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ANNALES AGRICULTURAE FENNIAE, VOL. 20: 275—280 (1981)
Seria ANIMALIA DOMESTICA N. 56 — Sarja KOTIELÄIMET n:o 56

THE EFFECT OF A LOW-PROTEIN DIET DURING EARLY PREGNANCY ON THE REPRODUCTIVE PERFORMANCE OF SOWS [1])

TIMO ALAVIUHKOLA ja KAIJA SUOMI

ALAVIUHKOLA, T. & SUOMI, K. 1981. **The effect of a low-protein diet during early pregnancy on the reproductive performance of sows.** Ann. Agric. Fenn. 275—280. (Agric. Res. Centre, Swine Res. Sta., SF-05840 Hyvinkää 4, Finland.)

A low-protein diet (LP) 10,9 per cent crude protein for sows during the first three months of pregnancy decreased the number of piglets born alive and weaned compared to normal feeding (HP) 15,6 per cent crude protein. The difference between the groups in three successive litters averaged 0,8 piglets/litter at birth and 0,6 piglets/litter at weaning (5 weeks). The number of sows was 37 in the LP group and 38 in the HP group. There were no differences between groups in weight gains of the sows or birth weights or vigour of the piglets.

Index words: protein level, gestation, sows, reproduction, culling rate, birth weight.

INTRODUCTION

The ARC recommends (1963) up to 14—21 % crude protein in the dry matter of the diet for pregnant sows. Later reports by RIPPEL et al. (1965), FROBISH et al. (1966), HOLDEN et al. (1968), HAWTON and MEADE (1971), RERAT and DUEE (1975) suggested that satisfactory reproductive performance can be achieved with lower protein levels. Also LIVINGSTONE et al. (1966) reported good reproductive performance of sows on low-protein feed (10 % c.p.) during pregnancy. In Finland most of the commercially-produced sow feeds contain 17—18 % crude protein. The purpose of this experiment, started in 1975, was to find a way to reduce protein costs for reproducing sow, with emphasis on barley as the source of energy and a weaning age of 5 weeks.

[1]) Finnish report of the co-operative study between the Institute of Animal Husbandry, Krakow, Poland and Agr. Res. Centre, Swine Exp. Station, Finland.

MATERIAL AND METHODS

Experimental diets (LP and HP) (Table 1) were fed at the rate of 2,3 kg/sow/day during the first three months of pregnancy. High-protein diet was fed to both groups during the last phase of pregnancy at the rate of 3,25 kg/sow/day. The latter diet (16,5 % c.p.) was fed in both groups, at rates up to 5,8 kg/sow/day, to sows with 10 piglets (± 0,3 kg/d./piglet). In addition to the above sows in both groups received 1 kg grass silage per day during gestation and lactation: the silage contained 44 g c.p., 22 g d.c.p. and 2,15 MJ DE/kg.

All animals were individually fed during gestation and lactation. Water was supplied ad lib.

Once farrowed, the sows at the Swine Research Station were divided into two groups according to their genetic background and live weight. They were fed with experimental diets twice daily during three successive reproductive cycles. The live weight of the sows was recorded weekly. The housing was heated and well-ventilated; the sows were kept indoors the whole time. Only those farrowings which occurred during the daytime were supervised.

Table 1. Composition of the diets.

	LP (10,9)	HP (15,6)	Lactation
Barley %	48,0	43,0	42,0
Oats %	48,1	43,3	41,2
Fish meal %	—	5,0	5,0
Soyabean meal %	—	5,0	5,0
Dried skimmed milk powder %	—	—	3,0
Mineral+*) vitamin mixt. %	3,9	3,7	3,8
MJ DE/kg	11,6	11,9	12,0
d.c.p. %	8,1	12,6	13,4
Ca g/kg	8,4	8,6	9,3
P g/kg	7,0	7,9	8,3
lysine g/kg	5,6	9,7	10,1
methionine+cystine g/kg	3,2	4,9	5,0
*) A-vitamin I.U./kg	11 200	11 200	11 200
D-vitamin I.U./kg	2 700	2 700	2 700

RESULTS AND DISCUSSION

The reproductive performance of the sows fed with HP or LP diets during the first three months of pregnancy is shown in Table 2. The number of piglets born was smaller in the litters of LP-sows. The difference between groups was statistically significant.

Baker et al. (1970) and the NCR-42 Committee (1978) reported decreased numbers of piglets per litter with low-protein diets (c.p. 8,5—10 %) during pregnancy compared to the results with normal feeding (c.p. 14—15 %), but the differences were not statistically significant. The difference in the number of piglets born was not significant in experiments covering three or four successive lactations (Holden et al. 1968, Mahan 1977, Greenhalgh et al. 1980). Young et al. (1976) reported that protein supplementation had no beneficial effect on the number of piglets born compared to an unsupplemented barley diet, but improved the vigour of the piglets. In this experiment gilts were used.

In Danish experiments (1978) and in the reports of Baker et al. (1970) and Mahan (1977) concerning low-protein diets during the three first months of pregnancy, the results were similar to that with normal feeding. However, the number of weaned piglets and the daily gain of the piglets increased. High-protein feeding during the first third of pregnancy did not improve the results compared to low-protein feeding during the whole pregnancy (Baker et al. 1970). Baker concludes that low-protein feeding during pregnancy does not cause lowered birth weights but decreases the milk production of the sows, and that a sufficient amount of protein in the feed is more important during the late phase

Table 2. Effect low-protein diet during early pregnancy on number of piglets.[1])

	Parity		diet c.p. % gestation 15,6 lactation 16,5	diet c.p. % gestation 10,9—15,6 lactation 16,5	
Number of sows			38	37	significance level
Total piglets/ litter	1		11,7	10,9	
	2		12,2	11,5	
	3		12,4	11,6	
		mean	12,1	11,3	P<0,05
Live piglets/ litter	1		11,2	10,5	
	2		11,8	11,2	
	3		11,6	11,3	
		mean	11,6	11,0	P<0,1
Stillborn piglets/litter	1		0,5	0,4	
	2		0,4	0,3	
	3		0,8	0,3	
		mean	0,5	0,4	P<0,1
Mummified piglets/litter	1		0,2	0,2	
	2		0,3	0,2	
	3		0,2	0,1	
		mean	0,2	0,1	
Weaned pigs/ litter	1		9,8	9,0	
	2		10,1	9,9	
	3		10,4	9,5	
		mean	10,1	9,5	P<0,05
Percent weaned	1		87,8	86,4	
	2		85,4	88,8	
	3		89,2	84,5	
		mean	87,5	86,6	
Pigs/litter, 8 weeks	1		9,8	9,0	
	2		10,0	9,8	
	3		10,4	9,5	
		mean	10,1	9,5	P<0,05

[1]) Corrected to the same percentage of artificial inseminations in both groups. The difference between natural mating and A.I. in this study was 0,71 live piglets/litter.

of pregnancy. The ability of the sow to mobilise body stores probably lessens the effects of low-protein feeding during pregnancy. One effect is to reduce the daily gains of the piglets due to lowered milk production (MAHAN 1975).

In the present experiment low-protein feeding during the first three months of pregnancy had no effect on the number of piglets born dead or mummified. The number of piglets at the age of 5 weeks (weaning) and 8 weeks was significantly lower ($P < 0,05$) in the group of sows fed low-protein diet compared to that of normally-fed sows. In the LP group the percentage proportion of weaned piglets in the last lactation was lower than that in the first and second (Table 2). This leaves the impression that even this experimental period might be too short to reveal the detrimental effect of protein under-nutrition on the reproductive performance of the sow.

The live-weight gain of the piglets is shown in Table 3. LP-feeding did not decrease the weight of the piglets at birth. The daily gain of piglets was the same in both groups but the lower weaning weight of the litters from LP-sows indicates decreased milk production.

The variation in the live weight of sows is shown in Table 4. The live-weight gain during

Table 3. Effect of low-protein diet during early pregnancy on litter performance. Weights in kg.

	Parity		diet c.p. % gestation 15,6 lactation 16,5	diet c.p. % gestation 10,9—15,6 lactation 16,5	
Number of sows			38	37	significance level
Litter birth weight (live piglets)	1		16,27	15,10	
	2		16,31	15,95	
	3		15,46	15,32	
		mean	16,01	15,46	P<0,1
Litter weaning weight (35 days)	1		92,93	83,72	
	2		89,04	90,38	
	3		92,23	84,50	
		mean	91,40	86,20	P<0,05
Piglet birth weight (live piglets)	1		1,45	1,45	
	2		1,38	1,44	
	3		1,33	1,37	
		mean	1,38	1,42	P<0,1
Pig weaning weight	1		9,44	9,33	
	2		8,81	9,18	
	3		8,89	8,93	
		mean	9,04	9,15	P<0,1
Live-weight gain, 0—35 days, g/day	1		228	225	
	2		212	221	
	3		216	216	
		mean	219	221	P<0,1

Table 4. Effect of low-protein diet during early pregnancy on performance of sows. Weights in kg.

	Parity	diet c.p. % gestation 15,6 lactation 16,5	diet c.p. % gestation 10,9—15,6 lactation 16,5
Number of sows		38	37
Breeding weight	1	153	156
	2	160	164
	3	163	164
	mean	159	161
Weight after 3 months of gestation	1	190	187
	2	190	192
	3	188	189
	mean	189	189
Weight at farrowing	1	210	210
	2	209	213
	3	208	210
	mean	209	211
Weight gain during gestation	1	56,6	54,0
	2	48,8	48,9
	3	45,0	45,9
	mean	50,1	49,6
Weight loss during lactation	1	19,3	17,5
	2	18,0	20,7
	3	17,5	17,5
	mean	18,3	18,4

pregnancy and loss during lactation was nearly the same in both groups. This result is in disagreement with the results of HOLDEN et al. (1968), BAKER et al. (1970) and GREENHALGH et al. (1980), and may be due to different rates of feeding. In the experiments guoted the sows were fed ad lib. during lactation. According to CLAWSON (1963) the effect of energy intake is more important in the weight gain of the sow than the effect of protein.

The daily feed allowance in this experiment was 28,8—29,6 MJ DE/day during the first three months of pregnancy and 40 MJ/day during the last phase. The ARC (1967) recommends for a 180 kg sow 25,5 MJ DE/d during weeks 1—12 and 27,1 MJ/d during weeks 13—16. Van SCHOUBROCK and van SPAENDONCK (1972) recommend 28,5 MJ DE/d during the whole gestation period. It can be concluded that the energy allowance of the sows in this experiment was within the recommended range.

The live-weight gain of the sows was normal (50 kg), and the increase in live weight from the second conception to the fourth indicated that the energy feeding of the sows was adequate. The daily crude protein allowance in the LP-group was 296 g, of which 4,3 % was lysine. These figures are lower than those recommended in many countries but higher than those of WHITTEJORE and ELSLEY (1976).

In most experiments concerning protein deficiency in pregnant sows maize was the basic feed. However, YOUNG et al. (1976) fed a barley diet and found that the number of piglets born was the same as that with sows fed barley-soybean meal.

The low-protein diet used during gestation (3 months) had no effect on the duration of the pregnancy or culling rate of the sows (Table 5).

In conclusion, barley feed supplemented with minerals and vitamins but not with protein, given to sows in the first 3 months of gestation decreased the number of piglets born, weaned and marketed significantly ($P < 0,05$) but had no effect on the weight gain of the sows during gestation or on the irculling rate. The difference was 1,26 piglets/sow/year in the number of piglets marketed, resulting in unprofitable production despite the much lower cost of the LP diet.

Table 5. Culling rate and reasons for culling of sows fed low or normal protein diet during 3 first months of gestation.

Crude protein in the gestation diet %	Group HP 15,6	Group LP 10,9
Reason for culling		
— No heat	10	6
— Not pregnant	4	6
— Leg weakness	2	1
— Muscular dystrophy	2	—
— Heart »	1	—
— Prolapse of rectum	1	—
— » of uterus	—	1
— Other	4	3
Total	24	17

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SELOSTUS

Tiineyskauden alussa käytetyn alhaisen rehun proteiinitason vaikutus emakoiden porsastuotantoon.

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Maatalouden tutkimuskeskus

Mahdollisuuksia säästää valkuaisrehuja emakoiden tiineyskauden alkuvaiheessa tutkittiin ruokintakokeen avulla. Tiedetään, että kolmen ensimmäisen tiineyskuukauden aikana sikiöiden kasvu on melko vähäistä, eikä proteiinin tarve näin ollen poikkea oletettavasti paljonkaan joutilaan emakon tarpeesta.

Koeaseman emakot jaettiin kahteen ryhmään, joiden ruokinta poikkesi toisistaan vain rehun valkuaispitoisuuden suhteen kolmen ensimmäisen tiineyskuukauden aikana. Rehujen valkuaispitoisuudet olivat seuraavat:

Väkirehuseoksen raakavalkuaispitoisuus %	vertailuryhmä (HP)	koeryhmä (LP)
kolmen ensimmäisen tiin.kk:n aikana	15,6	10,9
viimeisen tiin.kk:n aikana	15,6	15,6
imetysaikana (5 vk)	16,5	16,5

Kokeeseen otettiin kerran porsineita emakoita, jotka ruokittiin koedieeteillä kolmen peräkkäisen tiineys- ja imetyskauden ajan. Eläinmäärä oli koeryhmässä 37 ja vertailuryhmässä 38.

Niukka proteiiniruokinta tiineyskauden alussa vaikutti negatiivisesti porsastuotantoon. Ero oli 0,8 porsasta pahnuetta kohti huonompi syntyneiden porsaiden lukumäärässä ja vielä vierotusvaiheessa 0,6 porsasta/pahnue.

Koeryhmän emakoiden porsaat olivat vähän painavampia syntyessään kuin vertailuryhmän. Syynä tähän lienee juuri pienempi syntyneiden porsaiden lukumäärä pahnueessa.

Niukalla valkuaisruokinnalla ei ollut vaikutusta emakoiden painonmuutoksiin tiineys- tai imetyskaudella. Myös porsaiden painonkehitys oli sama.

Taloudellisesti ei ole kannattavaa alentaa tiineysajan rehun valkuaispitoisuutta kokeessa käytetylle tasolle. Se etu, minkä rehun hinnanalennus tuottaa, ei riitä korvaamaan menetyksiä porsastuotannossa, jotka kokeen mukaan ovat 1,2 porsasta emakkoa kohti vuodessa.

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Seria ANIMALIA DOMESTICA N. 57 — Sarja KOTIELÄIMET n:o 57

BARLEY, OATS AND WHEAT AS CALF FEED

Marja Sulka and Vappu Kossila

Sulka, M. & Kossila, V. 1981. **Barley, oats and wheat as calf feed.** Ann. Agric. Fenn. 20: 281—286. (Agric. Res. Centre, Inst. Anim. Husb. SF-31600 Jokioinen, Finland.)

In two feeding experiments with calves the effect of barley, oats and wheat on the growth and feed consumption of calves was compared and their suitability as foodconcentrate for calves was investigated. The calves were in the experiments from the 7th to the 49th days of age. In the first experiment calves received either barley, oats or wheat or barley-oats mixture as concentrate. The average daily weight gain of the calves was 512, 381, 536 and 488 g respectively. The average cereal consumption was 0,28; 0,16; 0,31 and 0,29 kg DM/calf/day. Growth rate and cereal intake of calves in the wheat and barley group and cereal intake of calves also in the barley-oats group was significantly better compared to calves in the oats group ($P < 0{,}05$).

In the second feeding experiment the calves received either barley-wheat, barley-oats or wheat-oats mixture or barley as concentrate. The average daily weight gain was 561, 516, 607 and 582 g and the average daily cereal consumption of the same groups was 0,43; 0,40; 0,40 and 0,47 kg DM, respectively. In the experiment 2 no significant differences could be found between the groups in growth rate, feed consumption or feed conversion. In both feeding experiments silage was used as roughage and skim milk powder as milk replacer. Cereals, silage and water were in both experiments available ad. lib.

Index words: calves, feeding, concentrate, barley, oats, wheat.

INTRODUCTION

In Finland mainly barley and oats are grown as feed grain. Wheat is grown chiefly for milling, but poor quality wheat is fed to animals. Present paper describes two calf feeding experiments, in which palatability and feed value of barley, oats and wheat was compared between 7 to 49 days of age.

Two feeding experiments with calves were carried out in 1980.

Experiment 1.

48 Ayshire male and female calves were divided into four groups. The experiment started when the calves were 7 days old and ended when they were 49 days old.

Calves in each group received either one cereal (barley, oats or wheat) or a mixture of two cereals (barley-oats) ad lib. (Table 1). The cereals were coarsely ground. All of the calves received skim-milk powder 600 g/d and grass silage ad lib. Half of the calves in each group received wilted grass silage and the other half unwilted.

Table 1. Feeding of calves (from the 7th to 49th days of age) in the experiments 1 and 2.

	Group	n	Milk-replacer	Concentrate	Rough-age
Exp. 1.				Cereal [1])	
	1	12	skim milk powder	barley	silage
	2	12	»	oats	»
	3	12	»	wheat	»
	4	12	»	barley-oats mixture: 47,5 barley 47,5 oats	»
Exp. 2.				Cereal mixture [2])	
	1	8	skim milk powder	barley-wheat 45 % barley 45 % wheat	silage
	2	8	»	barley-oats 45 % barley 45 % oats	»
	3	8	»	wheat-oats 45 % wheat 45 % oats	»
	4	8	»	barley	»

[1]) Cereal contains 5 % Mineral mixture.

[2]) Cereal mixture contains 5 % Mineral mixture and 5 % soybean meal.

Mineral mixture: Se Terki: P 6,0; Ca 24,0; NaCl 14,5; Mg 3,0 trace elements: Se, Fe, Zn, S, Cu, K, Co.

In both experiments 5 % mineral mixture was mixed into the cereals (Table 1). Fat soluble A-, D- and E-vitamines were given by injection to all of the calves in the beginning of the experiment.

The calves were kept individually and fed in single pens. Feedstuffs and residues were weighed daily and the calves were weighed weekly.

The chemical composition of the feedstuffs of the two experiments was analysed (Paloheimo 1969). The statistical significance of the differences between groups was calculated using Tukey's test (Steel and Torrie 1960).

Experiment 2.

The second feeding experiment with calves was carried out with the mixtures of these three cereals: barley, oats and wheat.

32 Ayshire and Hereford × Ayshire male and female calves were divided into four equal groups according to breed and sex. The cereals fed to the groups were barley-wheat, barley-oats, wheat-oats or barley (Table 1). All of the calves received skim milk powder 500 g/d, because all cereal mixtures contained 5 % soy meal. Grass silage was used as roughage (Table 1). The cereal mixtures, roughage and water were available ad lib. Otherwise the arrangement and management of the experiment were similar to that of the first experiment.

RESULTS

Experiment 1.

The best average daily gain was in the wheat group, 536 g. For the barley group daily gain was 512 and the barley-oats group 488 g. The group on oats grew least, average daily gain being 381 g. According to Tukeys test the significant differences in growth were found between the barley and the oats groups, also between the wheat- and oats-groups ($P < 0,05$) (Table 3).

Table 2. The chemical composition of feeds.

	Experiment 1							Experiment 2					
	SKM	B	0	W	B+0	S_1	S_2	SKM	B+W	B+0	W+0	B	S_1
DM in DM %	94,04	87,07	88;24	87,65	87,75	18,45	30,46	97,74	88,41	88,11	87,66	88,23	26,01
CP	36,56	12,62	11,38	14,99	12,11	18,11	16,93	36,58	14,81	14,50	14,98	12,88	16,88
EE	—	1,96	4,79	3,16	3,35	5,90	4,72	—	2,27	3,22	4,34	1,77	4,58
NFE	55,10	71,25	64,42	70,42	68,43	33,70	38,37	55,55	71,10	67,27	69,56	73,43	37,89
CF	—	6,05	10,01	4,00	8,07	32,93	26,96	—	4,71	7,51	6,49	5,38	30,70
Ash	8,34	8,12	9,40	7,43	8,03	9,29	13,03	7,87	7,10	7,50	4,63	6,53	9,96
Kg/FU	0,88	1,09	1,21	1,08	1,13	8,09	4,97	0,87	1,08	1,13	1,07	1,09	5,27
DCP g/kg DM	329	101	97	121	101	118	115	329	110	107	120	88	112
Mcal/kg DM .	3,50	2,98	2,64	3,16	2,83	2,18	2,15	3,52	3,03	2,85	3,09	2,90	2,25

SKM = skim milk powder
B = barley meal
O = oat meal
W = wheat meal
S_1 = unwilted silage
S_2 = wilted silage

DM = dry matter
CP = crude protein
EE = ether extract
NFE = nitrogen free extract
FU = feed unit = 0,7 starch equvivalent
DCP = digestible crude protein
CF = crude fiber

Table 3. Growth rate, feed consumption and feed conversion between calves 7 and 49 days of age.

	Live weight, kg		Gain		Feed consumption kg DM/calf/day		Feed conversion		
	at start	at end	total kg	g/day	cereal	total	/kg DM/kg gain	FU/kg gain	DCP, g/kg gain
Exp. 1.									
Group									
1. (B)	37,42	58,92	21,50	512 ± 44^{ab}	$0,28 \pm 0,02^{ab}$	$0,92 \pm 0,03^{ab}$	$1,91 \pm 0,12$	$2,15 \pm 0,14$	450 ± 34^{ab}
2. (0)	36,77	52,55	15,78	381 ± 33^{c}	$0,16 \pm 0,02^{c}$	$0,78 \pm 0,03^{c}$	$2,19 \pm 0,19$	$2,48 \pm 0,25$	576 ± 64^{a}
3. (W)	39,83	62,42	22,59	536 ± 31^{a}	$0,31 \pm 0,04^{a}$	$0,95 \pm 0,04^{a}$	$1,79 \pm 0,05$	$2,02 \pm 0,07$	427 ± 19^{bc}
4. (B+0) ...	37,71	58,21	20,50	488 ± 13^{abc}	$0,29 \pm 0,02^{ab}$	$0,94 \pm 0,03^{ab}$	$1,94 \pm 0,05$	$2,12 \pm 0,04$	445 ± 8^{abc}
Exp. 2.									
Group									
1. (B+W) ..	40,63	64,19	23,56	561 ± 31	$0,43 \pm 0,05$	$0,96 \pm 0,05$	$1,73 \pm 0,05$	$1,94 \pm 0,05$	365 ± 14
2. (B+0) ...	37,25	58,94	21,69	516 ± 37	$0,40 \pm 0,04$	$0,91 \pm 0,04$	$1,81 \pm 0,11$	$2,03 \pm 0,12$	393 ± 26
3. (W+0) ...	39,19	64,69	25,50	607 ± 42	$0,40 \pm 0,07$	$0,98 \pm 0,07$	$1,61 \pm 0,03$	$1,80 \pm 0,03$	349 ± 13
4. (B)	38,00	62,44	24,44	582 ± 42	$0,47 \pm 0,07$	$1,03 \pm 0,06$	$1,78 \pm 0,07$	$1,97 \pm 0,08$	352 ± 17

Means in the same column not having the same surperscript letter differ significantly ($P < 0,05$).

The average daily consumption of concentrate depended significantly on what cereal was fed. The most palatable was wheat, the least being oats. The calves ate on average 0,31 kg DM/d wheat and only 0,16 kg DM/d oats. Barley and barley-oats mixture were similar in palatability. The average daily consumption of barley was 0,28 kg DM/d and barley-oats mixture 0,29 (Table 3). The calves began to eat cereals in average at the age of 2—3 weeks and at the age of 7 weeks they ate DM daily the next amounts: wheat 0,95, barley 0,81, barley-oats mixture 0,77 and oats 0,48 kg DM/d (Fig. 1).

There was significant difference also in feed conversion rate, digestible protein g/kg gain, between the wheat- and the oats-group ($P < 0,05$).

Experiment 2.

The best average daily gain was with calves, which received wheat-oat mixture 607 g and with calves which received barley 582 g. The calves in the barley-wheat group grew on average 561 g daily and the calves in the barley-oat group 516 g daily (Table 3).

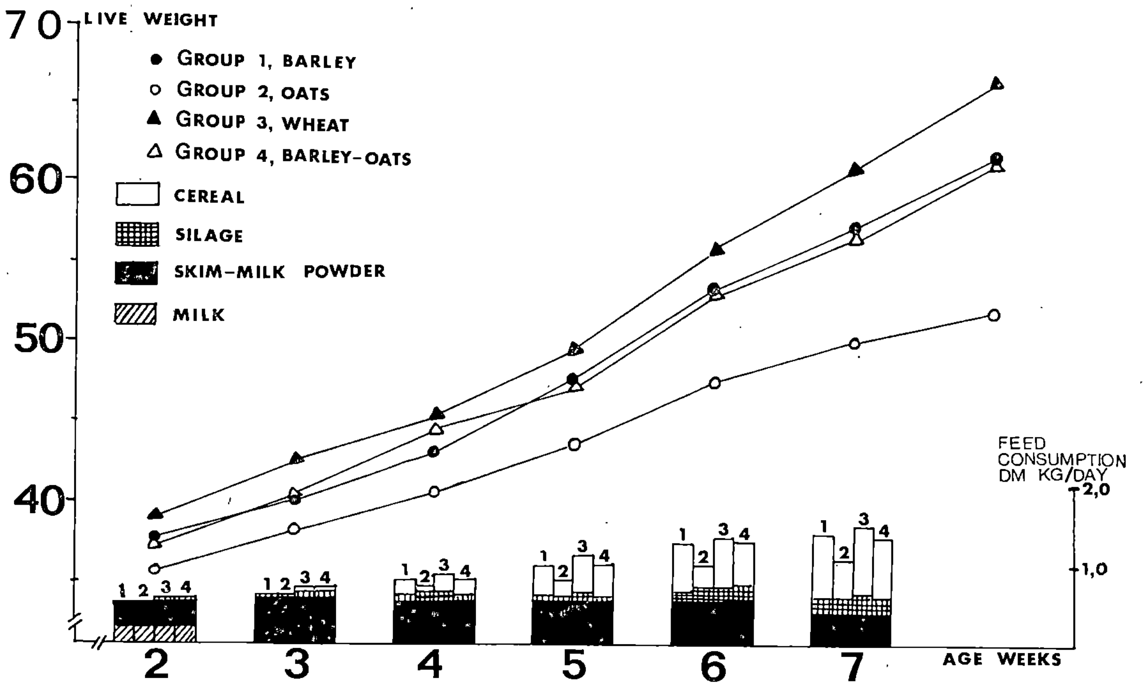

Fig. 1. The weekly growth rate and feed consumption of calves in feeding experiment 1.

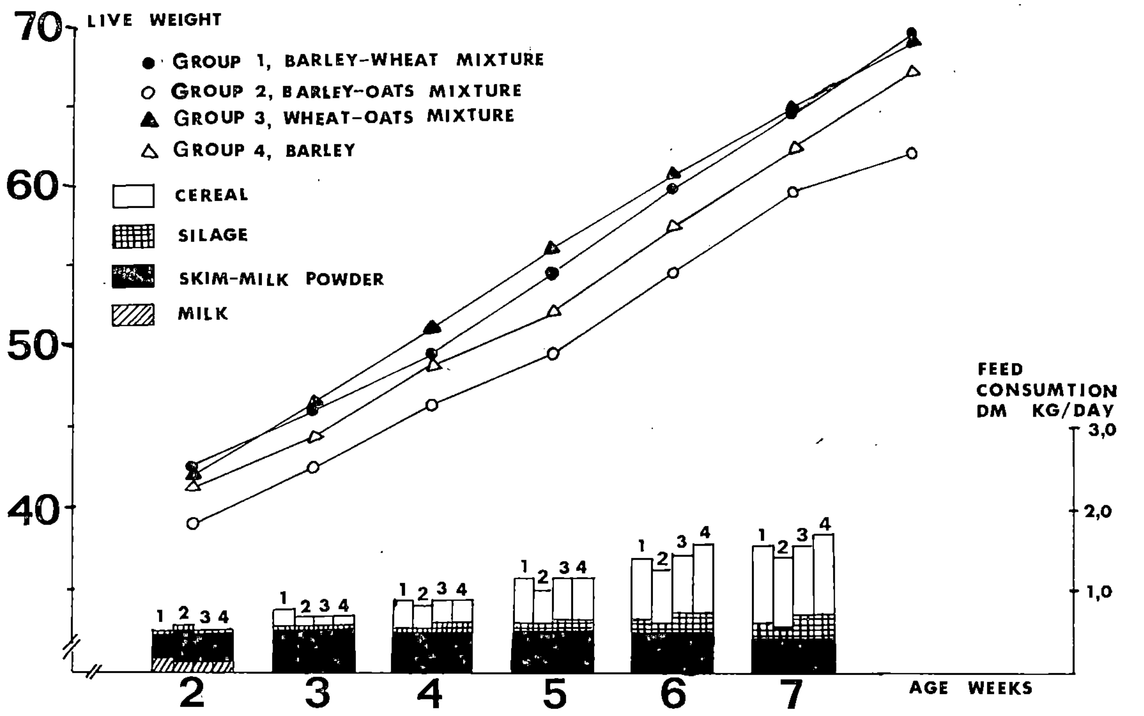

Fig. 2. The weekly growth rate and feed consumption of calves in feeding experiment 2.

The cereal mixtures were almost similar in palatability. The calves ate on average barley-wheat mixture 0,43 kg DM/d, barley-oats mixture 0,40 wheat-oats mixture 0,40; and barley 0,47 (Table 3). At the age of 7 weeks the average daily DM consumption of the same cereal mixtures were 0,95 kg DM, 0,85; 0,86 and 0,99 (Fig. 2.)

DISCUSSION

Right after birth the digestive system of calf is best cabable of utilizing the nutrients of milk. The utilization of lactose is in a young calf almost complete whereas the utilization of starch is poor (Huber 1969). Cereals contain 60—70 % starch and due to the high starch content they are mainly used as energy feedstuffs for animals (Becker and Nehring 1965). Digestibility of 23 % for starch was reported by Shaw et al. (1918) in two day old calves. The poor digestion of starch may be explained by the low activities of pancreatic amylase and maltase (Huber 1969). After the calf has developed to be a ruminant microbes break up starch in the rumen. Digestibilities of 98 % by 40 day old calves was reported by Shaw et al. When from the first days of birth dry feedstuffs are available to the calf, this induces a quicker development to a ruminant. Restricted feeding of milk or of milk replacers also helps speed up this process because thus calf begins to eat other feeds earlier. In experiments with pigs and broilers, where barley, oats and wheat were compared, the best growth results, as also in these experiments with calves, were achieved with wheat (Petersen 1969, Alaviuhkola 1975).

When barley, oats and wheat are compared with each other and especially with non-ruminants, the high hull content of oats reduce its digestibility. The hull content of oats can even be 40 % but is usually 22—30 %. The hull content of barley varies between 10 % to 12 % (Salo 1980). Because of a higher hull content in oats and barley than in wheat, the crude fibre content of barley is twice as much, and that of oats four times as much than found in wheat (Petersen 1972). The crude protein content of cereals is low, about 7—12 %, but this can be increased with breeding and with nitrogen fertilizers (Becker and Nehring 1965).

The results showed that wheat is suitable concentrate for little calves and can be fed either alone or mixed with barley or oats. Due to the fact that wheat has a low hull content, its feed value and digestible is better compared to barley and oats. In a mixture wheat improves the palatability of barley and especially oats and thus improves the growth rate of calves.

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SELOSTUS

Ohra, kaura ja vehnä vasikoiden rehuna

MARJA SULKA ja VAPPU KOSSILA

Maatalouden tutkimuskeskus

Kahdessa vasikoiden ruokintakokeessa verrattiin ohran, kauran ja vehnän vaikutusta vasikoiden kasvuun ja rehun syöntiin sekä tutkittiin näiden viljojen sopivuutta vasikoiden väkirehuksi. Vasikat olivat kokeissa ikävälillä 7—49 päivää. Ensimmäisessä ruokintakokeessa vasikat saivat väkirehuna ryhmittäin ohraa, kauraa, vehnää tai ohra-kaura seosta. Vasikoiden keskimääräinen päivittäinen lisäkasvu oli 512, 381, 536 ja 488 g, keskimääräinen väkirehun syönti oli 0,28, 0,16, 0,31 ja 0,29 kg ka/vasikka/päivä. Keskimääräinen lisäkasvu ja väkirehun syönti oli merkitsevästi parempi vehnä- ja ohraryhmän vasikoilla ja väkirehun syönti myös ohra-kauraryhmän vasikoilla verrattuna kaura-ryhmän vasikoihin ($P < 0,05$).

Toisessa ruokintakokeessa vasikat saivat ryhmittäin väkirehuna ohra-vehnä, ohra-kaura tai vehnä-kaura seosta tai ohraa. Keskimääräinen päivittäinen lisäkasvu oli 561, 516, 607 ja 582 g. Samojen ryhmien keskimääräinen väkirehujen syönti oli 0,43, 0,40, 0,40 ja 0,47 kg ka/vasikka/päivä. Toisessa ruokintakokeessa eivät erot kasvussa rehujen syönnissä tai rehun hyväksikäytössä ryhmien välillä olleet merkitseviä. Molemmissa ruokintakokeissa, karkearehuna käytettiin säilörehua ja juomarehuna kurrijauhetta. Vasikat saivat vapaasti väki- ja karkearehua sekä vettä molemmissa kokeissa.

ANNALES AGRICULTURAE FENNIAE, VOL. 20: 287—291 (1981)
Seria AGRICULTURA N. 67 — Sarja PELTOVILJELY n:o 67

THE IMPACT OF PRE-GERMINATED SEED ON THE YIELD AND SEEDLING VIGOUR OF RAPE (BRASSICA NAPUS L.) AND SUNFLOWER (HELIANTHUS ANNUUS L.)

UNTO TULISALO and KIMMO KOSKINEN

TULISALO, U. & KOSKINEN, K. 1981. **The impact of pre-germinated seed on the yield and seedling vigour on rape** *(Brassica napus* L.*)* **and sunflower** *(Helianthus annuus* L.*)*. Ann. Agric. Fenn. 20: 287—291. (Agric. Res. Centre, Inst. Pest Inv., SF-01300 Vantaa 30, Finland).

This study reveals the impact of liquid and osmotic pre-germination techniques on the yield and seedling vigour of spring rape (*Brassica napus*) and sunflower (*Helianthus annuus*). Liquid germination reduced the seedling stage of spring rape by 4 days, whilst osmotic germination only hastened growing at lower temperatures. The spring rape treatment time using osmotic germination (liquid concentration -14 Bar) was 14 days at 15 °C. Lower liquid concentrations were not able to prevent visible germination. Liquid germination resulted in earlier flowering and a non-significant increase in yield.

In sunflower, both pre-germination techniques hastened growing and flower opening occurred 5 days earlier than in the control plots. Earlier maturing and higher 1 000 seed weight were favoured in sunflower by both techniques.

Index words: rapeseed (*Brassica napus* L.), sunflower (*Helianthus annuus* L.), pre-germinated seed, osmotic pre-germination, liquid germination.

INTRODUCTION

It is possible to increase the rate of plant growth and to ensure the seedling growth of many plant species by using pre-germinated seed. It is thus possible, especially to lengthen the growing season and to obtain a uniform plant stand in cool conditions. There are two methods of pre-germination treatment in current use: liquid pre-treatment and osmotic pre-treatment. A fluid drill was developed for the sowing of vegetable seeds (CURRAH et al. 1974), and the best results have been obtained with horticultural crops e.g. celery (RENNINCK and TIERNAN 1978). This method has also been used for sugar beet resulting germination 3—10 days faster than normal (SALTER 1978).

In osmotic pre-treatment, the osmotic potential regulates the rate of water uptake, so that the seed begins to respire, but real germination does not occur. This method has been used with cereals and has resulted the emergence of cereals

1—5 days earlier than normal, depending on whether the seeds were dry before sowing (AKALEHIYWOT and BEWLEY 1977, GUY 1978).

In Finland, seedling emergence of rape depends mostly on the availability and usage of soil moisture in spring, especially when the soil has been badly cultivated or is very coarse. For this reason the delay of only a few days in seedling emergence can result in a severe weakening of seedling vigour. Thus a fluid drill can be of great help. When this system has been developed for large scale usage (HIRON and BALLS 1978) there is no technical obstacle to applying this method to the sowing of spring rape.

In summer 1979, experiments were carried out in which fluid drilling and osmotic pre-treatment techniques were assessed for their feasibility and effect on yield and seedling vigour of sunflower and rape. Laboratory experiments and pre-germination treatments were performed at the Department of Horticulture, University of Helsinki and field trials at the Agricultural Research Centre, Vantaa.

MATERIAL AND METHODS

A scaled down version of the apparatus described by DARBY and SALTER (1976) was used for the osmotic pre-treatment of seeds.

In preliminary experiments it was found rape seeds required less than 24 h for the pre-germination treatments to be effective. The seedlings should not be allowed to grow more than 2 mm prior to sowing, other wise they can be easily broken. Rape (cv. Regent) was germinated at 24 °C for 19 h and sunflower (cv. Sigco) was germinated at 22 °C for 46 h.

The pre-germination treated seeds were mixed with 0,8 % gel (31 g/l) prepared from coagulated FD-1 powder. Rate of seeding was 12 kg/ha with a row space of 25 cm. The seeds were hand sown using a FD-510 fluid drill.

Solutions for the osmotic pre-treatment of seed were obtained by dissolving varying amounts of polyethylene glycol (PEG 6 000) in distilled water, resulting in osmotic potentials ranging from -10 to -16,5 bars. The seeds were then placed in semi-porous cellulose-acetate bags, sunk in the treatment liquid, with their mouths open above the surface (enabling the seeds to respire).

The results of the osmotic pre-treatment depend on temperature, concentration and duration of the treatment. Rape seeds were treated with 34 % PEG at 20 °C for 8 days and sunflower seeds with 36,3 % PEG at 15 °C for 8 days.

Osmotically pre-treated seeds were also germinated in petri dishes.

Untreated and osmotically pre-treated seeds of spring rape and sunflower were sown on May 16 using an Øyjord precision seeder and liquid pre-treated seeds were sown using an FD-510 fluid drill at a rate of 12 kg/ha and 25 cm spacing, using a random block design. Each block was 10 m² in area and four replicates of each treatment were used.

Sunflowers were also transplanted to act as a comparison, in blocks of 10 m² with plant distances of 45 × 25 cm.

RESULTS

Spring rape

Laboratory experiments revealed that the osmotic pre-treatment did not affect germination speed at 15 °C, but emergence of seedlings was hastened by 2 days at 5 °C (Fig. 1). Five different combinations of treatments at 15 °C and 20 °C with osmotic potentials of -8 or -10 bars for 10 or 14 days were used. This revealed that the most effective treatments were those carried out

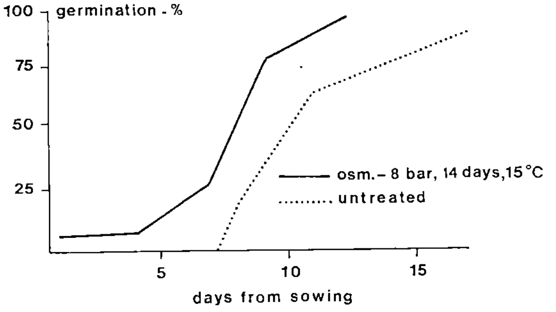

Fig. 1. The effect of osmotic treatment on the germination percentage of rape at 5 °C. Treatment time was 14 days at 15 °C.

at 15 °C for 14 days and 20 °C for 10 days. At lower temperatures the treatment time is of longer duration. Similar interactions between temperature and treatment time have previously been recorded (HEYDECKER 1974, 1978).

Although previous workers have shown that osmotic potentials of -8 or -10 bars were sufficient to prevent germination of Brassica plants during treatment, in this case neither these or -12 bars were sufficient and thus the seeds used in the field experiments were treated at -14 bars, to ensure that premature germination was avoided.

The osmotic pre-treatment reduced the germination rate of rape in the field but did not affect the speed of seedling emergence. Fluid drilling hastened the emergence of seedlings by 3-5 days (Table 1). The appearance of the fluid drilled rape was the same as that sown 5 days earlier using conventional methods.

By the end of June (21.6.) the fluid drilled rape was in the »yellow bud stage» (at least one bud was yellow), whereas those in the other treatments were in the »bud stage» (buds still in the middle of the leaf rosette) or in the »second bud stage» (buds just above the leaf rosette).

Table 1. The effect of pre-germinated seed on the seedling vigour of rape.

	seedlings/ row meter	days from sowing to seedling stage
Control	114	7,8
Liquid germination	93	4,3
Osmotic germination	71	8,1

Flowering started in the fluid drilled treatments 5 days earlier (24.6.) than in the other treatments (29.6.). By the beginning of July (3.7.), the pods of the fluid drilled rape were starting to fill, whereas in the other treatments, the pods were just beginning to form.

Fluid drilling increased the yield of spring rape by 28 %, but this was not significant as variation between blocks was very high. Osmotic pre-treatment also resulted in a small increase in yield (Table 2).

Table 2. The effect of pre-germinated seed on the yield of rape.

	kg/ha	relative yield value
Control	1 055	100
Liquid germination	1 350	128
Osmotic germination	1 154	109

Yield differences were statistically nonsignificant.

Sunflower

In the laboratory osmotic pre-treatment hastened germination by 4 days and clearly improved germination at 10 °C (Fig. 2). In field experiments, seedling emergence of sunflowers in optimum conditions was hastened by 4 days and the percentage of seedlings emerging was also

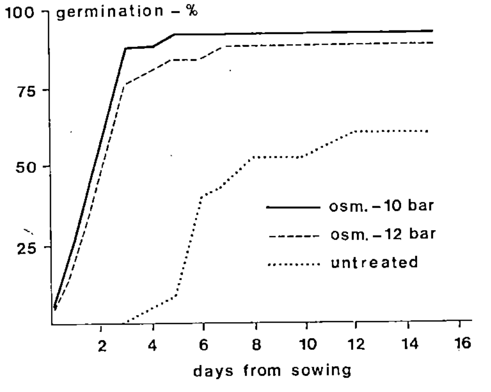

Fig. 2. The effect of osmotic treatment on the germination percentage of sunflower at 10 °C. Treatment time was 8 days at 15 °C.

improved (Table 3), although there was great inter-treatment variability. Sunflowers also required greater osmotic potentials to prevent germination during treatment than has previously been recorded.

In the field, both pre-germination treatments hastened seedling emergence and increased the percentage of seedlings emerging by 10 % (Table 4). As a result of these treatments treated plants were taller than control plants during the whole season. However, transplanted plants were clearly taller at the end of June, the greatest difference being 30 cm, but decreased gradually until by the end of the growing season the transplanted plants were shorter than any in the other treatments (Table 5). The transplanted and pre-treated plants began flowering 27 days and 4,5 days earlier than the control plants (Table 6).

Transplanting increased both the yield and weight of seeds. Osmotic pre-treatment increased yield slightly but had no effect on seed weight and liquid pre-treatment increased only seed weight (Table 7). No real conclusions can be drawn from the yield results as birds destroyed part of the harvest before control measures (nets) were undertaken.

Table 3. The effect of osmotic germination on the seedling vigour of sunflower in early sowing.*

	%-seedling	days from sowing to seedling stage
Control	57,7	18,8
— 13 bar PEG	38,5	17,9
— 14 bar PEG	65,4	17,9
— 15 bar PEG	73,1	14,9

*) Treatment time was 11 days at 15 °C.

Table 4. The effect of pre-germination on the seedling vigour of sunflower in field trial.

	%-seedling	
	25.5.	12.6.
Control	19,7	78,8
Liquid germination	55,8	89,9
Osmotic germination	46,2	88,0

Table 5. Plant height of sunflower during growing season. A = control, B = transplanting, C = osmotic germination, D = liquid germination.

	plant height, cm								
	30.5.	5.6.	12.6.	19.6.	26.6.	3.7.	10.7.	17.7.	24.7.
A	2,9	5,2	9,2	17,8	35,3	53,0	77,8	108,4	134,5
B	10,8	16,8	27,3	41,7	69,1	85,4	103,0	113,6	113,5
C	3,4	5,7	10,1	18,6	36,5	57,5	83,5	115,6	140,1
D	3,4	5,4	10,1	19,6	36,3	56,8	82,3	114,7	136,6

Table 6. The duration days of different growing stages of sunflower from sowing to harvesting.

	first rue leaves	bud stage	days from sowing		
			flowering		harvesting
			beginning	end	
Control	14	34	83	93	120
Transplanting	—	23	55	—	110
Osmotic germination	14	34	78	90	120
Liquid germination	14	34	78	90	120

Table 7. The yield and 1 000-seed weight of sunflower.

	yield g/6 plants	seed, g/100 piece		
		the whole seed	kernel	husk
Control	222,2	4,68	3,45	1,23
Transplanting	297,6	6,44	4,99	1,42
Osmotic germination	234,0	4,53	3,34	1,19
Liquid germination	201,7	5,49	3,94	1,51

DISCUSSION

The results presented in this paper indicate that fluid drilling is very effective in hastening seedling growth of spring rape by about 5 days, especially in those cases where the soils are very susceptible to drying out in springs. There are also indications that fluid drilling can increase the yield of rape, although the seed yields reported in this paper were quite modest. This was probably due in part, to the low level of fertilizer application (50 Kg N/ha). Osmotic pre-treatment of rape resulted in no enhancement of yield or growth rates, as the temperature at time of sowing was already so high, that due to the fact that rape grows quickly at low temperatures, any effects were masked.

Osmotic pre-treatment improved the speed of germination and seedling emergence of sunflower at low temperatures as with watermelon

(SACHS 1977). This is because in those plants that require higher temperatures for growth, the higher temperatures are more important in the germination process than in seedling emergence. Thus seeds that have been osmotically pre-treated are able to grow at temperatures lower than dry seeds would even be able to germinate.

In the field, liquid pre-treatment resulted in the weight of sunflower seeds being almost double that of normally seeded plants, thus indicating that this technique is not limited to the seedling stage but also affects seed ripening. However, with sunflower, the appropriate technology required for large scale sowing of pre-germinated seed is not yet available. It may be possible to first soak and then to dry the surface of the seeds enabling it to be sown by conventional methods, as work in USSR has shown that this increases the yield of sunflower as well as improving their resistance to drought (HENCKEL 1968).

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SELOSTUS

Esi-idätetty siemen kevätrapsilla ja auringonkukalla

UNTO TULISALO ja KIMMO KOSKINEN

Maatalouden tutkimuskeskus

Tässä tutkimuksessa selvitettiin nesteidätysten ja osmoottisen idätyksen vaikutusta kevätrapsin ja auringonkukan taimettumiseen ja satoon. Nesteidätys joudutti kevätrapsin taimettumista noin 3,5 vuorokaudella. Osmoottinen idätys joudutti itämistä vain alhaisessa lämpötilassa. Sopivin käsittelyaika osmoottisessa idätyksessä oli rapsille 14 vrk +15 °C:ssa liuosväkevyys -14 bar. Alhaisempi liuosväkevyys ei estänyt rapsin itämistä. Rapsin kukinta alkoi nesteidätetyssä koejäsenessä 5 vrk aikaisemmin kuin kontrollissa. Nesteidätys lisäsi satoa, mutta erotus ei ollut merkitsevä.

Auringonkukalla sekä osmoottinen idätys että nesteidätys nopeuttivat taimettumista. Kukinta alkoi noin 5 vrk aikaisemmin kuin kontrollissa. Esi-idätetty auringonkukka tuleentui aikaisemmin ja sen 1000-siemenen paino oli korkeampi kuin normaalikylvössä.

ANNALES AGRICULTURAE FENNIAE, VOL. 20: 292—303 (1981)
Seria AGRICULTURA N. 67 — Sarja PELTOVILJELY n:o 67

THE EMERGENCE OF WEEDS IN THE FIELD

LEILA-RIITTA ERVIÖ

ERVIÖ, L-R. 1981. **The emergence of weeds in the field.** Ann. Agric. Fenn. 20: 292—303. (Agric. Res. Centre, Inst. Plant Husb. SF-31600 Jokioinen, Finland.)

There were one or two emergence peaks of weeds in spring cereal, sugar beet and on unsown land. The first of these, in particular, regularly occurred in May or early June. Taking into account all the studied stands the main average emergence period in early summer was the 22nd week. The second peak, in mid-summer, was more irregular and did not appear every year.
Galeopsis spp. and *Polygonum* spp. emerged over a short period of time in early summer. Their rate of emergence was highest in the first week of June, after which it decreased suddenly. The emergence period of *Fumaria officinalis*, *Chenopodium album* and *Stellaria media* lasted from the end of May into July. The rate of emergence of *Viola arvensis* and *Lamium* spp. was greatest in mid-summer.

The proportions of different species changed yearly. The most dominant species in all stands were *Chenopodium album* and *Stellaria media*.

Several climatic factors affected the emergence of weeds at the same time. Temperature factors usually proved to be more important than rainfall. In early summer the low maximum temperature seemed to be favourable for the emergence of all weeds.

Different climatic requirements of weed species regulated their emergence. In early summer *Chenopodium album* and *Viola arvensis* were influenced by the maximum temperature sum: *C. album* was stimulated by a low sum and *V. arvensis* by a high sum. The minimum temperature sum affected the emergence period of *Polygonum* spp., whereas the emergence of *Galeopsis* spp. and *Stellaria media* depended on several climatic factors.

Even more simultaneous climatic factors affected the emergence of weeds in mid-summer than in early summer. The significance of climatic factors became apparent 6—14 days before emergence.

Index words: weed emergence, spring cereals, sugar beet, unsown land, climate, temperature, rainfall, *Chenopodium album*, *Fumaria officinalis*, *Galeopsis* spp., *Lamium* spp., *Polygonum* spp., *Stellaria media*, *Viola arvensis*.

INTRODUCTION

In order to plan control measures it is important to know the emergence period of different weeds. This is particularly important when trying to minimize the use of herbicides and in this respect to use them more accurately. However, there is little information on the emergence of weeds in the field. The subject has been studied in England (ROBERTS 1964), in Italy (ANON. 1971) and in Japan (WATANABE 1975 a and b, 1976). It was found that there is distinct periodicity in the emergence of weeds, which, despite the changes in weather, was noticeably regular.

The periods of emergence in spring presented in these above-mentioned studies were earlier than the start of the growing season in Finland. To obtain knowledge of the emergence of weeds under Finnish conditions a study was begun in 1969—1970 at the Department of Plant Husbandry of the University of Helsinki. It was continued at the Agricultural Research Centre in the Institute of Plant Husbandry in 1974—1979.

MATERIAL AND METHODS

The weeds were considered emerged when they had the first true leaf or leaf pair. They were counted and removed from the stand every 2—3 days from an area of $20 \times 0,10$ m² marked in the field. Emergence was studied in spring cereals in 1969—1970 and 1974—1979, on unsown land in 1969—1970 and 1976—1979, and in sugar beet in 1976—1978. The cereal was sown between May 6th and 16th (Table 1) and sugar beet between May 10th and 12th. The unsown plot was left untouched after tilling. It was situated in the same field as the cereal, except in 1976—1978 when it was in the sugar beet field. The experimental fields were sandy clay and received normal fertilizing according to the crop.

To find the principal climatic conditions affecting emergence a stepwise regression analysis was used. It was thought that a study of climatic conditions might be a way to predict emergence. The climatic factors studied were average temperature, minimum and maximum temperatures, the difference between them, minimum temperature sum from May 1st, maximum temperature sum above 0 °C, 5 °C and 10 °C, effective temperature sum and rainfall. The effect of each factor was studied 3, 6, 9, 12 and 14 days before emergence.

The soil temperature at a depth of 5 cm was measured in 1977—1978. As it differed only slightly from the official temperatures measured at Tikkurila, the climatic observations made at the Agricultural Research Centre at Tikkurila were used in the results. Between 1977 and 1979 soil moisture was determined from samples at the same time as the weeds were counted.

Table 1. Sowing time of cereals and start of weed emergence in 1969—1970 and 1974—1979.

Stand	Sown	Emergence days after sowing
1969 wheat	May 8th	20
1970 »	» 16th	25
1974 »	» 3rd	27
1975 oats	» 6th	10
1976 barley	» 14th	5
1977 wheat	» 12th	18
1978 »	» 11th	18
1979 »	» 15th	13

RESULTS

The interval between sowing date and emergence varied yearly (Table 1). In 1976 the emergence time in spring cereal was particularly short, and was the longest in 1970 and 1974. In comparison, the start of emergence in sugar beet varied less. In 1976 emergence began 12 days after sowing, in 1977 17 days after, and in 1978 11 days after sowing.

Emergence in spring cereal and on unsown land

Weeds clearly emerged periodically (Fig. 1). During the whole experiment, the highest rate of emergence in spring cereals occurred over a period of about two weeks, usually in the first two weeks of June. The number of emerging

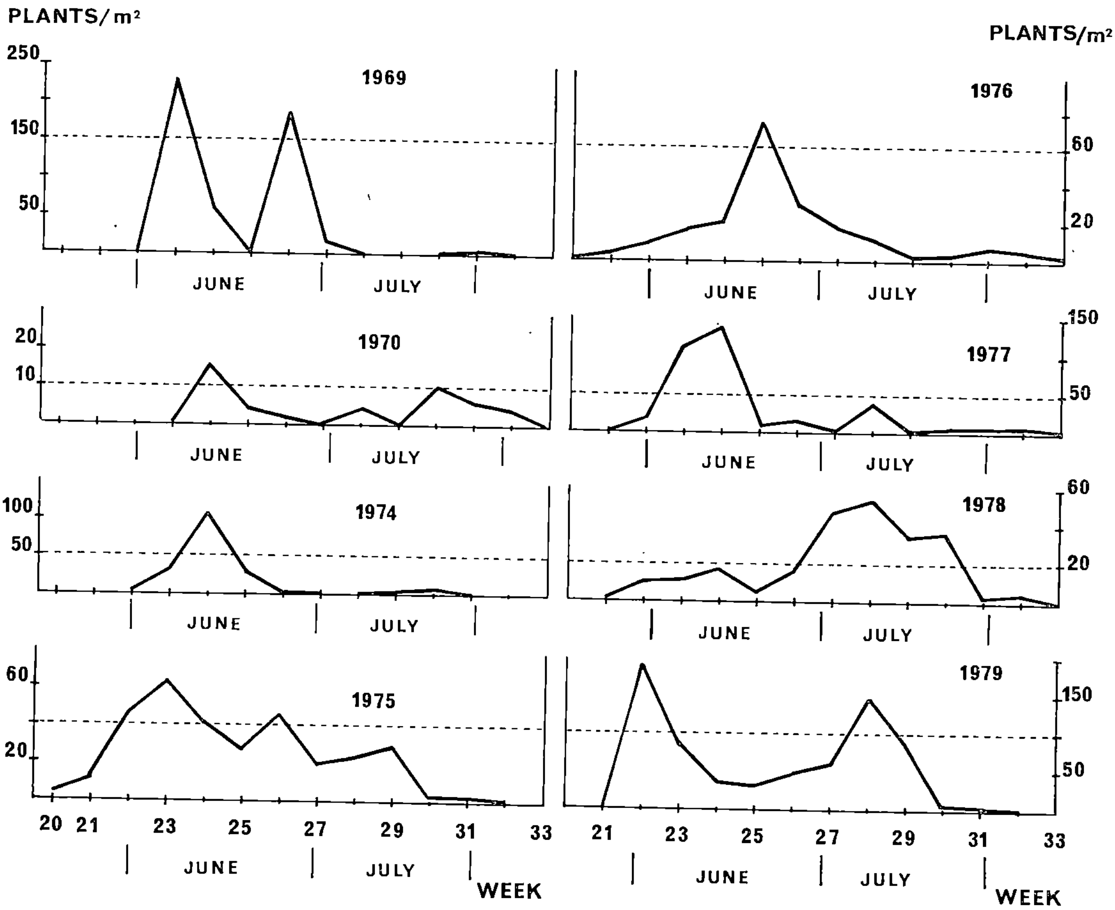

Fig. 1. Emergence of weeds in spring cereals in 1969—70 and 1974—79. The results of counts are summed weekly values in all figures.

weeds then decreased for a while, only to reach another peak at the end of June or in July, after which there was a sharp decrease in emergence. There was variation in the rates of emergence during periods of one week, too: the rate of emergence was particularly high on certain days (Table 3).

The second emergence peak in cereals was not as regular as the first (Fig. 1). In five years it occurred in late June or in early July, in two years there was no peak, and 1975 and 1978 the emergence rate continued to be relatively high even after the second peak.

Generally more weeds emerged on unsown land than in spring cereal (Table 2). The first peak was usually earlier on unsown land than in cereal in the same year (Fig. 2), the difference being about one or two weeks. Only in two years did the first major emergence of weeds occur at the same time in both cereal and on unsown land. On unsown land the second emergence peak was clearly apparent only in three years.

Table 2. Numbers of emerged weeds up to August 15th in the years of the experiment.

-	1969	—70	—74	—75	—76	—77	—78	—79
Spring cereal	495	45	165	314	208	379	236	687
Sugar beet	—	—	—	—	945	866	423	—
Unsown land	941	475	—	—	650	1 835	237	1 807

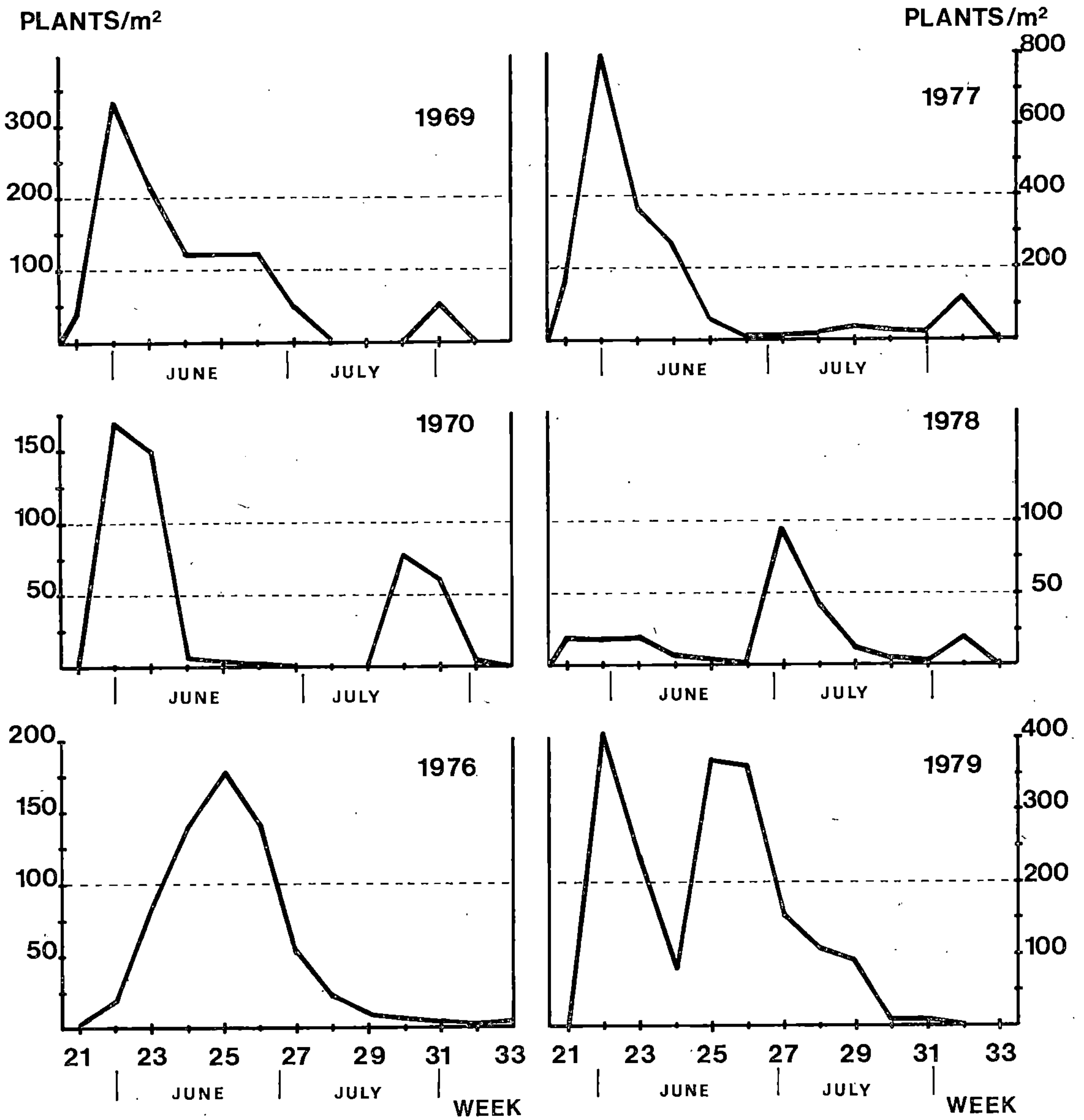

Fig. 2. Emergence of weeds on unsown land in 1969—70 and 1976—79.

Emergence in sugar beet

More weeds emerged in sugar beet than in cereal, but there were still fewer weeds than on unsown land in the same years. The curves showing emergence in sugar beet resemble the pattern of emergence on unsown land in 1977 and 1978 (Fig. 3). However, in 1976 there were two major emergence peaks in sugar beet, the first of which was earlier and the second at the same time as in cereal and on unsown land.

Table 3. Numbers of weeds emerged/day during emergence peaks

Year	Period	Plants/m²/day
Spring cereal		
1969	May 28th — June 4th	38
	June 19th — 26th	25
1970	June 5th — 10th	15
1974	June 5th — 14th	9
1975	May 24th — 25th	23
	June 19th — 26th	10
1976	June 11th — 18th	9
1977	June 13th — 18th	24
1978	June 7th — 12th	3
	July 8th — 11th	14
1979	May 26th — June 1st	27
	July 6th — 11th	24
Unsown land		
1976	June 3rd — 10th	23
	June 19th — 24th	23
1977	May 28th — June 3rd	114
1978	May 23rd — June 26th	3
	July 1st — 7th	13
1979	May 26th — June 1st	51
	June 15th — 20th	61
Sugar beet		
1976	May 24th — June 1st	42
	June 12th — 22nd	23
1977	May 27th — June 1st	63
	June 7th — 13th	39
1978	May 27th — 29th	4
	July 8th — 12th	31

Emergence of weed species

The most abundant weeds were *Chenopodium album*, *Fumaria officinalis*, *Galeopsis* spp., *Lamium* spp., *Polygonum* spp., *Stellaria media* and *Viola arvensis*. There were differences in periods of emergence between these species (Fig. 4—5). *Galeopsis* spp. emerged over a short period from the end of May to late June. *Polygonum* spp. emerged at almost the same time but emergence continued in to July. The highest rate of emergence occurred during early June in both species. *Fumaria officinalis*, *Stellaria media* and *Chenopodium album* had long periods of emergence, beginning in May and continuing up to July or even August (Fig. 4—5). These species emerged most abundantly from the end of May to the first week of June. *Viola arvensis* and *Lamium* spp. already began to emerge in May but their rate of emergence was highest in midsummer (Fig. 5).

Percentage of species

The numbers of emerged weeds differed noticeably between the years of the experiment (Table 2), as did the proportions of the most abundant species. The smallest numbers of weeds emerged in spring cereal in 1970, and the greatest numbers in 1979.

The proportions of weed species that emerged differed somewhat between the years of the experiment depending on the stand. *Chenopodium album* was dominant in spring cereal in four out of eight years (Fig. 6). In sugar beet and on unsown land its proportion of all emerged weeds, was

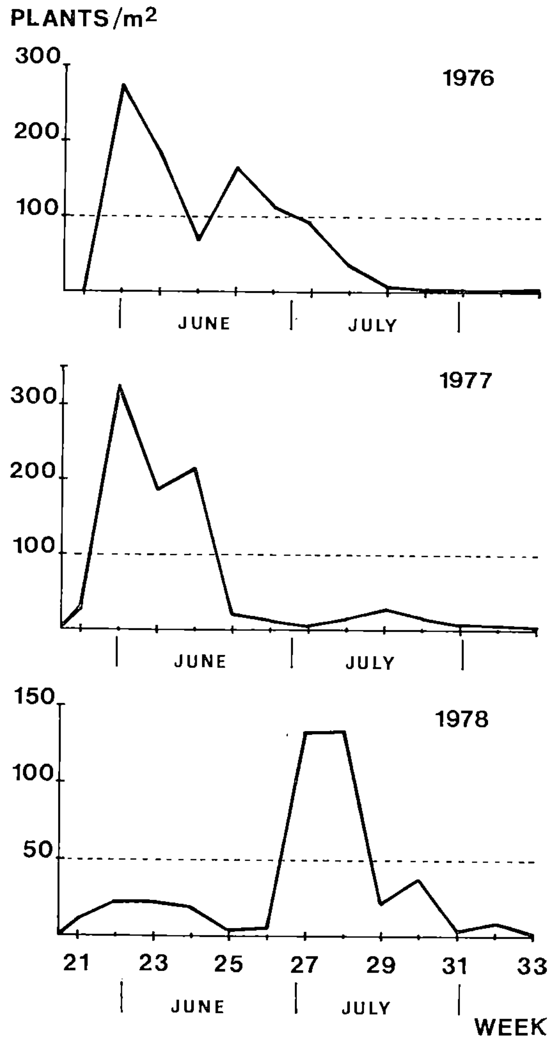

Fig. 3. Emergence of weeds in sugar beet in 1976—78.

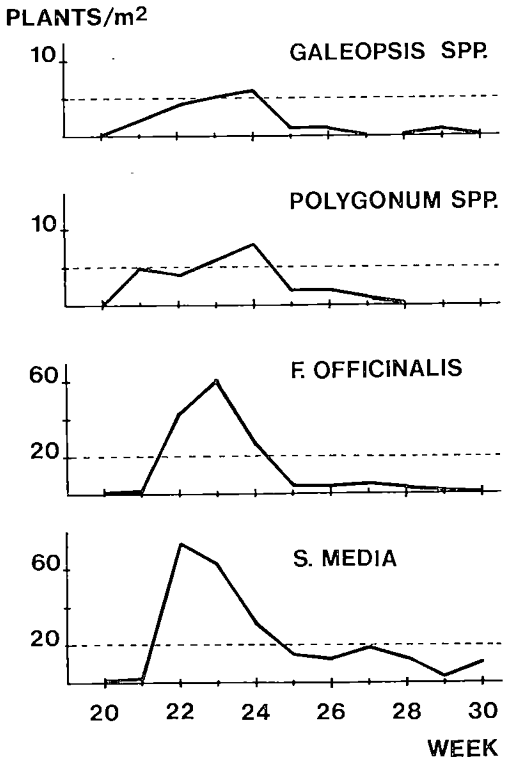

Fig. 4. Average emergence of weed species in all stands in 1979—70 and 1974—79.

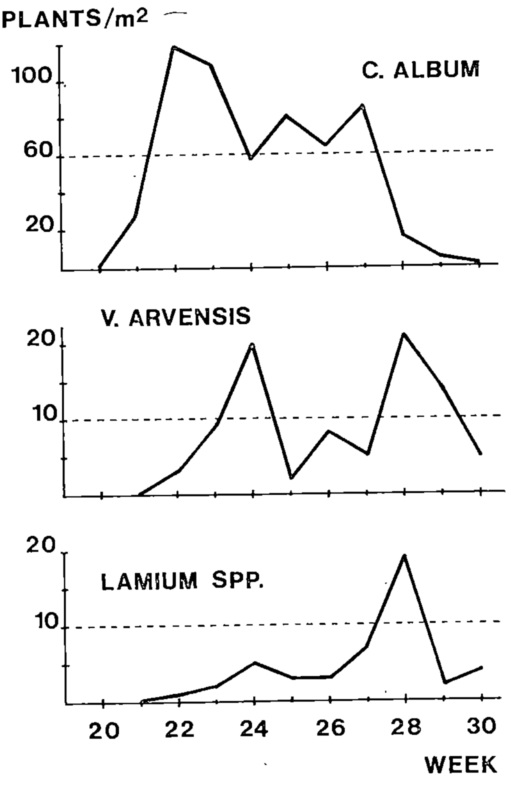

Fig. 5. Average emergence of weed species in all stands in 1969—70 and 1974—79.

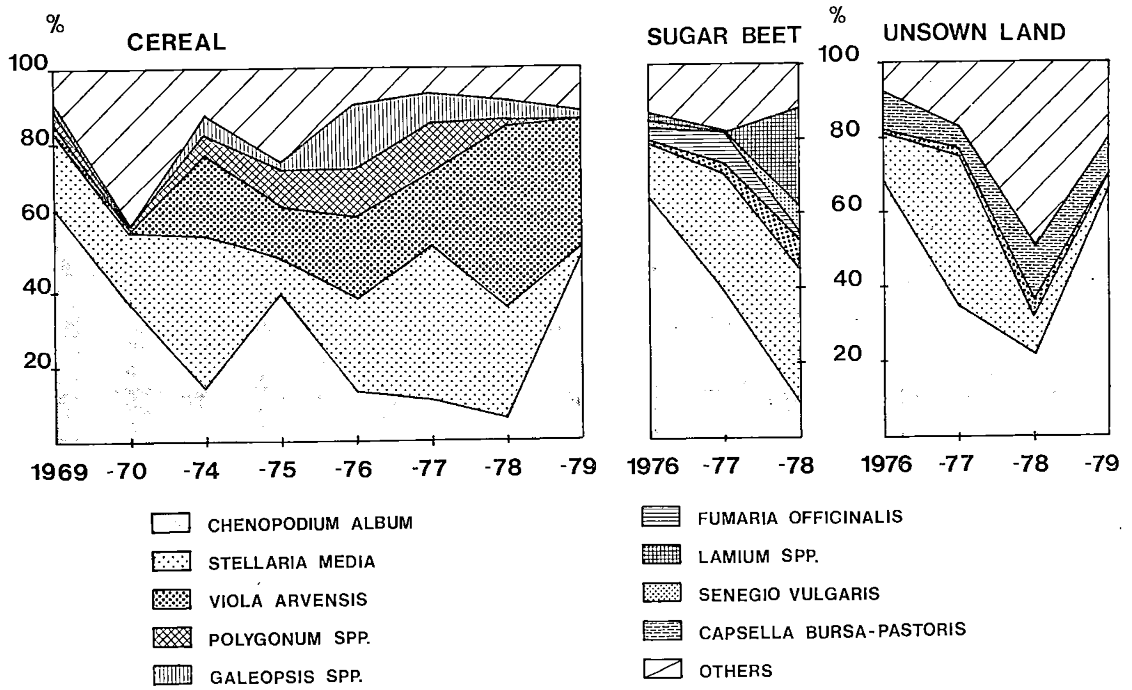

Fig. 6. Proportion of species of emerged weeds in different years.

the largest for many of the years covered by the experiment. *Stellaria media* was the main species to emerge in spring cereal in three years. It was dominant in sugar beet in 1978 and on unsown land in 1977, forming a very high proportion of the weeds in sugar beet in the same year. The proportion of emerged *Viola arvensis* was higher in spring cereal than in sugar beet and on unsown land.

In 1978 it was dominant in spring cereal and was also abundant the following year. *Polygonum* spp. and *Galeopsis* spp. generally emerged sparsely. In spring cereal the proportion of the former varied between 0 and 13 % and that of the latter between 0 and 17 %. Their proportions were highest in 1976 and 1977. In other stands their proportions remained so small that they were referred to as »others». *Fumaria officinalis* presented 2—8 % of the emerged weeds in sugar beet and *Senecio vulgaris* 0,3—7 %. In 1978 the proportion of *Lamium* spp. was particularly high (26 %) compared to other years. On unsown land the proportion of *Capsella bursa-pastoris* varied each year between 6 and 16 %.

The effect of climatic factors

Many climatic factors proved to have a statistically significant effect, at the same time, on the formation of the emergence peak (Tables 4 and 5).

The material from early and mid-summer was studied separately because it was assumed that different climatic factors affect the formation of the first and second emergence peaks. It most often appeared to be the conditions 12 days before emergence that were significant with regard to germination in both early and mid-summer. Temperature factors proved to be more important than rain.

Early summer

In the early summer, the maximum temperature seemed to be significant in the formation of the emergence peak (Table 4). The negative regression coefficient shows that a low maximum temperature stimulates emergence.

Of all the weed species, a maximum temperature sum > 0 °C starting 14 days before emergence seemed to affect the emergence of *C. album* during early summer. This temperature sum stimulated emergence when it was low, but the exact maximum temperature sum suitable for the emergence of this species was not discovered. The temperature sums varied considerably between different years in the period before emergence, but the variation was not noticeably connected to the emergence peaks of *Chenopodium album*. The maximum temperature sum also seemed to regulate the emergence of *Viola arvensis* so that the rate of emergence increased with the rise in temperature sum. Increasing minimum temperature sum stimulated the emergence of *Polygonum* spp.

Many climatic factors together affected the emergence of *Galeopsis* spp. and *Stellaria media*. Cool weather and only slight variation between maximum and minimum temperatures appeared to be favourable for *Galeopsis* spp. In the case of *S. media* the influence of some temperature factors seemed to oppose each other somewhat. Increasing rainfall decreased the rate of emergence of *S. media*.

Mid-summer

In mid-summer even more simultaneous climatic factors affected the emergence of weeds than in early summer (Table 5). Therefore their influence also was more difficult to interpret. The significance of climatic factors became apparent 6—14 days before emergence.

Rain had a clear effect on the emergence peak of the total amount of weeds, as did several temperature factors.

In contrast to early summer, a rise in temperature factors decreased the rate of emergence of *Polygonum* spp. *Viola arvensis* was favoured by increasing rainfall, high maximum and low minimum temperatures, and consequently large differences between those temperatures.

Table 4. Significant climatic factors in emergence of weeds during early summer.

Species	Factor	Days before emergence	Regression coefficient	F-value [1])
C. album	maximum temperature sum > 0 °C	6	— ,150	5,40*
	» » »	9	— ,151	5,46*
	» » » »	12	— ,148	5,49*
	» » » »	14	— ,143	5,09*
Galeopsis spp.	difference maximum—minimum temperatures	12	— ,391	7,57*
	average temperature	14	— ,601	5,87**
	maximum temperature	14	— ,440	5,18*
	» »	12	— ,426	5,33*
Polygonum spp.	minimum temperature sum	9	,066	5,32*
	» » »	14	,061	5,46*
S. media	minimum temperature sum	12	,134	5,27*
	maximum temperature	12	—1,369	10,19*
	minimum temperature	12	—1,721	6,15*
	rainfall	12	—3,135	4,90*
V. arvensis	maximum temperature sum > 0 °C	12	,029	4,83*
Total amount of weeds	maximum temperature	12	—5,040	4,62*

[1]) * = significant at 0,05 level df = 1
** = » at 0,01 »

Table 5. Significant climatic factors in emergence of weeds during mid-summer.

Species	Factor	Days before emergence	Regression coefficient	F-value [1])
C. album	maximum temperature sum > 0 °C	12	— ,088	7,77*
	average temperature	12	9,021	11,27*
	maximum temperature	12	5,257	5,97*
	effective temperature sum	12	— ,217	6,42*
Galeopsis spp.	average temperature	12	,213	5,80*
Polygonum spp.	maximum temperature sum > 0 °C	14	— ,010	8,53*
	maximum temperature	9	— ,437	9,32*
	minimum temperature	9	— ,278	6,63*
	average temperature	9	— ,573	14,22*
S. media	average temperature	12	3,675	7,81*
	difference maximum—minimum temperatures	12	1,393	7,66*
	minimum temperature sum	12	— ,156	11,38**
	» » »	14	— ,155	7,18*
	» » »	12	— ,112	9,70*
	effective temperature sum	14	— ,107	6,47*
	minimum temperature	12	2,581	9,46*
V. arvensis	rainfall	6	4,452	5,74*
	»	12	35,014	35,29**
	»	14	20,628	112,32***
	maximum temperature	14	1,120	7,91*
	minimum temperature	6	—3,218	5,36*
	difference maximum—minimum temperatures	14	0,668	6,14*
Total amount of weeds	average temperature	12	19,325	9,57*
	rainfall	12	105,751	10,39*
	minimum temperature sum	12	— ,824	9,00*
	maximum temperature	12	13,841	7,11*

[1]) * = significant at 0,05 level df = 1
** = » at 0,01 »
*** = » at 0,001 »

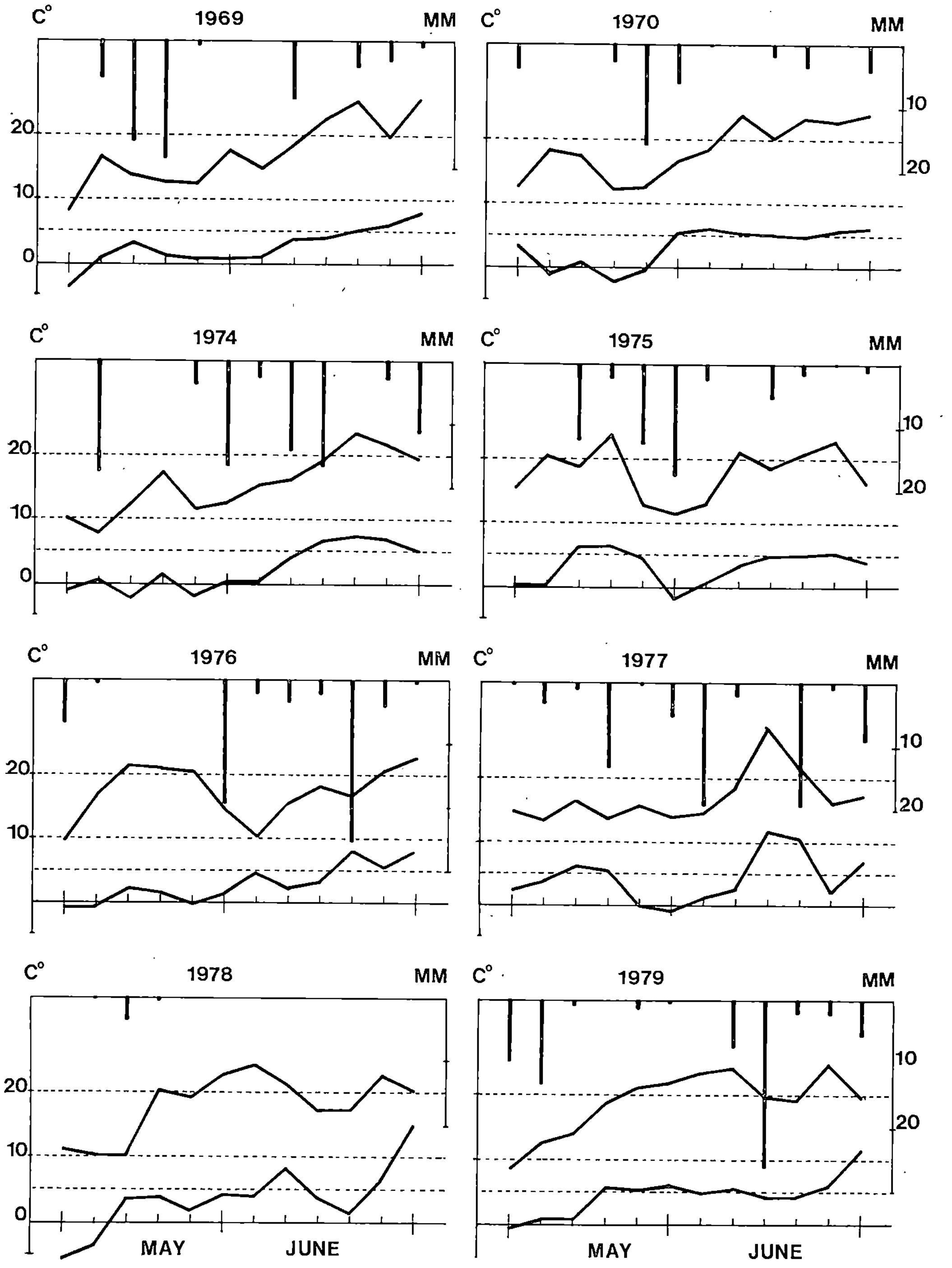

Fig. 7. Minimum (below) and maximum (above) temperature curves and rainfall in pentades 1969—70 and 1974—79.

Climate

The temperatures in early summer differed considerably from year to year (Fig. 7). The differences in the minimum and maximum temperatures during the three last pentades in May were particularly large in 1976 and 1978. They do not appear to have the same effect on emergence periods in those years.

In 1978 there was a dry period at the end of May, which continued long into June. Thus the soil moisture remained well under 55 % of the water-retaining capacity of the soil.

Early summer 1979 was exceptionally warm and favourable for growth. At that time the minimum temperature constantly remained, from the middle of May onwards, at around +5 °C. Weeds emerged in abundance that year.

DISCUSSION

The germination and emergence of weeds is a very complicated subject. They are influenced by the innate characteristics of weed seeds as well as by outside factors (Bünning 1956, Deunff 1974, Chang-Chi et al. 1978). It is therefore not easy to show, in uncontrolled conditions in the field, the reasons for the periodicity of emergence. According to the present study it was evident that many climatic factors conjointly influenced the emergence of weeds. Moreover the studied weeds had different climatic requirements, which may be a reason for the yearly variation in weed species (Fig. 6).

When studying the observations from different years of those climatic factors that proved to be significant, it was discovered that they varied to the extent that, for example, no limit values on the temperature sums needed for emergence could be determined. Because of this the detailed dependence of emergence periods on climatic factors remained unclear.

The factors controlling emergence have usually been studied in the laboratory or with weed seeds buried in soil in pots (e.g. Kolk 1947, Courtney 1968, Anon. 1971, Watanabe and Hirokava 1975 a, b, 1976). Thus no information in the literature corresponds directly to this study with respect to the natural weed flora. However, some information is closely related to this study. Changing temperature is known to improve the germination of weed seeds (Roberts and Benjamin 1979). According to Japanese studies, the minimum soil temperature, in particular, controls germination peaks. The bigger the difference between the maximum and minimum temperatures, the more effect it has (Watanabe and Hirokava 1975 a, b, 1976, Watanabe 1978). In the present emergence study, the minimum and maximum temperatures and their temperature sums affected the emergence of different weed species. The difference between these temperatures, however, was significant only in *Galeopsis* spp. in the early summer and in *Stellaria media* and *Viola arvensis* in connection with the second emergence peak (Table 4 and 5). The emergence of *Galeopsis* spp. and *Stellaria media* was then stimulated by small differences between the maximum and minimum temperatures and that of *Viola arvensis* by large differences between those temperatures.

The same temperature conditions seemed to affect the emergence peaks of early summer and mid-summer in different ways. It is usually assumed that the reason for the second emergence peak is the increased rainfall from the end of June onwards. The present emergence study showed that this assumption can be applied to *Viola arvensis* and to the total number of weeds (Table 5). The small number of emerged weeds in early summer 1978 can also be explained by the exceptional drought at that time of year (Fig. 1—3). The soil moisture was at that time well below the optimum for the germination of weeds, which is 55—60 % of the water-retaining capacity of the substrate (Kolk 1947, Noguchi and Nakayama 1979). The weeds therefore did not begin to emerge in abundance until the second emergence peak.

Rain did not appear to be the only important factor controlling the second emergence peak, because the rate of emergence decreased abruptly after mid-July, although rainfall in Finland normally increases towards the end of the summer. There must therefore be some other factor affecting the weed seeds at that time. It is assumed that the rise in temperature in middle and late summer makes weed seeds dormant again (WATANABE and HIROKAVA 1975 b). This was also seen in the present study in the case of some weed species whose rate of emergence decreased with rising temperature factors in mid-summer (Table 5). The vegetation covering the soil might also affect germination by changing the color of light (SILVERTOWN 1980). The present study does not support this theory because the same emergence phenomenon was noted on unsown land with no shading crop. Furthermore the weeds of the second emergence peak clearly did not rise from the deeper layers of the soil. An experiment was carried out to verify this, and it showed that weeds emerged only from the seeds sown in the top layer of soil.

This study showed that, although many climatic factors, such as particular temperature sums, control weed emergence, its timing cannot be predicted by them. The relatively regular emergence periods can, however, be utilized in adjusting the control of weeds. For example in sugar beet and other weakly competitive crops which are therefore frequently sprayed with herbicides, the control measures could be made more effective by timing the treatments according to the weed emergence peaks.

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SELOSTUS

Rikkakasvien taimettuminen pellolla

Leila-Riitta Erviö

Maatalouden tutkimuskeskus

Pellon luontaisten rikkakasvien taimettumista selvitettiin kevätviljoissa ja sokerijuurikkaassa sekä kylvämättä jätetyllä alalla. Kylvämätön ala sijoitettiin joko vilja- tai sokerijuurikaslohkolle ja se muokattiin ja lannoitettiin samalla tavoin kuin viljelykasvi.

Rikkakasvien taimettumishuippuja oli alku- ja keskikesällä yksi tai kaksi. Ensimmäinen taimettumishuippu osui melko säännöllisesti samaan ajankohtaan, vaikka vuotuiset säät poikkesivat toisistaan (kuvat 1—3, 7). Kahdeksana tutkimusvuotena se sattui kevätviljassa useimmiten 23. tai 24. viikolle. Keskikesän taimettumishuippu sijoittui ensimmäistä epäsäännöllisemmin 26. ja 30. viikon välille. Kahtena tutkimusvuotena ei selvää huippua ilmaantunut.

Rikkakasveista olivat yleisimpiä jauhosavikka peipit, peltoemäkki, pelto-orvokki, pihatähtimö, pillikkeet ja tatarlajit. Ne olivat taimettumisrytmiltään erilaisia (kuvat 4—5). Pillikkeet ja tatarlajit taimettuivat lyhyehkön ajan kuluessa keväällä ja alkukesällä. Peltoemäkin, pihatähtimön ja jauhosavikan taimettuminen kesti pitkään, toukokuusta heinäkuun lopulle tai elokuulle saakka. Niiden taimettumishuippu osui 22. ja 23. viikolle. Pelto-orvokin ja peippien taimettuminen alkoi jo toukokuussa, mutta painottui keskikesään.

Erilaisten taimettumishuippujen syitä etsittiin säätekijöistä tilastomatemaattisin menetelmin. Tulokset osoittivat, että useat tekijät vaikuttivat taimettumiseen samanaikaisesti. Lämpötiloilla oli suurempi merkitys kuin sateella. Lisäksi rikkakasvilajit suhtautuivat taimettumisessaan säätekijöihin erilailla (taulukot 4—5).

Rikkakasvien kanssa huonosti kilpailevissa viljelyskasvustoissa, joita joudutaan suojaamaan toistuvin herbisidikäsittelyin, tulisi rikkakasvien taimettumisjaksoja käyttää hyväksi torjunnan ohjelmoinnissa. Torjuntaa voitaisiin tehostaa ajoittamalla käsittelyt taimettumishuippujen mukaan ja samalla välttää herbisidien turhaa käyttöä.

ERRATA

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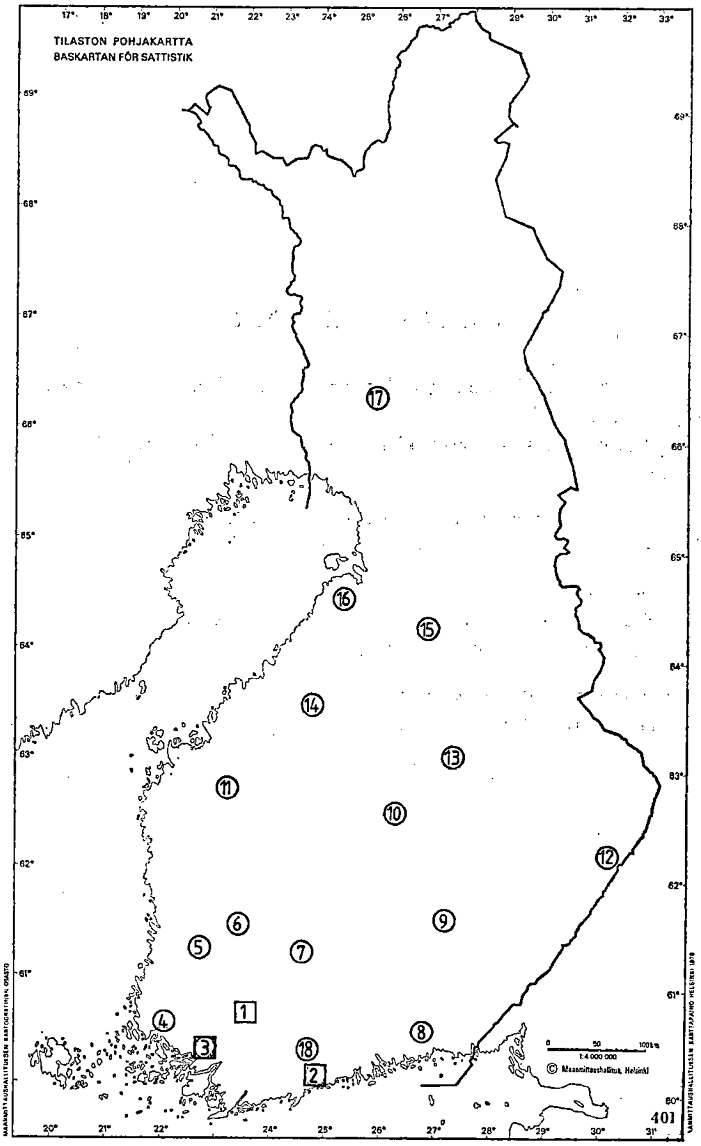

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