JOURNAL OF THE SCIENTIFIC AGRICULTURAL SOCIETY OF FINLAND
Maataloustieteellinen Aikakauskirja
Vol. 53:328–340, 1981

Genetic and management adaptation of field bean (Vicia faba L.) in Finland

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Abstract. The investigation of field bean adaptation in Finnish climatic conditions was carried out at the University of Helsinki in 1976–77. The main objectives were to study the effects of seeding time and population density on the quantity and quality of the yield and the vegetative features in the development of two different types of field bean varieties.

Field bean yielded 4061 kg/ha in 1976. In 1977 only 2042 kg/ha was harvested due to the lack of light during the grain filling period and the presense of plant diseases. Delayed seeding lowered yields in both years. Maximum yield was obtained with the seed rate of 240 kg/ha.

Two weeks delay in the seeding speeded up flowering by two days. Temperature sum in degree days from seeding to emergence was 140–170°C, from seeding to flowering 618–637°C and from seeding to maturity 1670–1890°C.

LAI was 5.7 for early variety and 4.3 for late variety at the time of pod setting representing very effective situation for CGR. Number and distribution of internodes, pods and seeds were primarily influenced by population density and secondly by the differences between varieties.

1. Introduction

The field bean was one of the most important crops for human nutrition in Europe until the early 17th century. Later it was replaced by potato and maize. In Finland field beans were cultivated since the early 16th century. Bean cultivation was concentrated in the western part of the country. Eastern type native cultivars have been maintained in Eastern Finland until today, although the rest of the Europe have long ago adopted breeded varieties (KIVI 1975).

Field bean is a long day plant. Minimum temperature requirement for germination being +1°C. The plant can tolerate short periods of –4°C growing conditions. Optimum temperature for growth lies between 23–28°C according to varieties. Field bean is considered very sensitive to the stress conditions caused by either lack of light or water (OSVALD 1959).

As a plant, with a heavy seed weight field bean's moisture requirements for germination are great. Deep tillage, good aeration of seed bed and relatively deep sowing ensure good emergence and favourable root development. Heavy soils are recommended for the cultivation of the crop (HULTKVIST & SVENSSON 1975).

According to OSVALD (1959), a 2 000 kg/ha grain yield together with 4 000 kg/ha straw yield contain 113 kg N, 13 kg P, 54 kg K and 27 kg Ca. As other legumes also field bean's K and Ca requirements are high. In Sweden and in Denmark N-fertilization is not recommended but inocculation in the soils without earlier field bean cultivation (SJÖDIN et al. 1972). In Finland a relatively cool spring together with minor bacterial activity give a good reason for the use of fertilizer nitrogen. HOVINEN (1977) recommends 40—60 kg N/ha for the start fertilization.

As a crop with a relatively long growing season requirement field bean should be seeded early in the spring. However, only a noticeable delay in the seeding date (30 days) have lead to the reduced yield (HULTKVIST and SVENSSON 1975), (CHRISTENSEN 1972). Similar results have been obtained by ROWLAND (1978) in Canada and BARRY and STOREY (1979) in Ireland.

In Sweden, BENGTSSON and BINGEFORS (1975) have studied factors relating to the rate of seeding. They have concluded that the seeding rate is dependent primarily on the variety and secondarily on the row spacing. Narrow raw spacing (12 cm) yielded more than stands with row distance 50 cm. Narrow row spacing gives requirement for a higher seed rate. Higher population density can be used with the varieties with low seed weight, although seeding rates are lower.

In Finland HOVINEN and KIVI (1975) have studied the growth behaviour of the most important Swedish varieties together with some Finnish native field bean cultivars. The variety with the highest production proved to be Primus from Svalöf, which matured in 130 days. Finnish native cultivar Mikko yielded 45 % less, but matured 20 days earlier.

In this investigation the primary aim was to study the variety and management questions of field bean. Study objectives were native cultivar, early maturing (110 growing days) Mikko with 1 000 seed weight = 220 g and late maturing (130 growing days) Swedish variety Arla with 1 000 seed weight = 350 g. Other objectives were seeding date, seeding rate and the effects of the studied management to the productivity, yield quality and to the vegetative features in the development of the two varieties.

2. Materials and methods

Field bean trials with different management and biological studies were carried out at the University farm in Helsinki in 1976—77. The research program consisted of the following type of experiments:

Field experiments:

		1976		1977	
Main plot:				Seeding times	
Early seeding	a.	May 11		May 6	
Midearly "	b.	May 17		May 16	
Late "	c.	May 24		May 23	
Sub-plot:				Varieties	
Early and small seed	a.	Mikko		Mikko	
Late and large seed	b.	Arla		Arla	
Sub-sub-plot:		Seeding rates			
		kg/ha	seeds/m^2	kg/ha	seeds/m^2
Mikko	a.	160	78	160	76
	b.	240	118	240	114
	c.	320	157	320	150
	d.	400	196	400	186
Arla	a.	160	45	270	76
	b.	240	60	405	114
	c.	320	91	540	150
	d.	400	113	675	186
Replications		4		4	
Plot size m^2		10		10	
Fertilization (15–20–15) kg/ha		670		670	
Row spacing cm		12.5		12.5	
Seeding depth cm		8		8	

Field observations consisted of the dates of emergence, flowering and maturing and the existence of plant diseases. Stand density plants/m^2 was determined by counting the plants in the rows 3 × 1 m/plot. Plant height was measured once per week at three places of the plot. The scale for lodging was 0–100 %. The plots were harvested with combine machine and dried to 13 % water content in DM.

Laboratory studies:

LAI was measured twice in 1976 by using a planimeter at the time of flowering and pod setting. Together with LAI measurements was determined the number of leaves per plant. At the time of maturity the number of internodes per plant, number of internodes per plant carrying pods, number of pods per internode, number of pods per plant, number of seeds per pod and per plant and the distance from soil surface to the first internode carrying pods was determined . Botanical study consisted of material from 2 × 1 m length of seeding row.

Crude protein was determined by the Kjeldahl method.

3. Weather conditions

The growing seasons 1976 and 1977 were both cooler than average (Table 1). Precipitation of both growing seasons was close to normal. Heavy rainfall in July of 1977 developed an extra stress factor causing Chocolate spot disease (Botrytis cinerea) to attack plants and destroy the normal development of the stand. Both the temperature sum in degree days and the cumulative radiation sum (Wh/cm^2) were higher in 1976 than those of 1977 (Fig. 1.).

Table 1. Average temperatures and amount of precipitation (mm) during time period of May—Sept. in 1976—77 and average 1931—60 at Malmi Airport.

	Avg. temperature °C			Precipitation mm		
Month	1976	1977	1931—60	1976	1977	1931—60
May	10.7	9.4	8.4	46	22	41
June	13.0	14.4	14.1	42	36	47
July	15.9	14.7	17.2	52	122	68
Aug.	15.2	14.5	15.6	45	47	70
Sept.	8.1	8.3	10.5	48	73	66
$\overline{X}$	14.5	14.1	15.1	233	300	292

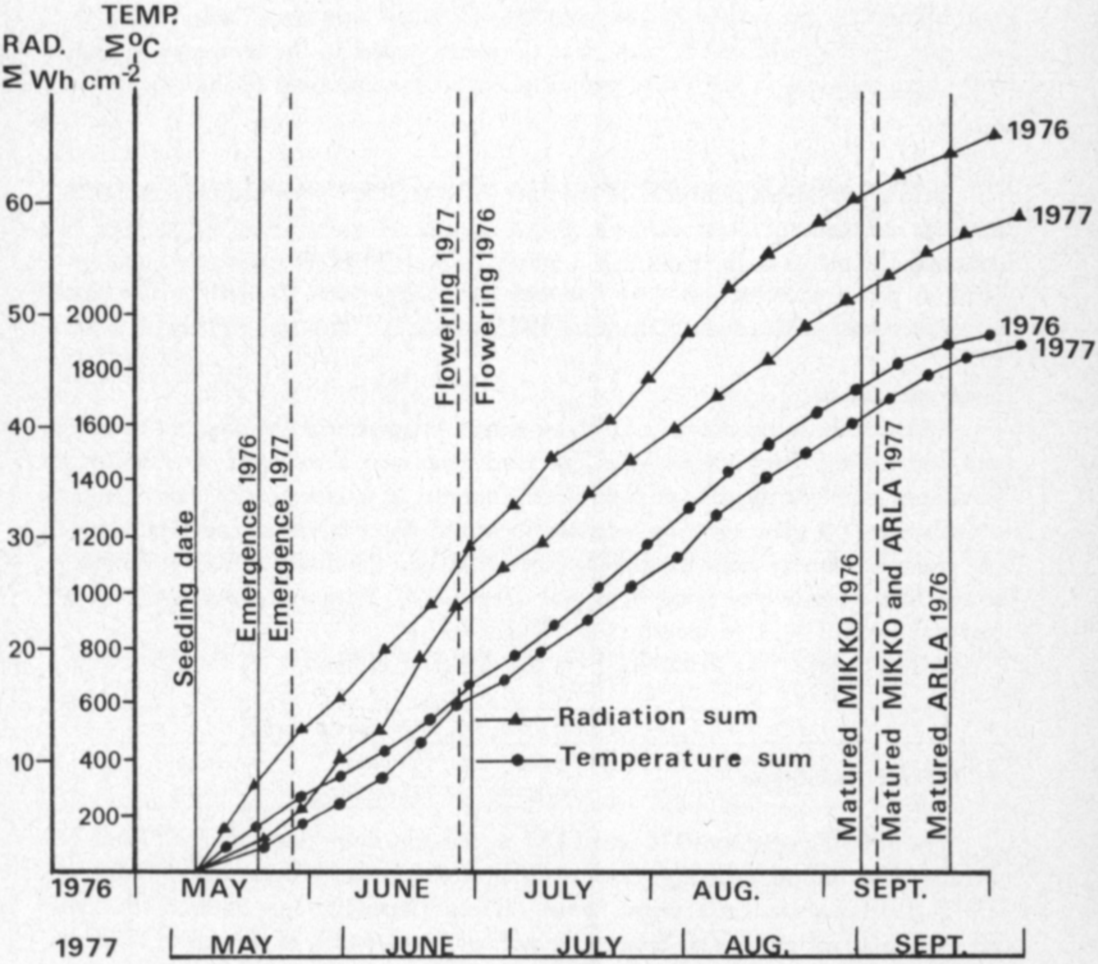

Fig. 1. Temperature sum ($\sum C^{\circ} > 0$) in degree days and total radiation sum ($\sum Wh/cm^2$) in 1976 and 1977 together with the developmental data of two field bean cultivars.

4. Results and discussion

Growing time, temperature and radiation requirements:

The time period between the date of seeding and the time of emergence varied from 11 to 17 days, primarily according to the spring temperature conditions (Table 2). Weather conditions were related to the seeding date. As a consequence, in early seeding, many temperature degrees are likely to be lost due to the warming of the seed bed, as can be seen in Table 3. During the time period of the stand emergence, around 12 % of the total radiation of the growing season was used for nonphotosynthetic purposes (Table 4).

From seeding to flowering the field bean stand used a temperature sum of 616—637°C in degree days (Table 3). Plant development seemed to be bound tightly to the temperature conditions around the plant. A one week delay in the seeding time speeded up the development by one day for both varieties (Table 2). The vegetative phase of variety Mikko was only two days shorter than that of variety Arla. The real variety differences were developing in the generative phase of plant development, and the variety Arla with a bigger seed size used more time for legume grain filling than the variety Mikko with 40—50 % less seed size (Tables 2 and 3). Since the development of the plant was primarily bound to the temperature sum, more light was lost in the early seedings than in the late ones (Table 4).

Table 2. Average growing time requirements (days) of two field bean varieties during different phases of plant development in 1976—77.

			Growing days	
Variety	Seeding time	Seeding — emergence	Seeding — flowering	Seeding — maturity
Mikko	Early	14	48	121
	Midearly	13	47	120
	Late	14	46	119
Arla	Early	14	50	128
	Midearly	13	49	127
	Late	14	48	126

Table 3. Average temperature sum requirements in degree days of two field bean varieties during different phases of plant development in 1976—77.

			Temperature sum C°	
Variety	Seeding time	Seeding — emergence	Seeding — flowering	Seeding — maturity
Mikko	Early	170	621	1710
	Midearly	144	616	1680
	Late	140	618	1667
Arla	Early	170	637	1789
	Midearly	144	635	1751
	Late	140	633	1705

Table 4. Average radiation requirements (Wh/cm^2) of two field bean varieties during different phases of plant development in 1976–77.

		Total radiation Wh/cm^2		
Variety	Seeding time	Seeding – emergence	Seeding – flowering	Seeding – maturity
Mikko	Early	7.20	26.35	56.96
	Midearly	7.24	25.63	55.31
	Late	6.84	24.01	52.63
Arla	Early	7.20	27.11	56.00
	Midearly	7.24	25.83	56.73
	Late	6.84	24.76	54.39

Finnish growing conditions are very much of those described by NAIMARK (1977) in Russia with a temperature sum of 1877–1898°C and with an average temperature of growing season 13.7–14.6°C. Optimum temperature conditions for RGR are 24°C (EL NADI 1969) or from 23 – to 30°C depending on varieties as described by EVANS (1957).

Maturity observations in 1977 were disturbed by the strong appearance of Chocolate spot disease caused by Botrytis cinerea. However, important observation was that two weeks delay in the seeding date introduced only two days shorter growing time by both varieties. Results show the same trend as observed by CHRISTENSEN (1972).

Yields:

In Scandinavia and in Finland the yields of field bean have varied between 500 and 5 000 kg/ha (HOVINEN 1977). Yields in 1976 represented relatively high yield levels as results 4 240 kg/ha for Mikko and 3 880 kg/ha for Arla show. Better productivity of Mikko compaired to Arla was not earlier experienced (HOVINEN 1977). The growing season 1977 represents about 50 % of the yields observed in 1976. Mikko also showed better productivity in rather poor growing conditions in 1977 (Table 5). Statistically the seeding densities 118 plants/m^2 for Mikko and 68 plants/m^2 for Arla in 1976 and 114 plants/m^2 for both varieties in 1977 produced highest yields although yields slightly increased when seeding rates were raised up to the highest level studied. Two year results show 200 kg/ha better average yields for the earliest seeding than the seeding two weeks later, although the yield difference was not significant. In Fig. 2. reduced net yields show distinct decrease in late seeding especially at high seed rates. Arla shows the same trend as pointed by BENGTSSON & BINGEFORS (1975) and THOMPSON and TAYLOR (1977) when the optimum seeding rate was 80 plants/m^2.

According to the results obtained (Tables 5 and 7), the temperature sum had primary effect on the plant development. On the other hand, light was primarily responsible for the yield formation. The temperature sums in degree days are almost equal in 1976 and 1977 (Table 6). Poor light conditions representing 12 %-units less total radiation in 1977 during the grain filling period resulted in a diseased stand and 50 % less yield than in 1976.

Table 5. Effect of seeding rate and time of sowing on the yield, crude protein and 1 000 seed weight of the field bean cultivars Mikko and Arla 1976 and 1977.

	Seeding rate kg/ha 1976													Rates
	160			240			320			400				
	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mean	F-test
Yield, kg/ha	3885	3649	3767 a	4296	3837	4067 b	4373	3966	4170 b	4407	4075	4241 b	4061	xx
Crude protein, %	30.3	31.9	31.1 a	10.4	32.0	31.2 a	29.9	32.1	31.0 a	30.0	31.9	31.0 a	31.1	N.S
1000 seed weight, g	221	324	273 a	218	337	278 a	212	272	242 b	207	330	269 ab	273	N.S
	Seeding rate kg/ha 1977													
Yield, kg/ha	1943	1833	1888 a	2241	1846	2044 ab	2211	1964	2088 ab	2246	2047	2147 b	2042	N.S
Crude protein, %	27.9	28.6	28.3 a	27.5	28.3	27.9 b	28.2	28.3	28.3 ac	28.1	28.4	28.3 ac	28.2	N.S
1000 seed weight, g	167	252	210 a	162	243	203 ab	159	247	203 ab	154	241	198 bc	203	x

	Time of sowing 1976									Times	
	Early			Medium			Late				
	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mean	F-test
Yield, kg/ha	4262	4093	4178 a	4097	3919	4008 a	4362	3634	3998 a	4061	N.S.
Crude protein, %	31.1	32.7	31.9 a	30.2	32.4	31.3 a	29.2	30.9	30.1 b	31.1	xxx
1000 seed weight, g	225	344	285 a	218	328	273 ab	201	320	261 b	273	x
	Time of sowing 1977										
Yield, kg/ha	2388	2342	2365 a	2040	1757	1899 a	2053	1669	1861 a	2042	N.S.
Crude protein, %	27.9	27.4	27.7 a	27.5	29.2	28.4 a	28.3	28.7	28.5 a	28.2	N.S
1000 seed weight, g	154	250	202 a	151	238	195 a	176	249	213 a	203	N.S.

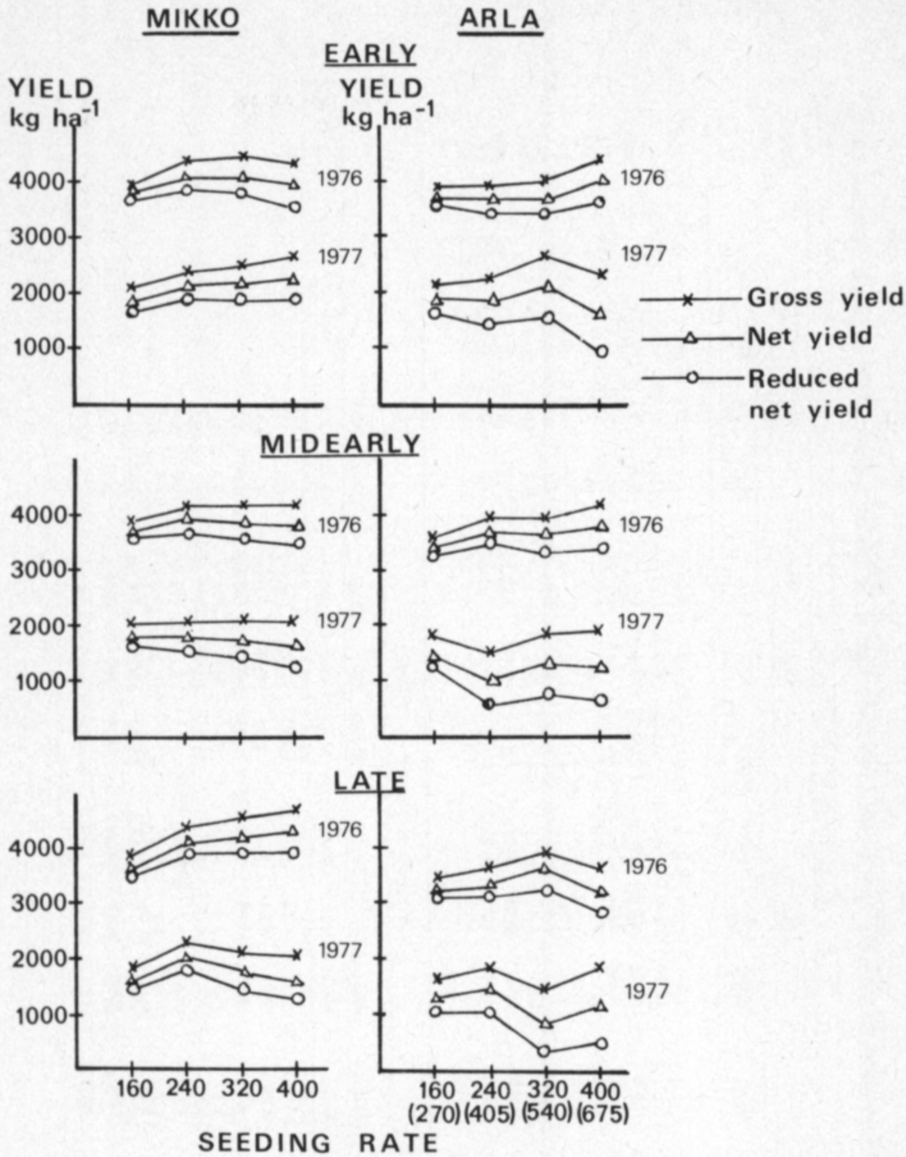

Fig. 2. Gross yield, net yield and reduced net yield of two field bean cultivars in 1976 and 1977 seeded at three different dates and four population densities.

Table 6. Temperature sum ($\Sigma C° > 0$) and total radiation ($\Sigma Wh/cm^2$) and relative number (RN) in 1976 and 1977 from the early seeding to the maturity of the last seeding.

Year	Temperature		Radiation	
	$\Sigma C° > 0$	RN	$\Sigma Wh/cm^2$	RN
1976	1918	100	66.15	100
1977	1862	97	58.54	88

Table 7. Effect of seeding rate and sowing time on some yield components of the field bean cultivars Mikko and Arla 1976.

	Seeding rate kg/ha													Rates
	160			240			320			400				
	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mean	F-test
No. of nodes/stem	14.3	16.7	15.5 a	13.6	15.3	14.5 b	12.6	14.2	13.4 c	11.8	13.5	12.7 c	14.0	xxx
No. of podding nodes/stem	5.2	6.3	5.8 a	4.6	5.0	4.8 b	3.7	4.1	3.9 c	3.2	3.8	3.5 c	4.5	xxx
No. of pods/node	0.71	0.92	0.82 a	0.56	0.68	0.62 ab	0.44	0.58	0.51 ab	0.39	0.47	0.43 bc	0.60	xxx
No. of pods/stem	8.0	10.3	9.2 a	6.7	7.8	7.3 b	5.3	6.2	5.8 c	4.3	5.4	4.9 d	6.8	xxx
No. of seeds/stem	26.2	29.7	28.0 a	21.7	22.2	22.0 b	16.1	17.2	16.7 c	13.3	14.8	14.1 d	20.2	xxx
No. of seeds/pod	3.3	2.9	3.1 a	3.2	2.8	3.0 b	3.1	2.7	2.9 c	3.1	2.7	2.9 c	3.0	xxx
Height of 1st pod, cm	21.4	24.1	22.8 a	24.0	28.9	26.5 b	28.4	33.7	31.1 c	29.8	30.9	30.4 c	27.7	xxx
LAI at flowering	2.13	1.93	2.03 a	2.15	2.24	2.20 ab	3.32	2.14	2.73 bc	3.57	3.04	3.31 c	2.57	xxx
" at podsetting	4.49	3.92	4.21 a	4.67	4.23	4.45 ab	6.44	4.11	5.28 bc	7.34	4.86	6.10 c	5.01	xxx

	Time of sowing									Times	
	Early			Medium			Late				
	Mikko	Arla	Mean	Mikko	Arla	Mean	Mikko	Arla	Mean	Mean	F-test
No. of nodes/stem	12.5	14.4	13.5 a	12.8	14.0	13.4 a	13.9	16.3	15.1 b	14.0	xx
No. of podding nodes/st.	3.8	4.8	4.3 a	4.0	4.3	4.2 a	4.7	5.3	5.0 b	4.5	x
No. of pods/node	0.46	0.67	0.57 a	0.53	0.58	0.56 a	0.59	0.74	0.67 a	0.60	N.S.
No. of pods/stem	5.4	7.6	6.5 a	6.0	6.4	6.2 a	6.9	8.2	7.6 b	6.8	xx
No. of seeds/stem	17.0	22.1	19.6 a	19.3	18.0	18.7 a	21.7	22.9	22.3 a	20.2	N.S.
No. of seeds/pod	3.2	2.9	3.1 a	3.2	2.7	3.0 a	3.2	2.6	2.9 a	3.9	N.S.
Height of 1st pod, cm	26.4	29.9	28.2 a	25.7	29.1	27.4 a	25.6	29.2	27.4 a	27.7	N.S.
LAI at flowering	3.64	2.56	3.10 a	2.79	2.55	2.67 a	1.95	1.90	1.93 b	2.57	xx
" at podsetting	5.95	4.14	5.05 a	5.20	4.39	4.80 a	6.04	4.31	5.18 a	5.01	N.S

Yield quality:

Field bean as a protein rich crop is valuable raw material in animal feeding. Its protein completes cereal grain protein by containing more lysin. Lack of sulphur containing amino acids restricts the use of field bean protein alone as a protein source for nonruminants. Also tannic acids and some glycosides of field bean grains are harmful in animal diet (NEHRING et al. 1972).

Studies in 1976—77 showed that variety Mikko had lower protein content (30.2 % in 1976 and 27.9 % in 1977) than Arla (32.0 % in 1976 and 28.4 % in 1977). In 1977 the differences between varieties were smaller due to the less favourable growing conditions (Table 5). Delayed seeding date resulted in a lower protein content in field bean grains, as experienced by ROWLAND (1978) in Canada and CHRISTENSEN (1972) in Denmark. This trend was interfered by Chocolate spot disease in 1977 by infecting the early seedings and early variety more heavily than late seedings or late variety Arla. Seeding rate had no statistically significant effect on the raw protein content of both field bean varieties as shown also by BENGTSSON and BINGEFORS (1975) in Sweden.

Seed weights for Mikko and Arla in 1976 were 215 and 331, in 1977 160 g an 246 g respectively. A relatively cool growing season together with plant diseases in 1977 did not allow a complete grain filling, especially when lack of light was also a limiting factor. Normal seed weights for Mikko and Arla are 220 g and 360 g, respectively. Field bean seed weight decreased as seeding date was delayed or seeding rate increased (Table 5) as shown also by CHRISTENSEN (1972).

Stand characteristics:

The stand height of variety Arla was at the end of August in 1976 100—110 cm against Mikko with an average stem length of 80 cm (Fig. 3). Stands with low seed rates developed faster than the ones with a high population density. The trend was reversed at the end of the growing season. Results are equal to those obtained by BARRY and STOREY (1979) or CHRISTENSEN (1972). Because of the greater height of the stand more lodging (24—41 %) could be found amongst the variety Arla, whereas the short variety Mikko stayed relatively upright.

Leaf area index (LAI) was mostly influenced by variety and seed rate. Mikko had higher LAI at the beginning of pod setting; average 5.73 for Mikko against 4.28 for Arla. LAI increased when the population density of both varieties increased (Table 7). LAI 3 was reached at the time of flowering only with early seeding and with high seed rates. According to BULL (1968) at the time of LAI = 3, daily temperature has the most important effect on plant growth. When LAI is raised beyond LAI 3, leaves and developing pods have increasing competition for light which can be considered the next limiting growth factor. In this study stands reached LAI 4 at the time of pod setting. LAI 4 is known to be the most effective leaf area for crop growth rate (CGR) of field bean.

Number and distribution of internodes, pods and seeds were mostly influenced by population density based on seed rates. Dense population with high seed rate had less pod carrying internodes per plant, less pods per internode and fewer seeds per pod than the stands with a sparse population density (Table 7). Results agree with those obtained by BARRY and STOREY (1979) and THOMPSON and TAYLOR (1977). Also distinct differences between varieties could be found. The variety Arla had a greater number of internodes, more pod carrying internodes and pods per

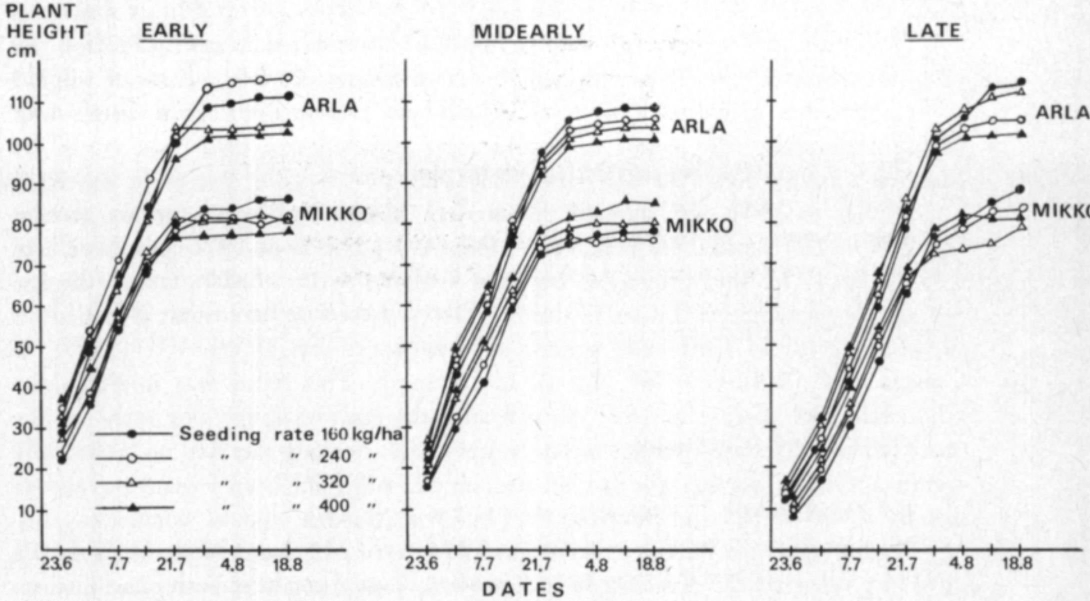

Fig. 3. Plant height development of two field bean cultivars in 1976 seeded at three different dates and four population densities.

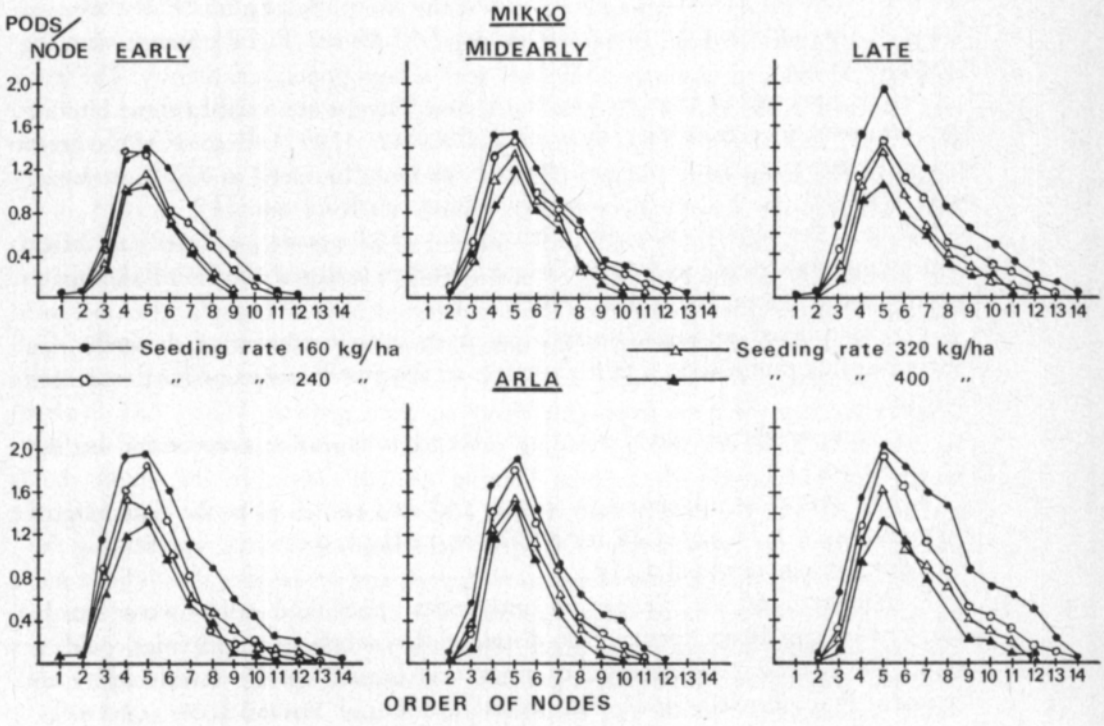

Fig. 4. Number of pods per internode of two field bean cultivars seeded at three different dates and four population densities.

internode but less seeds per pod than the variety Mikko. Late seedings showed a greater number of internodes and better production of pods as found by BARRY and STOREY (1979) in Ireland. The highest concentration of pods was located in the fourth and fifth internode (Fig. 4). Pods showed closely the normal distribution around those internodes.

The distance from the soil surface to the first pod carrying internode was 25.9 cm for Mikko and 29.4 cm for Arla. Pod distance varied according to the population density. Variation among Mikko variety was from 24.1 cm at seed rate 160 kg/ha to 29.8 cm at the seed rate of 400 kg/ha. Pod distances were higher than those obtained by HOVINEN (1977) but a similar trend to that obtained by BENGTSSON and BINGEFORS (1975) in Sweden.

5. Summary and conclusions

The investigation of field bean adaptation in Finnish climatic conditions was carried out at the University of Helsinki in 1976—77. The main objectives were to study the effects of seeding time and population density on the quantity and quality of the yield and the vegetative features in the development of two different types of field bean cultivars. The following results have been drawn:

1. Yielding ability and quality characteristics of field bean vary from year to year. Field bean still has certain primitive features such as long growing season requirements, and low drought and disease resistance. Regardless of the relatively cool summer field bean yielded in 1976 4 061 kg/ha. In 1977 the lack of light and attack of deseases resulted in an average yield of 2 042 kg/ha. Early seeding produced the highest yield. Seeding rate of 240 proved to be optimum for the maximum yield.

2. The time period from seeding to the stand emergence varied from 11 to 17 days representing temperature sums in degree days from 140 to 170°C. From seeding to flowering field bean used 46 to 50 days or from 618 to 637°C in degree days. Growing time from seeding to maturity varied from 119 to 135 days according to the variety and to the seeding time. High population density increased the growing time from 2 to 3 days. Temperature sum in degree days from seeding to maturity varied from 1670 to 1890°C.

3. The delayed seeding date resulted lower protein content of the grain dry matter. Seeding rate had no significant effect on the protein content of both varieties studied.

The seed weight decreased when the seeding date was delayed or the seeding rate increased.

4. LAI was most influenced by variety and seed rate. LAI at the beginning of pod setting was 5.73 and 4.28 for Mikko and Arla, respectively representing the most effective situation for CGR.

5. Number and distribution of internodes, pods and seeds were mostly influenced by population density. Also distinct differences between varieties could be found. The highest concentration of pods was located in the fourth and fifth internode. Pods showed closely the normal distribution around those internodes. The pod distance from soil surface to the first pod carrying internode varied according to the population density.

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Ms received December 10, 1981.

SELOSTUS

Härkäpavun geneettinen ja viljelyteknillinen sopeutuminen Suomen kasvukauteen

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Helsingin yliopiston Kasvinviljelytieteen laitoksella tutkittiin vuosina 1976–77 härkäpavun kylvöajan ja kylvötiheyden vaikutusta härkäpavun sadonmuodostukseen, sadon laatuun ja kasvin morfologiaan. Tutkittavina lajikkeina olivat pienisiemeninen, aikainen Mikko ja suurisiemeninen, myöhäinen ruotsalaislajike Arla. Tutkimuksista voidaan vetää seuraavat johtopäätökset:

Härkäpavun riskialttiuden vähentäminen edellyttää pienisiemenisen ja aikaisen lajikkeen jalostamista, joka on nykyisiä lajikkeita taudin- ja kuivuudenkestävämpiä. Viljelytekniikassa tulee pyrkiä aikaisimpaan mahdolliseen kylvöajankohtaan. Kylvömäärällä 240 kg/ha (120 siementä/m^2) saavutettiin maksimisato. Härkäpavun viljelyynotto edellyttää lisäksi, että sen sisältämät parkkihapot ja glukosinolaatit voidaan jalostusteitse poistaa, jotta sen täysipainoinen käyttö rehuseoksissa voitaisiin toteuttaa.