+ 0.4	+ 0.1	± 0	± 0
60 early	— 1.0	± 0	— 1.4	+ 1.4
60 late	± 0	± 0	± 0	— 0.5

Nitrogen did not alter the total growing time of the different varieties to any notable degree. In Arvo and Karri there was a very slight trend towards quicker ripening with earlier fertilization than with a later spreading of the same amounts of fertilizer.

Though the total growing time of the six-rowed Pirkka was a good ten days shorter than that of the two-rowed barleys, its growth rhythm was very similar, regardless of the treatment.

S t r a w l e n g t h. The effect of nitrogen on the vegetative growth was largely the same as on the grain yield: early nitrogen treatment increased the straw length of all the varieties (Table 5). Karri and Pirkka reacted more noticeably than the other two varieties. Both Pirkka and Karri are known for their rather weak straw. No remarkable differences were noted in lodging, but this was due to the dry weather in all three summers.

Table 5. Straw lengths of the four varieties. Zero nitrogen: averages for whole trial; other nitrogen treatments: differences from zero nitrogen.

	Straw length, cm				
	Zero N	30 early	30 late	60 early	60 late
Arvo	60.0	+ 2.0	+ 1.6	+ 6.3	+ 2.0
Ingrid	60.3	+ 1.3	+ 1.7	+ 6.3	+ 1.7
Karri	59.3	+ 4.0	+ 1.9	+ 8.7	+ 2.0
Pirkka	64.0	+ 5.7	— 0.3	+ 10.3	— 0.3

	F value	LSD (0.05) cm
Nitrogen treatment	14.4***	4.0
Variety	62.9***	1.1
Treatment × variety	5.4***	

Adventitious shoots. Late nitrogen treatment increased the frequency of adventitious shoots in all the varieties, resulting in uneven ripening of stands.

Discussion

Rapid use of nitrogen by plants is very important in growing barley for malting, especially under conditions like those prevailing in Finland, where the vegetative development of the barley plant is extremely rapid — as has been demonstrated by the EBC trials performed in Finland and the paper published by the EBC Barley Committee (Lang 1966, Kivi 1967):

Country	Latitude (°N)	Days from sowing to heading	Days from sowing to yellow ripening
Portugal	37	111	149
France	49	79	121
Netherlands	52	101	135
Finland	60	59	97

(The figures in the EBC paper represent averages for three two-rowed varieties, those for Finland refer to the standard variety, the two-rowed Kenia.)

In Finland the placement of fertilizers has been found to be an efficient method of fertilizing because it improves the ability of plants to make effective use of the fertilizers (Pessi 1967). This method is also used widely for brewing barley cultivation, because it makes all the necessary nutrients rapidly available to the plants, including nitrogen. It also keeps the protein content down better than do conventional methods. In this study the placement of fertilizers was used in 1968 and 1969.

This may have been part of the reason why the crude protein contents in those years were considerably lower than in 1967 even in plots treated early with nitrogen.

The liability of varieties to increase their protein content when higher doses of nitrogen fertilizer are given is partly due to genetic differences. In Finland, another important reason is the frequency of drought in the early summer, and the effect of such weather

on the mineral soils that are otherwise more suitable for cultivating barley for brewing than humus-rich soils with a natural abundance of nitrogen reserves. Ingrid is a variety with high growth requirements. It is probably unable to utilize nutrients given early in summer as well as Karri and Arvo, which thrive better under such conditions in Finland. In Ingrid crops, therefore, more nitrogen may be left in the soil in the middle of summer, when the plants start their heading and the generative stage, and when rainy periods are a normal occurrence in Finland. This causes large amounts of nitrogen to be transferred to the developing kernels later, resulting in a greater protein content. Karri has the smallest growth requirements and under the Finnish circumstances it is more certain to produce yields with a satisfactorily low protein content, even during unfavourable weather.

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SELOSTUS

TYPPILANNOITUKSEN VAIKUTUS ERÄIDEN MALLASOHRALAJIKKEIDEN OMINAISUUKSIIN

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Artikkeli sisältää osan Panimolaboratorion ohrakomitean aloitteesta toteutetun tutkimuksen tuloksista. Tarkoituksena oli selvittää vaihtelevien typpimäärien ja eri aikaan tapahtuvan levityksen vaikutusta virallisesti hyväksyttyjen mallasohriemme, kaksitahoisten Ingridin, Karrin ja Arvon sekä monitahoisen Pirkan, eräisiin ominaisuuksiin. Kysymys mallasohran typpilannoituksesta on aivan viime vuosina noussut keskeisellä tavalla esiin eri maissa suoritetuissa tutkimuksissa, kuten Euroopan panimoteollisuusjärjestön, EBC:n mallasohrakokeissa.

Koelajikkeet saivat peruslannoituksena 800 kg/ha PK-lannosta. Vaihtelevat typpitasot 0, 30 ja 60 kg N/ha annettiin salpietarina. Typpi levitettiin joko kylvömuokkauksessa tai oraille, noin kaksi viikkoa orastumisen jälkeen.

Aikainen typpilannoitus lisäsi kaikkien lajikkeiden satoa enemmän kuin myöhään annettu. Viime mainittu sen sijaan lisäsi sadon valkuaispitoisuutta. Nimenomaan Pirkka ja Ingrid reagoivat herkästi myöhään annettuun typpilannoitukseen. Karri oli puolestaan vähiten herkkä typpilannoituksessa esiintyneille vaihteluille.

Mallasohran typpilannoitus on ensi kädessä viljelyteknillinen kysymys, johon kuitenkin vaikuttavat sekä kasvukauden sääolot että lajikkeen vaateliaisuus. Aikainen typen käyttö ja sen anto muiden ravinteiden tapaan rivimullaten tai sijoittaen merkitsee huomattavinta varmuustekijää olutmaltaan raaka-aineeksi tulevan ohran viljelyssä. Vaateliaitten lajikkeiden, kuten tekniseltä käyttöarvoltaan parhaan mallasohramme Ingridin, viljely olisi pyrittävä sijoittamaan edullisille paikoille, missä sadon valkuaispitoisuuteen kohottavasti vaikuttavat tekijät olisi mahdollisimman pitkälle eliminoitu.