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Cluster Analysis of 137 Soybean Lines Based on Root System Architecture Traits Measured in Rhizoboxes

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Abstract

The reported study was motivated by the necessity to select 30 soybean lines from a total of 137 for a sophisticated 3-D phenotyping analysis of the Root System Architecture (RSA), which would not allow that all the lines be included and replicated. A representative subset of size 30 was found after performing four cluster analyses and comparing the results of two more particularly. These two cluster analyses are based on the data for 12 RSA-related traits previously collected in 2D on three replicates of the 137 soybean lines and the first six principal components representing 95% of the total dispersion after data standardization in a preliminary Principal Component Analysis (PCA). The two cluster analysis procedures provided 16 soybean lines that were the closest to the centroid of their respective cluster in both cases. Fourteen more were found to be common and at a distance from the centroid below a pre-set threshold value without being the closest. The final selection of 30 excludes two soybean lines that were the second member selected from their cluster, and includes instead two soybean lines that are the closest and second closest to their respective centroid in the cluster analysis after PCA on standardized data, but are not well represented in the other cluster analysis. In conclusion, the 93.3% overlap between the two sets of results shows a robust clustering structure in RSA 2-D phenotyping in soybean. Our statistical approaches and procedures can be followed and applied in other biological frameworks than plant phenotyping.

Keywords: Cluster analysis • Data standardization • Distance to the centroid • Plant phenotyping • Principal component analysis • Root system architecture

Introduction

One of the main difficulties in experimental research of biological systems is the bidirectional relationship between genotype and phenotype. Researchers in the omics sciences [1-7], including phenomics [8], are continuously developing new technologies that produce enormous amounts of data, which help improve our understanding of the complexity of living organisms provided they are analysed appropriately. To enable drawing biologically relevant conclusions, statistical methods, among others [9-12], must be optimized in parallel. To share raw data from omics experiments, they are presented in figures and visualized with meaningful representations. The primary goal of agricultural phenomics, or field omics [13], is to measure and compare phenotypes of crop plants. With the interpretation of dendrograms and proximity to centroids, cluster analysis represents a potential, very effective means to meet that objective. Different clustering algorithms exist that can, for given criteria, group individuals and identify them as cluster members [14].

Phenotypic variation in a germplasm pool is necessary for plant breeders to progress through selection. In this study, we have analysed phenotypic data for the Root System Architecture (RSA) of 137 soybean lines; source of data: [15]. The primary or tap root is the first organ formed by hypophysis in germinating seeds [16]. The thick soybean primary root produces primordia from the pericyclic cells, which grow into lateral roots [17]. Numerical variables, such as the quantity of secondary lateral roots, average root diameter, and root length, typically describe the size and abundance of the root system components. In other measured variables, the focus is on the topology or structure of the root system, like the type and angle of root connections [18]. Here, 12 RSA-related traits had previously been measured from 2-D images of the content of rhizoboxes in which soybean seedlings were grown: Total Length of Roots (TLR), Length of Primary Root (LPR), Length of Secondary Roots (LSR), Distribution of Total Root Length (DTLR), Total Number of Roots (TNR), Median number of roots (Med), Maximum Number of Roots (Max), Depth of Root System (DRS), Width of Root System (WRS), Surface of Root System (SRS), Diameter of Primary Roots (DR), and Surface Area of primary Root (SAR) [15].

We first performed cluster analysis on the dataset introduced above in four ways: without *vs.* with data standardization, combined or not with the application of a Principal Component Analysis (PCA) to reduce data dimensionality, and then focused on two ways called "Approach 1" and "Approach 2". In doing so, our motivation was to answer best the questions: How to analyse RSA multivariate data to objectively define a given number (e.g., 30) of clusters? How can a relevant member (i.e., a soybean line) be identified for each of the 30 clusters? These questions are addressed while keeping in mind that the resulting 30 soybean lines would later be used for a sophisticated, time-consuming RSA phenotyping in 3D. We used the SAS software, Version 9.4 for Windows (SAS Institute Inc., Cary, NC, USA), to design and perform our cluster analyses.

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Materials and Methods

Source of experimental data

The dataset used in the multivariate analyses described below consists of the mean values of phenotypic data collected for three seedlings per line (N=3) from 137 lines of soybean grown in Canada. The seeds were first germinated in Petri dishes filled with fine vermiculite and then transplanted into custom-designed rhizoboxes filled with vermiculite. After 10 days of growth, images of the roots were taken using a camera. The Automatic Root Image Analysis (ARIA) software was used to extract the RSA-related traits from each 2-D image: TLR, LPR, LSR, DTLR, TNR, Med, Max, DRS, WRS, SRS, DR, and SAR [15].

Cluster analysis

This multivariate statistical method is aimed at identifying "clusters", or groups of individuals, and their "members" for given criteria of proximity in the multidimensional space of a quantitative dataset. In the plethora of existing cluster analysis procedures, clustering depends on the definition of proximity and the type of distance or similarity involved; see, e.g., [14]. In all cases, the basic principles of the method are the same: grouping individuals that are more similar in the same cluster around a "centroid", in a way that maximizes the separation among clusters while minimizing the distances between members within clusters. We applied cluster analysis to obtain 30 clusters from 137 soybean lines (1 individual=1 soybean line). As a starting point in a given approach, we identified the soybean lines with greatest proximity to the centroid as representatives of the clusters. Our motivation is to select objectively 30 soybean lines for future research work that is practically impossible to undertake with all the 137 soybean lines (i.e., RSA phenotyping based on computed tomography scanning).

In this study, we performed disjoint cluster analyses with the SAS procedure FASTCLUS, in which a nearest centroid sorting algorithm is implemented. We used it without the option of cluster seeds as first guess for centroids, so that the algorithm initially considered each individual as a separate cluster. Distances between two individuals, between one individual and the centroid of one cluster with more than one member, and between two centroids of clusters with several members were computed based on the values of the input variables (using means when centroids of non-singleton clusters are involved); see the VAR statement in SAS scripts A1 and A3 in the appendix. By default, the Euclidean distance is used to assess the proximity among individuals and clusters. The algorithm merges the two closest clusters at each step until the desired number of clusters (MAXC) is reached. Unlike the SAS procedure CLUSTER, PROC FASTCLUS assigns each individual to a single cluster without organization in a hierarchical tree structure.

We developed and followed two approaches for clustering.

Approach 1: Cluster analysis with the 12 RSA-related traits. In SAS script A1, "MAXC=30" specifies the requested number of clusters, and the final cluster assignments are saved as output in "work.fastclus_scores".

Approach 2: Cluster analysis with 6 principal components (Prin1-Prin6). In this approach, results of a preliminary PCA are used; see the text below and SAS scripts A2 and A3. The input variables VAR in A3 are "Prin1-Prin6". These were chosen for cluster analysis after PCA (see below) showed that they accounted for 95% of the variability in the data table after column standardization. Prior to standardization, the data table (with 137 rows and 12 columns) contained the mean values (N=3) per soybean line for each of the 12 RSA-related traits. The other options in A3 (i.e., MAXC, OUT) are the same as in A1.

Principal component analysis

That multivariate statistical method can be performed on the same dataset as cluster analysis, but has a different aim than cluster analysis. PCA is used to examine the relationships among quantitative variables observed on a number of individuals in order to reduce dimensionality of the data space [14]. Matrix algebra tools applied to the sample correlation matrix (with ones as diagonal entries and standardized covariances off the diagonal) provides "principal components" based on eigenvalues and associated orthogonal eigenvectors. By performing PCA, we aimed to identify structural patterns in association of the 12 RSA-related traits over the 137 soybean lines and assess differences in cluster analysis results obtained with well-defined principal components (Approach 2) *vs*. with no data standardization and no dimensionality reduction (Approach 1).

In SAS script A2 in the appendix, the procedure PRINCOMP is called with "DATA=PCA_Seck_et_al_2020" to specify the input dataset and the option STANDARD to perform PCA on the 12 × 12 sample correlation matrix (i.e., after transforming the data for each variable to a sample variance of 1.0). The latter option facilitates the interpretation of results by focusing on associations among variables *via* correlations, while avoiding scale effects related to data dispersion and measurement units if the 12 × 12 sample variance-covariance matrix was used.

Results and Discussion

The first 6 principal components (out of a maximum of 12; there are 12 variables provided by the 12 soybean root traits) explain about 95% of the variability in the data table (Figure 1, top left panel). Several of the RSA-related traits are redundant; see SAR, DRS, DTLR, LSR, TLR and WRS, RS in the PCA biplots (Figure 1, other panels). The latter result confirms the correlation analysis results reported in Seck W, et al. [15].

In a PCA with standardization of the data table, which is equivalent to performing the PCA on the sample correlation matrix [14], "variance", "dispersion", "variation". And "variability" tend to mean the same thing.

Using the criterion of greatest proximity or smallest distance to the centroid, 16 soybean lines are found to be common to the lists of 30 names obtained in the cluster analyses along Approach 1 and Approach 2; see the yellow highlights in Table 1. Loosening the required proximity to a maximum difference of 0.15 with the smallest distance to the centroid on both sides, 14 more lines were

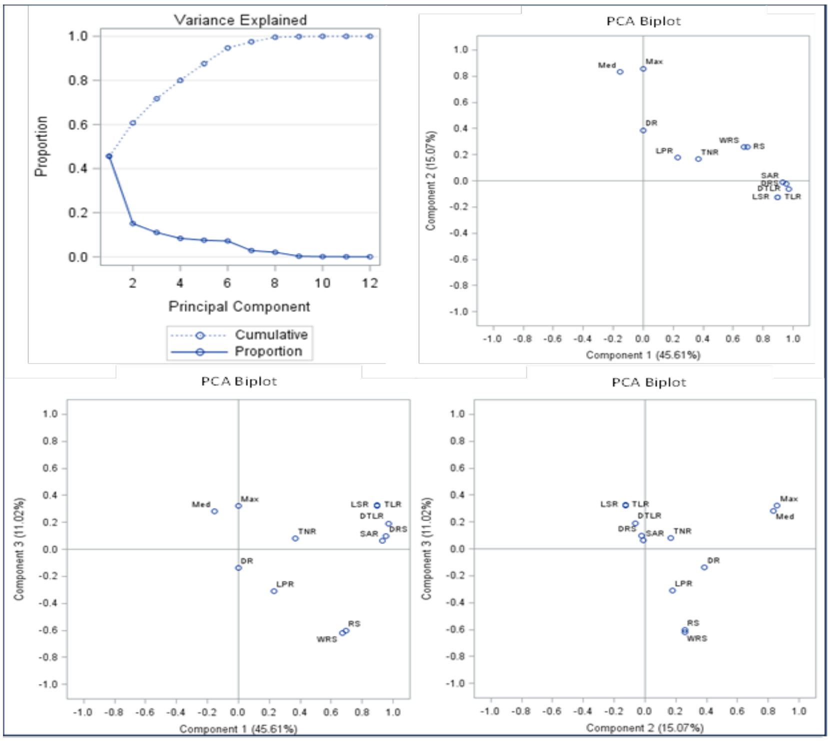

Figure 1. Principal Component Analysis (PCA) results. Top left panel: Percentage of the variability in the data table explained by the 12 principal components, cumulative or not. Other panels: Biplots of Prin2 against Prin1, Prin3 against Prin1, and Prin3 against Prin2; Prin1, Prin2, Prin3 denote the first three principal components in descending order of the associated eigenvalues.

Table 1. A summary of the initial cluster analysis results obtained in Approach 1 (Analysis with the 12 RSA-related traits) and Approach 2 (Analysis with Prin1-Prin6). Only the soybean lines that are the closest to the centroid of the cluster to which they belong are listed. Those that are highlighted in yellow appear in both lists. Complete results are given in Tables B1 and B2 in the appendix.

Analysis with the 12 RSA-related traits			Analysis with Prin1-Prin6		
Cluster	Soybean line	Distance to the centroid	Cluster	Soybean line	Distance to the centroid
1	4004P4J	1.232596	1	4004P4J	1.330548
2	4005_24j	0	2	4005_24j	0
3	PS44	0.969116	3	PS44	0.903904
4	Jari	1.385713	4	OAC 7-26C	1.124655
5	Tundra	0	5	Gretna	1.020093
6	Delta	0	6	Madoc	0.844417
7	OAC 7-26C	1.222566	7	OAC Prudence	1.121011
8	Casino	1.379225	8	OAC Wallace	0.944889
9	5055_43G	0	9	5055_43G	1.239143
10	Costaud	1.251672	10	Costaud	1.10524
11	Madoc	1.357312	11	Mandarin	0.929683
12	Maple Ambr	1.10394	12	Venus	0
13	OAC 8-21C	0.898254	13	OAC 7-6C	0
14	Woodstock	0	14	Maple Glen	1.025438
15	S05-T6	1.191081	15	Bravor	1.111696
16	Albinos	1.447583	16	Tundra	0
17	OAC 9-35C	1.088592	17	SECAN8-1	1.026367
18	Clinton	1.169068	18	Woodstock	0
19	Maple Isle	1.057824	19	Jutra	0.775305
20	OAC Oxford	1.118181	20	OT94-47	0.728379
21	S14-P6	1.081495	21	Alta	0.651441
22	McCall	1.27531	22	McCall	1.090354
23	Gentleman	1.505267	23	4067P17j	1.107881
24	Flambeau	1.091571	24	S03-W4	0
25	OAC 7-6C	0	25	Roland	0.975369
26	OAC Wallace	0.954529	26	Maple Belle	1.015101
27	S03-W4	0	27	OAC 7-4C	0.812049
28	Venus	0	28	S14-P6	1.002491
29	Gaillard	0.844357	29	Mario	0.924578
30	OAC 7-4C	0.998249	30	OT05-20	1.209572

Table 2. Final selection of 30 soybean lines based on their membership of one of the 30 clusters identified in Approach 1 (Analysis with 12 root traits) and Approach 2 (Analysis with Prin1-Prin6) and their distance from the centroid. The 14 soybean lines highlighted in yellow here were also highlighted in yellow in Table 1; see text and Tables B1 and B2 for the selection of the other 16 soybean lines. In particular, Madoc and McCall, which are highlighted in yellow in Table 1, were eventually discarded to keep not more than one member per cluster after merging the two sets of cluster analysis results.

No.	Soybean line
1	4004P4J
2	4005_24J
3	5055_43G
4	AC2001
5	Albinos
6	Casino
7	Clinton
8	Costaud
9	Delta
10	Elora
11	Gaillard
12	Gentleman
13	Mandarin
14	Maple Arrow
15	OAC 7-26C
16	OAC 7-4C
17	OAC 7-6C
18	OAC 8-21C
19	OAC 9-22C
20	OAC 9-35C
21	OAC Oxford

22	OAC Wallace
23	PS44
24	Proteus
25	S03-W4
26	S14-P6
27	SECAN7-27
28	Tundra
29	Venus
30	Woodstock

found to be common and at a distance from the centroid below 0.15 without being the closest. The final selection of 30 (Table 2) excludes two soybean lines (Madoc, McCall) that were the second member selected from their cluster, and includes instead two soybean lines (Mandarin, Maple Arrow) that are the closest and second closest to their respective centroid in Approach 2, but are not well represented in Approach 1.

The reported overlap of 93.3% [i.e., (16+14–2)/30=0.933] shows a robust clustering structure in RSA 2-D phenotyping in soybean. Thus, we compiled, in a rational way, a list of 30 representative soybean lines with distinct RSA patterns that provide a good basis for 3-D investigation. Of course, germination tests with available seed banks as well as preliminary tests with growing media other than vermiculite justify adjustments to that list later. It is worth mentioning that OAC Bayfield readily provides a substitute to OAC 7-26C if required, as these soybean lines belong to the same cluster with two members in both approaches (Tables B1 and B2); they are therefore at equal distance from the centroid and either can be randomly picked. A comparison with genomic clustering results falls beyond the scope of a Brief Report, but could be the topic of another, broader study.

Conclusion

The selected 30 soybean lines will be used in RSA phenotyping with state-of-the-art equipment, followed by sophisticated 3-D data and image analyses. Selecting representative lines that showcase the diversity in root system architecture and possess biological relevance is crucial. The soybean lines in Table 2 are objective starting points for further investigation into the functionality of specific RSA-related traits on plant performance and adaptation. Our cluster analysis results provide insight into phenotypic variation within the germplasm pool. Understanding root system diversity is crucial for breeders aiming to progress through selection. Advanced 3-D phenotypic analyses, e.g., based on computed tomography scanning, is expected to deepen our understanding of the RSA and its impact on plant productivity and stress tolerance.

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Appendix A

SAS scripts

A1. Cluster analysis with the 12 RSA-related traits (Approach 1)

```
PROC FASTCLUS DATA=work.soybean_scores MAXC=30 OUT=work.fastclus_scores;
VAR TLR LPR LSR DTLR TNR MED MAX DRS WRS RS DR SAR;
RUN;
PROC PRINT DATA=work.fastclus_scores;
RUN;
```

A2. Principal component analysis (PCA) on the estimated correlation matrix of the 12 RSA-related variables (Approach 2)

```
PROC PRINCOMP DATA=PCA_Seck_et_al_2020 STANDARD OUT=work.soybean_scores PLOTS=ALL;
VAR TLR LPR LSR DTLR TNR Med Max DRS WRS RS DR SAR;
RUN;
PROC PRINT DATA=work.soybean_scores;
RUN;
```

A3. Cluster analysis with the first 6 principal components accounting for 95% variability in the PCA (Approach 2)

```
PROC FASTCLUS DATA=work.soybean_scores MAXC=30 OUT=work.fastclus_scores;
VAR Prin1-Prin6;
RUN;
PROC PRINT DATA=work.fastclus_scores;
RUN;
```

Appendix B

Supplementary Tables

Table B1. Numerical information presented in supplement to that in Table 1 (left half) for the cluster analysis performed on the dataset for the 12 RSA-related traits, including the distance to the centroid and the 12 mean values (N=3) for each of the 137 soybean lines. White and yellow colors are used to highlight lines that are members of different clusters from Cluster 1 to Cluster 30, while red is used to identify clusters with only one member.

Distance	Cluster	Line	TLR	LPR	LSR	DTLR	TNR	Med	Max	DRS	WRS	RS	DR	SAR
1.232596	1	4004P4J	-0.348528	0.084837	-0.287234	-0.299541	-2.51404	0.232022	-1.09612	-0.158	1.20193	1.190868	0.575045	-0.181478
1.232596	1	5017_25B	-0.425579	0.171899	-0.357599	-0.625231	-1.52771	-1.501224	-1.344395	-0.614391	0.364107	0.306162	0.858839	-0.556334
0	2	4005_24j	0.224331	0.171899	0.198512	0.677532	-2.175664	-0.618249	-1.535376	0.819981	1.52417	1.729632	-2.092616	0.815232
0.969116	3	PS44	0.023328	2.174313	-0.05571	0.351841	0.754527	-0.945277	-1.344395	0.559186	1.073035	1.15117	-0.219578	0.623445
1.323891	3	SECAN9-3	0.338233	1.390759	0.282496	0.677532	1.496075	-1.174196	-1.287101	0.885179	0.364107	0.306162	-0.787165	0.850102
1.421002	3	Phoenix	0.542586	2.696682	0.455003	1.003223	0.898517	-0.74906	-1.210708	1.145974	1.330826	1.309963	-0.957441	1.102912
1.496352	3	OAC9-48C	-0.160925	1.869598	-0.236163	0.02615	0.29376	-1.599332	-0.064822	0.298391	0.750795	0.748515	-0.900683	0.475246
1.497452	3	Hercule	0.375083	0.911921	0.331297	0.677532	-0.354194	-0.520141	-0.962433	0.950378	0.879691	0.964021	-1.184476	0.922749
1.385713	4	Jari	-0.296043	2.130782	-0.331496	0.02615	-0.325396	0.460942	1.386634	0.102795	0.750795	0.805227	1.142632	0.088767
1.566451	4	SECAN7-2	-0.236859	1.303698	-0.249782	0.02615	1.229694	0.55905	-0.007528	0.167994	1.008587	1.111472	2.16429	0.364823
1.696042	4	SECAN8-1	-0.302744	1.303698	-0.273615	0.02615	1.445678	0.787969	1.138359	0.037596	0.106316	0.0623	0.404769	0.085861
1.852344	4	OACAyton	-0.311677	1.260167	-0.28156	-0.299541	0.29376	2.194188	1.558517	-0.027602	0.944139	1.088787	2.16429	-0.039091
2.020686	4	Misty	-0.259193	0.955452	-0.264536	0.02615	0.077775	0.689861	-0.064822	0.167994	1.52417	1.729632	-0.219578	0.170131
0	5	Tundra	-0.059306	-0.306939	-0.075004	0.351841	1.805653	-0.422033	-1.344395	0.428789	3.199816	2.387491	-0.446613	0.536269
0	6	Delta	-0.261426	-1.482269	-0.20325	0.02615	-0.541381	2.81554	1.711302	0.102795	1.330826	1.338319	1.71022	0.167225
1.222566	7	OAC7-26C	3.990905	1.173106	3.980065	3.28306	0.106573	-1.599332	-0.523177	2.319551	0.621899	0.691803	-0.673648	1.945612
1.222566	7	OACBayfield	4.677665	-0.35047	4.717763	3.28306	0.322558	-0.520141	-0.580471	2.38475	-0.087028	-0.073808	-0.162819	2.215857
1.379225	8	Casino	-0.905753	0.346022	-0.946623	-1.927995	-0.663772	0.689861	1.004672	-1.461974	-0.66706	-2.495409	-0.957441	-3.061186
1.379225	8	Colby	-0.769517	-1.395208	-0.762766	-1.276613	-0.613375	0.460942	0.431729	-1.65757	-1.375987	-1.349827	-1.297994	-1.73902
1.880963	8	Altona	-0.709216	-1.786984	-0.70602	-1.276613	-0.786163	-0.193113	0.508121	-1.592371	-1.440435	-1.446238	-0.730406	-1.637315
0	9	5055_43G	-0.404362	-0.437532	-0.364409	-0.299541	-1.383721	1.540133	0.374434	-0.418795	-1.956018	-1.633387	-2.37641	-0.303525
1.251672	10	Costaud	0.207581	-0.655185	0.203051	0.677532	-0.591777	-0.422033	-0.141214	0.819981	0.235211	0.136026	-0.616889	0.791985
1.381823	10	5070_26j	0.390717	-2.439946	0.434575	1.003223	-1.362122	0.133914	-0.828746	1.015577	-0.34482	-0.215588	-0.446613	0.934372
1.80892	10	KG-41	0.037845	-1.177554	0.043028	0.351841	-0.303797	0.886078	0.126159	0.559186	-0.860403	-0.65227	-1.411511	0.637974
1.839598	10	DH618	-0.062657	-0.437532	-0.075004	0.351841	-0.570178	-0.618249	0.469925	0.36359	-0.602612	-0.612572	-1.241235	0.530457
1.87685	10	5146_41j	0.407467	-1.003431	0.414146	1.003223	-1.189334	-1.174196	-1.019727	1.015577	-0.989299	-0.901803	0.688562	1.050606
1.357312	11	Madoc	-0.73155	-0.698716	-0.757091	-1.276613	-0.159808	0.362833	0.565415	-1.65757	-1.247091	-1.208048	0.404769	-1.663467
1.497941	11	OAC1-26	-0.557347	-0.872839	-0.564155	-0.625231	0.106573	-0.095005	1.463026	-0.940384	-1.118195	-0.964186	0.631804	-0.806238
1.721228	11	Victoria	-0.679066	-1.308146	-0.687861	-0.950922	1.906446	-0.422033	0.049767	-1.396775	-1.956018	-1.64473	0.461527	-1.509457
1.766948	11	OT09-03	-0.521613	-1.351677	-0.524432	-0.625231	0.509745	-1.174196	-0.580471	-0.744788	-1.440435	-1.463251	-0.843924	-0.739404
1.10394	12	MapleAmbr	-0.076057	-0.219878	-0.094298	0.351841	-0.138209	-0.291222	-0.064822	0.36359	0.364107	0.238107	-0.219578	0.495587
1.282034	12	OAC9-22C	-0.258076	-0.089286	-0.236163	0.02615	0.250563	-1.272304	-1.09612	0.167994	0.557451	0.527338	-0.389854	0.178848
1.326013	12	Naya	0.082512	0.041307	0.057782	0.677532	0.077775	-1.730143	-0.141214	0.754782	0.686347	0.720159	0.972356	0.664127
1.397447	12	OT05-20	-0.30386	-0.002224	-0.239568	0.02615	0.509745	-0.520141	-0.332196	0.037596	-0.087028	-0.124849	0.518286	-0.021656
1.400147	12	MapleRidge	-0.225692	0.346022	-0.213464	0.02615	0.034579	-0.422033	-1.287101	0.233192	0.041868	-0.011425	-0.049301	0.373541
1.426872	12	Katrina	0.12383	-0.045755	0.102043	0.677532	-0.181406	0.232022	0.183453	0.754782	0.815243	0.805227	0.631804	0.739679
1.510466	12	OACChampion	-0.292693	0.128368	-0.27702	0.02615	0.344157	-0.291222	-0.064822	0.102795	1.395274	1.474428	0.461527	0.112014
1.567332	12	KORADA	-0.253609	0.650737	-0.249782	0.02615	-0.253401	-0.74906	-0.580471	0.167994	1.266378	1.253251	1.369667	0.251495
1.664315	12	Bloomfield	-0.311677	-0.872839	-0.224814	0.02615	-0.757365	-0.422033	-0.064822	0.037596	0.493003	0.521667	-0.219578	-0.036185
1.745247	12	OT11-03	0.351633	-1.177554	0.36194	0.677532	0.610538	-0.520141	-0.580471	0.885179	1.008587	1.139828	0.80208	0.876255
2.011681	12	Bravor	0.255598	-0.002224	0.234829	0.677532	-0.735767	-1.828251	-1.726357	0.819981	0.299659	0.20408	0.518286	0.829761
0.898254	13	OAC8-21C	3.26171	-0.35047	3.277549	2.305987	0.178568	-1.174196	-0.446784	1.86316	1.975306	1.979165	-0.276336	1.765448
1.574772	13	OT94-47	3.879236	-1.046962	3.924454	2.957369	0.632136	-0.945277	-0.198509	2.254352	2.104202	2.120944	-0.219578	1.814848
2.085458	13	MapleArrow	2.486732	-0.829308	2.503534	2.305987	-0.138209	-1.076088	-1.287101	1.86316	0.364107	0.311833	0.177734	1.695708
0	14	Woodstock	4.7804	-0.829308	4.833524	3.934441	4.570256	0.232022	2.284245	3.036737	2.233097	2.279738	0.234492	2.364055
1.191081	15	S05-T6	0.007695	0.476614	-0.027337	0.351841	1.157699	0.035806	0.183453	0.428789	0.299659	0.226765	0.404769	0.539175
1.23831	15	SECAN7-4	0.012161	-1.395208	0.026004	0.351841	1.229694	0.55905	0.813691	0.428789	0.557451	0.601064	1.029115	0.550798
1.333946	15	Supra	0.227681	-1.003431	0.231424	0.677532	1.762456	1.213105	1.081064	0.819981	0.106316	0.056629	0.631804	0.818138
1.443426	15	Ohgata	-0.242443	0.650737	-0.238433	0.02615	0.632136	0.55905	1.32934	0.167994	0.428555	0.413915	0.064216	0.315424
1.447583	16	Albinos	-0.810835	-2.570538	-0.774115	-1.276613	-0.807762	-0.422033	-0.714158	-1.722769	-0.215924	-0.181561	0.120975	-1.744831
1.508762	16	ACGlengarry	-0.739367	-1.438739	-0.730988	-1.276613	-0.951751	-1.403115	-1.09612	-1.65757	-1.762675	-1.565333	0.631804	-1.73902
1.67886	16	9004	-0.877836	-1.003431	-0.883067	-1.927995	-1.189334	-0.74906	-0.69506	-1.201179	-0.860403	-2.296917	0.461527	-1.959865
1.780846	16	Dundas	-0.864435	-2.178761	-0.838805	-1.602304	-0.498184	-0.520141	-0.064822	-1.722769	0.041868	0.005588	1.653461	-1.936618
2.567814	16	4028P7j	-0.614298	-0.568124	-0.62998	-0.950922	-1.887685	-0.74906	-0.007528	-1.13598	-1.956018	-1.809194	1.142632	-1.050331

1.088592	17	OAC9-35C	-0.670132	0.476614	-0.725313	-0.950922	0.272162	1.343916	1.463026	-1.266378	-0.473716	-0.538846	0.34801	-1.274082
1.446458	17	OAC7-3C	-0.527197	-0.785777	-0.544861	-0.625231	0.106573	2.750135	2.341539	-0.809987	-0.860403	-0.754352	0.34801	-0.774274
1.800249	17	SECAN8-1	-0.674599	-1.177554	-0.686726	-0.950922	1.373683	1.442024	1.577615	-1.331576	-1.440435	-1.36117	0.234492	-1.378693
1.854362	17	Amasa	-0.693583	-0.045755	-0.735527	-1.276613	-0.757365	1.114997	1.081064	-1.461974	-1.440435	-1.355499	1.369667	-1.532704
2.037467	17	90A07	-0.475829	-0.655185	-0.387107	-0.625231	-1.023746	2.324999	1.844989	-0.679589	-1.440435	-1.463251	-0.673648	-0.631887
2.047961	17	PS36	-0.533897	0.476614	-0.583448	-0.625231	0.682533	1.343916	1.272045	-0.809987	0.299659	0.181395	0.972356	-0.77718
1.169068	18	Clinton	-0.445679	-0.785777	-0.353059	-0.625231	-0.663772	-0.291222	-0.523177	-0.614391	-1.182643	-0.986871	0.064216	-0.579581
1.174657	18	OT11-01	-0.540597	-0.9599	-0.552805	-0.625231	0.538543	-0.847168	-1.287101	-0.809987	-0.409268	-0.442436	-0.219578	-0.785897
1.209177	18	Alta	-0.613182	-0.524593	-0.628845	-0.950922	-0.786163	-0.618249	-0.523177	-1.070782	-0.924851	-0.788379	0.80208	-1.035801
1.275985	18	OAC9-17C	-0.586381	-0.742247	-0.598202	-0.950922	0.178568	-0.193113	-1.153414	-1.005583	-0.215924	-0.187232	0.80208	-0.858544
1.443737	18	DH530	-0.588614	0.171899	-0.62317	-0.950922	-0.570178	-0.520141	-0.637765	-1.070782	-1.247091	-1.145664	0.745321	-0.902132
1.487421	18	Madison	-0.643332	-0.045755	-0.683321	-0.950922	-0.159808	-1.403115	-1.210708	-1.13598	-0.215924	-0.204246	0.972356	-1.157848
1.58304	18	OAC8-22C	-0.338477	-1.395208	-0.239568	-0.299541	0.178568	-1.501224	-1.287101	-0.092801	-0.860403	-0.708982	1.25615	-0.056526
1.653653	18	Purdy	-0.386495	-0.742247	-0.338306	-0.299541	1.085704	-0.095005	-1.210708	-0.353596	-0.924851	-0.828077	0.064216	-0.262843
1.945617	18	90B11	-0.338477	-0.9599	-0.249782	-0.299541	-0.97335	-1.730143	-2.242006	-0.092801	-0.538164	-0.55586	0.064216	-0.047809
1.057824	19	MapleIsle	-0.476946	0.215429	-0.41094	-0.625231	-0.037416	0.362833	-0.332196	-0.679589	-1.247091	-1.088952	-0.049301	-0.646416
1.263809	19	AC2001	-0.404362	-0.219878	-0.370083	-0.299541	-0.951751	0.787969	-0.38949	-0.353596	-0.924851	-0.896132	0.34801	-0.280278
1.429133	19	Lotus	-0.197775	-0.219878	-0.170337	0.02615	-0.181406	0.886078	0.374434	0.233192	-0.538164	-0.595558	-0.333095	0.408411
1.467523	19	Heather	-0.408828	0.650737	-0.397321	-0.625231	-0.375792	1.114997	0.890083	-0.483993	-0.602612	-0.618243	-0.787165	-0.35583
1.487397	19	Gretna	-0.616532	0.346022	-0.654948	-0.950922	-0.397391	0.689861	0.374434	-1.13598	-0.538164	-0.572874	-0.049301	-1.056142
1.525628	19	OT11-02	-0.460196	1.43429	-0.425694	-0.625231	0.58174	0.232022	0.240748	-0.614391	-0.860403	-0.754352	0.461527	-0.599922
1.614869	19	OAC9-44C	-0.342944	0.346022	-0.288369	-0.299541	0.272162	2.09608	-0.962433	-0.158	-0.795956	-0.646599	0.518286	-0.079773
1.659508	19	OAC8-11C	-0.421112	1.260167	-0.381432	-0.625231	0.14977	0.689861	-0.103018	-0.549192	0.170764	0.079314	-0.787165	-0.431382
2.352987	19	Perth	-0.194425	0.346022	-0.181687	0.02615	0.754527	0.232022	1.272045	0.298391	-1.182643	-1.009556	-0.900683	0.425846
1.118181	20	OACOxford	-0.416645	0.389552	-0.398456	-0.625231	0.466548	-0.291222	-0.828746	-0.483993	-1.247091	-1.111637	-0.446613	-0.370359
1.278577	20	Roland	-0.644449	-0.219878	-0.681051	-0.950922	1.114502	-0.618249	-1.287101	-1.201179	-1.182643	-1.071939	0.120975	-1.169471
1.377195	20	OAC7-23C	-0.624348	0.389552	-0.665162	-0.950922	0.106573	-0.291222	-0.198509	-1.13598	-0.602612	-0.635257	-0.503371	-1.06486
1.526821	20	OT11-09	-0.545064	0.737798	-0.602742	-0.625231	0.632136	-1.599332	-1.974633	-0.940384	-1.698227	-1.497278	-0.730406	-0.800427
2.150815	20	Stratfor	-0.503747	0.171899	-0.544861	-0.625231	1.712059	-0.422033	-0.198509	-0.744788	-0.473716	-0.550189	0.745321	-0.719063
2.163745	20	ACOrford	-0.637749	1.086044	-0.69694	-0.950922	-0.930153	-1.403115	-0.370392	-1.13598	-0.087028	-0.113507	0.34801	-1.070672
1.081495	21	S14-P6	-0.339594	1.086044	-0.304258	-0.299541	1.208095	-0.095005	-0.771452	-0.092801	0.815243	0.907309	-0.333095	-0.076867
1.282782	21	Walton	-0.49258	0.868391	-0.443853	-0.625231	2.021637	-1.174196	-0.714158	-0.679589	0.815243	0.895966	-1.241235	-0.681286
1.438648	21	S12-A5	-0.405478	2.261374	-0.437044	-0.299541	1.208095	-0.618249	-0.714158	-0.418795	-0.34482	-0.306327	-0.730406	-0.341301
1.27531	22	McCall	-0.346294	1.347229	-0.319012	-0.299541	0.077775	-0.520141	2.608913	-0.158	1.395274	1.349662	0.518286	-0.149514
1.306172	22	OACLakeview	-0.329544	0.346022	-0.275885	-0.299541	0.466548	-0.095005	2.03597	-0.027602	0.557451	0.544352	-0.503371	-0.047809
1.605831	22	Proteus	-0.009056	-0.263409	-0.026203	0.351841	1.042507	0.133914	2.284245	0.428789	2.039754	2.115273	0.064216	0.536269
2.579318	22	OACKent	-0.566281	-0.481062	-0.583448	-0.950922	0.394553	1.343916	2.03597	-1.005583	0.944139	1.1058	0.291251	-0.844015
1.449025	23	5091_50j	-0.122957	-0.089286	-0.146504	0.351841	-1.239731	-0.618249	-0.714158	0.36359	-0.538164	-0.595558	-0.446613	0.489775
1.505267	23	Gentleman	-0.361928	1.347229	-0.368948	-0.299541	-0.447787	0.035806	-0.332196	-0.223198	0.170764	0.096328	0.404769	-0.207631
1.509005	23	4067P17j	-0.248026	0.650737	-0.244107	0.02615	-1.6717	0.787969	-0.141214	0.167994	-0.215924	-0.192903	0.631804	0.306706
1.514055	23	Evans	0.022211	1.173106	-0.031877	0.351841	-0.498184	-0.193113	0.374434	0.493987	-0.02258	-0.056795	0.858839	0.60601
1.590677	23	ACProtei	0.016628	0.781329	-0.027337	0.351841	-0.858158	-0.356627	0.126159	0.428789	-1.247091	-1.162678	1.199391	0.562422
1.591632	23	4042_6Bp	-0.284877	1.129575	-0.294044	0.02615	-1.794091	-0.422033	-0.198509	0.102795	0.106316	0.050958	0.858839	0.146884
1.612227	23	Carman	-0.377561	0.955452	-0.374623	-0.299541	-0.663772	-0.945277	-1.153414	-0.288397	-0.34482	-0.334683	0.518286	-0.254125
1.690578	23	90A01	0.019978	0.041307	-0.003504	0.351841	-1.045345	0.55905	0.374434	0.493987	-1.118195	-0.924488	-0.56013	0.600198
1.711989	23	91M10	-0.419995	-0.655185	-0.331496	-0.625231	-0.951751	-0.095005	0.240748	-0.549192	-0.731508	-0.640928	0.858839	-0.381983
1.741604	23	9063	-0.49593	1.086044	-0.56075	-0.625231	-1.146138	-1.076088	-0.38949	-0.679589	-0.473716	-0.499148	-0.10606	-0.704533
1.74669	23	Brant	-0.460196	1.173106	-0.418885	-0.625231	-0.757365	0.232022	0.049767	-0.614391	0.170764	0.096328	0.575045	-0.597016
1.091571	24	Flambeau	-0.561814	-0.9599	-0.566424	-0.625231	-0.469386	1.016889	0.126159	-1.005583	-0.34482	-0.2723	0.064216	-0.81205
1.097031	24	Drayton	-0.349644	-0.9599	-0.296313	-0.299541	-0.498184	1.114997	-0.007528	-0.158	-0.02258	-0.03411	-0.10606	-0.204725
1.266823	24	Elora	-0.374211	-0.481062	-0.332631	-0.299541	-0.498184	0.55905	0.126159	-0.223198	-0.34482	-0.300656	0.858839	-0.239596
1.284333	24	OAC7-48C	-0.483646	-1.351677	-0.375758	-0.625231	0.14977	0.362833	-0.255803	-0.679589	0.493003	0.430928	-0.446613	-0.672569
1.354878	24	OACMorris	-0.514913	0.215429	-0.557345	-0.625231	0.466548	1.213105	0.508121	-0.744788	0.041868	0.01126	0.291251	-0.724874
1.379223	24	Krios	-0.329544	0.041307	-0.266806	-0.299541	-0.181406	1.114997	0.183453	-0.092801	0.621899	0.612406	-0.219578	-0.047809
1.49045	24	OT10-02	-0.464663	0.084837	-0.393917	-0.625231	0.538543	0.232022	-0.38949	-0.679589	0.493003	0.521667	0.631804	-0.620263
1.648873	24	5030_46B	-0.315027	-0.263409	-0.242972	-0.299541	-1.434117	0.722564	0.374434	-0.027602	-0.280372	-0.204246	-0.616889	-0.039091
1.70438	24	Jutra	-0.672366	-1.351677	-0.679916	-0.950922	-0.325396	-0.095005	0.049767	-1.331576	-0.151476	-0.164547	0.404769	-1.320576
1.919037	24	Altesse	-0.642215	-1.438739	-0.635655	-0.950922	-0.786163	0.133914	-0.714158	-1.13598	-0.409268	-0.45945	-0.446613	-1.143318
1.924057	24	MapleBelle	-0.52273	-0.176347	-0.55621	-0.625231	-0.138209	1.213105	1.520321	-0.744788	0.750795	0.748515	0.404769	-0.739404
2.02974	24	SECAN8-1	-0.349644	-0.829308	-0.298583	-0.299541	1.445678	0.133914	0.049767	-0.158	-0.409268	-0.465121	-0.333095	-0.184384
2.367129	24	Dares	-0.127424	-0.524593	-0.139695	0.02615	-0.541381	0.035806	1.577615	0.298391	0.041868	-0.022768	-1.070959	0.48687
2.525529	24	4043P2j	-0.667899	0.433083	-0.723043	-0.950922	-1.743695	0.035806	-0.38949	-1.201179	-0.602612	-0.606901	-1.0142	-1.224682

0	25	OAC7-6C	-0.826468	-1.395208	-0.820646	-1.602304	0.14977	-1.501224	-1.478082	-1.787967	-1.311539	-1.236403	-5.895452	-1.834913
0.954529	26	OACWalla	0.063529	-0.785777	0.060051	0.677532	0.488146	-0.095005	0.183453	0.754782	1.781962	1.905439	0.34801	0.652504
1.211037	26	MapleGlen	0.302499	0.346022	0.272281	0.677532	-0.066214	0.787969	0.31714	0.885179	1.330826	1.338319	0.291251	0.847196
1.297784	26	DH420	0.602887	-0.91637	0.611622	1.003223	-0.591777	0.362833	-0.198509	1.211173	2.426441	2.33645	-0.333095	1.11163
1.786338	26	Ginty	-0.172092	-0.045755	-0.197575	0.02615	-0.426189	0.460942	-0.141214	0.298391	1.330826	1.275936	-0.616889	0.440376
0	27	S03-W4	-0.167625	0.520145	-0.20779	0.02615	1.1361	-1.174196	-0.637765	0.298391	0.364107	0.379887	-4.703519	0.47234
0	28	Venus	2.090309	2.217843	2.020058	1.980296	1.805653	0.232022	1.272045	1.797961	-1.311539	-1.310129	0.007457	1.646308
0.844357	29	Gaillard	-0.06489	0.998983	-0.114726	0.351841	-0.469386	2.652026	1.577615	0.36359	-0.02258	-0.051124	-0.787165	0.524646
1.153577	29	Auriga	-0.254726	1.260167	-0.26794	0.02615	-0.757365	2.09608	2.150558	0.167994	-0.409268	-0.368711	0.518286	0.21953
1.374628	29	Mario	0.189714	1.086044	0.139496	0.677532	0.034579	2.750135	1.577615	0.819981	0.106316	0.050958	-0.162819	0.777456
0.998249	30	OAC7-4C	0.851907	0.520145	0.805694	1.003223	0.14977	-0.422033	-0.198509	1.34157	0.106316	0.01126	-0.276336	1.34991
1.081087	30	PRO25-53	1.648103	0.476614	1.616026	1.328914	0.653735	0.362833	0.31714	1.602365	0.493003	0.453613	0.234492	1.596908
1.142876	30	Mandarin	0.918908	0.868391	0.865844	1.328914	-0.138209	0.232022	-0.255803	1.471968	0.686347	0.742844	-0.219578	1.437086
1.257739	30	OACPrudence	1.257263	-0.132816	1.235828	1.328914	0.488146	-0.618249	-1.09612	1.602365	0.686347	0.703145	-0.219578	1.544603
1.55522	30	Kamichis	1.201429	-0.91637	1.198376	1.328914	-0.210204	0.133914	-0.141214	1.471968	0.879691	1.066102	0.234492	1.460333
1.607012	30	MapleDonovan	0.710088	-0.002224	0.695606	1.003223	-0.109411	0.55905	0.870985	1.34157	0.621899	0.618078	-0.276336	1.280169
1.755262	30	Toki	0.641971	0.041307	0.626376	1.003223	1.784054	-0.618249	-0.714158	1.276372	0.428555	0.385559	0.34801	1.222052
1.882818	30	Saska	2.071326	-0.045755	2.05978	1.654605	1.589668	-0.193113	0.126159	1.667564	0.493003	0.419586	-0.10606	1.643402
2.167402	30	MaplePresto	0.505735	1.173106	0.458408	1.003223	-0.015818	-0.618249	0.431729	1.080776	-0.409268	-0.380053	-0.56013	1.100006
2.451485	30	SECAN8-2	0.899925	0.607206	0.852225	1.003223	1.474476	-0.520141	-0.007528	1.406769	-0.989299	-0.918817	0.80208	1.425462
2.482569	30	5085_8Bp	1.24833	0.998983	1.197241	1.328914	-1.333324	-0.945277	-0.007528	1.537166	1.266378	1.270265	0.915597	1.503921

Table B2. Numerical information presented in supplement to that in Table 1 (right half) for the cluster analysis applied to the first six principal components from the preliminary PCA performed on the dataset for the 12 RSA-related traits after standardized, including the distance to the centroid and the Prin1-Prin6 scores for each of the 137 soybean lines. White and yellow colors are used to highlight lines that are members of different clusters from Cluster 1 to Cluster 30, while red is used to identify clusters with only one member.

Distance	Cluster	Line	Prin 1	Prin 2	Prin3	Prin 4	Prin 5	Prin 6
1.330548	1	4004P4J	-0.20656	-0.15432	-2.04757	-1.67709	0.729894	-1.7157
1.392867	1	5017_25B	-0.959	-1.45933	-1.76732	-1.12985	0.965888	-0.0868
1.436877	1	Bloomfield	-0.07392	-0.33199	-0.59798	-0.86269	-0.59623	-0.6398
0	2	4005_24j	1.770632	-1.68441	-1.91051	-0.19973	-0.53428	-3.00415
0.903904	3	PS44	1.654187	-0.72875	-2.17273	1.57129	0.758509	0.345872
0.964755	3	OAC9-48C	0.942252	-0.69559	-1.64217	1.770093	0.431012	-0.17159
1.251096	3	SECAN9-3	1.862934	-1.39112	-0.77204	1.812982	0.172326	0.751896
1.34092	3	Phoenix	2.931238	-0.71081	-1.87471	2.256634	0.712191	-0.19064
1.488738	3	Hercule	1.914302	-0.97251	-1.06208	0.772799	0.040392	-1.13871
1.124655	4	OAC7-26C	6.7597	-2.06606	1.649882	0.286508	0.972291	-0.28298
1.124655	4	OACBayfield	6.82274	-1.881944	3.47351	-0.88718	0.548711	0.08972
1.020093	5	Gretna	-2.16439	0.630564	0.07599	0.345438	0.186796	-0.20604
1.090915	5	OAC7-23C	-2.0634	-0.42744	-0.18394	0.837152	-0.0877	0.231784
1.097175	5	MapleIsle	-1.8243	-0.2931	0.738313	0.460852	0.483973	0.203445
1.198203	5	AC2001	-1.4314	-0.05938	0.691225	-0.54135	0.739782	-0.4879
1.341361	5	9063	-1.50845	-0.98326	-0.71424	0.455144	1.173753	-0.41458
1.400791	5	4043P2j	-2.49156	-0.70061	-0.29292	0.306708	0.343006	-1.4895
1.49227	5	91M10	-1.53114	-0.01207	0.399357	-1.09618	0.562365	0.025838
1.578476	5	Flambeau	-1.84004	0.587904	0.277908	-0.71493	-0.59813	-0.30498
1.712594	5	ACOrford	-1.80092	-0.81489	-1.43354	0.250367	1.019184	0.127051
1.748471	5	Heather	-1.33331	0.953854	0.672347	0.976158	0.155887	-0.91943
1.997445	5	OT11-02	-1.34319	0.512374	0.141019	1.230973	1.083498	0.817481
0.844417	6	Madoc	-3.27298	0.365985	0.817858	-0.31146	-0.16569	0.602869
1.273004	6	Colby	-3.54467	-0.34459	1.296343	-0.00344	-1.26405	-0.6403
1.314424	6	Altona	-3.50214	-0.6549	1.313351	-0.63567	-1.05128	-0.26649
1.489835	6	Casino	-4.3733	0.470132	0.960399	1.06709	-0.14135	-0.4645
1.924092	6	Amasa	-3.29733	1.37474	1.033897	-0.62224	1.030084	0.415849
1.121011	7	OACPrudence	3.286357	-1.1774	0.047875	-0.20711	-0.08967	0.045533
1.390005	7	Saska	4.128291	-0.21712	1.317002	0.276166	-0.352	0.807936
1.500751	7	MapleArrow	4.470498	-2.06206	1.262645	-1.34669	0.266108	0.0513
0.944889	8	OACWallace	1.979215	0.758553	-1.48555	-0.90498	-1.18758	0.104095
1.369858	8	OT11-03	1.907641	-0.25256	-0.73211	-1.2991	-0.72994	0.744836
1.477678	8	Katrina	1.394601	0.651079	-0.55116	-0.66183	0.195316	-0.19687
1.524441	8	DH420	3.002459	0.525476	-1.58467	-1.3401	-1.32931	-1.33768
1.69266	8	Kamichis	3.090677	-0.04358	0.270452	-1.28362	-0.35887	-0.48238
1.239143	9	5055_43G	-2.11929	-0.31204	2.389781	0.88467	-0.33172	-2.4206

1.239143	9	90A07	-2.34637	1.781666	2.380786	-0.00465	-0.14879	-1.48129
1.10524	10	Costaud	1.066894	-0.711	0.213361	-0.44821	-0.29761	-0.87539
1.366054	10	KG-41	-0.00345	-0.3005	1.694259	0.02242	-0.8619	-1.24762
1.397004	10	DH618	0.005746	-0.81758	0.938972	0.329501	-0.25406	-1.00099
1.410547	10	5070_26j	0.894363	-1.32447	1.261415	-2.07979	-0.71783	-1.33707
0.929683	11	Mandarin	2.87362	0.017451	-0.06222	0.284094	0.630874	-0.76464
0.929683	11	5085_8Bp	3.406451	-0.21081	-0.92999	-0.93938	1.563431	-0.80522
1.989973	11	MapleDonovan	2.319144	0.829031	0.497107	-0.10366	-0.08078	-0.85576
0	12	Venus	3.504441	0.443113	3.07661	2.264172	1.865961	0.992531
0	13	OAC7-6C	-3.51238	-3.94506	0.694758	2.791207	-3.81182	-1.94384
1.025438	14	MapleGlen	1.950515	1.212767	-0.87818	-0.29554	-0.05199	-0.57655
1.133581	14	Misty	0.957905	1.125098	-1.93175	0.473249	-0.33819	-0.6243
1.376547	14	Proteus	1.862329	2.421973	-1.29305	-0.01608	-1.58936	0.147437
1.554006	14	Ginty	0.825602	0.481711	-1.31164	-0.13592	-0.74981	-1.10093
1.561721	14	OACChampion	0.803258	0.570236	-1.82936	-0.28124	-0.47042	0.300974
1.111696	15	Bravor	1.286329	-2.17981	-0.94501	-0.84149	0.940364	0.100996
1.149608	15	MapleRidge	0.16274	-1.0078	-0.64594	0.215294	0.378599	0.086198
1.403277	15	OAC9-22C	0.392876	-1.3315	-1.21992	0.127763	-0.42205	0.238089
1.568972	15	Naya	1.448332	-0.66196	-1.08196	-0.65097	0.511245	0.759397
1.907814	15	90B11	-0.85748	-2.8683	-0.50978	-1.08654	0.303269	0.071198
2.06738	15	5146_41j	0.804575	-1.97405	1.088615	-1.53843	1.158925	-0.17975
0	16	Tundra	2.392434	-0.00919	-3.11959	0.165908	-2.23717	0.720008
1.026367	17	SECAN8-1	-2.82205	1.656586	1.940391	0.237208	-1.0961	1.254622
1.035492	17	OAC1-26	-2.06458	0.71528	1.119125	-0.44278	-0.12782	0.755036
1.50557	17	OAC9-35C	-2.24928	1.980036	0.392426	0.583123	0.026494	0.28567
2.170144	17	OAC7-3C	-2.02314	3.050042	1.847766	-0.2462	-0.55075	-0.29354
2.555418	17	Victoria	-2.94044	-0.50777	1.515473	0.249691	-0.86856	2.487679
0	18	Woodstock	9.434811	1.821216	2.576142	0.148041	-2.45656	2.60001
0.775305	19	Jutra	-2.25111	0.019309	-0.27515	-1.10176	-0.86656	0.401377
1.241702	19	Dundas	-3.03428	0.057752	-0.82016	-2.42551	-0.91257	1.23992
1.249249	19	Albinos	-3.00033	-0.94026	-0.37114	-1.98963	-1.63841	0.19325
1.345855	19	OAC9-17C	-1.7492	-0.5939	-0.66762	-0.7842	-0.24144	0.999309
1.486543	19	Altesse	-2.3293	-0.75828	0.003871	-0.89567	-0.9591	-0.41837
0.728379	20	OT94-47	7.153823	-0.95995	0.814329	-1.47658	-1.23569	0.056048
0.728379	20	OAC8-21C	6.152977	-1.13569	0.116077	-1.04452	-0.65484	-0.22312
0.651441	21	Alta	-2.35283	-0.78953	-0.05158	-0.87575	0.539341	0.475198
0.991284	21	DH530	-2.391	-0.8336	0.151482	-0.22234	1.057945	0.594303
1.351991	21	Clinton	-1.84107	-0.97596	0.685349	-0.57948	0.181966	0.008464
1.418812	21	9004	-3.90855	-1.3628	0.397868	-0.96748	0.360247	0.33015
1.460741	21	ACGlengarry	-3.62941	-2.08626	0.507335	-1.30224	0.226576	0.849288
1.664939	21	4028P7j	-3.1541	-0.97794	1.043664	-1.32752	1.585948	0.020585
1.701912	21	Madison	-1.88605	-1.2658	-1.2704	-0.54916	0.438511	1.191067
2.058549	21	OAC8-22C	-0.87265	-1.78016	0.123878	-1.40592	0.241705	1.52625
1.090354	22	McCall	0.475332	2.283749	-1.54313	0.617624	0.181623	0.036456
1.371486	22	SECAN7-2	0.94133	1.734751	-1.62682	0.013336	1.001819	1.648522
1.374978	22	Jari	0.42858	2.092761	-1.22674	0.615443	1.582439	-0.10791
1.46743	22	Ohgata	0.391732	1.576233	-0.18138	0.728714	-0.07183	0.077655
1.916493	22	SECAN8-1	0.190037	1.766774	-0.0326	1.395136	0.323586	0.893865
1.924913	22	KORADA	0.796046	0.138305	-2.16059	-0.71115	0.748024	0.503303
2.183383	22	OACAyton	0.239793	3.639512	-0.91773	-0.30924	1.03602	0.492437
1.107881	23	4067P17j	-0.35706	0.419181	-0.10133	-0.60456	1.522713	-1.18046
1.352671	23	Gentleman	-0.44099	0.189333	-0.96034	0.480739	1.112223	-0.14512
1.400772	23	4042_6Bp	-0.208	-0.13436	-0.91994	-0.5139	1.894501	-0.85746
1.42335	23	Evans	0.610755	0.41395	-0.22497	0.11068	1.564922	-0.06937
1.456422	23	Brant	-1.02616	0.581807	-0.95137	0.176985	1.040441	-0.2483
1.476966	23	ACProteina	-0.19762	-0.28835	0.941623	-0.26989	2.229461	0.135455
1.506418	23	5091_50j	-0.10773	-1.35208	0.286443	-0.27505	0.703671	-0.99715
1.614032	23	Carman	-0.77737	-1.16541	-0.86105	0.110712	1.347852	0.188331
1.695816	23	90A01	-0.20019	-0.1248	1.456272	0.107134	0.76088	-1.25805
1.714167	23	5030_46B	-0.80477	0.269737	0.3752	-0.34397	0.082361	-1.58965
0	24	S03-W4	0.701144	-2.11331	-0.40465	3.411648	-2.53768	-1.61214
0.975369	25	Roland	-2.32112	-1.28779	0.111746	0.56415	-0.20373	1.62888

1.059605	25	OACOxford	-1.4738	-1.0613	0.539552	0.99529	0.337259	0.50819
1.270806	25	OT09-03	-2.08124	-1.86289	1.097987	0.184749	-0.90676	0.731327
1.41349	25	OT11-09	-2.05585	-2.73331	0.140375	1.497938	0.596295	1.056014
1.429122	25	Purdy	-1.05801	-1.01881	0.540989	0.119985	-0.42711	1.190377
1.578908	25	OT11-01	-1.52352	-1.47635	-0.31697	-0.16788	-0.83495	0.888424
1.015101	26	MapleBelle	-0.95299	2.235698	-0.60345	-0.36073	-0.65182	-0.26621
1.039663	26	OACKent	-1.05662	2.771455	-0.68902	-0.26498	-1.3645	0.020862
1.821556	26	Delta	0.303821	3.615807	-0.21025	-2.33322	-0.74948	-0.54365
1.968453	26	PS36	-1.1232	2.320863	-0.30653	0.214177	-0.0081	0.710073
0.812049	27	OAC7-4C	2.272425	-0.59879	0.507522	0.389385	0.576357	-0.24987
1.395186	27	MaplePresto	1.586797	-0.4355	0.734765	1.109277	1.026007	-0.44825
1.465076	27	Toki	2.471991	-0.55593	-0.01277	0.371975	-0.18009	1.378587
1.479554	27	PRO25-53	3.493394	0.404747	0.932426	0.10011	0.424079	0.095749
1.524081	27	SECAN8-2	1.997174	-0.44931	1.592664	0.663056	1.201516	1.502396
1.002491	28	S14-P6	0.366651	0.053917	-1.57329	1.268256	-0.36551	0.61092
1.224986	28	Walton	-0.18636	-0.71032	-1.81004	2.044111	-1.41811	1.160473
1.432934	28	S12-A5	-0.49183	-0.6201	-0.78764	2.549722	0.707164	0.732004
0.924578	29	Mario	1.025956	2.75571	1.076591	0.858192	0.535622	-1.19659
1.152542	29	Gaillard	0.260606	2.470455	0.988941	1.000909	0.292871	-1.79438
1.643582	29	Auriga	-0.39575	2.785033	0.956169	0.476558	1.326183	-1.06425
1.209572	30	OT05-20	-0.13876	-0.31209	-0.28224	-0.01688	0.184863	0.822197
1.242202	30	OAC9-44C	-0.9444	0.715403	0.627507	0.176825	0.639816	0.109285
1.25876	30	Lotus	-0.31278	0.448477	0.955385	0.134457	0.049093	-0.58529
1.277664	30	OACMorris	-1.23343	1.407253	-0.16387	0.310295	-0.25968	0.29335
1.304901	30	SECAN8-1	-0.62958	0.001721	0.61987	0.442547	-1.121	0.988649
1.340199	30	Drayton	-0.7802	0.535816	0.28064	-0.74783	-0.59344	-0.65564
1.34577	30	Elora	-0.93223	0.512442	0.225457	-0.88579	0.372077	0.058868
1.349564	30	Krios	-0.14737	1.03599	-0.56197	-0.00327	-0.44704	-0.67298
1.376278	30	OT10-02	-0.73834	0.478623	-1.09659	-0.11302	-0.28274	0.781664
1.459258	30	MapleAmbr	0.577359	-0.2273	-0.26634	-0.14262	-0.18475	-0.31502
1.506564	30	OACLakeview	0.047398	1.480173	-0.2673	0.822498	-0.67953	-0.16291
1.658561	30	S05-T6	0.906997	0.536344	-0.20045	0.562478	0.078445	0.863491
1.709452	30	Dares	0.089725	0.599769	0.655969	0.157708	-0.69857	-1.21514
1.711745	30	OAC8-11C	-0.78862	0.486544	-0.63292	1.385123	0.051295	-0.4716
1.747889	30	OAC7-48C	-0.9968	0.07935	-0.48931	-0.61869	-1.60996	-0.0756
2.027466	30	Perth	-0.3454	0.439457	1.598644	1.439207	-0.00559	-0.03862
2.101681	30	Stratford	-1.23741	0.015423	-0.13725	0.664496	-0.11212	2.059081
2.293443	30	SECAN7-4	0.912087	1.319651	0.220788	-1.02794	-1.03815	1.112695
2.591547	30	Supra	1.26182	1.643742	1.186795	-0.22983	-0.90362	1.081433