The difference in development rate of rye in relation to the number of spikelets per ear

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Summary

In winter rye plants of the *Petkuser* and *Zelder* varieties four groups of plants were distinguished having 11, 12, 13 and 14 leaves on the main axis. *Within these groups it was possible to distinguish sub-groups with a difference in rhythm of emergence, viz. a rapid rate after winter (with a previous slow rate), and a slow rate after winter (with a rapid rate during the youth). Apparently a low rate of emergence after winter goes together with large upper-stalk leaves, a slightly higher number of spikes per ear, longer upper internodes and longer leaf sheats of the upper leaves.*

It was also found that a larger total number of stalk leaves is accompanied by a larger total leaf-surface area, possibly a slightly higher number of spikelets per ear, and a greater average stalk length.

This pattern does not fully reflect the rectilinearity because not all possible categories have been distinguished. But the simplicity of the pattern in question (FIG. 8) shows that the rectilinear aspect is a general characteristic, one that does not merely relate to the leaves but to other parts of the plant as well.

1. Introduction

The number of leaves ultimately formed by rye plants depends, among other factors, on the hereditary predisposition of the plants (HOOGLAND, 1961, 1962). In order to examine whether this leaf number has any effects on plant productivity an investigation was made into the relationship between leaf number, leaf area and ear emergence (HOOGLAND, 1964). It was found that a larger number of leaves went together with a larger leaf area and a larger number of spikelets in the ear. These relationships are examined in more detail in the present article, closer attention being paid to the above-mentioned difference in rhythm of leaf emergence. The relationships between leaf surface area, length of the accompanying stalk internode and leaf sheath are also discussed.

2. Method of research

The investigation was carried out in 1962—63, following the same method as that employed in 1961—62. The date of sowing was advanced to 25th September, 1962 and the number of observations were increased by determining the length of the internodes and leaf sheaths as far as possible. Since the number of measurements have to be kept to the minimum to prevent damage to the plants, the length of the leaf

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sheath (usually already present) of the leaf which is to be measured showed an indication when the leaf ligula had emerged, so that the date on which the leaves were fully grown could be more readily calculated.

The surface area of the leaves was calculated by multiplying the length by the width taken to the nearest mm. The calculation of the width is particularly subject to reading errors. As the plants should be touched as little as possible these values are rather to be considered as reasonable estimates. Although in transition cases, *e.g.* when the correct is 4,5 mm, the reading result may be 4 mm or 5 mm, the average result is very satisfactory despite such inaccuracy.

According to ANIKIEV and KUTUZOV (1961) the actual leaf area is best calculated by again multiplying the length × width product by 2/3, but since we are here concerned with relative figures this method was not employed.

Of the 125 grains sown of each variety, 112 plants of the *Petkuser* variety and 109 of the *Zelder* variety remained for complete observation.

3. Results

The aim envisaged, *i.e.* to obtain a greater distribution of the total number of leaves by advancing the sowing date, was not achieved. Although there was a greater number of leaves, the number of groups proved to be the same as in the previous year. There were plants that were finally found to have produced 11, 12, 13 and 14 leaves (previous year 10, 11, 12 and 13 respectively). TABLE 1 lists the number of plants, as well as the data on leaf-surface area, the number of spikelets and the mean date on which the leaves of a particular serial number were fully grown.

TABLE 1. Average leaf surface (mm²), leaf number and average number of spikelets; in brack

Varieties	Number of plants	Average leaf area in mm2 (leaf sequence 1—14)						
		1	2	3	4	5	6	7
11-leaves group								
Petkuser	3	434	577	1020	1404	1261	932	160
		(16/10)	(21/10)	(3/11)	(20/11)	(4/2)	(14/3)	(28/
Zelder	7	406	610	1059	1277	1149	921	150
		(16/10)	(16/10)	(2/11)	(18/11)	(28/1)	(11/3)	(28/
12-leaves group								
Petkuser	47	342	522	811	1040	977	778	118
		(16/10)	(21/10)	(3/11)	(20/11)	(20/1)	(15/3)	(28/
Zelder	53	444	717	1037	1298	1296	973	122
		(16/10)	(16/10)	(3/11)	(12/11)	(1/1)	(10/3)	(26/
13-leaves group								
Petkuser	48	350	521	782	994	1043	859	93
		(16/10)	(20/10)	(4/11)	(16/11)	(4/1)	(27/2)	(20/
Zelder	44	424	651	940	1180	1250	933	101
		(16/10)	(16/10)	(2/11)	(6/11)	(20/12)	(3/3)	(22/
14-leaves group								
Petkuser	14	349	505	790	1001	1130	1022	87
		(16/10)	(18/10)	(3/11)	(10/11)	(23/12)	(22/2)	(17/
Zelder	5	457	602	903	1112	1334	1137	84
		(15/10)	(15/10)	(4/11)	(4/11)	(20/12)	(13/2)	(15/

The figures shown for the date are averages of the dates on which the leaves in question were first found to be fully grown, where necessary corrected by means of an estimate of the number of days that had elapsed since full emergence.

3.1. The rate and rhythm of leaf emergence

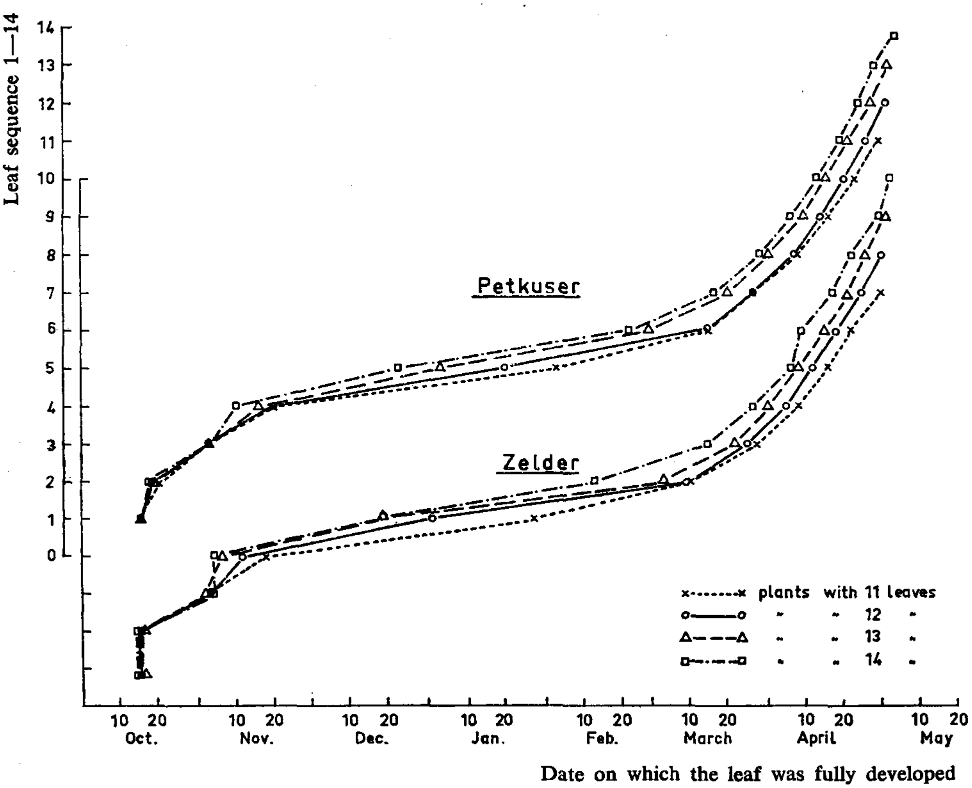
Although there is a tendency for the last leaf to emerge somewhat later when the number of leaves increases (FIG. 1), this is of so little importance compared to the total period of leaf emergence that the average rate of emergence is necessarily higher according as more leaves are formed. It was found, however, that this average rate does not adequately typify the behaviour of the plants. Thus within the groups with a given, final number of leaves it is still possible to distinguish plants with an originally greater number of already emerged leaves than other plants, although the latter afterwards exhibit a high rate (the average emergence rate remaining substantially unchanged) (see TABLE 2 and FIG. 2). It was found that the date on which the two sub-groups could be most readily distinguished by the number of leaves was 14th March or a little earlier, *viz.* the first observation after a severe winter. Owing to the small number of plants such distinctions in emergence rhythm are impossible to make in the group of *Petkuser* and *Zelder* plants with 11 leaves, as also in the group of *Zelder* plants with 14 leaves. It can easily be seen that up to the 6th leaf the originally backward subgroup in the *Petkuser* group with 14 leaves is able to develop approximately the same rate as the originally rapid sub-group in the *Petkuser* group with 12 leaves.

TABLE 2 also shows that the average date of emergence of the last leaf is somewhat earlier in plants exhibiting a low rate in spring within the same group. Selection

erages of measuring dates, *i.e.* of the dates on which the leaf was fully developed

Average leaf area in mm^2 (leaf sequence 1—14)								Number of spikelets	
8	9	10	11	12	13	14	total	initiated	full-grown
2599	3881	4240	2028				19978	35	31,7
(8/4)	(16/4)	(23/4)	(29/4)						
2330	3303	3763	2098				18420	34,3	32
(8/4)	(16/4)	(22/4)	(30/4)						
1847	2620	3108	2944	1201			17378	31,7	28
(7/4)	(14/4)	(20/4)	(26/4)	(1/5)					
2022	2833	3455	3228	1475			19998	33,8	31,5
(5/4)	(12/4)	(18/4)	(25/4)	(30/4)					
1537	2299	2870	3282	2736	1072		19278	33	20
(1/4)	(9/4)	(15/4)	(21/4)	(27/4)	(1/5)				
1588	2293	2955	3395	2863	1134		20619	33,3	30,9
31/3)	(8/4)	(15/4)	(21/4)	(26/4)	(1/5)				
1274	1984	2613	3271	3343	2616	852	21625	34,6	31,3
29/3)	(6/4)	(13/4)	(19/4)	(24/4)	(28/4)	(3/5)			
1206	1758	2382	2976	3217	2613	939	21483	33,2	31,2
27/3)	(6/4)	(9/4)	(17/4)	(22/4)	(29/4)	(2/5)			

FIG. 1. Leaf-formation rhythm in the *Petkuser* and *Zelder* varieties



tests have shown that this type of difference in rhythm of leaf emergence is also hereditary, as in some families this difference becomes a permanent character. The tests have also shown that after four years of continuous selection it is possible to considerably advance the date of heading.

3.2. The leaf surface area

Although the total surface area as well as the average surface area per leaf (TABLE 1) are greater than in the previous year, *viz.*:

total leaf area of main axis	11.200 to 17.300 mm^2	17.400 to 21.600 mm^2
average area per leaf	1.121 to 1.330 mm^2	1.450 to 1.660 mm^2

the differences per group are considerably smaller.

TABLE 3 shows the average surface areas of the successively emerging leaves for the groups with the same leaf number, and within these groups the sub-groups of varying emergence rhythm, referred to in 3.1. FIG. 3 shows the trend of the leaf surface area.

It can be seen from the above that there is a remarkable difference in both the size of the last two leaves and their rhythm of emergence after the winter. The last two

TABLE 2. Average dates on which the plants with the same leaf-formation rhythm were fully developed

Varieties	Leaf sequence 1—14													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
11-leaves group														
Petkuser I	16/10	21/10	3/11	20/11	3/2	14/3	28/3	8/4	16/4	23/4	29/4			
Zelder I	16/10	16/10	2/11	18/11	28/1	11/3	28/3	8/4	16/4	22/11	30/4			
12-leaves group														
Petkuser I	16/10	22/10	2/11	8/12	23/2	21/3	2/4	10/4	17/4	22/4	28/4	2/5		
II	16/10	20/10	3/11	16/11	11/1	14/3	28/3	7/4	13/4	20/4	26/4	1/5		
Zelder I	16/10	16/10	2/11	5/12	28/2	26/3	1/4	9/4	17/4	22/4	26/4	30/4		
II	16/10	16/10	3/11	12/11	11/1	9/3	26/3	5/4	12/4	18/4	25/4	30/4		
13-leaves group														
Petkuser I	16/10	16/10	2/11	20/11	14/3	28/3	7/4	10/4	18/4	22/4	28/4	2/5	4/5	
II	16/10	20/10	3/11	20/11	14/1	14/3	27/3	5/4	11/4	17/4	23/4	28/4	2/5	
III	16/10	21/10	4/11	9/11	25/12	6/2	14/3	27/3	7/4	13/4	19/4	25/4	30/4	
Zelder I	16/10	16/10	2/11	9/11	26/12	14/3	27/3	6/4	9/4	16/4	22/4	26/4	1/5	
II	16/10	16/10	2/11	2/11	20/12	19/2	14/3	27/3	8/4	15/4	20/4	26/4	30/4	
14-leaves group														
Petkuser I	16/10	18/10	3/11	18/11	29/12	12/3	21/3	2/4	9/4	15/4	20/4	26/4	29/4	3/5
II	16/10	18/10	2/11	5/11	20/12	25/1	14/3	27/3	5/4	11/4	18/4	23/4	28/4	2/5
Zelder I	15/10	15/10	4/11	4/11	20/12	13/2	15/3	27/3	6/4	9/4	17/4	22/4	29/4	2/5

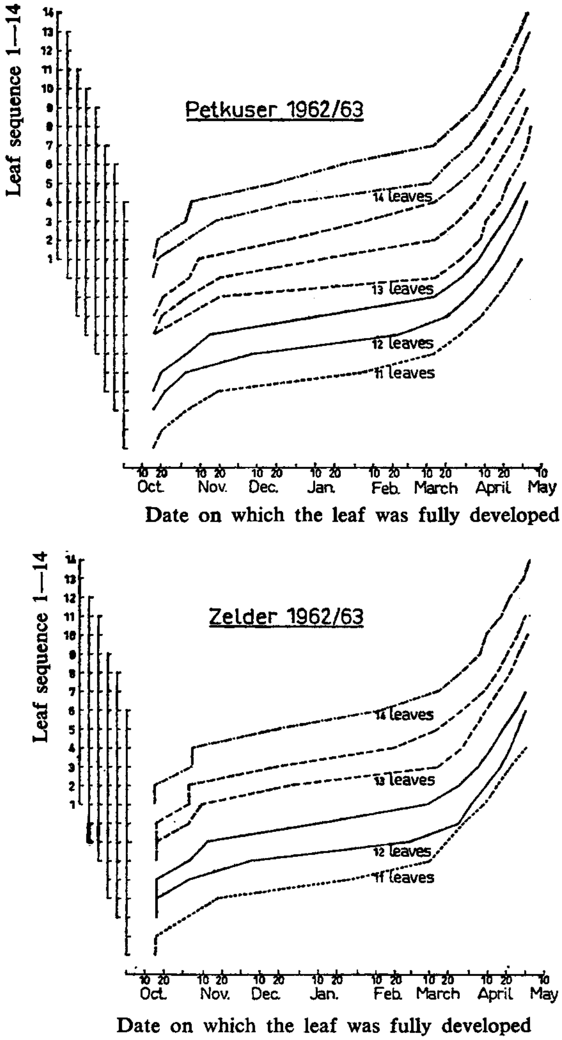


FIG. 2
Leaf-formation rhythm of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties (in the groups represented by more than one line the lower lines relate to sub-groups with an initially slow leaf formation; at a later stage there is a catch-up effect)

leaves of plants with 13 leaves are significantly larger in plants with a slow emergence rhythm after the winter than in plants with a rapid emergence rhythm (level of significance at *Petkuser* 1 %, at *Zelder* 5 %). A low emergence rate after the winter, which is particularly the case when there are a small number of leaves, goes together with large upper-stalk leaves; a rapid emergence rate means small leaves. Since a rapid emergence rate after the winter is usually accompanied by a slow emergence rate before the winter and *vice versa,* the overall trend of the successive leaf sizes of the two sub-groups within the groups with a given number of leaves is also unequal (FIG. 4).

It can be clearly seen from FIG. 5, in which the surface area of each leaf is plotted against the sum, that the site of the kink due to the small area of the first leaf measured after the winter depends on the leaf-emergence rhythm in the autumn. There are indications that this kink denotes the commencement of stalk initiation.

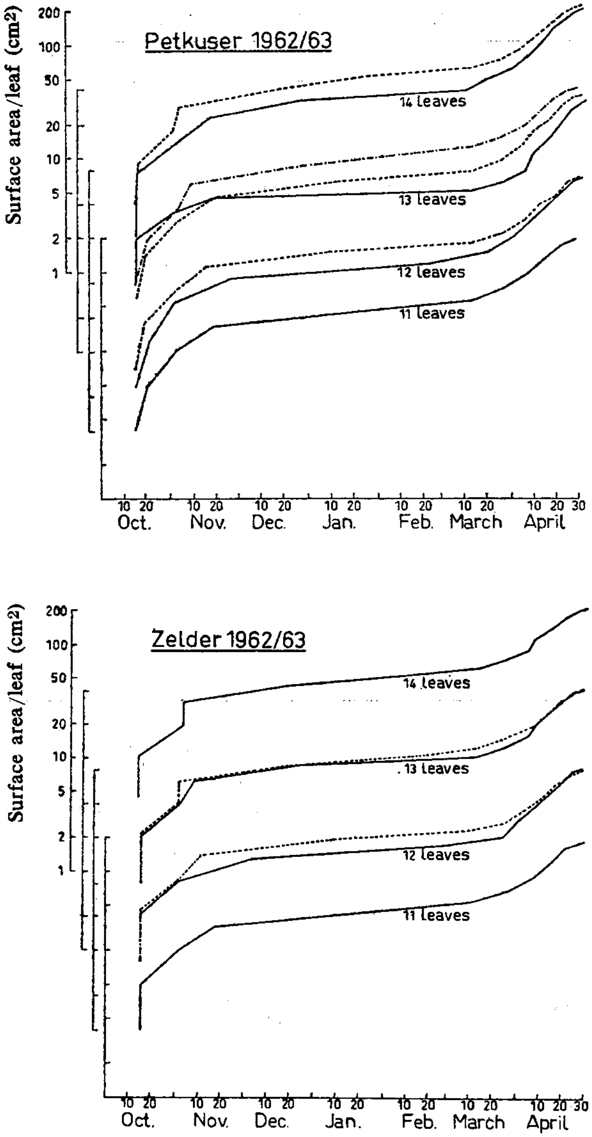


FIG. 3
Sum total (summation) of leaf-surface area (cm²) of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties (ordinate log. scale); for groups represented by more than one line see FIG. 2

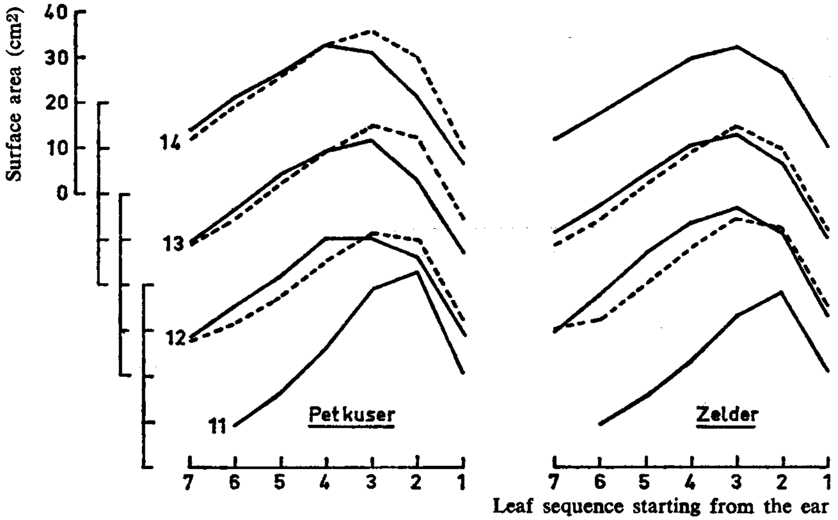
3.3. The number of spikelets per ear

TABLE 3 also lists the numbers of spikelets initiated in the various groups. It can be seen that in this year there is not the same close correlation between the number of spikelets and the total leaf-surface area as in 1962. Ignoring the group with 11 leaves owing to the small number of plants, the only noticeable increase is in *Petkuser*. As noted above (3.2.) there is not the same increase in leaf-surface area as in the previous year, although there is an indication that the number of spikelets initiated

TABLE 3. Average leaf surface (mm²), leaf number and average number of spikelets; classific

Varieties	Number of plants	Average leaf area in mm² (leaf sequence 1—14)					
		1	2	3	4	5	6
11-leaves group							
Petkuser I	3	434	577	1020	1404	1261	932
Zelder	7	406	610	1059	1277	1149	921
12-leaves group							
Petkuser I	8	257	374	703	936	696	860
II	39	353	543	829	1056	1021	759
Zelder I	2	417	630	1126	1198	850	947
II	51	445	720	1033	1302	1313	973
13-leaves group							
Petkuser I	1	400	585	720	576	380	438
II	23	306	435	677	885	879	704
III	24	395	590	882	1138	1245	1035
Zelder I	23	404	624	963	1211	1232	913
II	21	453	675	897	1159	1273	1009
14-leaves group							
Petkuser I	6	304	437	713	903	981	700
II	8	382	555	847	1075	1242	1263
Zelder I	5	457	602	903	1112	1334	1137

FIG. 4. Surface area (cm²) of the last six (or seven) leaves of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties (the solid lines represent sub-groups with an initially slow leaf formation; at a later stage there is a catch-up effect)



on according to the groups distinguished in TABLE 2

Average leaf area in mm² (leaf sequence 1—14)									Number of spikelets initiated
7	8	9	10	11	12	13	14	total	
1602	2599	3881	4240	2028				19978	35
1504	2330	3303	3763	2098				18420	34,3
1507	2210	3014	3012	2635	946			17150	31,8
1130	1771	2530	3109	2974	1217			17292	32,2
1739	2688	3393	3697	3075	1277			21037	29
1200	1996	2811	3445	3234	1482			19954	33
840	1512	2364	2860	2717	1992	420		15804	29
973	1654	2417	2883	3125	2281	719		17938	31,5
914	1459	2214	2897	3480	3197	1434		20880	34,1
1147	1754	2430	3057	3343	2717	997		20792	32,5
855	1420	2206	2922	3433	3000	1235		20537	33,7
863	1357	2107	2650	3239	3081	2114	653	20102	30
885	1212	1892	2586	3295	3539	2993	1001	22767	34,8
847	1206	1758	2382	2976	3217	2613	939	21483	33,2

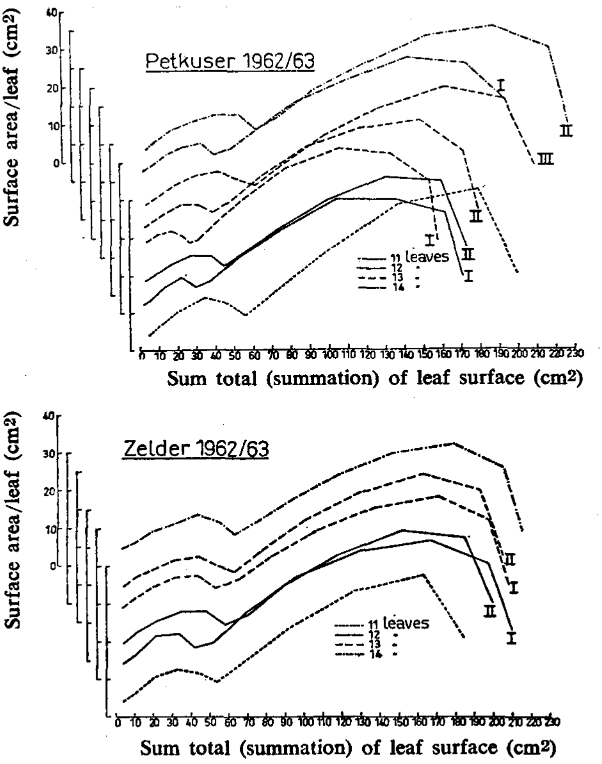


FIG. 5
Surface area per leaf (cm²) plotted against the total leaf-surface area of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties; for groups represented by more than one line see FIG. 2

TABLE 4. Average length of internodes and stalks (mm); classification according to the groups distinguished in TABLE 2

Varieties	Sequence of internodes starting from the ear (No. 1 is the peduncle)								Stalk
	7	6	5	4	3	2	1	total	
11-leaves group									
Petkuser		12	93	157	216	497	559	1534	1619
Zelder		4	76	176	202	431	541	1430	1523
12-leaves group									
Petkuser I	4	71	147	177	219	490	575	1719	1743
II		33	134	175	224	488	563	1617	1690
Zelder I		75	147	158	199	448	573	1600	1680
II		36	133	170	223	461	562	1585	1678
13-leaves group									
Petkuser II	21	107	163	182	231	494	547	1745	1805
III		60	140	176	235	481	565	1657	1734
Zelder I	9	94	159	180	239	479	546	1706	1806
II	1	59	149	184	236	494	569	1692	1777
14-leaves group									
Petkuser I	56	141	163	175	258	462	515	1770	1847
II	13	89	162	186	257	515	573	1795	1874
Zelder I	39	109	153	171	229	469	484	1654	1736

TABLE 5. Average length of the leaf sheaths (mm); classification according to the groups distinguished in TABLE 2

Varieties	Sequence of the leaf sheaths starting from the ear							
	7	6	5	4	3	2	1	total
11-leaves group								
Petkuser		32	91	119	149	168	187	746
Zelder		9	84	122	147	169	179	710
12-leaves group								
Petkuser I	17	61	111	134	143	163	185	814
II	1	50	98	131	154	170	192	796
Zelder I		78	123	136	145	160	183	825
II		38	99	132	152	166	188	775
13-leaves group								
Petkuser II	36	85	117	138	152	169	189	886
III	12	71	110	138	154	169	190	844
Zelder I	19	78	122	143	154	170	189	875
II	2	53	109	137	155	168	187	811
14-leaves group								
Petkuser I	56	103	127	138	146	165	182	917
II	50	96	128	151	166	181	198	970
Zelder	32	97	122	140	151	168	181	891

within one group with a given number of leaves increases with increasing size of the last leaves, *i.e.* as shown in 3.2. it increases with a decreasing leaf-emergence rate after the winter. But without further investigation it is impossible to establish whether this is a causal relationship, since in the comparison between the sub-groups with varying rhythm of emergence the emergence rate of the later leaves is closely bound up with the emergence rate of the early leaves appearing before the winter. Hence it is quite conceivable that the number of spikelets (which is, of course, determined in the early spring before heading is completed) is connected with the leaf-emergence rate up to that date.

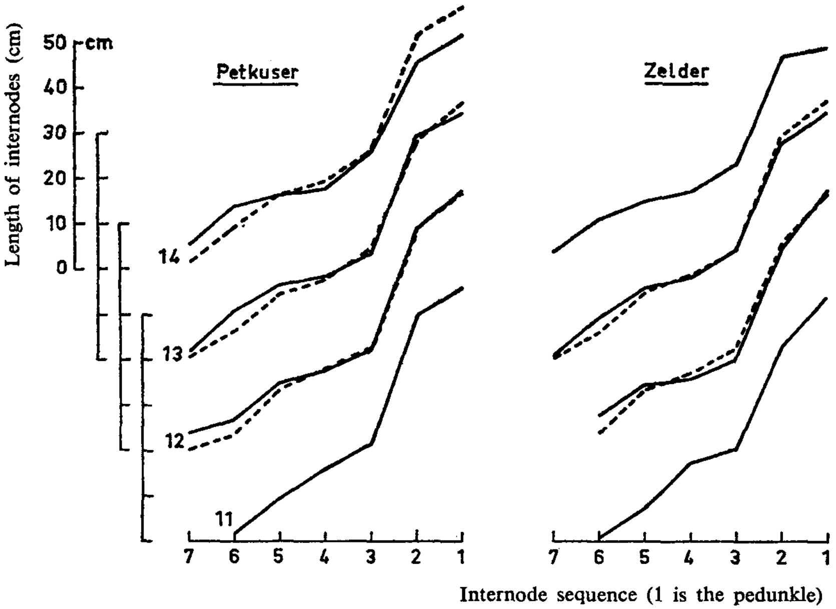
3.4. The lengths of internodes and leaf sheaths

So far as possible, for each leaf blade measured the accompanying sheath was also measured as well as the internode underneath; these measurements were, of course, confined to the post-winter period of growth. The results are shown in TABLES 4 and 5 in which the figures for the sub-groups with varying leaf-emergence rhythm are also separately listed.

The number of mensurable (*i.e.* visibly stretched) internodes and leaf sheaths increases with the number of leaves. This is also true of the average stalk length.

It was found that within a group of plants with the same number of leaves, the sub-group with a rapid post-winter leaf-emergence rate was found to have longer bottom internodes, although actually shorter top internodes than the sub-group with a slow leaf-emergence rate.

FIG. 6. Length (cm) of the last six (or seven) internodes of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties; for the meaning of the solid lines see FIG. 4



Internode sequence (1 is the pedunkle)

FIG. 7. Length (cm) of the last six (or seven) leaf sheaths of plants with the same emergence rhythm in the *Petkuser* and *Zelder* varieties; for the meaning of the solid lines see FIG. 4

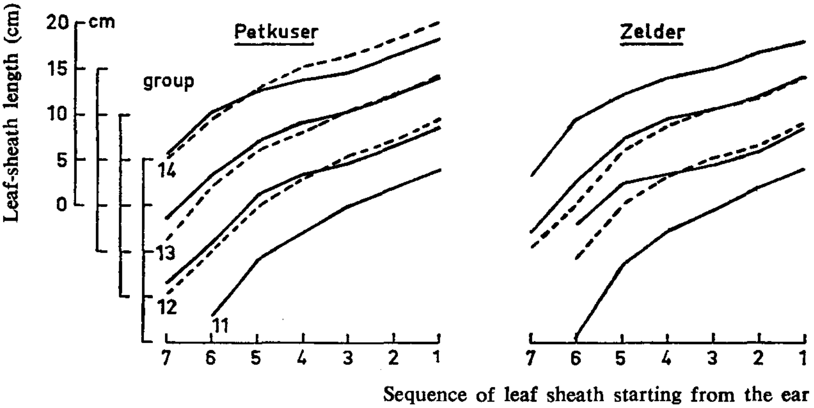
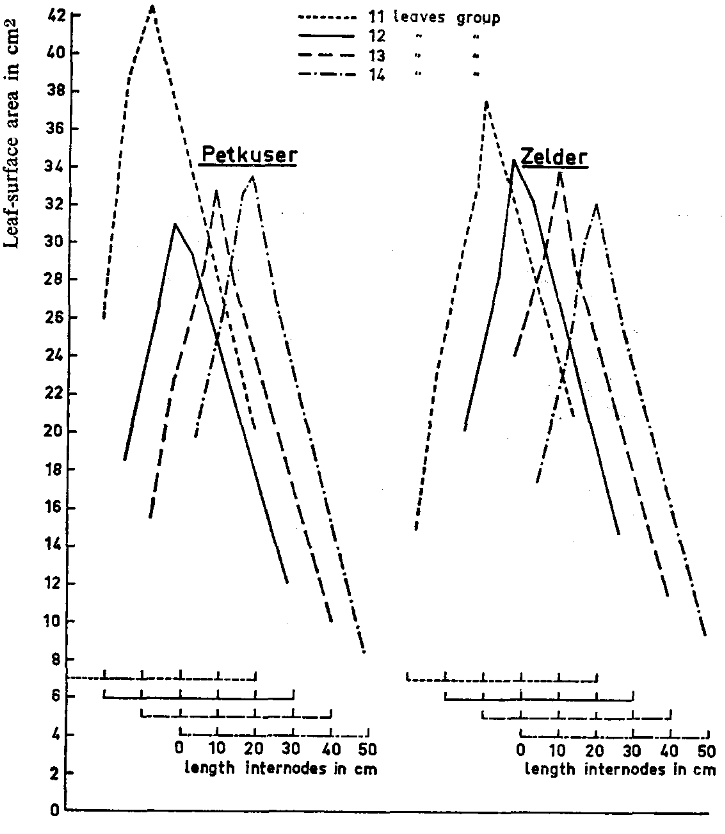


FIG. 8. Length (cm) of the last six (or seven) internodes plotted against the surface area of the corresponding leaf of plants with the same total leaf number in the *Petkuser* and *Zelder* varieties



The lengths of the leaf sheaths exhibit the same general trends as the accompanying internodes, as is illustrated by FIGS. 6 and 7.

When the lengths of the internodes are plotted against the surface area of the corresponding leaf it can be seen that the resultant line shows a very distinct kink (FIG. 8). The point at which this kink appears depends on the number of leaves on the plant in question. In the groups with 11 leaves it occurs at the 10th leaf, and in those with 12, 13 and 14 leaves on the 10th, 11th and 12th leaf respectively.

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