A Statistical Study of Similarities and Dissimilarities in Results Between Districts Used in Swedish Crop Variety Trials

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Uppsala 2009

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Amiri, S., Forkman, J. & von Rosen, D.
Report from the Department of Crop Procuction Ecology (VPE) ● No. 8
Swedish University of Agricultural Sciences (SLU)
Uppsala 2009
ISSN 1653-5375
ISBN 978-91-86197-53-7

Content

Abstract

The annual results of Swedish crop variety trials are presented in reports and on the internet for Sweden divided into seven regions (production areas) A-G covering southern Sweden. The yield results for test varieties are usually presented as ratios relative to the yield of a control variety. These ratios are presented per region, with the implicit assumption that differences in ratios may exist between regions.

In this report, the division of agricultural districts into regions was investigated through cluster analyses. Districts that produced similar levels of yield or similar ratios were clustered into groups of similar districts. Cluster analyses were performed on regions, districts and soil types for spring barley, winter wheat and oats, based on a large data set of results from variety trials performed during the period 1997-2006.

The study revealed that some regions, districts and soil types produce similar levels of yield or similar yield ratios. However, clusters of regions, districts or soil types that produce similar levels of yield do not always produce similar yield ratios.

Sammanfattning

Den svenska sortprovningen redovisas årligen i rapporter (t.ex. Larsson och Hagman, 2009) och på Internet (www.ffe.slu.se). Sorternas skördar redovisas antingen i absoluta tal, t.ex. i kg/ha, eller relativt en mätarsort i procent. För ändamålet är södra Sverige indelat i sju regioner A–G (figur 1.1), och resultaten från fältförsöken redovisas ofta per region. Dessa sju regioner har sitt ursprung i en indelning av Sverige i naturliga jordbruksområden, utarbetad av Ernst Höijer år 1921 (Larsson, 2006). De sju regionerna består av 38 mindre distrikt (figur 1.2).

I den här rapporten undersöks vilka regioner och distrikt som ger liknande skördenivåer och vilka som ger olika. Dessutom undersöks vilka regioner och distrikt som ger liknande relativtal, dvs. liknande kvoter mellan skördenivåer, och vilka som ger olika. Sortprovningen syftar nämligen snarare till att fastställa relationerna mellan sorterna än till att fastställa exakta skördenivåer. Undersökningen baseras på ett stort datamaterial med sortförsök i vårkorn, höstvete och havre, utförda under perioden 1997–2006. Det är vanligt att halva försöket görs med behandling mot svamp, och halva utan. I den här undersökningen har därför undersökts likheter och olikheter såväl vid behandling mot svamp som vid avsaknad av behandling.

Många andra faktorer än regioner och distrikt kan förklara variationen i resultat. Jordart är en sådan viktig faktor. I den här rapporten jämförs 7 jordarter: sand (Sa), mo (Mo), mjäla (Mj), lättlera (LL), mellanlera (ML), styv lera (SL) och mulljord (M).

Klusteranalys (se t.ex. Gordon, 1999) har använts för att avgöra vilka regioner, distrikt och jordarter som ger liknande skördenivåer och kvoter. Resultaten av klusteranalyserna presenteras i dendrogram i avsnitt 5. För varje gröda (vårkorn i avsnitt 5.1, höstvete i avsnitt 5.2 och havre i avsnitt 5.3) visas först vilka regioner som liknar varandra, sedan vilka distrikt som liknar varandra och slutligen vilka jordarter som ger liknande värden. För varje gröda finns fyra dendrogram: de två första avser resultat med fungicidbehandling, och de två sista avser resultat utan fungicidbehandling. Första och tredje figuren avser likhet i skördenivå, andra och fjärde avser likhet i logaritmerad kvot (dvs. likhet i sortrelation).

Av figur 5.1.1, till exempel, framgår att regionerna E och G brukar ge liknande skördenivåer vid behandling mot svamp. Av övriga regioner är region C den som mest liknar E och G. Regionerna A, B, D och F ger däremot skördar som avviker från skördarna i C, E och G. Dendrogrammet ger ingen information om vilket kluster: {A, B, D, F} eller {C, E, G}, som brukar ge högst skörd. Något år kanske skörden är högst i {A, B, D, F}, men något annat år kan den vara högst i {C, E, G}. Dendrogrammet säger bara att regionerna A, B, D och F brukar ge liknande skördar, och att regionerna C, E och G brukar ge liknande skördar.

Av figur 5.1.2 framgår att sortrelationerna inte är väsentligt mer lika i ett par av regioner än i ett annat par av regioner. Det går inte att dela in regionerna i två eller flera grupper av regioner som ger liknande sortrelationer. Även i havre är det lättare att gruppera regionerna med avseende på skörd än på relativtal (jämför figurerna 5.3.1 med 5.3.2, samt 5.3.3 med 5.3.4). I höstvete, däremot, visar sig regionerna F och G ge andra relativtal än övriga regioner (figurerna 5.2.2 och 5.2.4). Kanske är det inte förvånande att skillnaderna mellan regionerna i relativtal är tydligare i höstvete, som växer på vintern, än i vårkorn och havre, som sås på våren.

I en del fall har objekten, dvs. regionerna, distrikten eller jordarterna, blivit indelade i ett litet antal grupper med ungefär lika många objekt i varje grupp (t.ex. figur 5.2.3). I dessa fall skulle det kanske vara möjligt att slå ihop objekten till större grupper utan att variationen i resultaten inom gruppen skulle öka. I många andra fall har objekten successivt adderats till ett enda stort kluster, ett objekt i taget (t.ex. figur 5.2.10). Dessvärre finns det i de fallen ingen uppenbar indelning av objekten i två eller flera homogena grupper.

1. Introduction

The results of the variety trials performed in southern and central parts of Sweden are presented every year in summary tables on the internet (www.ffe.slu.se) and in written reports (e.g. Larsson and Hagman, 2009). Because results may differ between different parts of the country, Sweden is divided into seven agricultural regions (production areas) and the results are presented by region. These regions are denoted A-G (Figure 1.1) and originate from a division of Sweden suggested by Ernst Höijer in 1921 (Larsson, 2006).

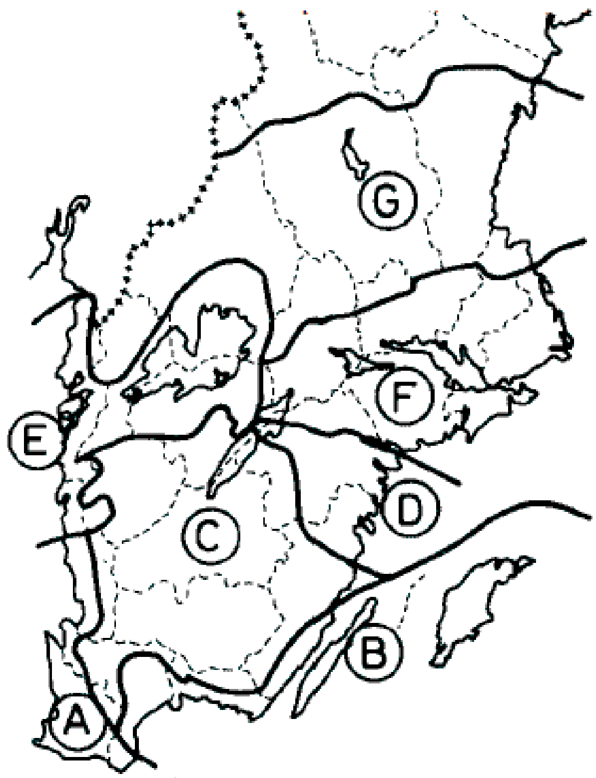

Figure 1.1: Current division of southern and central Sweden into agricultural regions A-G (source: www.ffe.slu.se, accessed 25 May 2009).

Regions A-G are subdivided into 38 districts according to Figure 1.2 and Table 1.1. One part of district 13e is located in region F, while the other part is located in region G.

The results of variety trials may depend on regions and districts, but also on many other factors, soil type being one of the most important. In this study, the following soil types are considered: Sand (Sa), Fine sand with coarse silt (Mo), Fine silt (Mj), Loam (LL), Clay loam (ML), Heavy clay (SL) and Organic soil (M).

This study, which formed part of the project *Production Areas for Variety Trials*, examined similarities and differences in results between regions, districts and soil types.

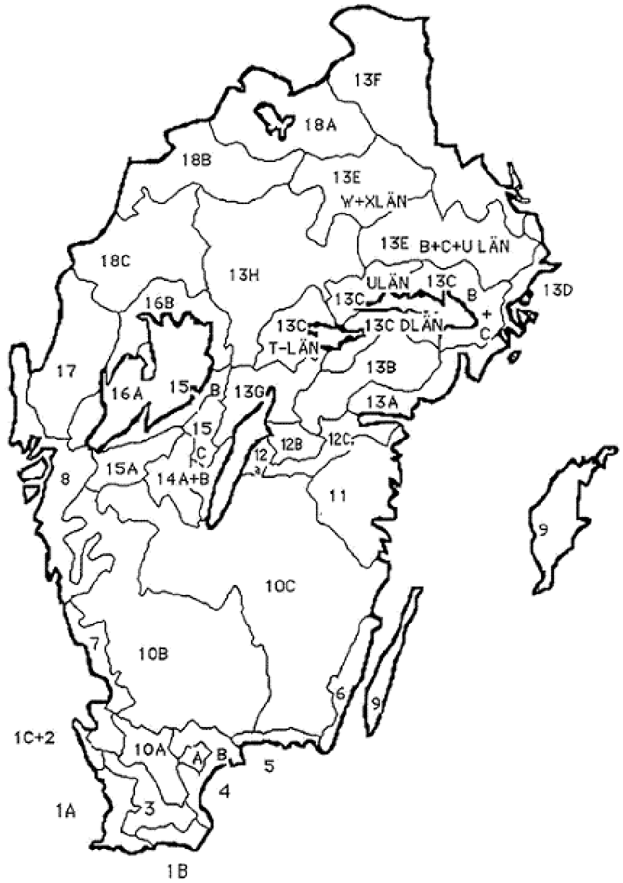

Figure 1.2: Current subdivision of regions A-G into 38 districts (source: www.ffe.slu.se)

Table 1.1: Current subdivision of southern and central Sweden into districts by region

Region	*District*
A	1a 1b 1c 2 3 7
B	4a 4b 5 6 9
C	10a 10b 10c 14a 14b
D	11 12a 12b 12c
E	8 15a 15b 15c 16a 16b
F	13a 13b 13c 13e 13f 13g
G	13e 13f 13h 17 18a 18b 18c

2. Objectives

The main objective of this study was to examine similarities and dissimilarities in results between regions, districts and soil types in the Swedish variety trials. The following questions were addressed:

1. Which regions, districts and soil types produce similar yields in trials that include fungicide treatment?
2. Which regions, districts and soil types produce similar yield ratios between varieties in trials that include fungicide treatment?
3. Which regions, districts and soil types produce similar yields in trials that do not include fungicide treatment?
4. Which regions, districts and soil types produce similar yield ratios between varieties in trials that do not include fungicide treatment?

The investigation covered spring barley, winter wheat and oats.

3. Methods

Cluster analyses (e.g. Gordon, 1999) were used for the clustering the regions (districts and soil types) into groups. The following fictitious example describes the method.

3.1. Example

In the same year, variety 9622 and 20313 were included in trials carried out in districts 2, 12a, 12b and 10c. The average yields are presented in Table 3.1. Note that the data set consists of 4 objects (2, 12a, 12b and 10c) and 2 variables (9622 and 20313).

Table 3.1: Yield (g/m^2) per variety and district

District	9622	20313
2	500	518
12b	510	500
12a	490	500
10c	450	490

Because there are only two varieties, the results can be illustrated in a two-dimensional space, as in Figure 3.1a. In this space, the (Euclidian) distance between districts 12a and 12b is 20 g/m^2 (Figure 3.1b), which is slightly smaller than the distance between 12a and 2 and the distance between 12b and 2 (both these distances are 20.6). Since the distance between 12a and 12b is the smallest Euclidian distance between any two districts in the data set, these districts are regarded as the most similar. In the next step, districts 12a and 12b are merged together (Figure 3.1c). The smallest distance between any two points in Figure 3.1c is 18 g/m2, which is the distance between district 2 and the cluster of 12a and 12b. For this reason, a cluster including districts 2, 12a and 12b is formed. The distance between this cluster of districts and district 10c is 53.5 g/m^2.

The distances between the districts can be summarised in a distance matrix (Table 3.2). The square root of the average of all squared distances is 40.69.

Table 3.2: Distance matrix

	10c	12a	12b	2
10c	0	.	.	.
12a	41.2311	0	.	.
12b	60.8276	20	0	.
2	57.3062	20.5913	20.5913	0

The clustering process can be described by a dendrogram (Figure 3.2). This figure tells us that district 12a and 12b are the most similar districts. The standardised distance between 12a and 12b is the Euclidian distance between the districts divided by the square root of the average of all squared distances, in this case 20/40.69 = 0.49. The standardised distances between the districts and the clusters that are grouped together during the process of cluster analysis are shown on the y-axis of the dendrogram. When districts 12a and 12b are merged, the distance between their centroid and district 2 is slightly smaller than the original distance between districts 12a and 12b. The cluster analysis ends when all districts belong to one single cluster. In this example, district 10c is not merged into any cluster until the very last step. The standardised distance between district 10c and the cluster of the other districts is 1.31, which is comparatively large. It can be concluded that district 10c produces yields dissimilar to those obtained in the other districts.

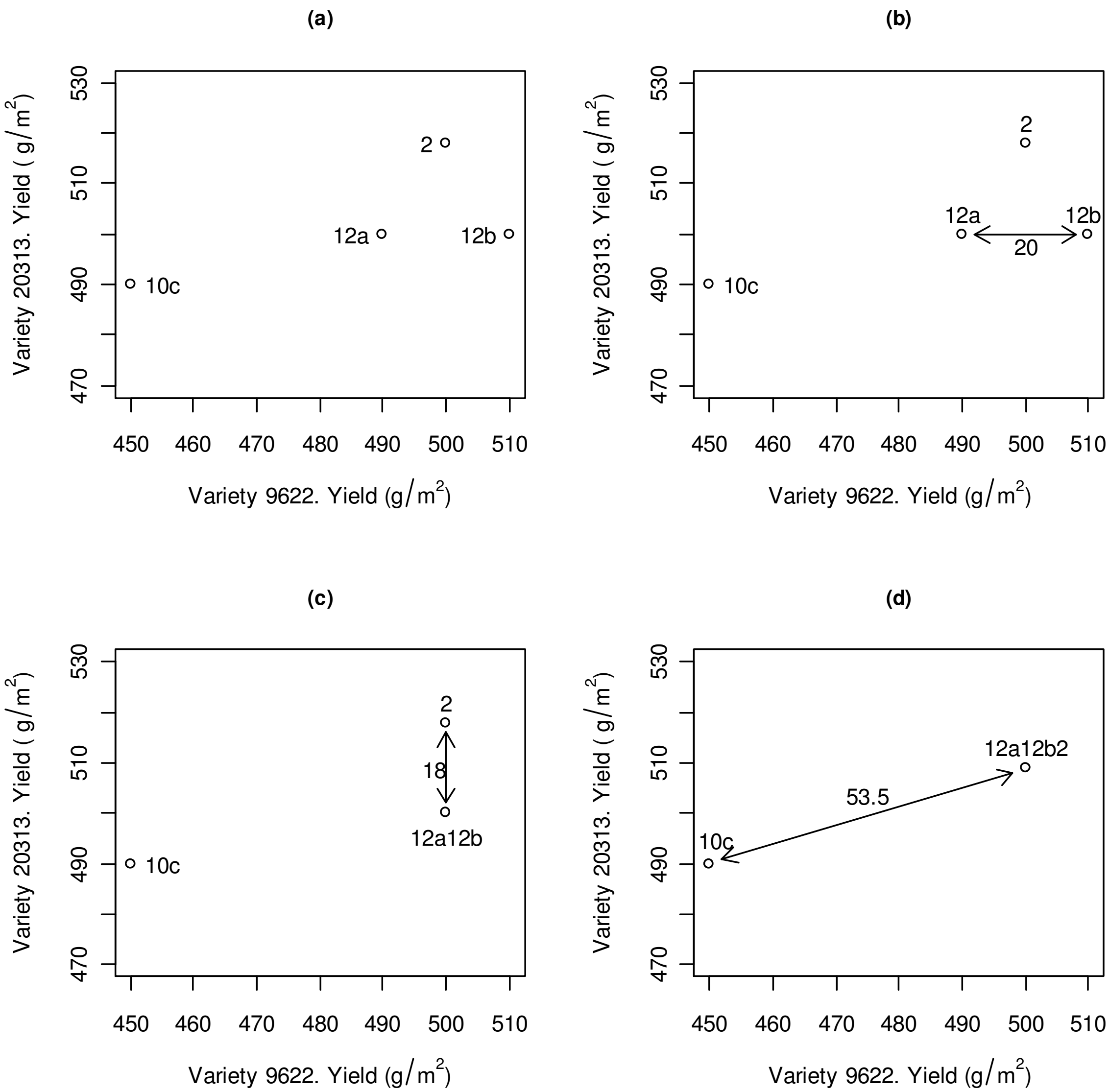

Figure 3.1: Clustering of districts 2, 12a, 12b and 10c based on observed yields of two varieties, 9622 and 20313. (a) The observed yields (g/m^2) illustrated in a two-dimensional space. (b) The smallest distance is 20 g/m^2. (c) The distance between district 2 and the cluster of districts 12a and 12b is 18. (d) The distance between district 10c and the cluster of districts 12a, 12b and 2 is 53.5.

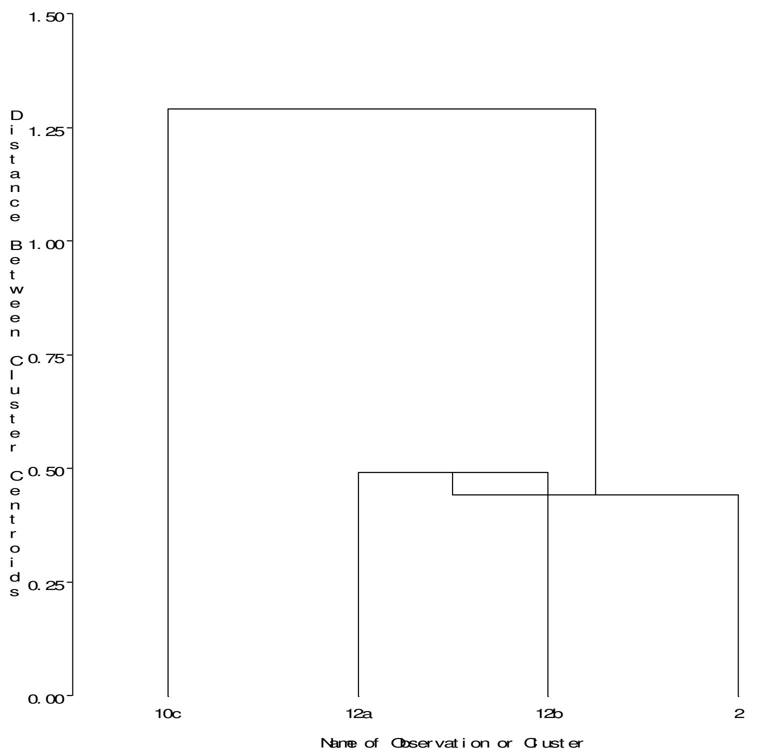

Figure 3.2: Clustering of districts based on yield.

3.2 Cluster analyses in the study

Cluster analyses were performed in order to group regions, districts and soil types according to similarity. The analyses were made on two datasets, one comprising trials on plots that were treated with fungicide and the other comprising trials on plots that were not treated with fungicide.

The objects (i.e. regions, districts or soil types) were clustered according to similarities in yield and in log ratio.

In the cluster analyses based on yield, each combination of year and variety formed a variable. For example, the spring barley data set with fungicide-treated trials included 615 pairs of year and variety. The cluster analysis of the regions was consequently performed on a data set with 7 objects (A-G) and 615 variables. Mean yields were used as elements in the cluster analysis. In other words, for each combination of object and variable, the mean yield was calculated and used in the cluster analysis. Objects were grouped according to similarity in mean yield. In the cluster analysis of the districts, it was necessary to exclude some of the districts because few varieties had been trialled in those districts. Otherwise it would not have been possible to calculate the distance matrix.

For the cluster analyses based on log ratio, in each trial all pair-wise differences in yield between varieties were calculated. In a trial including v varieties, there are $v(v-1)/2$ pair-wise differences in yield. The objects were classified according to similarities in pair-wise differences in log yield, as calculated by year. In the spring barley data set with observations from plots treated with fungicide, there were 8684 combinations of year and pair of varieties. The distances between the regions were accordingly measured in an 8684-dimensional space.

The results of the cluster analyses are presented in dendrograms.

4. Descriptive statistics

4.1 Spring barley

The data set of spring barley included 16,005 observations from trials performed during 1997-2006, with a total of 255 varieties and 539 trials. Descriptive statistics on yields are presented in Table 4.1.1, while Figure 4.1.1 shows a box-and-whisker plot which displays the variation in yield between and within years. A box-and-whisker plot displays data as follows: the median is represented by horizontal line inside the box. The top and bottom of the box represent the 3rd quantile (75th percentile) and the 1st quantile (25th percentile), respectively. The higher and lower edges are maximum and minimum observations, respectively, while the plus symbol in the side box is the mean of observations.

Table 4.1.1: Descriptive statistics on spring barley yields (dry matter content, g/m^2)

Mean	Std	Min	Max	N
528.50	128.58	111.53	946.93	16005

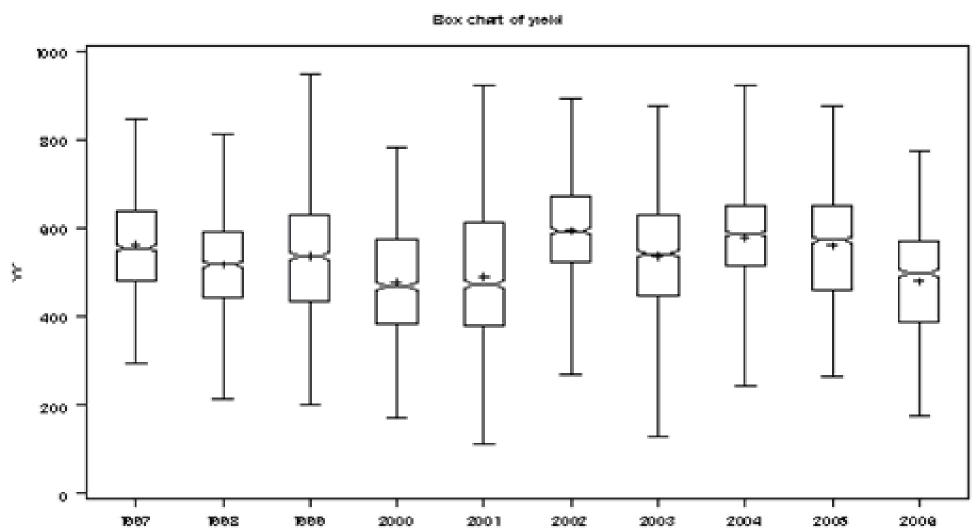

Figure 4.1.1: Box-and-whisker plot of spring barley yields (dry matter content, g/m^2).

The varieties Sortblandning (a variety mix), Orthega, Otira and Baroness, coded 9801, 9610, 9814 and 9101 respectively, have been included in many trials. Descriptive statistics for these frequent varieties are given in Table 4.1.2. Additional descriptive statistics on these and other frequent varieties are given in Appendix A.

Table 4.1.2: Descriptive statistics on yield (dry matter content, g/m^2) for the four most frequent varieties of spring barley in Swedish trials

Variety	Mean	Std	Min	Max	1st quantile	Median	3rd quantile	N
9801	524.72	123.13	199.89	850.40	438.28	526.56	613.44	853
9814	531.51	129.64	189.77	898.16	433.03	536.52	624.02	660
9610	540.46	126.00	203.31	871.88	452.95	548.56	623.37	608
9101	518.84	115.91	250.91	864.57	434.48	512.75	603.15	604

The range of yields was 835 g/m^2, which is high compared with the mean (Table 4.1.1). Based on the range of yields, three categories were constructed: Low, Medium and High, representing yield <465 g/m^2, 465-588 g/m^2 and >588 g/m^2, respectively (Table 4.1.3). The cut-off values, 465 and 588 g/m^2, are the 33rd and the 66th percentiles, respectively, in the distribution.

Table 4.1.3: Data on the different categories (Low, Medium, High) of spring barley yield

Category	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Low	5243	32.76	5243	32.76
Medium	5274	32.95	10517	65.71
High	5488	34.29	16005	100.00

Table 4.1.4 shows the productivity of the most frequent varieties.

Table 4.1.4: Number of observations (N) and distribution into different yield categories for the four most frequent varieties of spring barley in Swedish trials

Variety		Category		
		High	Medium	Low
9801	N	275	307	271
	percent	32.24	35.99	31.77
9814	N	218	227	215
	percent	33.03	34.39	32.58
9610	N	215	220	173
	percent	35.36	36.18	28.45
9101	N	180	215	209
	percent	29.80	35.60	34.60

Table 4.1.5 shows yield per region, based on complete data set with trials performed 1997-2006. Region A had the highest productivity, with 58.64% of the observations belonging to the High yield category. Region G was the region with lowest productivity, producing 0.93% High yields and 86.87% Low yields.

Table 4.1.5: Number of observations (N) per region and proportion of spring barley yields in the different yield categories

Region		Category		
		Low	Medium	High
A	N	506	1451	2775
	percent	10.69	30.66	58.64
B	N	660	827	1048
	percent	26.04	32.62	41.34
C	N	416	246	40
	percent	59.26	35.04	5.70
D	N	336	636	487
	percent	23.03	43.59	33.38
E	N	1070	697	84
	percent	57.81	37.66	4.54
F	N	1600	1325	1047
	percent	40.28	33.36	26.36
G	N	655	92	7
	percent	86.87	12.20	0.93
Total	N	5243	5274	5488
	percent	32.76	32.95	34.29

It is clear from Table 4.1.5 that there are differences in yield between the regions. To investigate whether there are also differences between the regions in yield ratios, the log ratio of the yield of the test variety to the yield of the control variety (9801) was calculated for all varieties in each trial. The log ratios were categorised into three categories: Low, Medium and High, each including approx. 33% of the observations. A contingency table with the regions and the log ratio categories was then drawn up (Table 4.1.6). Note that in Table 4.1.5, less than 1% of the observations from region G showed high yield, but by using the variety mix 9801 as the control, this value increased to 23.47%.

Table 4.1.6: Number of observations (N) per region and log ratio category of spring barley yields (relative to variety mix 9801)

Region		Category		
		Low	Medium	High
A	N	1135	1503	1447
	percent	27.78	36.79	35.42
B	N	605	695	839
	percent	28.28	32.49	39.22
C	N	168	156	210
	percent	31.46	29.21	39.33
D	N	304	430	418
	percent	26.39	37.33	36.28
E	N	541	463	580
	percent	34.15	29.23	36.62
F	N	960	1060	1151
	percent	30.27	33.43	36.30
G	N	166	59	69
	percent	56.46	20.07	23.47

Results from cluster analyses made on soil types, as defined in Section 1, are presented below. Table 4.1.7 is a contingency table of soil type and productivity.

Table 4.1.7: Number of observations (N) per soil type and spring barley yield category (Low, Medium, High) on the different soil types

		category		
		Low	Medium	High
LL	N	536	898	1558
	percent	17.91	30.01	52.07
ML	N	1359	1103	1376
	percent	35.41	28.74	35.85
Mj	N	138	107	55
	percent	46.00	35.67	18.33
Mo	N	330	536	478
	percent	24.55	39.88	35.57
SL	N	1421	1114	641
	percent	44.74	35.08	20.18
Sa	N	327	400	610
	percent	24.46	29.92	45.62
M	N	87	59	16
	percent	53.70	36.42	9.88

Table 4.1.8 is a contingency table of soil type and log ratio category.

Table 4.1.8: Number of observations (N) by soil type and log ratio category of spring barley yields (relative to variety mix 9801) on the different soil types

		Category		
		Low	Medium	High
LL	N	708	858	857
	percent	29.22	35.41	35.37
ML	N	846	1043	999
	percent	29.29	36.11	34.59
Mj	N	64	83	68
	percent	29.77	38.60	31.63
Mo	N	336	367	387
	percent	30.83	33.67	35.50
SL	N	867	870	894
	percent	32.95	33.07	33.98
Sa	N	295	369	445
	percent	26.60	33.27	40.13
M	N	30	30	49
	percent	27.52	27.52	44.95

4.2 Winter wheat

The data set of winter wheat included 15,191 observations from trials performed during 1997-2006 with a total of 217 varieties and 468 trials. Descriptive statistics on yields are presented in Table 4.2.1, while Figure 4.2.1 includes more information about the variation between and within years.

Table 4.2.1. Descriptive statistics on winter wheat yields (dry matter content, g/m^2).

Mean	Std	Min	Max	1st quantile	Median	3rd quantile	N
715.36	182.00	23.76	1309.17	596.06	719.76	841.74	15191

Table 4.2.2 presents descriptive statistics on yields for the varieties Kosack (7084), Olivin (9921), Hadm Tarso (9342) and Ceb Ritmo (9343), which have high frequency in Swedish trials in comparison with other varieties. Additional descriptive statistics on these and other frequent varieties are given in Appendix B. Table 4.2.3 shows the distribution of the most frequent varieties over categories of yield.

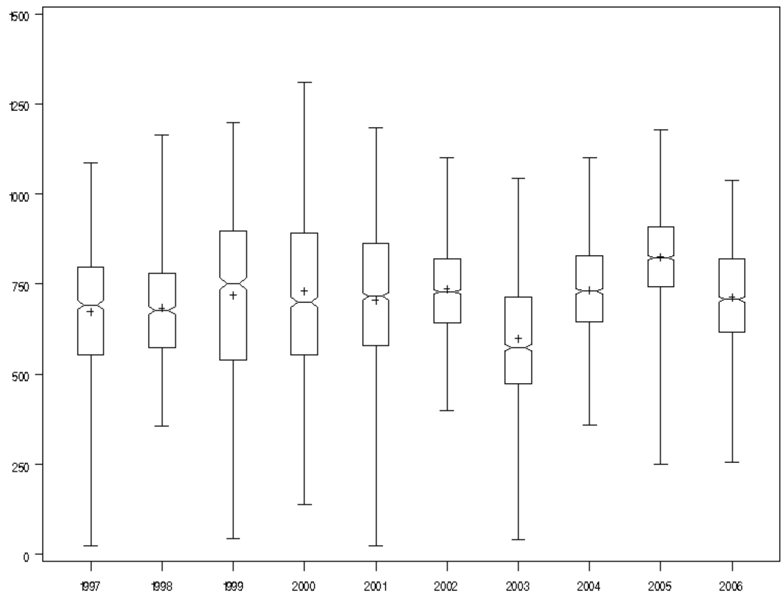

Figure 4.2.1: Box-and-whisker plot of winter wheat yields (dry matter content, g/m^2).

Table 4.2.2: Descriptive statistics on yield (dry matter content, g/m^2) for the four most frequent varieties of winter wheat in Swedish trials

	Yield							
	Mean	Std	Min	Max	P25	P50	P75	N
7084	681.48	151.18	53.74	1073.98	576.62	679.89	789.16	780
9921	697.66	148.43	312.12	1050.41	597.88	702.70	802.81	471
9342	637.31	151.16	42.64	1057.30	538.64	632.71	739.89	469
9343	690.35	203.14	54.33	1207.74	550.56	674.63	827.31	464

Table 4.2.3: Number of observations (N) and distribution into different yield categories for the four most frequent varieties of winter wheat in Swedish trials

		Category		
		Low	Medium	High
7084	N	313	280	187
	percent	40.13	35.90	23.97
9921	N	162	188	121
	percent	34.39	39.92	25.69
9342	N	240	154	75
	percent	51.17	32.84	15.99
9343	N	199	128	137
	percent	42.89	27.59	29.53

Tables 4.2.4 and 4.2.5 provide information about regions and show the distribution of observations over categories of yield in each different region.

Table 4.2.4: Number of observations (N) per region and proportion of winter wheat yields in the different yield categories

		Category		
		Low	Medium	High
A	N	615	1381	3004
	percent	12.30	27.62	60.08
F	N	1525	1081	647
	percent	46.88	33.23	19.89
E	N	1658	934	235
	percent	58.65	33.04	8.31
B	N	472	952	781
	percent	21.41	43.17	35.42
D	N	475	622	476
	percent	30.20	39.54	30.26
C	N	156	42	9
	percent	75.36	20.29	4.35
G	N	120	6	0
	percent	95.24	4.76	0

Table 4.2.5: Number of observations (N) per region and log ratio category of winter wheat yields (relative to variety 7084)

		Category		
		Low	Medium	High
A	N	1255	1456	2289
	percent	25.10	29.12	45.78
F	N	1538	1034	681
	percent	47.28	31.79	20.93
E	N	996	1031	800
	percent	35.23	36.47	28.30
B	N	528	791	886
	percent	23.95	35.87	40.18
D	N	571	563	439
	percent	36.30	35.79	27.91
C	N	74	91	42
	percent	35.75	43.96	20.29
G	N	56	46	24
	percent	44.44	36.51	19.05

Table 4.2.6 is a contingency table based on soil type and category of yield, while Table 4.2.7 is a contingency table based on soil type and category of log ratio.

Table 4.2.6: Number of observations (N) per soil type and yield category of winter wheat yields (Low, Medium, High) on the different soil types

		Category		
		Low	Medium	High
ML	N	1349	1269	1211
	percent	35.23	33.14	31.63
SL	N	1702	1305	773
	percent	45.03	34.52	20.45
LL	N	826	938	1448
	percent	25.72	29.20	45.08
Mo	N	299	242	357
	percent	33.30	26.95	39.76
Mj	N	42	140	190
	percent	11.29	37.63	51.08
Sa	N	134	40	66
	percent	55.83	16.67	27.50
M	N	15	51	6
	percent	20.83	70.83	8.33

Table 4.2.7: Number of observations (N) per soil type and log ratio category of winter wheat yields (relative to variety 7084) on the different soil types

		Category		
		Low	Medium	High
ML	N	1092	1163	1574
	percent	28.52	30.37	41.11
SL	N	1613	1238	929
	percent	42.67	32.75	24.58
LL	N	889	1087	1236
	percent	27.68	33.84	38.48
Mo	N	275	291	332
	percent	30.62	32.41	36.97
Mj	N	93	116	163
	percent	25.00	31.18	43.82
Sa	N	73	71	96
	percent	30.42	29.58	40.00
M	N	23	29	20
	percent	31.94	40.28	27.78

4.3 Oats

The data set of oats includes 4,242 observations from trials performed during 1997-2006, with a total of 108 varieties and 292 trials. Descriptive statistics on yields are presented in Table 4.3.1. Figure 4.3.1 provides more information about the variation in yield between and within years.

Table 4.3.1. Descriptive statistics on oat yields (dry matter content, g/m^2).

Mean	Std	Min	Max	1st quantile	Median	3rd quantile	N
520.80	130.61	102.69	942.40	428.82	510.00	607.72	4242

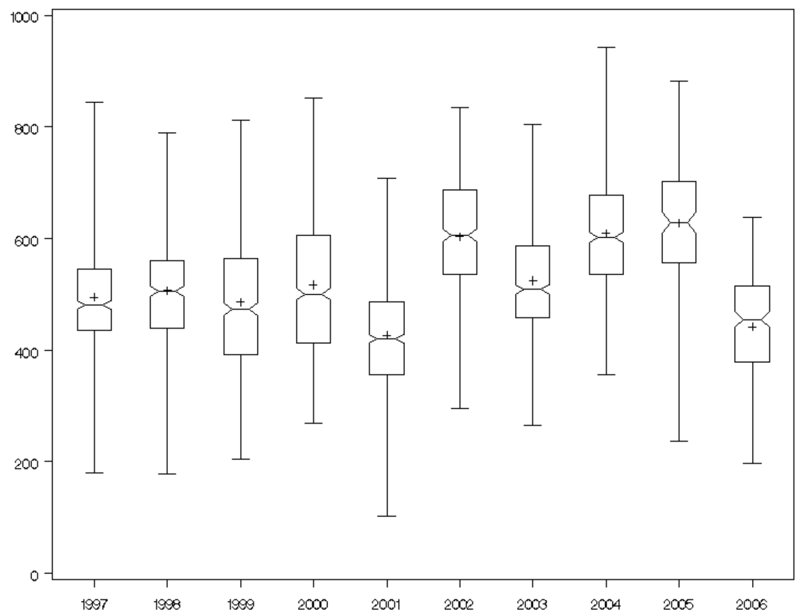

Figure 4.3.1: Box and-whisker plot of oat yields (dry matter content, g/m^2)

Descriptive statistics for frequent oat varieties are given in Table 4.3.2. The frequent varieties are Belinda (9430), Freddy (9720), Ser Chantilly (9819) and Stork (9431). Appendix C gives statistics for other frequent varieties of oats. Additional information about the most frequent varieties is given in Table 4.3.3.

Table 4.3.2: Descriptive statistics on yield (dry matter content, g/m^2) for the four most frequent varieties of oats in Swedish trials

	Mean	Std	Min	Max	1st quantile	Median	3rd quantile	N
9430	526.15	124.81	169.76	895.19	433.88	517.61	602.75	482
9720	532.98	134.01	163.18	919.25	434.07	531.53	624.10	321
9819	524.66	130.47	150.28	903.95	433.29	516.99	616.89	289
9431	523.42	126.52	214.23	843.41	432.85	513.54	594.87	265

Table 4.3.3: Number of observations (N) and distribution into different yield categories for the four most frequent varieties of oats in Swedish trials

Variety		Category		
		Low	Medium	High
9430	N	146	162	174
	percent	30.29	33.61	36.10
9720	N	98	94	129
	percent	30.53	29.28	40.19
9819	N	88	97	104
	percent	30.45	33.56	35.99
9431	N	85	81	99
	percent	32.08	30.57	37.36

Tables 4.3.4 and 4.3.5 are contingency tables with information about the number of observations in categories of yield and log ratio, respectively, by region. Tables 4.3.6 and 4.3.7 show the distribution of the observations over categories of productivity and log ratio, respectively, for each soil type.

Table 4.3.4: Number of observations (N) per region and proportion of oat yields in the different yield categories

		Category		
		Low	Medium	High
A	N	78	292	714
	percent	7.20	26.94	65.87
B	N	31	78	215
	percent	9.57	24.07	66.36
C	N	282	265	102
	percent	43.45	40.83	15.72
D	N	65	114	187
	percent	17.76	31.15	51.09
E	N	518	485	87
	percent	47.52	44.50	7.98
F	N	556	443	485
	percent	37.47	29.85	32.68
G	N	219	70	11
	percent	73.00	23.33	3.67

Table 4.3.5: Number of observations (N) per region and log ratio category of oat yields (relative to variety 9430)

		Category		
		Low	Medium	High
A	N	378	395	311
	percent	34.87	36.44	28.69
B	N	99	98	127
	percent	30.56	30.25	39.20
C	N	206	161	282
	percent	31.74	24.81	43.45
D	N	133	117	116
	percent	36.34	31.97	31.69
E	N	457	322	311
	percent	41.93	29.54	28.53
F	N	616	440	428
	percent	41.51	29.65	28.84
G	N	179	58	63
	percent	59.67	19.33	21.00

Table 4.3.6: Number of observations (N) per soil type and yield category of oat yields (Low, Medium, High) on the different soil types

		Category		
		Low	Medium	High
LL	N	385	413	388
	percent	32.46	34.82	32.72
ML	N	533	531	619
	percent	31.67	31.55	36.78
Mj	N	35	65	24
	percent	28.23	52.42	19.35
Mo	N	69	152	292
	percent	13.45	29.63	56.92
SL	N	464	439	343
	percent	37.24	35.23	27.53
Sa	N	189	125	117
	percent	43.85	29.00	27.15
M	N	15	1	9
	percent	60.00	4.00	36.00

Table 4.3.7: Number of observations (N) per soil type and log ratio category of oat yields (relative to variety 9430) on the different soil types

		Category		
		Low	Medium	High
LL	N	477	357	352
	percent	40.22	30.10	29.68
ML	N	645	515	523
	percent	38.32	30.60	31.08
Mj	N	54	34	36
	percent	43.55	27.42	29.03
Mo	N	172	154	187
	percent	33.53	30.02	36.45
SL	N	529	364	353
	percent	42.46	29.21	28.33
Sa	N	147	139	145
	percent	34.11	32.25	33.64
M	N	12	6	7
	percent	48.00	24.00	28.00

5. Results

Results of the cluster analyses for spring barley, winter wheat and oats are presented in Sections 5.1, 5.2 and 5.3, respectively.

5.1 Spring barley

The results of cluster analyses for spring barley are presented below based on similarities in yield and log ratio. The present regions A-G are clustered in Section 5.1.1, the districts are clustered in Section 5.1.2, and the soil types in Section 5.1.3. Within each section, results based on fungicide-treated plots are presented first, followed by results based on untreated plots. All results are given in dendrograms.

5.1.1 Clustering of regions

The cluster analyses indicate similar levels of spring barley yield in regions C, E and G (Figures 5.1.1 and 5.1.3). Two groups of regions can possibly be distinguished: one composed of regions {A, B, D, F} and the other composed of {C, E, G}. The yield should be homogeneous within these two groups of regions. However, the differences between the regions were similar regarding log ratios, especially when treated with fungicide (Figure 5.1.2). On untreated plots, regions A and D produced most similar ratios in yield between varieties (Figure 5.1.4).

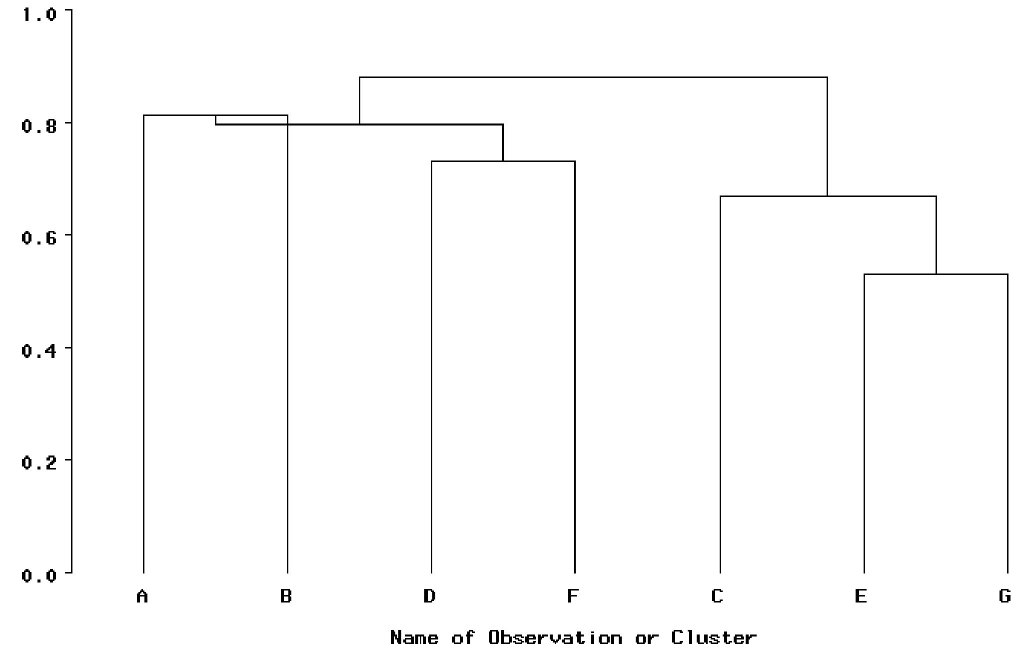

Figure 5.1.1: Clustering of regions based on spring barley yield when treated with fungicide.

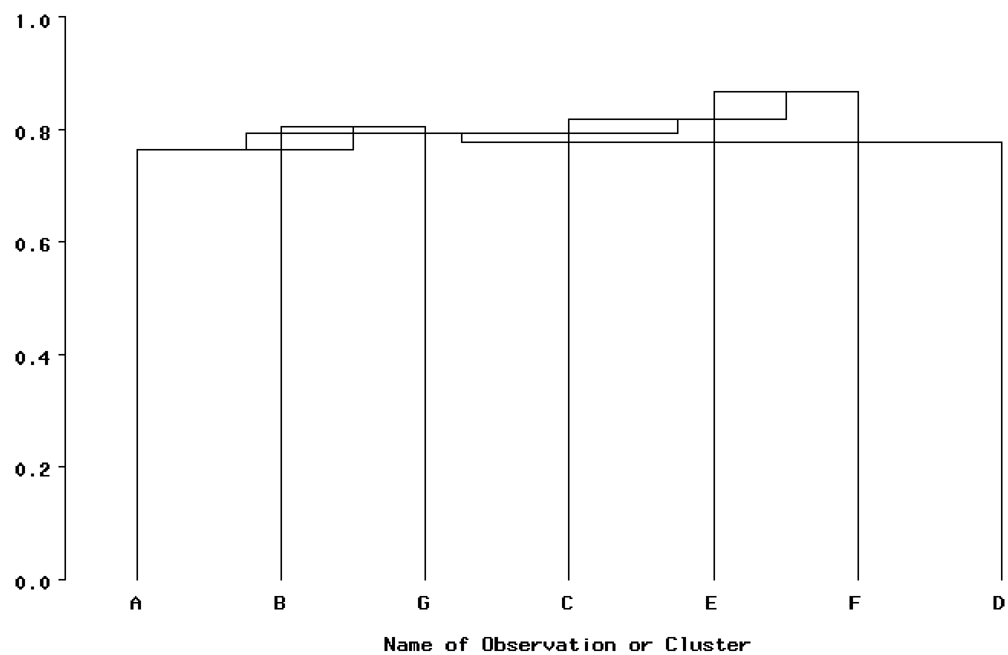

Figure 5.1.2: Clustering of regions based on log ratio when treated with fungicide.

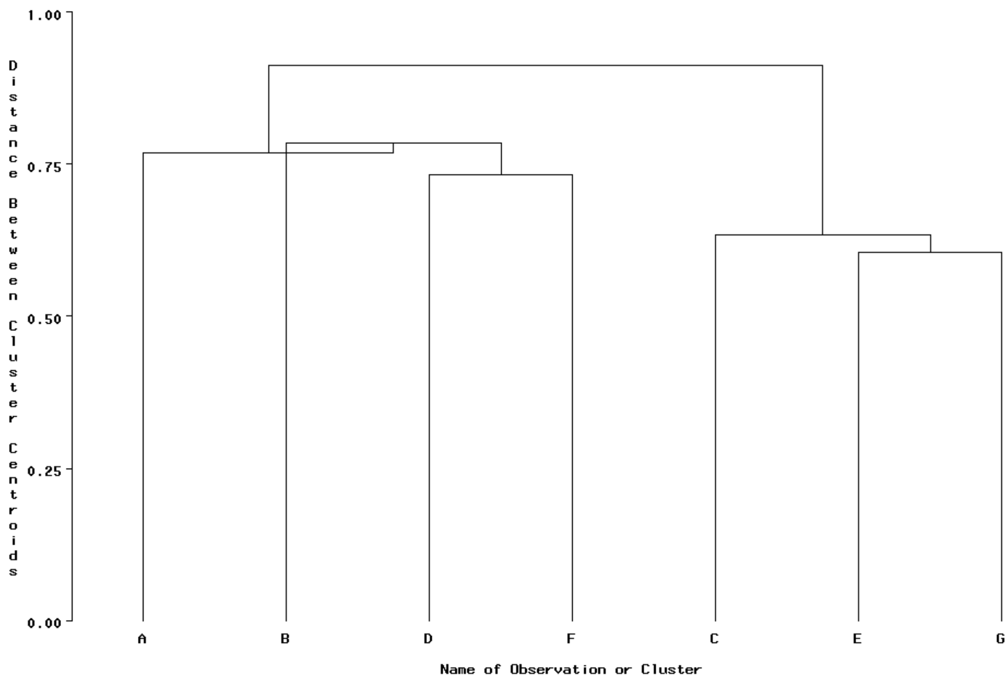

Figure 5.1.3: Clustering of regions based on spring barley yield when not treated with fungicide.

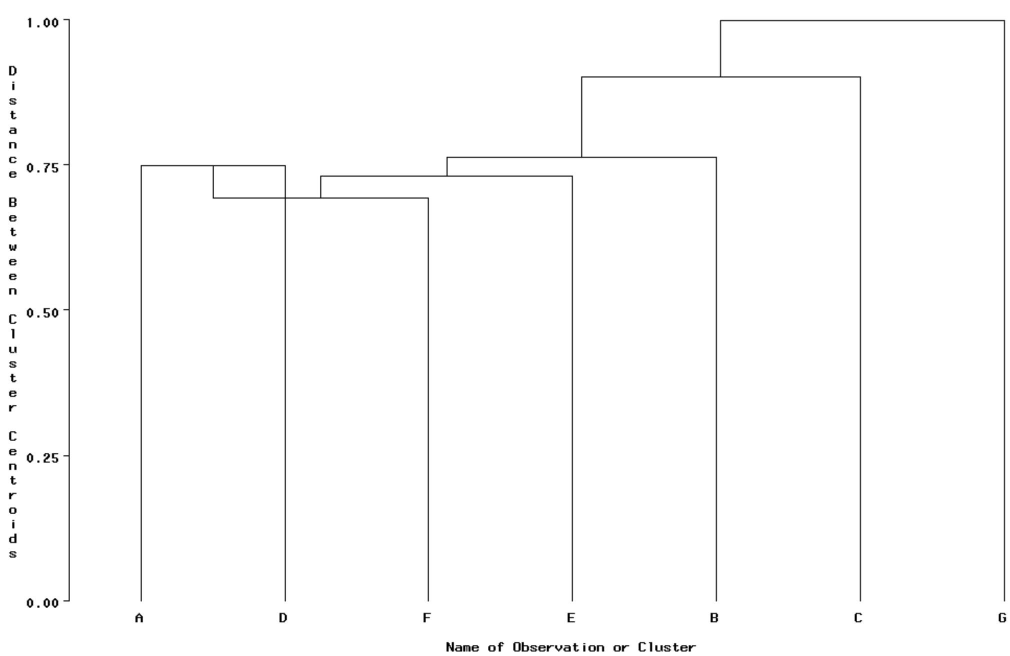

Figure 5.1.4: Clustering of regions based on log ratio when not treated with fungicide.

5.1.2 Clustering of districts

The data set included no spring barley trials from districts 10a, 13d, 13g, 13h, 14a, 17, 18b and 18c. Furthermore, it was not possible to include districts 12c, 14b, 15c and 18a in the cluster analyses of the districts, because an insufficient number of varieties had been trialled in these districts. Inclusion of these districts would have yielded a distance matrix with missing values. Few variety trials with spring barley were conducted in the excluded districts.

According to Figure 5.1.5, two clusters of districts, each giving homogeneous levels of spring barley yield on fungicide-treated plots, could be formed: {1a, 1b, 1c, 2, 3, 4a, 4b, 7, 12a, 12b} and {5, 6, 8, 9, 10b, 10c, 11, 13a, 13b, 13c, 13e, 13f, 15a, 15f, 16a, 16b}. The first of these clusters includes districts in Skåne, Halland and Östergötland. On untreated plots, almost the same two clusters appear, the only difference being the classification of district 6 (Figure 5.1.7). No clear clusters were obtained in the analyses of log ratios (Figures 5.1.6 and 5.1.8). On fungicide-treated plots, district 16b (north of Vänern) produced unusual ratios in yield between varieties (Figure 5.1.6). On untreated plots, districts 5, 13f and 16b showed different ratios than the other districts.

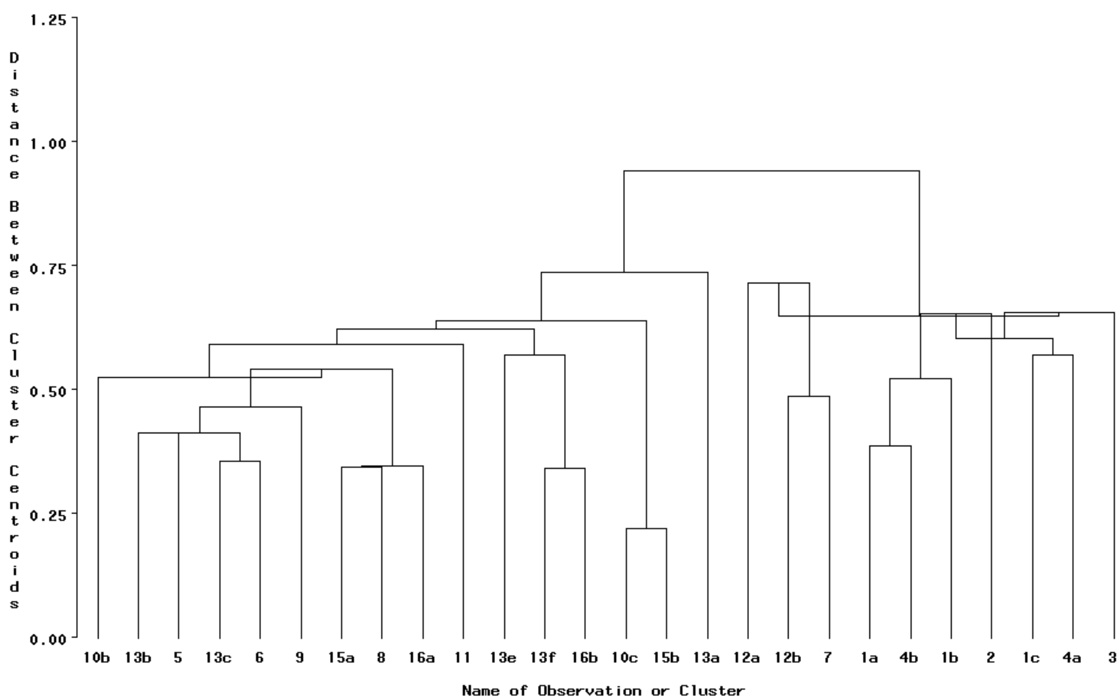

Figure 5.1.5: Clustering of districts based on spring barley yield when treated with fungicide.

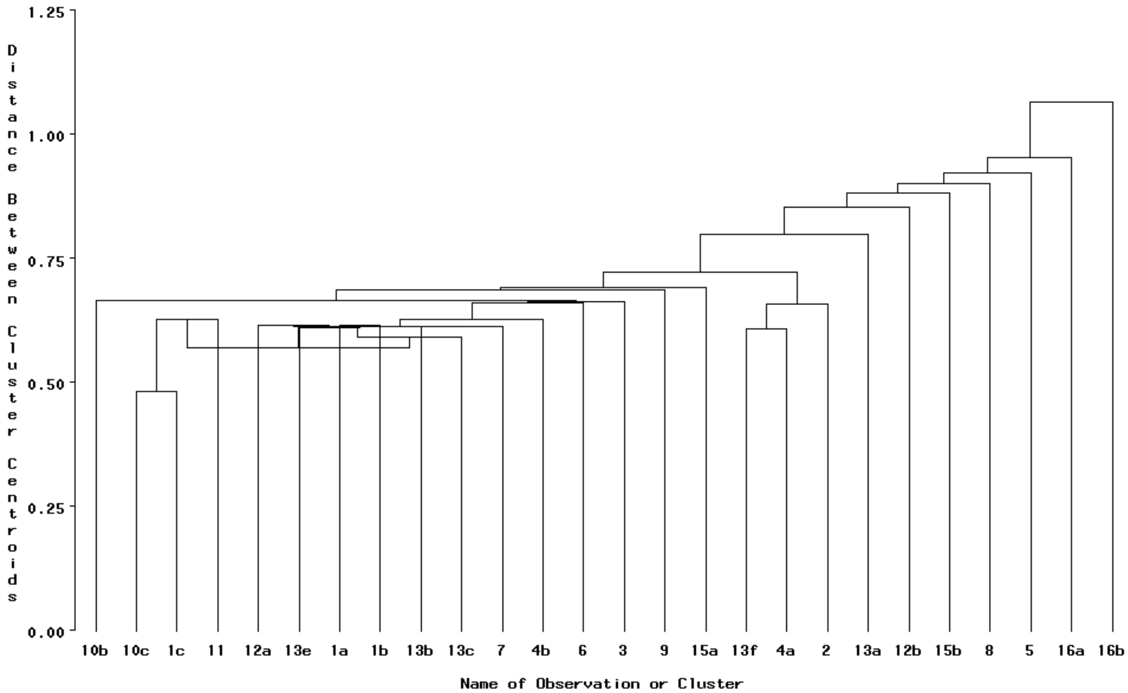

Figure 5.1.6: Clustering of districts based on log ratio when treated with fungicide.

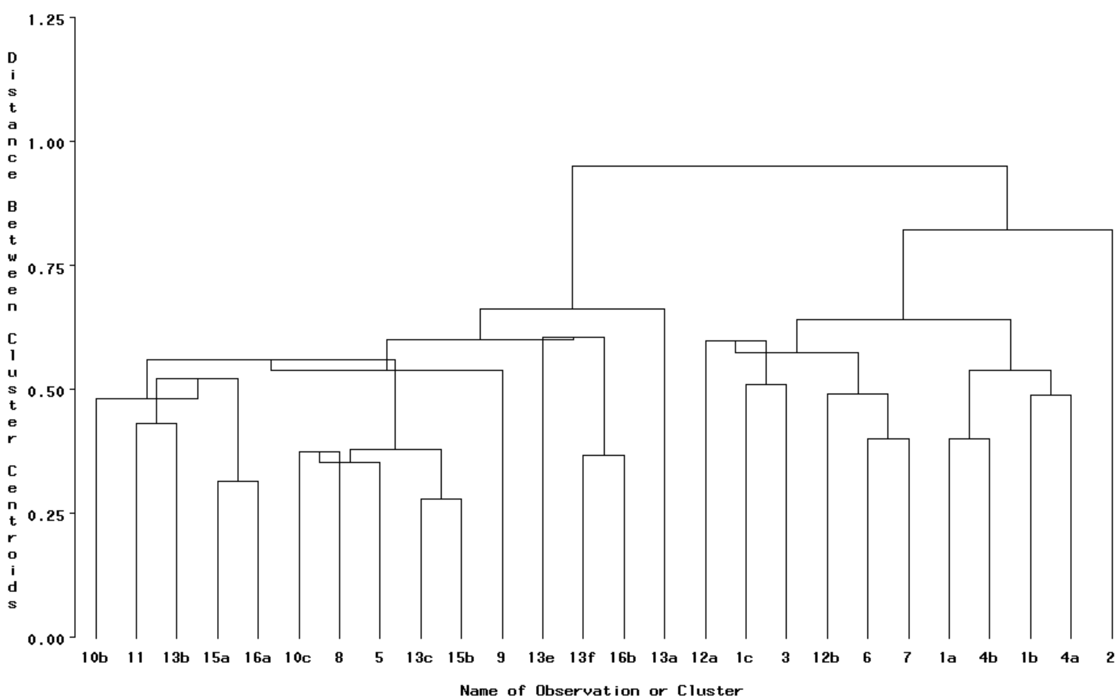

Figure 5.1.7: Clustering of districts based on spring barley yield when not treated with fungicide.

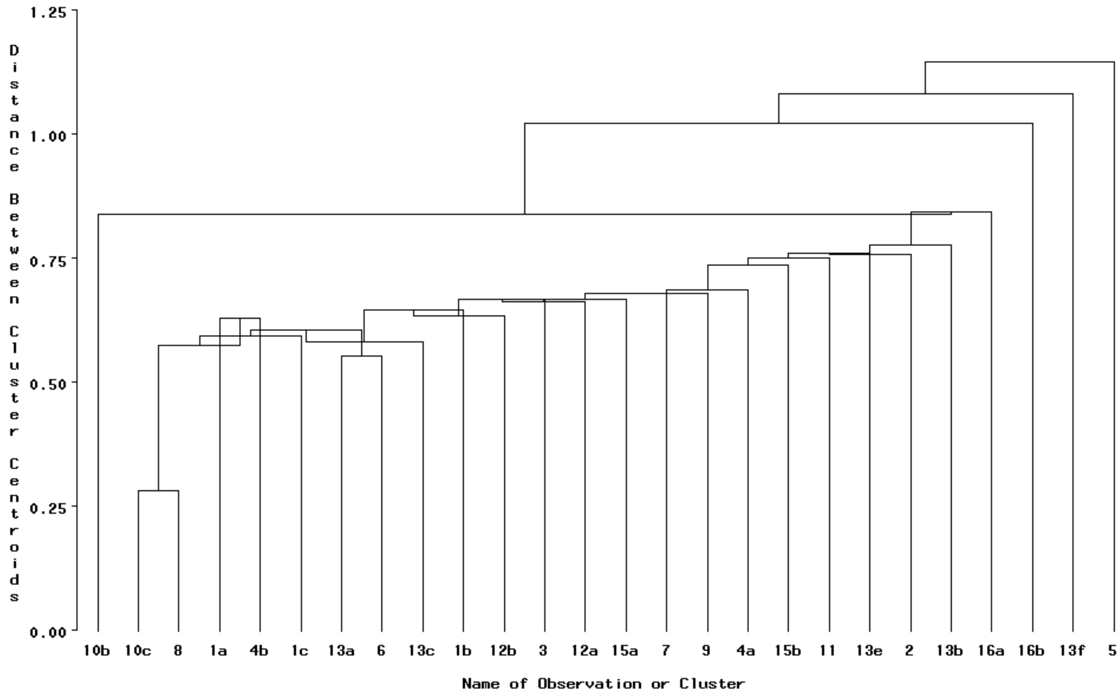

Figure 5.1.8: Clustering of districts based on log ratio when not treated with fungicide.

5.1.3 Clustering of soil types

Loam (LL) and sand (Sa) produced similar levels of yield on fungicide-treated and untreated plots (Figures 5.1.9 and 5.1.11). Organic soil (M) and heavy clay (SL) showed similar yields on fungicide-treated plots (Figure 5.1.9), as did clay loam (ML), heavy clay (SL) and fine silt (Mj) on untreated plots (Figure 5.1.11).

No pair of soil types showed notably more similar log ratios than any other pair of soil types in trials with plots treated with fungicide (Figure 5.1.10). Organic soil (M) produced differing levels of yield and differing log ratios on untreated plots (Figures 5.1.11 and 5.1.12, respectively).

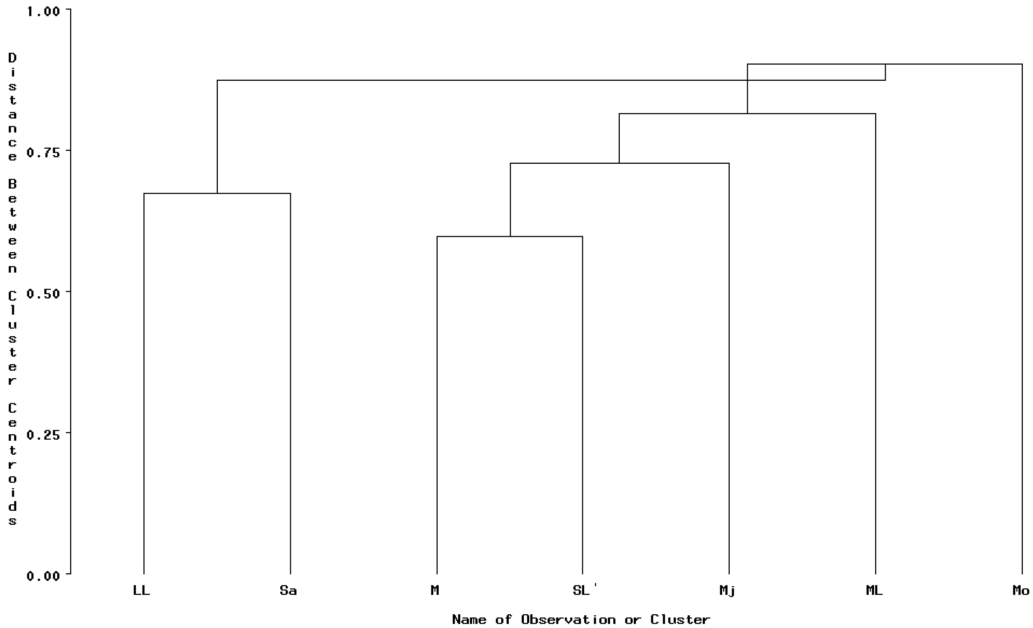

Figure 5.1.9: Clustering of soil types based on spring barley yield when treated with fungicide.

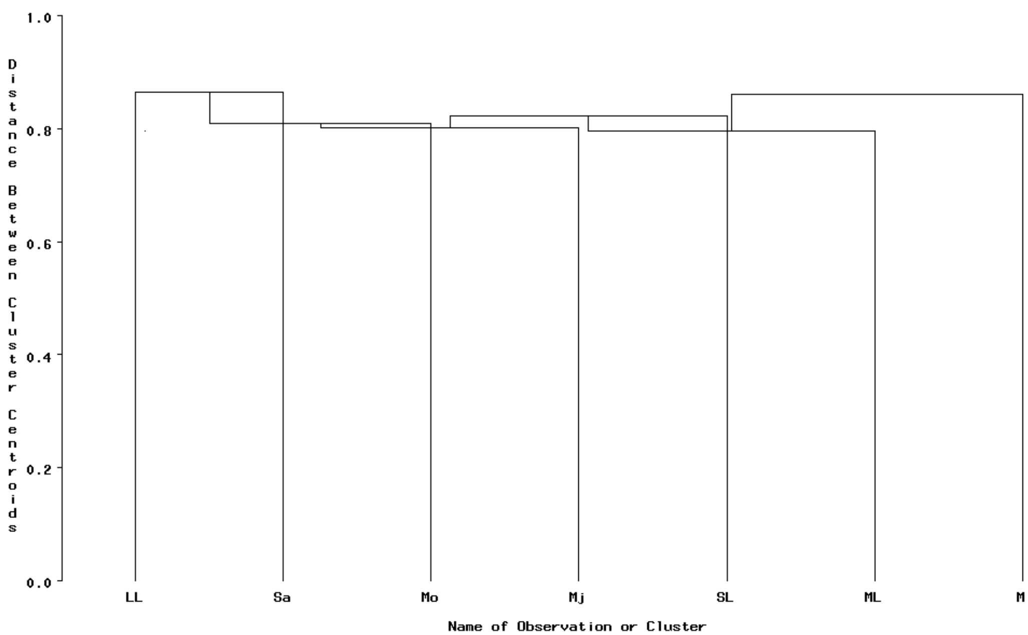

Figure 5.1.10: Clustering of soil types based on log ratio when treated with fungicide.

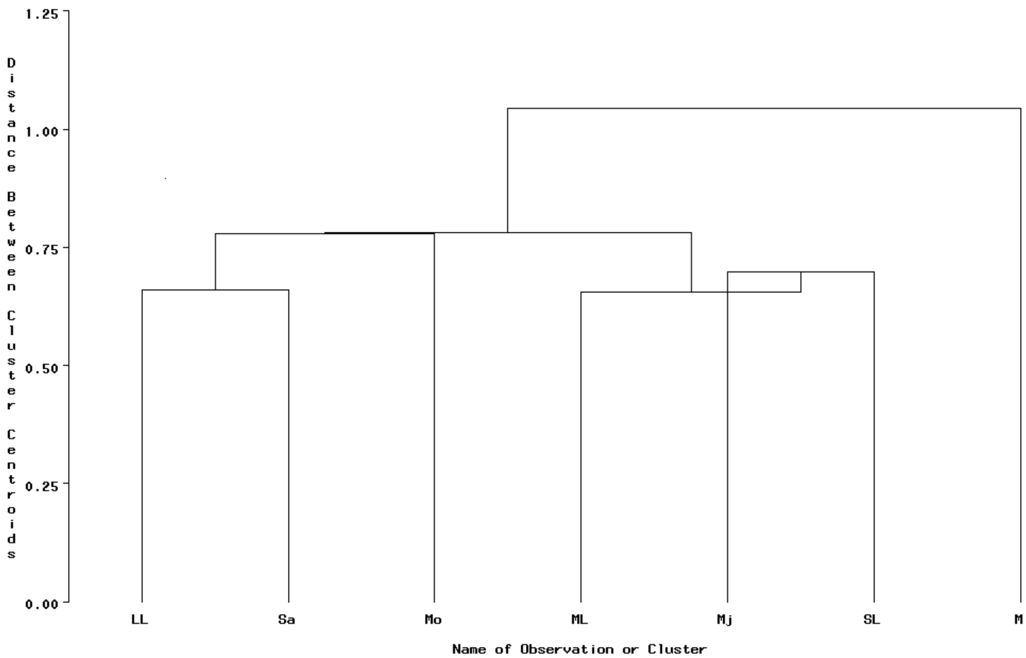

Figure 5.1.11: Clustering of soil types based on spring barley yield when not treated with fungicide.

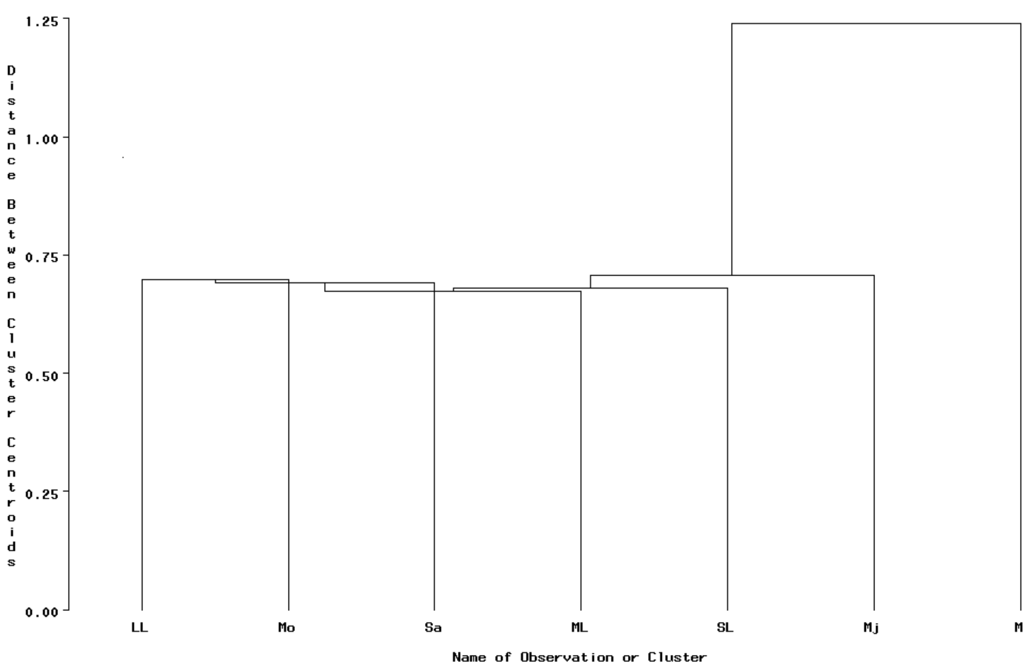

Figure 5.1.12: Clustering of soil types based on log ratio when not treated with fungicide.

5.2 Winter wheat

5.2.1 Clustering of regions

Regions C and E gave the most similar levels of winter wheat yield, although regions A and B also produced similar levels (Figures 5.2.1 and 5.2.3). Furthermore, regions A and B produced similar ratios between varieties on fungicide-treated plots (Figure 5.2.2), as well as on untreated plots (Figure 5.2.4). The cluster analyses on log ratios also suggest clustering of regions F and G (Figures 5.2.2 and 5.2.4).

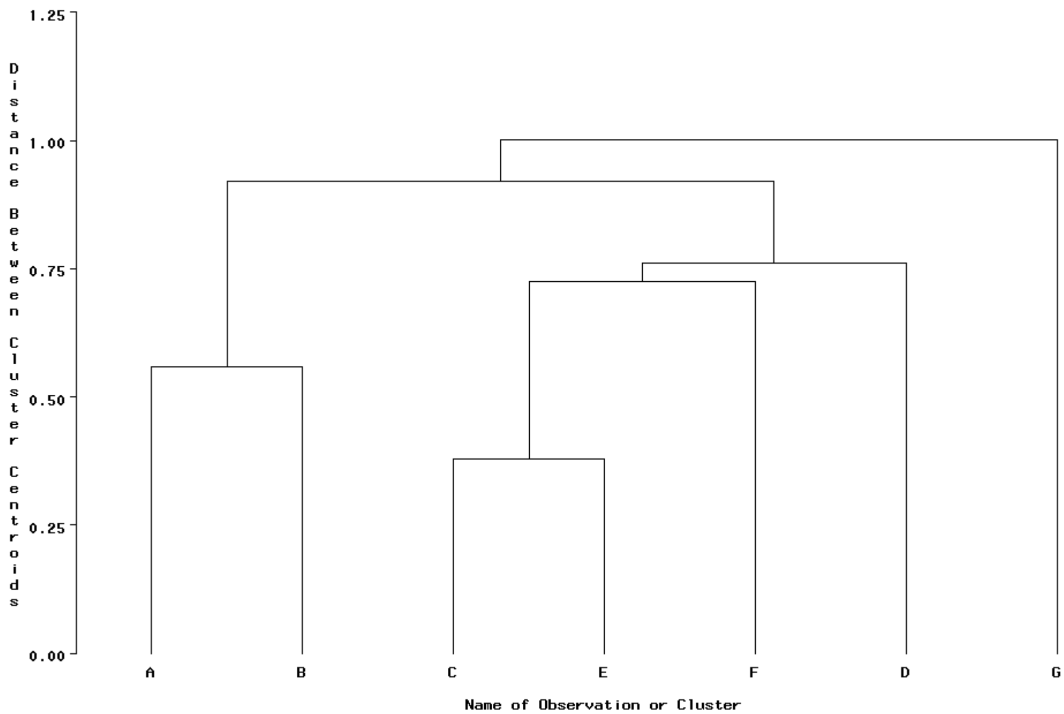

Figure 5.2.1: Clustering of regions based on winter wheat yield when treated with fungicide.

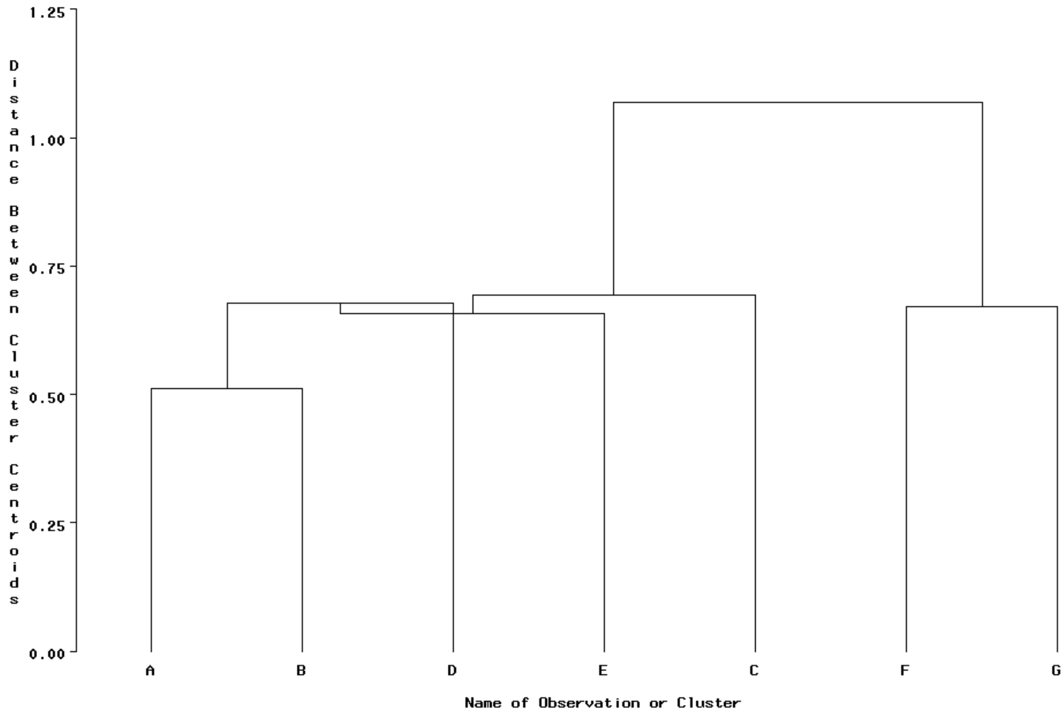

Figure 5.2.2: Clustering of regions based on log ratio when treated with fungicide.

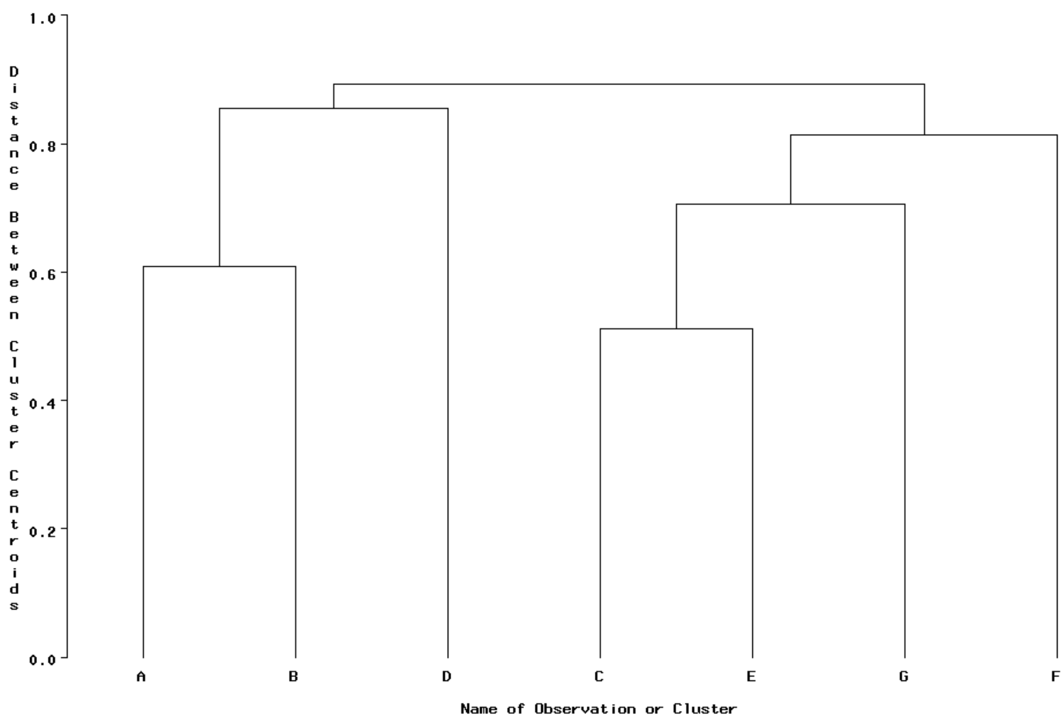

Figure 5.2.3: Clustering of regions based on winter wheat yield when not treated with fungicide.

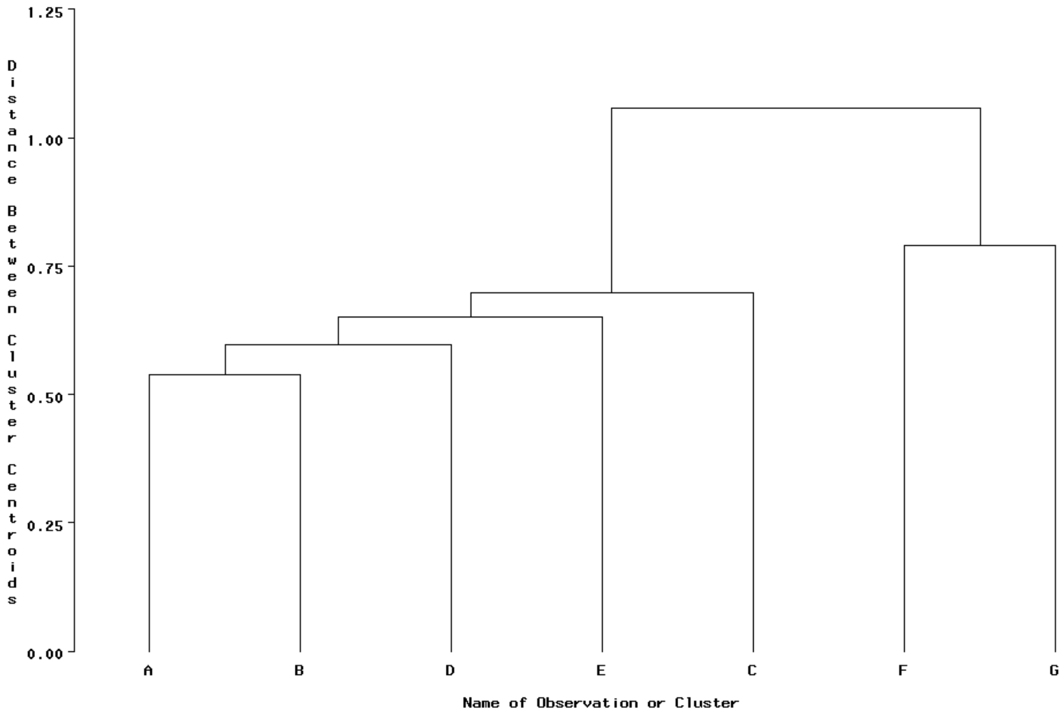

Figure 5.2.4: Clustering of regions based on log ratio when not treated with fungicide.

5.2.2 Clustering of districts

For winter wheat, it was not possible to include districts 4b, 10b, 10c, 12a, 12c, 13g and 15b in the cluster analyses of the districts. Few trials with winter wheat were performed in districts 10b, 10c, 12a, 12c, 12e and 13g. Different varieties were trialled in districts 4b and 4a, in districts 4b and 1c, and in districts 15b and 15c, making it impossible to measure the distance (i.e. the degree of similarity) between these districts. The data set included no data from districts 10a, 13d, 13f, 13h, 14a, 17, 18a, 18b and 18c.

It is not easy to distinguish any distinct set of clusters in Figures 5.2.5-5.2.8. However, some interesting observations can be made. In the cluster analysis presented in Figure 5.2.5, district 13e, which belongs to regions F and G, was merged together with the districts 1a, 1b, 2, 4a, all located in Skåne, indicating that 13e gives similar levels of yield as 1a, 1b, 2 and 4a when treated with fungicide. In Figure 5.2.6, it can be noted that districts giving dissimilar log ratios on fungicide-treated plots, namely districts 8, 13a, 13c, 14b, 16a and 16b, are all located close to water and on approximately the same latitude.

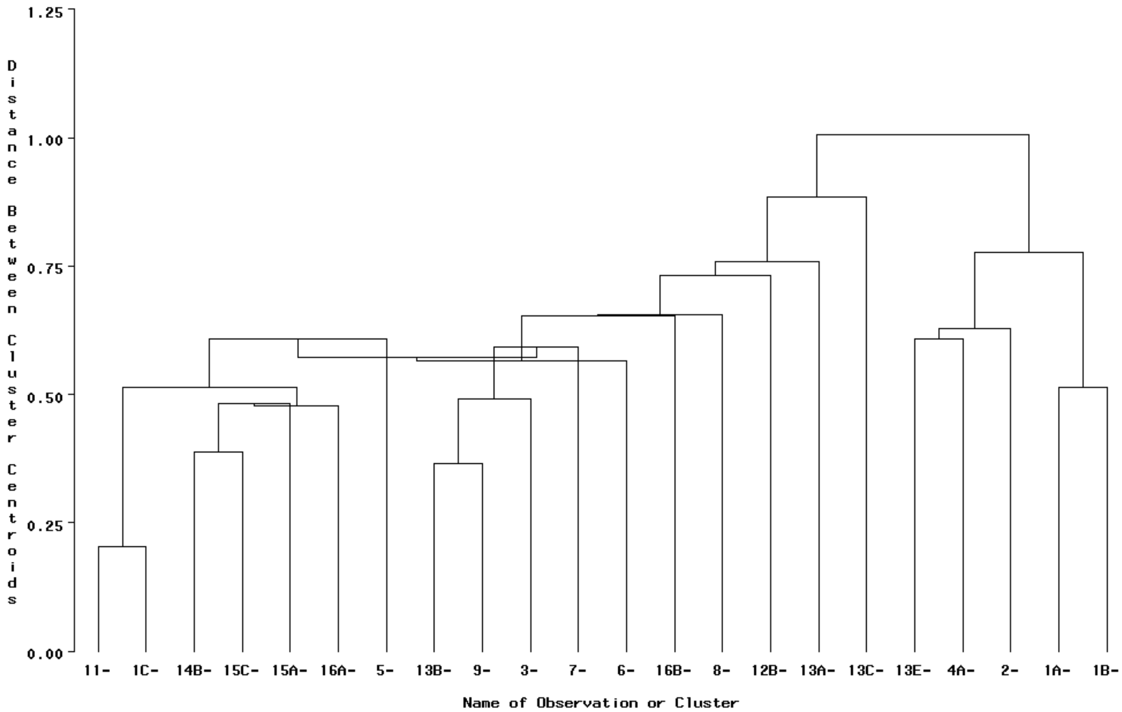

Figure 5.2.5: Clustering of districts based on winter wheat yield when treated with fungicide.

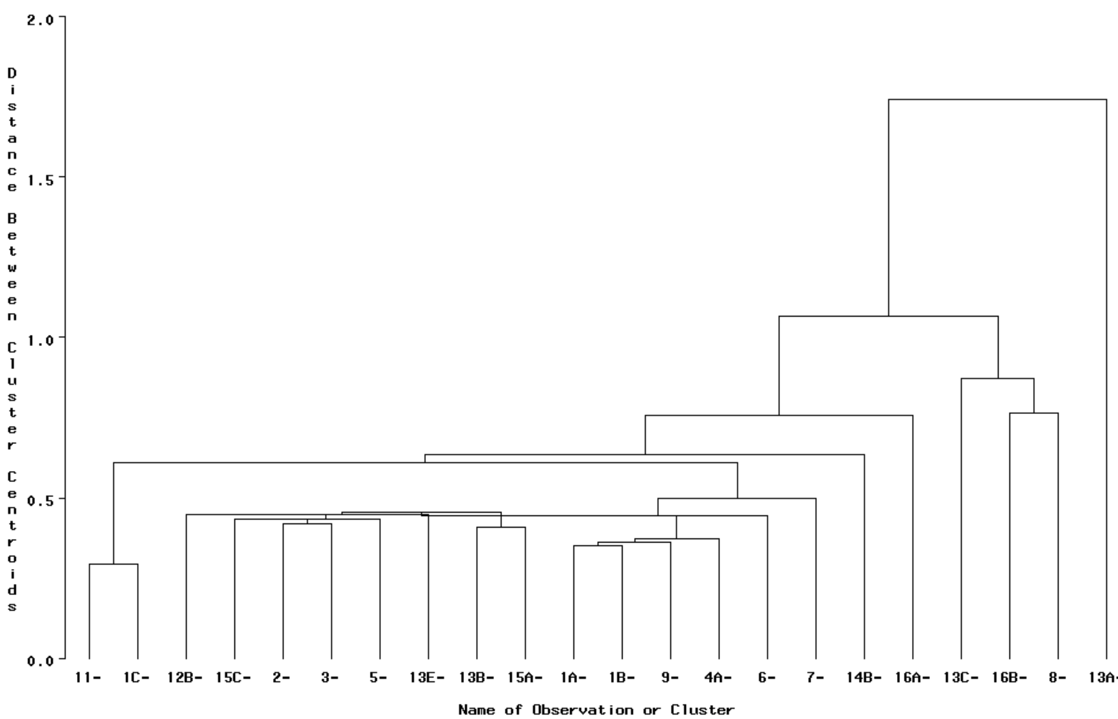

Figure 5.2.6: Clustering of districts based on log ratio when treated with fungicide.

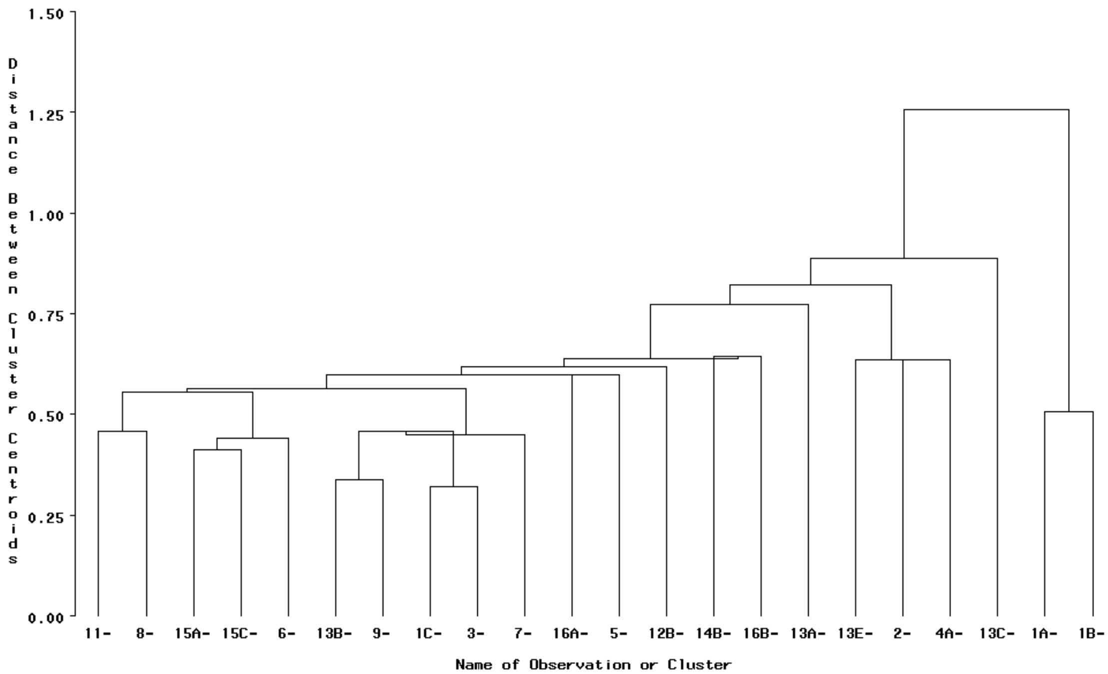

Figure 5.2.7: Clustering of districts based on winter wheat yield when not treated with fungicide.

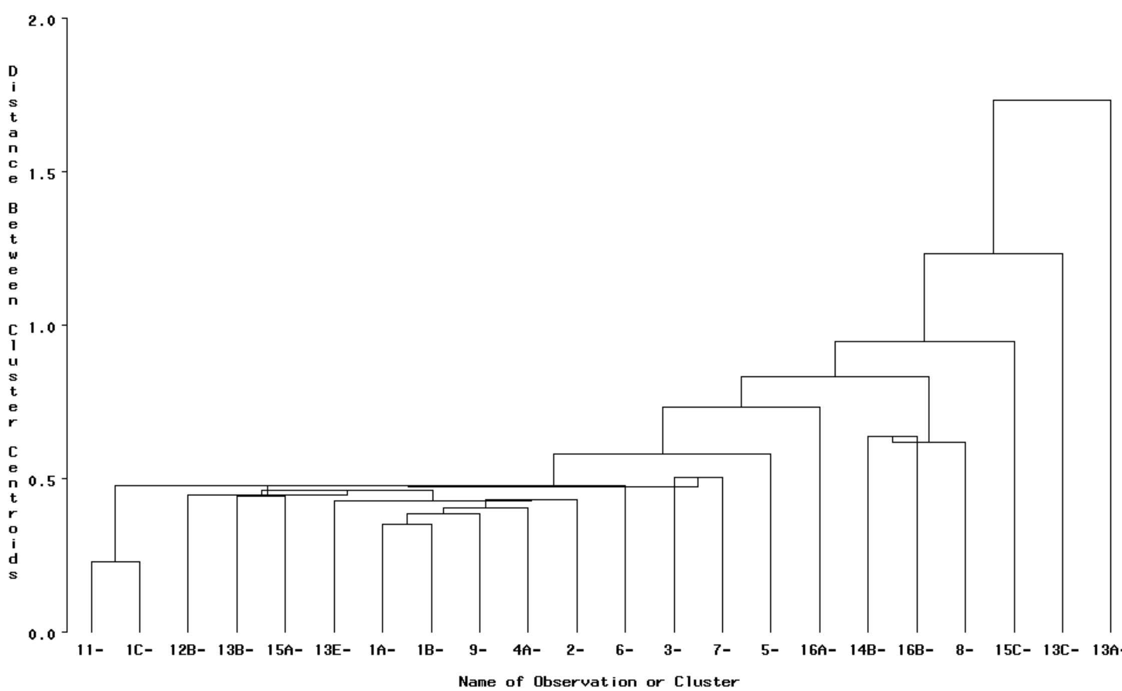

Figure 5.2.8: Clustering of districts based on log ratio when not treated with fungicide.

5.2.3 Clustering of soil types

Few trials were performed on the organic soil type (M) and it was necessary to exclude those trials in order to get a complete distance matrix.

Clay loam (ML) and fine silt (Mj) produced the most similar levels of winter wheat yield, while the yields of the trials performed on sand (Sa) differed from those of the trials with other soil types (Figures 5.2.9 and 5.2.11). In contrast, when analysing log ratios on untreated plots, sand (Sa) and fine silt (Mj) were the most similar soil types (Figure 5.2.12). On fungicide-treated plots, loam (LL) and fine silt (Mj) produced the most similar log ratios (Figure 5.2.10).

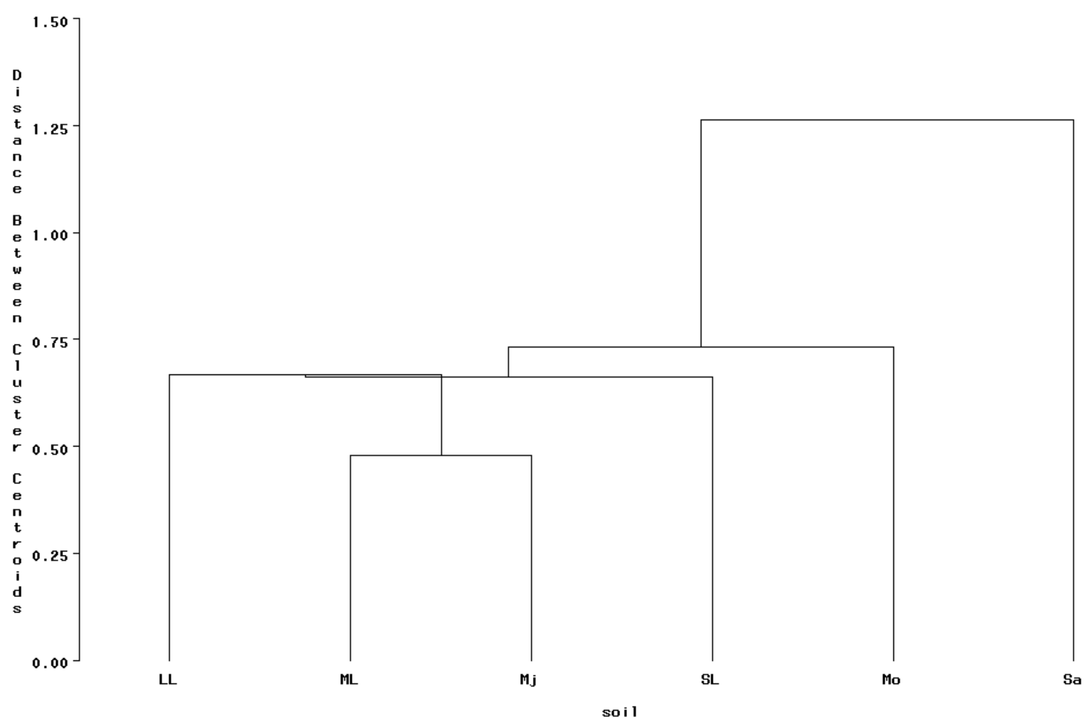

Figure 5.2.9: Clustering of soil types based on winter wheat yield when treated with fungicide.

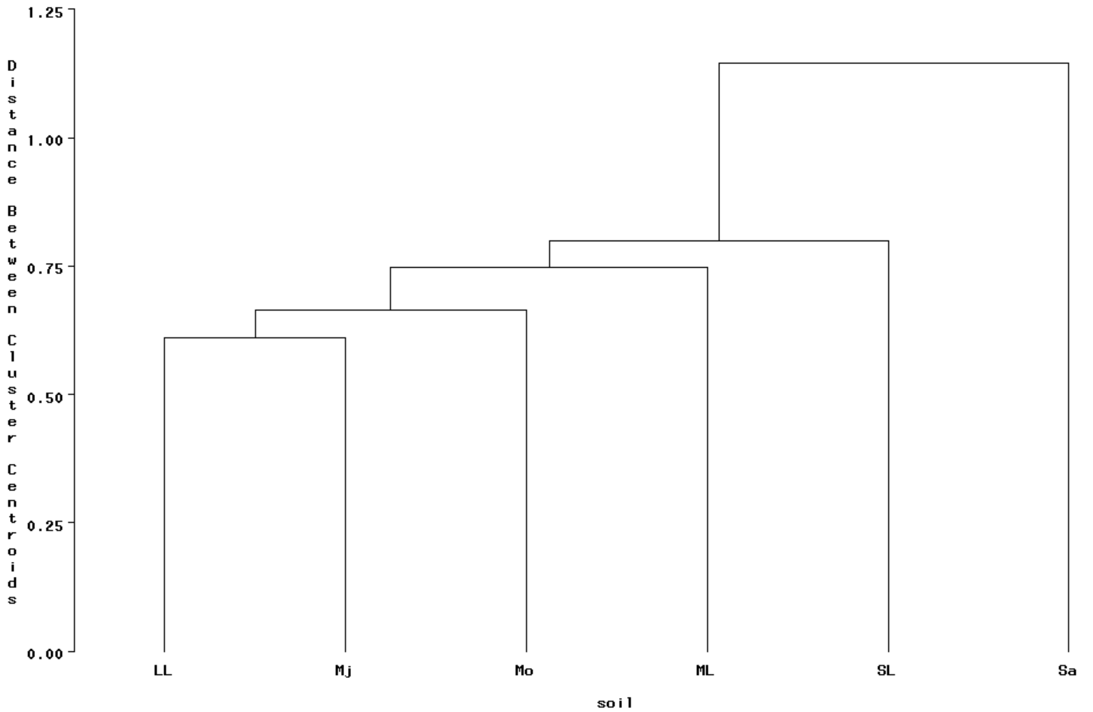

Figure 5.2.10: Clustering of soil types based on log ratio when treated with fungicide.

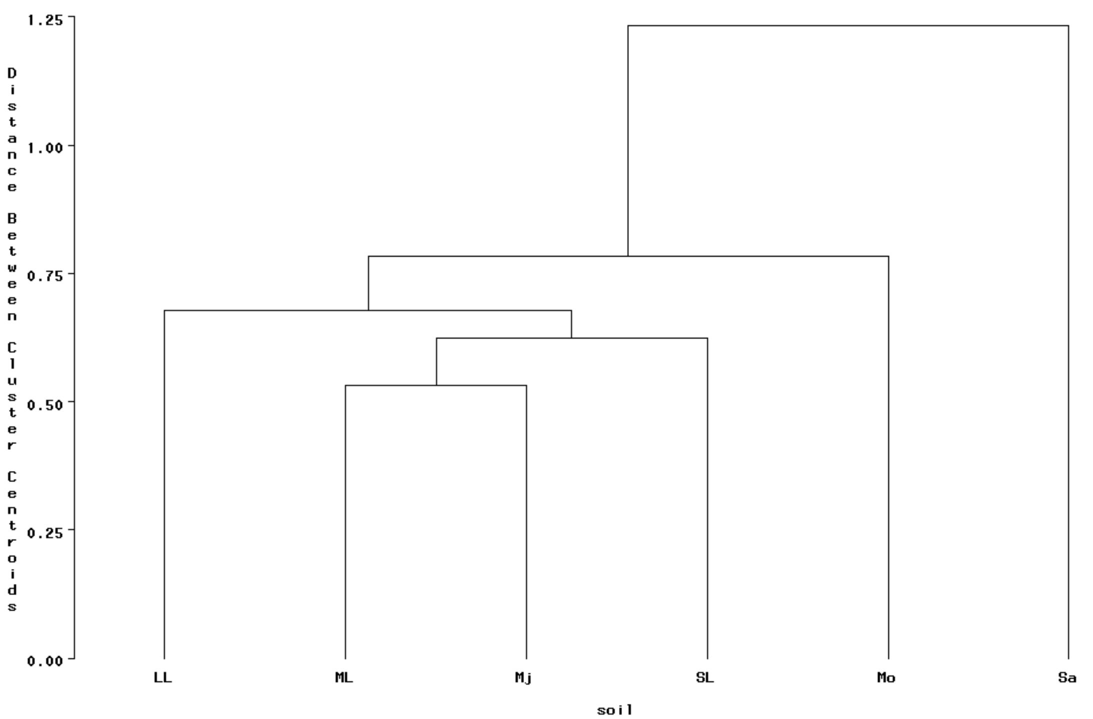

Figure 5.2.11: Clustering of soil types based on winter wheat yield when not treated with fungicide.

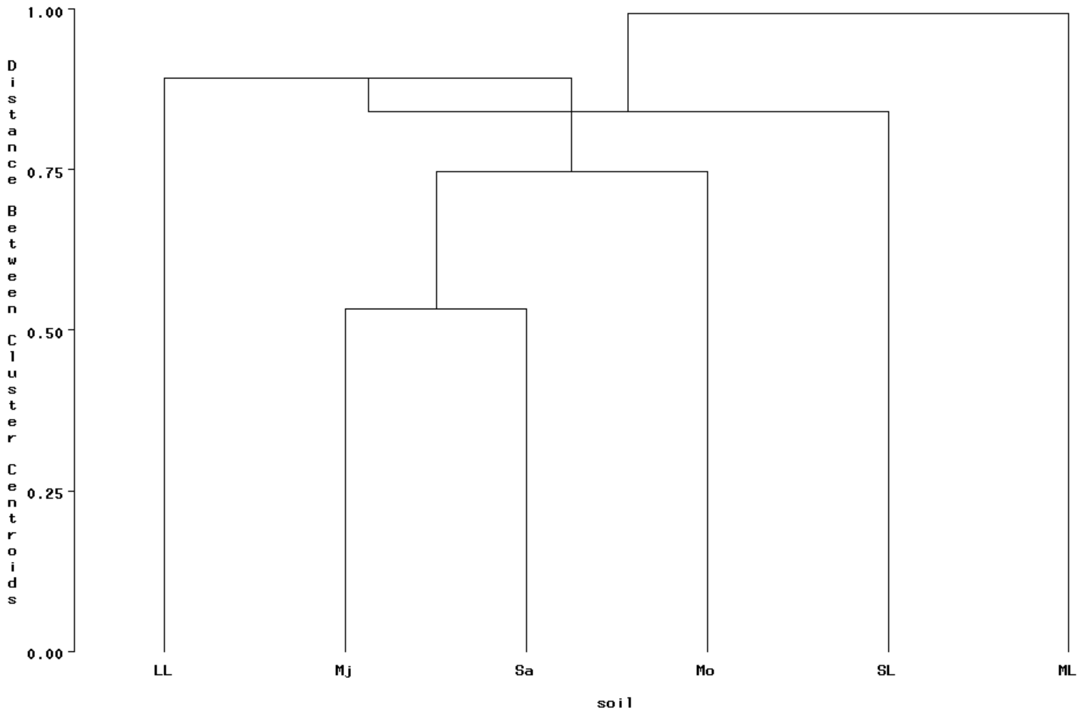

Figure 5.2.12: Clustering of soil types based on log ratio when not treated with fungicide.

<u>*5.3 Oats*</u>

5.3.1 Clustering of regions

In fungicide-treated as well as untreated trials, regions A, B and D produced similar levels of yield, as did regions C, E and G. The yields obtained in region F were more similar to the yields obtained in {C, E, G} than to the yields obtained in {A, B, D} (Figures 5.3.1 and 5.3.3). Differences and similarities in log ratios were less distinct (Figures 5.3.2 and 5.3.4).

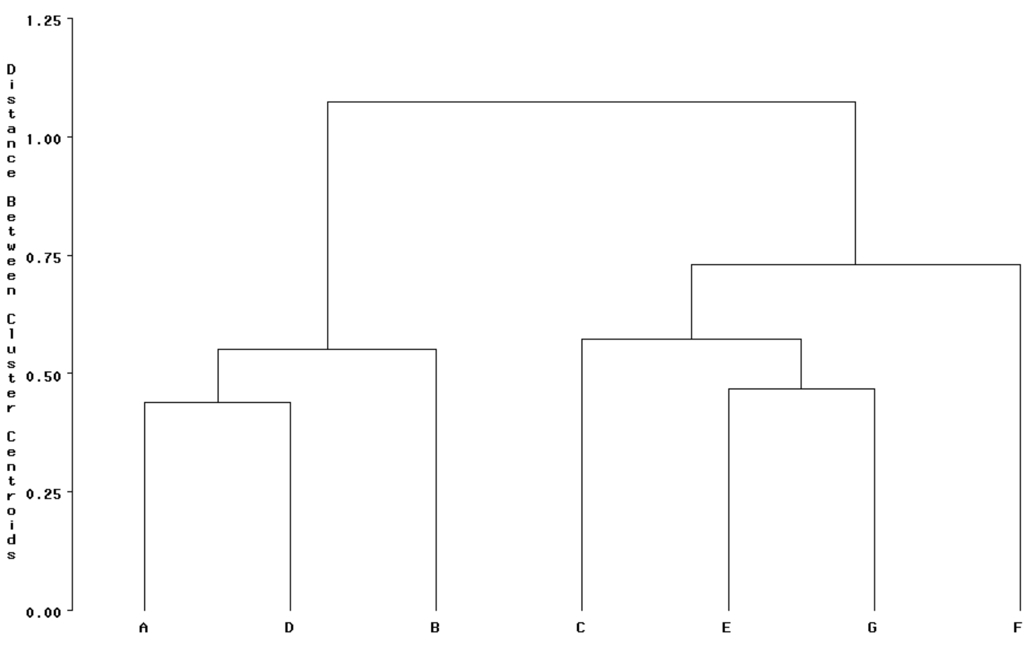

Figure 5.3.1: Clustering of regions based on oat yield when treated with fungicide.

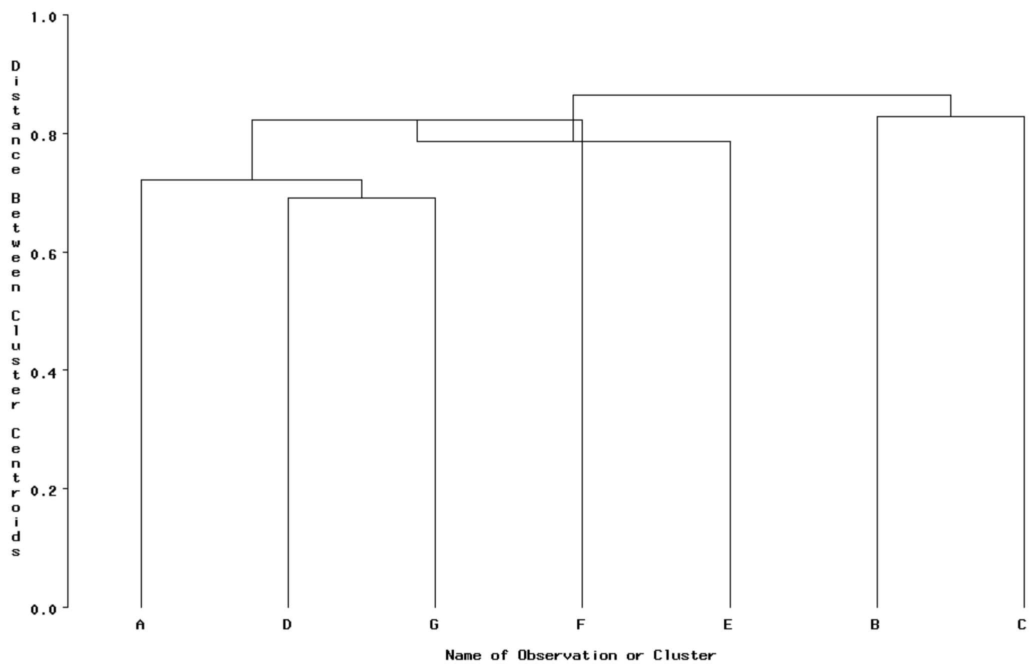

Figure 5.3.2: Clustering of regions based on log ratio when treated with fungicide.

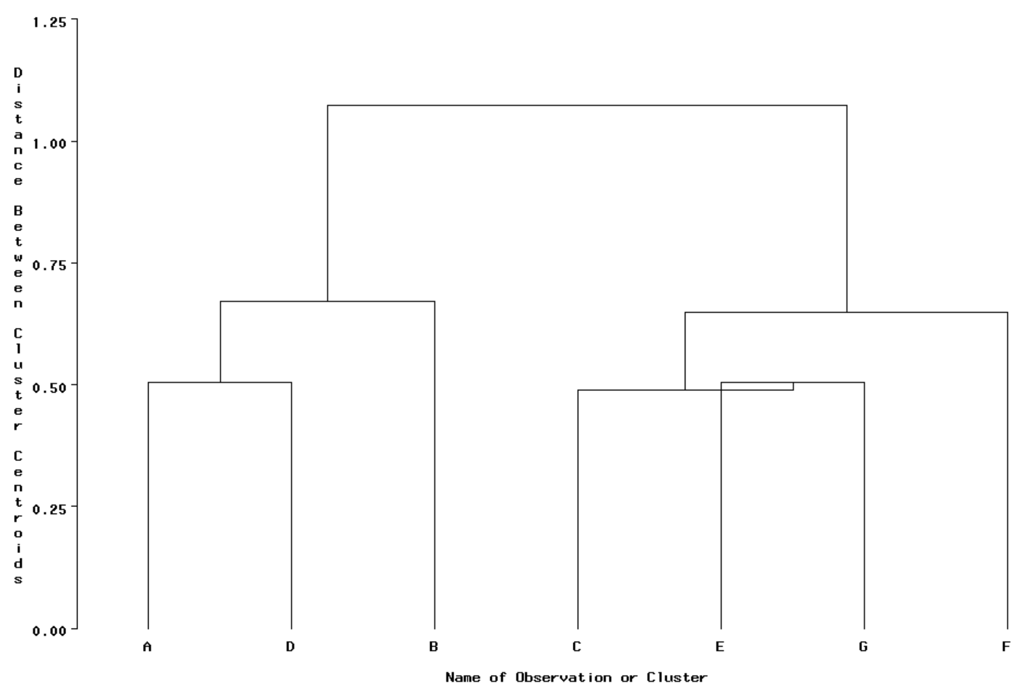

Figure 5.3.3: Clustering of regions based on oat yield when not treated with fungicide.

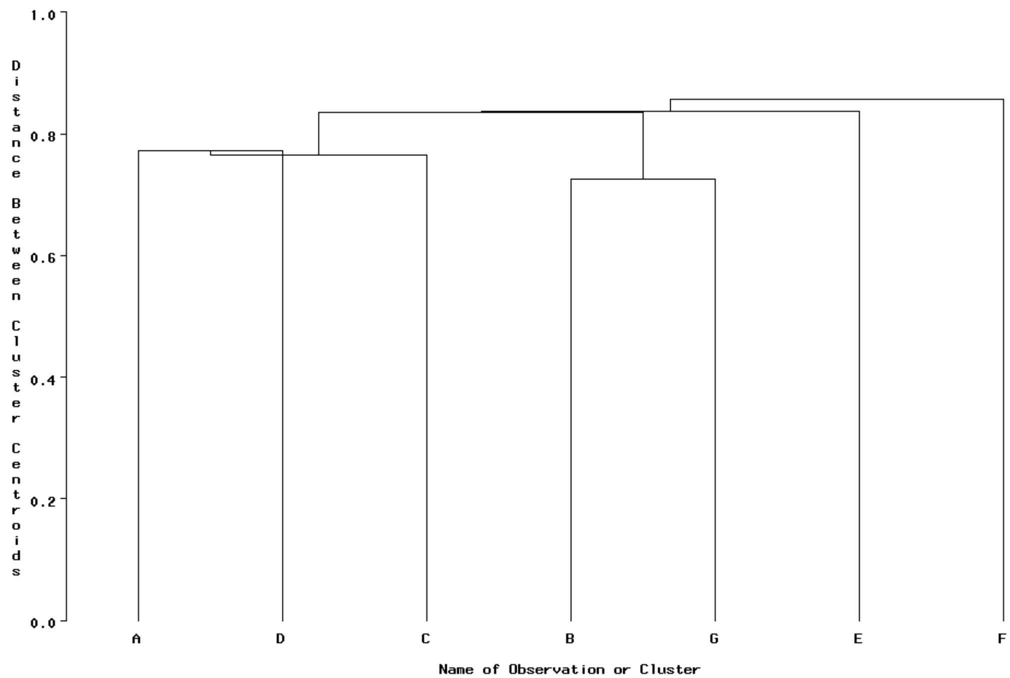

Figure 5.3.4: Clustering of regions based on log ratio when not treated with fungicide.

5.3.2 Clustering of districts

For oats, it was not possible to include districts 3, 4b, 5, 6, 7, 8, 9, 12c, 13b, 14a, 15c and 18a in the cluster analyses of the districts, as an insufficient number of varieties had been trialled in these districts and their inclusion would have yielded a distance matrix with missing values. In most of the excluded districts, few trials had been performed. Different varieties than those trialled in district 7 were trialled in districts 10c, 13f, 1a and 4b, while different varieties than those trialled in district 8 were trialled in districts 11, 12b and 7. No data were available from districts 10a, 12a, 12c, 13d, 13g, 13h, 15b, 17, 18b and 18c.

The cluster analyses on oat yield suggest the following five clusters for fungicide-treated trials: {1c, 2, 10b}, {10c, 13f, 16b}, {11, 13a, 13e, 14b, 15a, 16a}, {13c} and {1a, 1b, 4a, 12b} (Figure 5.3.5). The three middle clusters could possibly be merged into one, producing a total of three clusters. Districts 10b and 10c produced similar yields on untreated plots, as did districts 1a, 1b, 1c, 4a and 12b (Figure 5.3.7). Although Figures 5.3.6 and 5.3.8 reveal that some pairs of districts produced more similar ratios in variety yields than others, the districts could not be categorised into any distinct set of clusters.

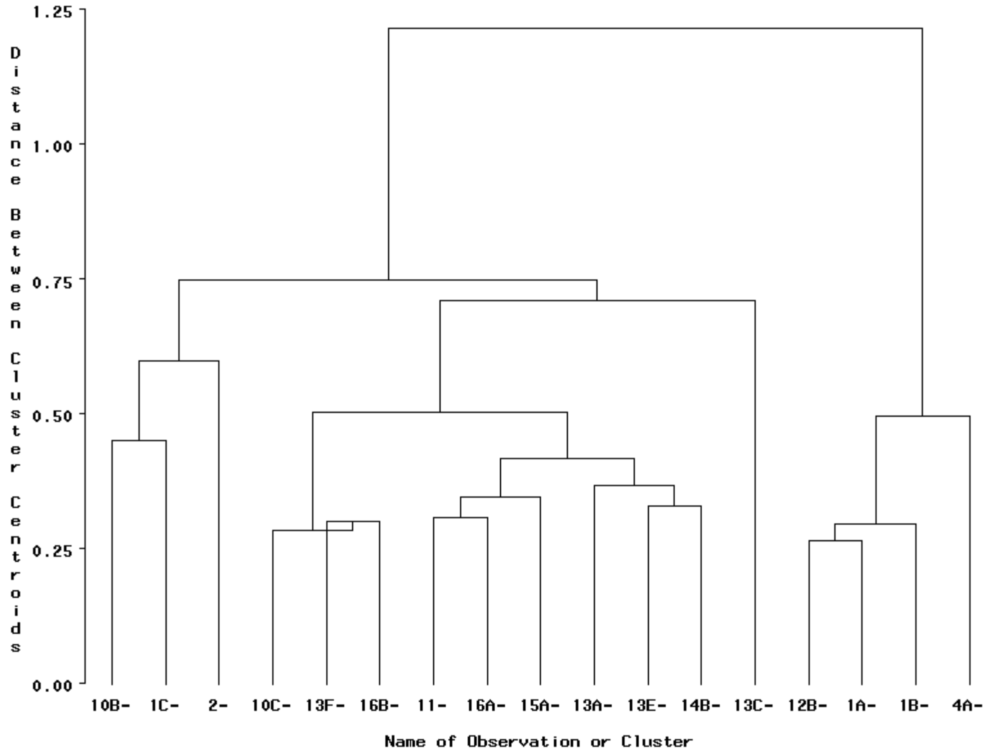

Figure 5.3.5: Clustering of districts based on oat yield when treated with fungicide.

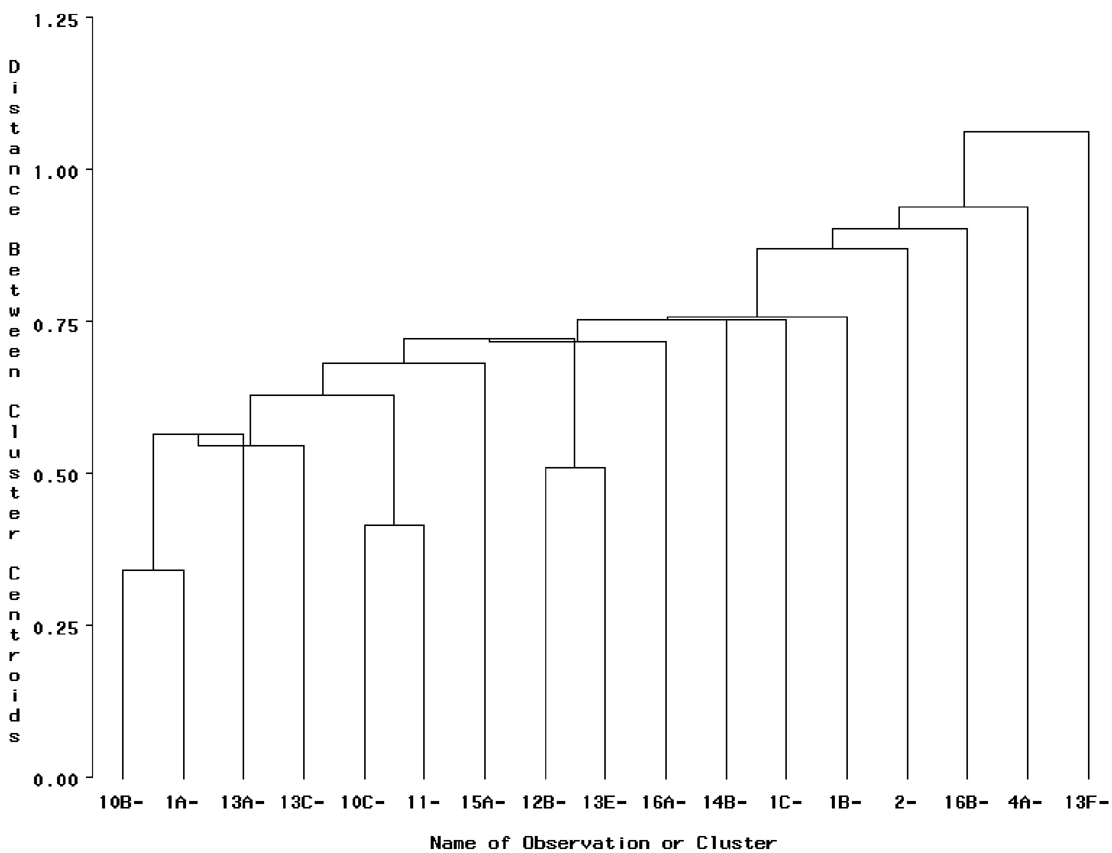

Figure 5.3.6: Clustering of districts based on log ratio when treated with fungicide.

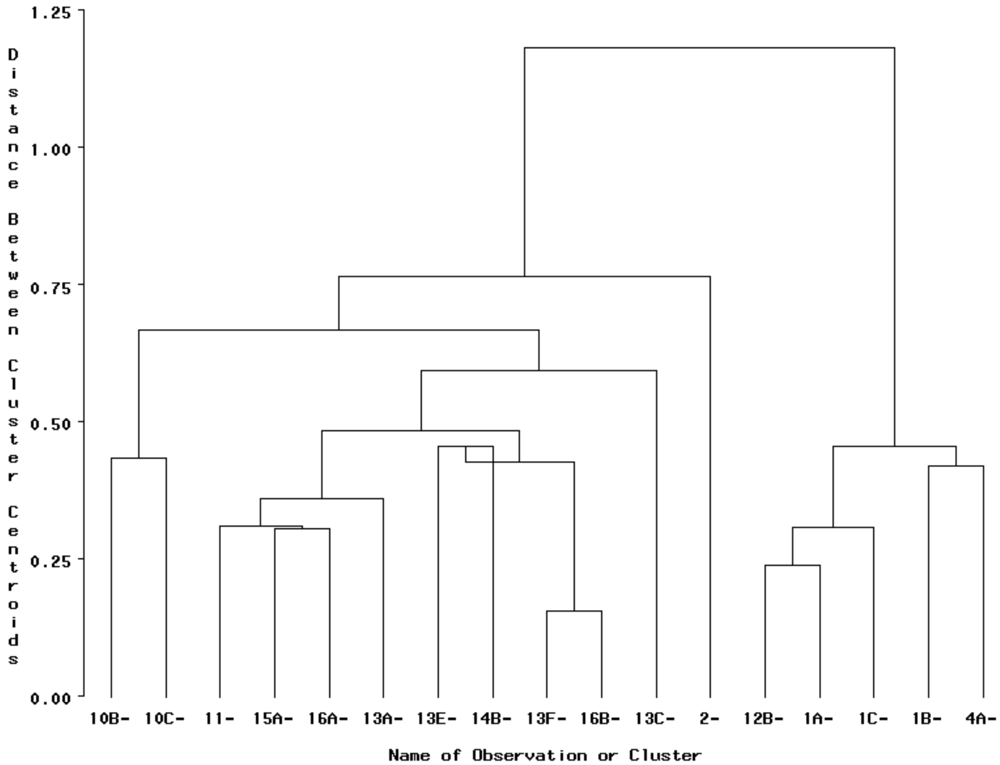

Figure 5.3.7: Clustering of districts based on oat yield when not treated with fungicide.

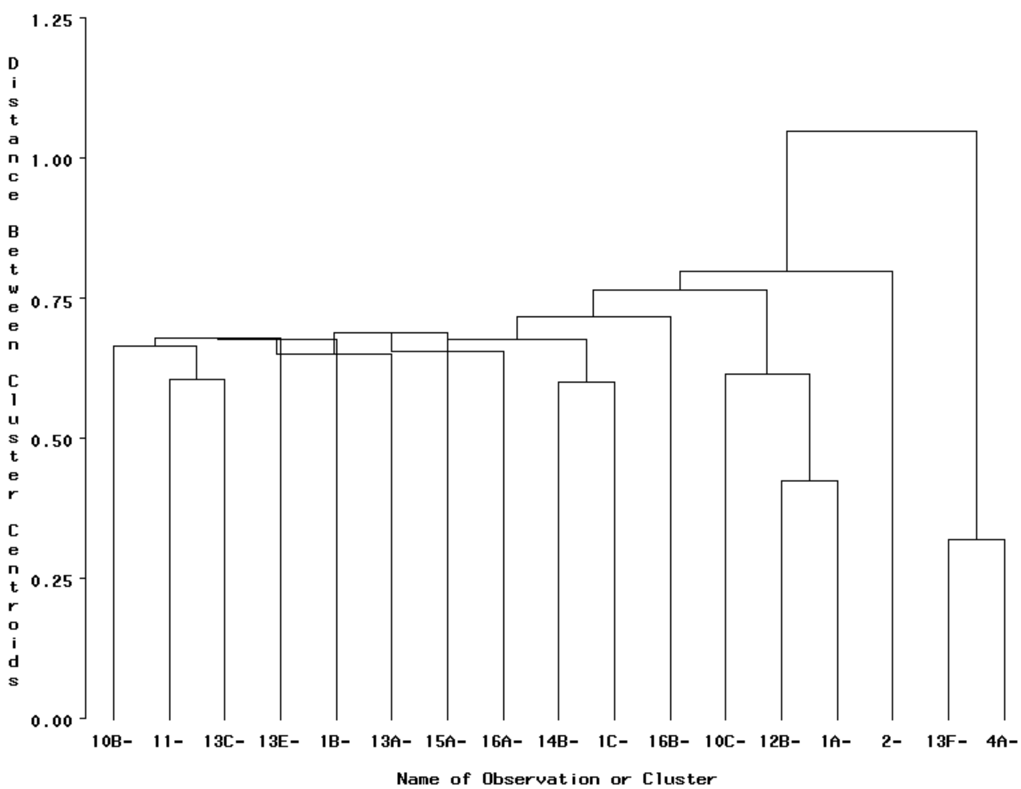

Figure 5.3.8: Clustering of districts based on log ratio when not treated with fungicide.

5.3.3 Clustering of soil types

The organic soil type (M) was missing from the data set. No clear clustering of soil types was obtained when studying yield (Figures 5.3.9 and 5.3.11). Clay loam (ML), sand (Sa) and fine silt (Mj) produced similar ratios between varieties on fungicide-treated plots (Figure 5.3.10), as well as on untreated plots (Figure 5.3.12).

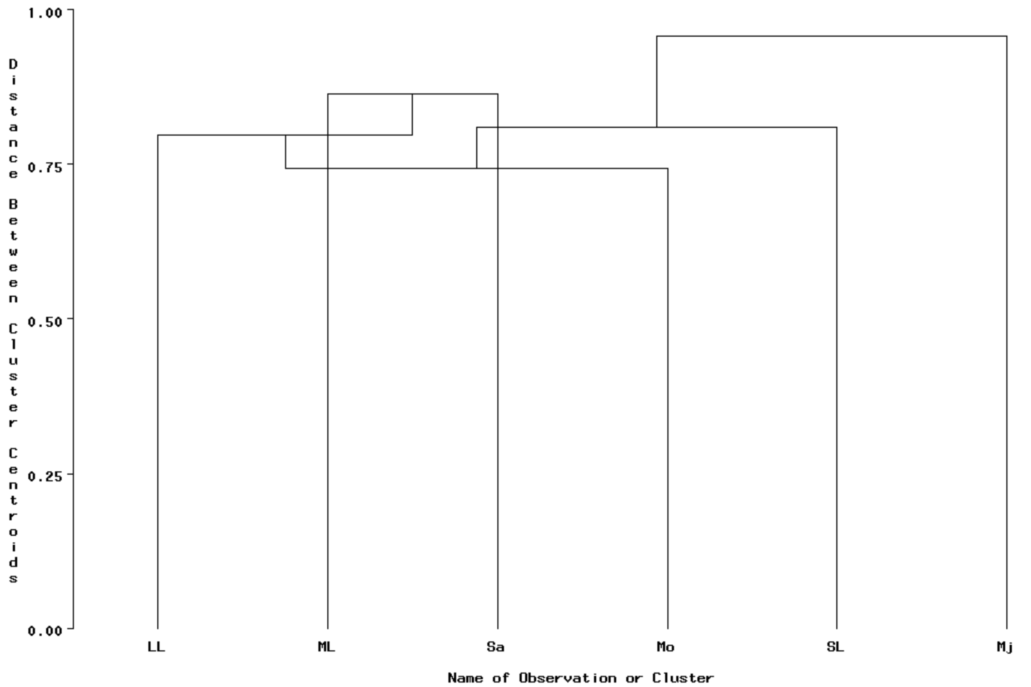

Figure 5.3.9: Clustering of soil types based on oat yield when treated with fungicide.

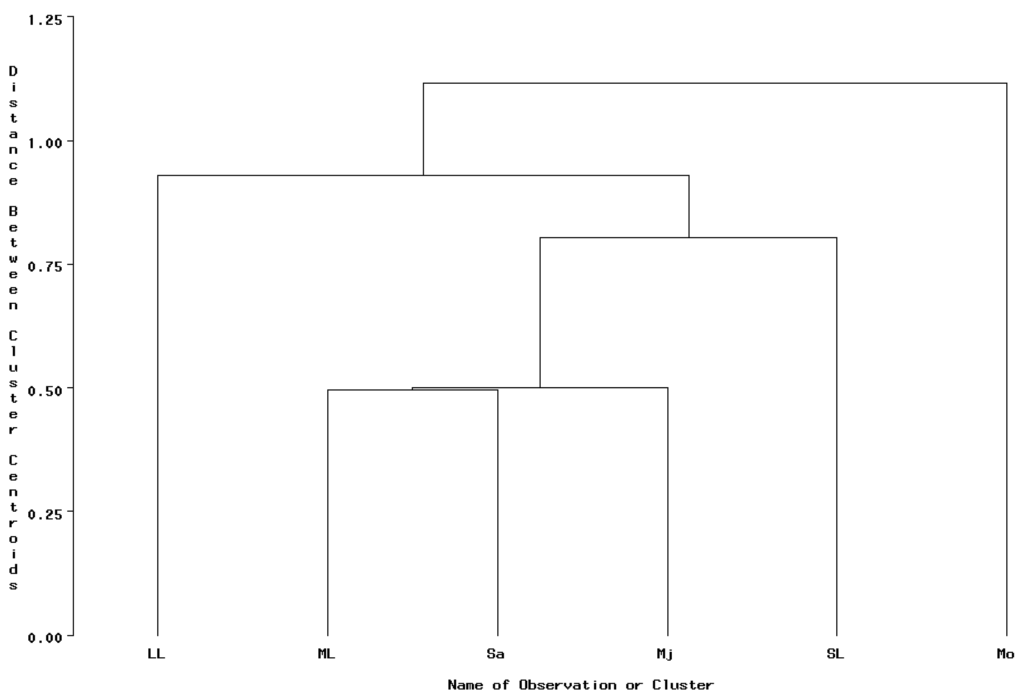

Figure 5.3.10: Clustering of soil types based on log ratio when treated with fungicide.

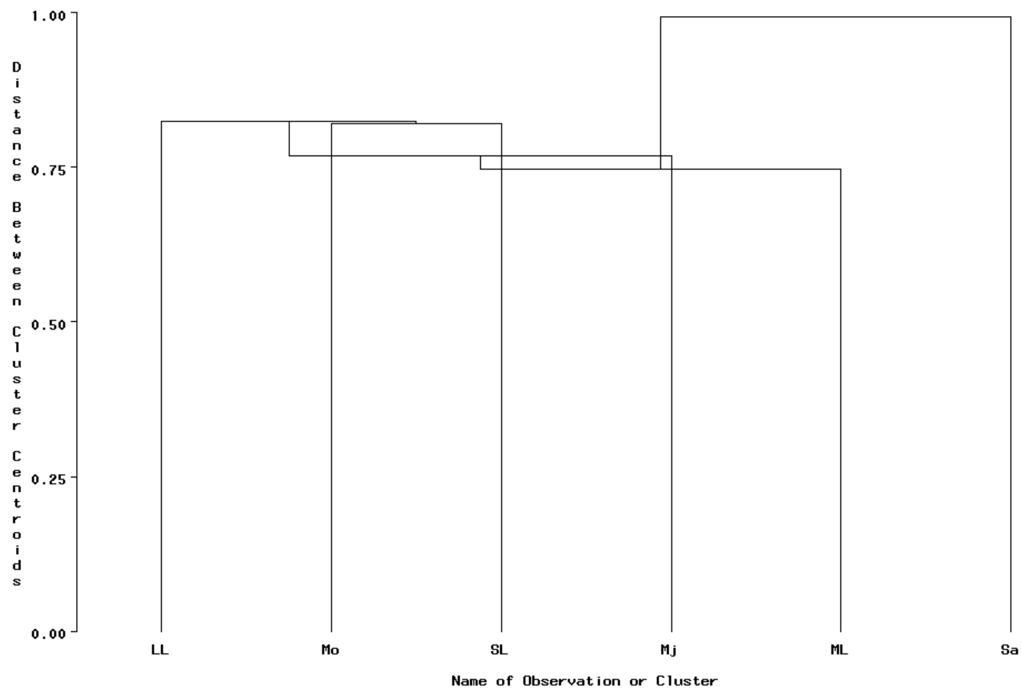

Figure 5.3.11: Clustering of soil types based on oat yield when not treated with fungicide.

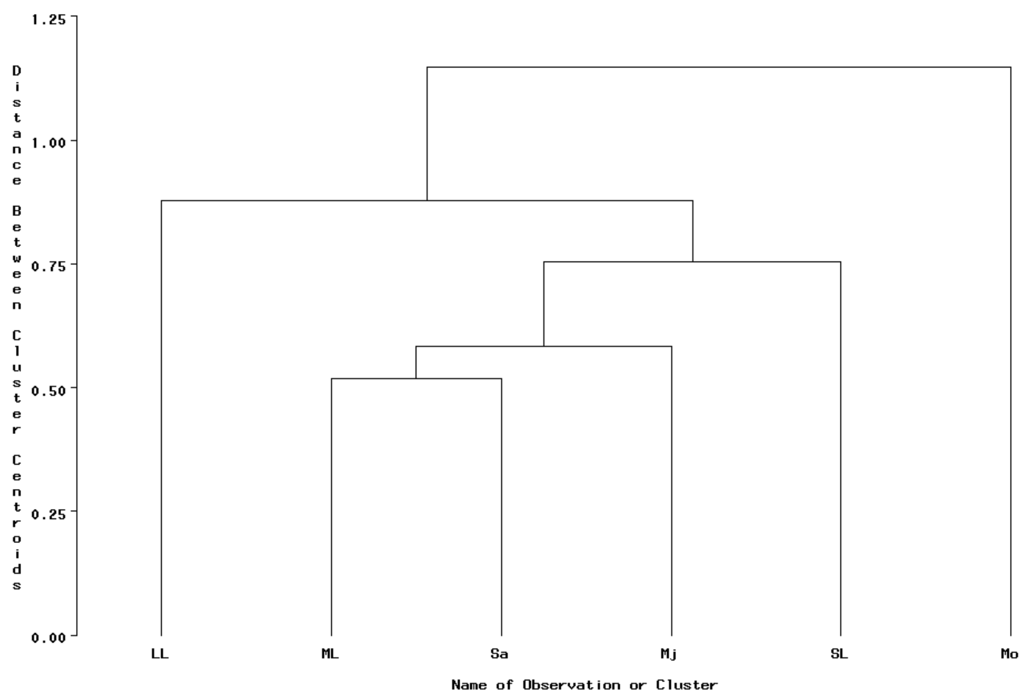

Figure 5.3.12: Clustering of soil types based on log ratio when not treated with fungicide.

6. Discussion

In this study, an unprejudiced search for an optimal grouping of regions, districts and soil types was carried out. Similarities and dissimilarities were investigated with regard to yield and yield ratios.

It is well known that yield varies between regions, districts and soil types. This study confirmed that persistent similarities and differences exist. However, variety trials are not aimed at estimating absolute levels of yield. Rather, the objective is estimation of differences or ratios in yield between varieties. Regions, districts or soil types that give similar levels of yield do not necessarily give similar ratios in yield.

Log ratios were analysed instead of yield ratios, because the size of a log ratio is not dependent on which variety is in the numerator and which is in the denominator. As discussed by Cole (2003), the log scale is the natural scale on which to express percentage differences. Regions, districts or soil types that are similar with regard to log ratios are also similar with regard to ratios.

Regions and districts differed less in ratios than in absolute values, especially for spring barley and oats. For example, in spring barley, there were differences in yield between the clusters {C, E, G} and {A, B, D, F} (Figures 5.1.1 and 5.1.3). Consequently, regions C, E and G produced different levels of yield than A, B, D and F. However, the cluster analyses did not reveal which cluster produced more and which produced less. The analyses only provided the information that regions C, E and G usually produce similar yield, as do regions A, B, D and F. In some years, regions C, E and G may give smaller yields than regions A, B, D and F, but in other years they may give larger yields. Interestingly, the two clusters, {C, E, G} and {A, B, D, F} were not distinguishable in log ratio (Figures 5.1.2 and 5.1.4). There may be differences in log ratio between the regions, but the log ratios between the variety yields obtained in regions C, E and G did not consistently differ from the log ratios obtained in regions A, B, D and F.

For oats too, regions can easily be grouped into clusters of regions that produce similar levels of yield. Regions A, B and D produced different levels than regions C, E, F and G (Figures 5.3.1 and 5.3.3), but when it came to log ratios, the similarities and dissimilarities between the regions vanished (Figures 5.3.2 and 5.3.4).

In winter wheat, regions A and B gave similar levels of yield (Figures 5.2.1 and 5.2.3), but also similar log ratios (Figures 5.2.2 and 5.2.4). Regions F and G produced similar ratios between the varieties (Figures 5.2.2 and 5.2.4). It is perhaps not surprising that differences in ratios between the regions are revealed in winter wheat, which is sown in the autumn, but not in spring barley and oats, which are sown in the spring. There are regional differences in winter weather, and some varieties tolerate hard weather conditions better than others.

In some cases the cluster analyses produced a small number of almost equal-sized distinct clusters. For example, the cluster analysis of regions with regard to yield of oats generated two clear clusters (Figure 5.3.1). The objects (i.e. the regions, districts or soil types) may then be merged according to the results of the cluster analysis, possibly without severe effects on the precision. In other cases, the observations were added one at a time, as in the clustering of soil types with regard to similarities in log ratio of winter wheat (Figure 5.2.10). Unfortunately, in these cases there was no obvious clustering of the objects into homogeneous groups.

Some clusters of similar regions, districts and soil types are suggested in this report. These clusters are further evaluated, in particular as regards the effects on the precision of the results, by Forkman, Amiri and von Rosen (2009).

Acknowledgements

This study was supported by the Swedish Farmers' Foundation for Agricultural Research (SLF). We thank Ingemar Gruvaeus, Staffan Larsson, Torbjörn Leuchovius and Arne Ljungars för all help in the project.

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Appendix A: Mean spring barley yield (g/m^2) by variety and year

	year																			
	1997		1998		1999		2000		2001		2002		2003		2004		2005		2006	
Variety	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
9801	.	.	95	513	95	535	101	491	113	496	50	601	105	528	99	587	97	551	98	462
9814	.	.	51	533	62	556	79	491	119	506	52	613	107	535	95	576	57	527	38	429
9610	44	604	65	551	70	524	67	522	73	526	20	666	71	546	73	566	57	565	68	449
9101	88	563	103	501	109	529	117	474	117	513	50	610	14	428	6	455	.	.	.	.
9622	17	633	26	580	26	576	61	492	87	473	44	548	95	510	99	553	62	542	14	499
9747	10	585	10	571	24	564	62	513	62	517	20	658	63	566	55	572	34	548	52	446
9901	.	.	.	.	32	598	46	510	50	525	20	652	63	539	60	564	48	580	52	487
9424	74	570	81	533	78	522	77	462	53	532	6	617	.	.	.	.	.	.	.	.
8487	74	545	85	477	78	499	67	416	.	.	.	.	.	.	.	.	.	.	.	.
7542	45	539	39	480	44	507	46	437	26	434	8	565	33	464	26	534	1	406	6	425
9865	.	.	12	540	12	522	37	535	28	496	12	639	47	522	51	598	38	521	36	447
8804	68	542	60	490	55	535	46	485	40	397	.	.	.	.	.	.	.	.	.	.
9604	14	582	53	504	60	507	66	466	40	406	6	543	30	491	.	.	.	.	.	.
9605	14	605	73	501	69	534	46	409	38	434	6	594	18	491	.	.	.	.	.	.
20130	.	.	.	.	.	.	.	.	20	555	34	627	67	536	61	567	50	581	.	.
9909	.	.	.	.	24	73	41	520	46	525	20	638	50	562	14	553	10	508	.	.
9929	.	.	.	.	17	575	18	502	26	574	20	628	24	615	16	565	16	612	62	457
20313	.	.	.	.	.	.	.	.	.	.	.	.	26	557	53	627	36	621	66	450
20322	.	.	.	.	.	.	.	.	.	.	.	.	59	540	58	573	34	620	28	467
20306	.	.	.	.	.	.	.	.	.	.	.	.	20	594	18	673	65	581	74	496
20220	.	.	.	.	.	.	.	.	.	.	12	647	24	665	36	608	42	607	52	494
9524	65	553	54	548	46	525	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7829	20	608	24	589	26	593	29	545	28	568	14	638	16	458	4	643	.	.	.	.
20328	.	.	.	.	.	.	.	.	.	.	.	.	26	577	30	615	39	524	66	475
9515	43	560	60	519	52	511	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20327	.	.	.	.	.	.	.	.	.	.	.	.	18	581	28	604	40	613	52	494
20203	.	.	.	.	.	.	.	.	.	.	18	448	20	506	32	589	28	516	36	497
20132	.	.	.	.	.	.	.	.	20	523	18	493	34	609	30	608	30	592	.	.
9922	.	.	.	.	17	576	18	521	48	519	20	622	28	558	.	.	.	.	.	.
2277	84	550	20	571	20	648	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9757	12	553	32	584	35	550	40	414	.	.	.	.	.	.	.	.	.	.	.	.
20324	.	.	.	.	.	.	.	.	.	.	.	.	18	544	24	608	36	563	36	437
9902	.	.	.	.	43	559	68	493	.	.	.	.	.	.	.	.	.	.	.	.
9528	53	534	56	483	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20046	.	.	.	.	.	.	16	398	38	412	14	550	16	460	13	511	6	353	6	301
20103	.	.	.	.	.	.	.	.	34	566	20	685	52	552	.	.	.	.	.	.
9725	10	577	16	556	28	532	48	486	.	.	.	.	.	.	.	.	.	.	.	.
9923	.	.	.	.	17	588	18	538	53	537	14	654	.	.	.	.	.	.	.	.
20417	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	570	34	610	28	478
20519	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16	566	74	468
6298	2	500	2	432	6	507	8	397	8	475	8	523	18	476	19	549	12	468	2	496
20418	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28	604	28	565	28	483
20222	.	.	.	.	.	.	.	.	.	.	12	598	16	541	.	.	34	591	20	531
9454	6	443	23	-514	14	437	16	358	14	406	8	526	.	.	.	.	.	.	.	.
9620	16	682	38	540	26	608	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20026	.	.	.	.	.	.	41	518	38	508	.	.	.	.	.	.	.	.	.	.
20136	.	.	.	.	.	.	.	.	14	423	8	530	16	476	13	527	14	497	14	412
20101	.	.	.	.	.	.	.	.	30	537	20	631	28	558	.	.	.	.	.	.
20135	.	.	.	.	.	.	.	.	41	401	2	660	20	460	15	575	.	.	.	.
20217	.	.	.	.	.	.	.	.	.	.	20	674	18	634	20	566	20	606	.	.
20305	.	.	.	.	.	.	.	.	.	.	.	.	20	551	58	577	.	.	.	.
20028	.	.	.	.	.	.	6	523	26	593	14	692	16	539	4	582	4	493	6	435
20204	.	.	.	.	.	.	.	.	.	.	18	498	20	539	32	592	6	456	.	.
20055	.	.	.	.	.	.	8	356	6	315	8	495	14	472	13	480	14	448	10	336
9638	44	550	14	582	14	651	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9928	.	.	.	.	17	615	18	516	37	467	.	.	.	.	.	.	.	.	.	.
20311	.	.	.	.	.	.	.	.	.	.	.	.	32	546	40	579	.	.	.	.
8329	69	552	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20148	.	.	.	.	.	.	.	.	4	323	4	584	12	469	17	583	12	523	20	454
9519	56	519	10	547	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Appendix B: Mean winter wheat yield (g/m^2) by variety and year

	year																			
	1997		1998		1999		2000		2001		2002		2003		2004		2005		2006	
Variety	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
7084	69	682	65	679	62	687	74	680	102	676	109	687	111	594	95	680	90	787	8	653
9342	53	647	61	673	47	622	46	608	68	644	75	678	65	553	59	650	.	.	.	.
9343	45	657	53	688	45	726	60	728	90	734	86	715	53	520	32	715	.	.	.	.
9489	.	.	.	.	.	.	14	547	18	706	35	781	43	555	53	689	49	762	44	667
9611	10	662	10	608	8	886	10	926	10	881	12	742	12	727	12	777	12	797	9	768
9622	11	726	14	711	28	656	42	705	42	610	47	711	39	509	49	683	47	741	32	671
9702	.	.	10	660	7	691	40	614	34	654	37	658	33	533	6	711	.	.	2	735
9705	.	.	10	644	40	706	27	664	46	713	59	736	55	602	52	751	52	812	23	705
9734	.	.	4	872	15	864	34	874	40	692	47	741	49	632	65	743	52	764	53	675
9739	.	.	4	819	8	990	.	.	16	856	12	701	12	795	.	.	10	905	.	.
9803	.	.	.	.	15	806	32	839	36	696	22	742	47	576	32	775	25	843	23	714
9902	.	.	.	.	.	.	18	785	18	765	43	711	53	588	83	737	84	790	73	636
9921	.	.	.	.	.	.	31	747	38	729	61	717	101	587	83	715	84	767	73	698
9999	.	.	.	.	.	.	2	426	8	893	12	767	8	745	12	773	6	715	2	481
20001	.	.	.	.	.	.	.	.	18	754	55	744	38	596	47	681	26	739	.	.
20002	.	.	.	.	.	.	.	.	18	724	45	751	44	618	43	746	.	.	.	.
20003	.	.	.	.	.	.	.	.	18	749	34	810	44	624	52	747	47	845	.	.
20004	.	.	.	.	.	.	.	.	18	738	34	776	34	620	24	779	26	873	.	.
20015	.	.	.	.	.	.	.	.	16	719	40	778	24	720	55	730	39	836	19	737
20101	.	.	.	.	.	.	.	.	.	.	18	748	36	620	27	736	12	834	13	700
20102	.	.	.	.	.	.	.	.	.	.	18	761	47	566	10	804	.	.	.	.
20104	.	.	.	.	.	.	.	.	.	.	18	793	29	686	27	785	29	852	.	.
20105	.	.	.	.	.	.	.	.	.	.	18	747	44	611	27	749	28	806	18	609
20106	.	.	.	.	.	.	.	.	.	.	65	767	60	504	61	708	49	812	33	694
20107	.	.	.	.	.	.	.	.	.	.	18	795	19	655	31	781	43	842	25	696
20108	.	.	.	.	.	.	.	.	.	.	18	796	19	536	10	768	.	.	.	.
20110	.	.	.	.	.	.	.	.	.	.	18	809	19	614	37	756	29	822	.	.
20201	.	.	.	.	.	.	.	.	.	.	.	.	111	603	93	740	94	794	89	694
20206	.	.	.	.	.	.	.	.	.	.	.	.	19	623	20	740	.	.	.	.
20207	.	.	.	.	.	.	.	.	.	.	.	.	19	609	20	735	27	874	.	.
20211	.	.	.	.	.	.	.	.	.	.	.	.	19	667	20	763	39	853	34	742
20231	.	.	.	.	.	.	.	.	.	.	.	.	10	850	25	798	49	879	53	700
20235	.	.	.	.	.	.	.	.	.	.	.	.	21	572	21	703	32	745	22	726
20305	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	730	44	860	.	.
20308	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	727	30	838	26	727
20310	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	733	20	822	17	798
20311	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	727	20	832	.	.
20312	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	761	20	890	24	740
20313	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	708	20	837	9	816
20314	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	689	20	800	.	.
20315	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	720	20	849	.	.
20316	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	767	20	856	36	727
20326	.	.	.	.	.	.	.	.	.	.	.	.	.	.	51	731	41	852	22	798
20335	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18	799	17	884	12	798
20336	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	845	30	861	.	.
20337	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	774	10	837	.	.
20342	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	822	39	854	34	747
20401	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	830	20	742
20403	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	834	20	700
20404	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	846	20	716
20405	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	835	20	698
20406	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	850	20	682
20407	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	869	20	688
20413	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39	831	35	740
20414	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39	851	34	697
20415	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39	801	34	714
20417	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39	847	28	737
20418	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39	836	34	759
20434	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17	860	18	677
20437	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	849	34	752

Appendix C: Mean oat yield (g/m^2) by variety and year

	Year																			
	1997		1998		1999		2000		2001		2002		2003		2004		2005		2006	
Variety	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
52	19	498	21	469	28	476	33	494	33	404	14	544	31	481	27	576	4	584	.	.
637	3	496	3	369	.	.	4	443	6	284	.	.	.	.	.	.	4	467	.	.
2563	12	521	12	444	6	430	6	450	6	454	.	.	.	.	.	.	.	.	.	.
3675	53	491	46	481	57	477	60	502	5	549	14	623	8	648	.	.	.	.	.	.
9250	46	496	40	505	32	499	34	542	23	486	12	660	.	.	.	.	.	.	.	.
9430	53	507	46	508	57	481	65	529	62	439	34	602	64	528	70	617	13	645	18	468
9431	40	485	33	541	36	490	36	552	42	452	26	627	44	530	6	637	2	779	.	.
9531	28	518	29	516	26	498	32	530	.	.	.	.	.	.	.	.	.	.	.	.
9535	9	369	1	462	11	404	11	425	17	333	6	592	6	474	4	511	.	.	.	.
9718	7	542	11	544	18	532	26	564	34	459	26	609	37	545	45	594	7	682	10	404
9720	7	557	26	552	37	468	47	511	49	432	26	618	44	545	54	627	13	644	18	449
9808	.	.	6	514	12	495	34	529	35	433	20	655	.	.	.	.	.	.	.	.
9810	.	.	6	507	12	471	30	521	27	456	24	626	28	555	.	.	.	.	.	.
9811	.	.	11	550	21	574	34	541	29	486	22	684	34	552	43	615	2	851	4	504
9819	.	.	28	540	28	477	41	521	43	411	26	604	50	525	45	607	12	653	16	440
9862	.	.	.	.	6	373	8	447	18	333	6	604	12	468	14	545	4	600	6	388
9930	.	.	.	.	12	503	16	551	25	454	20	665	42	538	54	627	11	639	18	452
9999	.	.	.	.	1	297	.	.	.	.	.	.	.	.	4	816	.	.	2	287
20127	.	.	.	.	.	.	.	.	13	409	8	509	6	506	42	653	13	647	18	443
20128	.	.	.	.	.	.	.	.	13	391	8	476	.	.	20	594	6	646	2	382
20208	.	.	.	.	.	.	.	.	.	.	8	484	22	543	.	.	.	.	.	.
20209	.	.	.	.	.	.	.	.	.	.	8	514	36	530	32	621	.	.	.	.
20229	.	.	.	.	.	.	.	.	.	.	20	615	39	541	45	597	13	630	18	441
20243	.	.	.	.	.	.	.	.	.	.	10	618	10	433	.	.	.	.	.	.
20244	.	.	.	.	.	.	.	.	.	.	6	565	6	395	.	.	.	.	.	.
20245	.	.	.	.	.	.	.	.	.	.	.	.	6	452	.	.	.	.	.	.
20315	.	.	.	.	.	.	.	.	.	.	.	.	14	461	.	.	.	.	.	.
20316	.	.	.	.	.	.	.	.	.	.	.	.	14	483	.	.	.	.	.	.
20317	.	.	.	.	.	.	.	.	.	.	.	.	14	458	.	.	.	.	.	.
20318	.	.	.	.	.	.	.	.	.	.	.	.	23	545	18	566	.	.	.	.
20329	.	.	.	.	.	.	.	.	.	.	.	.	23	600	20	614	.	.	.	.
20333	.	.	.	.	.	.	.	.	.	.	.	.	6	363	.	.	.	.	.	.
20334	.	.	.	.	.	.	.	.	.	.	.	.	10	528	12	562	4	597	.	.
20406	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	590	3	585	14	463
20407	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	552	.	.	.	.
20408	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	565	.	.	.	.
20409	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	560	.	.	.	.
20421	.	.	.	.	.	.	.	.	.	.	.	.	.	.	31	641	4	789	12	462
20422	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	533	2	745	.	.
20426	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19	642	.	.	.	.
20441	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	599	2	781	.	.
20507	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	604	.	.
20508	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	503	4	377
20509	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	549	.	.
20510	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	529	8	392
20526	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	558	14	422
20624	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	500
20625	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	490
20626	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	467
20627	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	509
20633	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	424