Analysis and Selection Program for Malt Quality in Barley by Microcomputer[1]

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ABSTRACT

An analysis and selection program for malting barley quality was developed using Lotus 1-2-3 spreadsheet software. The program stores the raw data for one agronomic and nine quality traits, performs all calculations, and executes a selection index based on an evaluation of the level and the importance of each trait to overall malt quality. The data may then be queried to select breeding lines for any set of criteria contained in the data base that is desired by the breeder. This program affords barley breeders an efficient method of summarizing the quality traits of experimental lines and a relatively objective means of selecting for overall malt quality. It is adaptable to selection of other traits and to other crops as well.

Barley breeders use malting tests to select good malt quality. Large numbers of experimental lines can be analyzed for quality factors using micromalting systems (approximately 20–100 g of seed) and microscale (0.1–5 g) tests (Bendelow 1981). This allows screening of early and advanced generation materials. Computerization of the micromalting process (Gothard and Smith 1986) and malt analysis (Nolte et al 1985) allows more samples to be screened in less time.

This paper describes a microcomputer spreadsheet template developed at the Washington State University Barley Quality Laboratory that stores the raw data from quality tests, calculates various quality traits from the data, and executes selection indices that take into account malting quality and other important traits of the 1,000 or more barley samples selected for testing each year.

The selection criteria are based on the American Malting Barley Association's analytical guidelines for two- and six-rowed barley and the goals of the Washington State University barley breeding program.

MATERIALS AND METHODS

To develop this computerized system we used Lotus 1-2-3 spreadsheet software (Lotus Development Corp. 1982). The system requires a minimum of 300KB of main memory that includes 192KB for the Lotus software, which contains all necessary functions, and about 90KB for the spreadsheet. For flexibility, at least 512KB of memory is preferable. A hard disk would be required if more than 200 barley selections were to be analyzed and selected simultaneously.

The micromalting and analysis procedures used were modified from those described in Lejeune and Privette (1978) and Ullrich et al (1981). Seed samples of F_3 to F_5 lines were analyzed for the quality traits listed in Table I.

Our analyses were not replicated because of the large amount of material that needed to be rapidly screened. A seed sample of the industry standard cultivar, Morex, was included with each set of samples malted as a check of the malting process. Furthermore, flour from a single batch of malted Morex seed was included in each set of assays for a check on the consistency of the assays. The influence of the field environment was taken into account by malting and analyzing field checks of Klages (two-rowed) or Morex (six-rowed) grown interspersed among the experimental lines.

RESULTS

The program is laid out in sections as shown in Figure 1. The identification of each barley line evaluated and data from the field or laboratory analyses are entered first. Formulas in the Quality Results section convert the raw data into the quality trait results. The guidelines for quality traits vary for two- and six-rowed barley, so there are two sets of criteria listed under Selection Criteria. The correct set of criteria for the type of barley being analyzed is copied into the Selection Program section.

Each trait in columns D through M (Fig. 1) is assigned a value from 0 to 5 depending on how well the trait meets established criteria and how important each trait is to overall malt quality. This is accomplished by using the logical operator @IF, which is built in to the Lotus program. The @IF operator sets up a statement or condition and tests whether it is true or false. In this program, if the statement is true, a number indicating the value of that trait is assigned to that cell. If the statement is false, zero is assigned. Multiple @IF statements can be made concerning a single trait.

The criteria statements used for rating the quality traits of six-rowed barley (cells AD through AU) are shown in Table I. For example, three formulas displayed in cells AD–AF set up conditional tests for percentage of plump kernels. The first statement says if the percentage of plump kernels is greater than or equal to 85 and less than 90, give this trait a value of 3. The next statement says if the percentage plump is greater than or equal to 90 and less than 95, assign a value of 4. The third statement completes the evaluation by stating that if the percentage plump is greater than or equal to 95, assign a value of 5. If the percentage of plump kernels in a given line were 93, the values in cells AD, AE, and AF would be 0, 4, and 0, respectively. As many statements may be made as are needed to adequately rate each trait. In this way, the relative importance and the level of the trait are taken into account by the range of values each trait may receive. For example, a trait

TABLE I
Selection Program Formulas from Computer Spreadsheet for Quality Analysis of Six-Rowed Malted Barley

Cell	Quality Traits	Criteria Statements
AD4	Kernel plumpness (%)	@IF($E4 > =85#AND#$E4 < 90,3,0)
AE4	Kernel plumpness (%)	@IF($E4 > =90#AND#$E4 < 95,4,0)
AF4	Kernel plumpness (%)	@IF($E4 > =95,5,0)
AG4	Viscosity (cps)	@IF($G4 < 1.7#AND#$G4 > =1.6,1,0)
AH4	Viscosity (cps)	@IF($G4 < 1.6,2,0)
AI4	Total protein (%)	@IF($H4 > =12#AND#$H4 < =13.5,4,0)
AJ4	Total protein (%)	@IF($H4 > 13.5,1,0)
AK4	Soluble protein (%)	@IF($I4 > =5.2,3,0)
AL4	Soluble/Total protein	@IF($J4 > =0.4#AND#$J4 < =0.44,3,0)
AM4	α-Amylase (20° DU)	@IF($K4 > =35#AND#$K4 < 40,3,0)
AN4	α-Amylase (20° DU)	@IF($K4 > =40,4,0)
AO4	Diastatic power (° L)	@IF($L4 > =130#AND#$L4 < 145,1,0)
AP4	Diastatic power (° L)	@IF($L4 > =145#AND#$L4 < 160,2,0)
AQ4	Diastatic power (° L)	@IF($L4 > =160,3,0)
AR4	Malt extract (%)	@IF($M4 > =80#AND#$M4 < 81,3,0)
AS4	Malt extract (%)	@IF($M4 > =81#AND#$M4 < 82,4,0)
AT4	Malt extract (%)	@IF($M4> = 82,5,0)
AU4	Malt quality total	@SUM($AD4 . . $AT4)

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such as percentage of malt extract is given more potential points (5) than the viscosity of malt extract (2).

The final column (AU) of the Selection Program section uses the @SUM command to total all the numbers in cells AD–AT for each barley line to give an overall malt quality total. The highest malt totals indicate the highest potential malt quality, based on the parameters tested. The malt quality total column is then copied into column F with the rest of the finished results to allow for the final query process to select the top lines.

The Query Criteria are statements that must be true for a line to be selected. This selection program was written with malt quality total as the only criterion because it takes all the quality traits into account. Lines meeting or exceeding the specified total are entered into the Query Output section and represent the most promising selections for overall malt quality that will be retained in the breeding program. Table II shows an example printout of all test results and the selections from a given malt run (columns A–M of spreadsheet).

DISCUSSION

This selection program offers breeders and the malting and brewing industry a means of estimating the overall malt quality of lines or malt lots. Complex calculations of laboratory analyses are performed rapidly from stored formulas. The multiple parameters from a large number of lines create a large data base for effective manual selection. This program allows the few outstanding lines to be rapidly and relatively objectively selected within seconds. All lines within one barley type are evaluated by the same standards. The malt quality totals for check samples of Klages and Morex can be used to set the criteria for malt total quality in the query process.

The use of multiple @IF statements greatly improves the ability of this program to weigh the various quality traits. A ranking system, in which individual traits are evaluated by ascending or descending order, or by their difference from an established optimum, is not as versatile or informative. For example, 10 selections from a single cross may all have values between 12 and 13.5% for total protein and may all be acceptable. However, a ranking system would order them 1–10, rating some more acceptable than others. A ranking system also cannot compare samples from different micromalts unless all the data are examined together, resulting in a spreadsheet that might be too big for a microcomputer to process in a reasonable time. This spreadsheet program can compare results from different malts and analyses by determining how well each sample meets guidelines for each trait. To compare all malt quality totals from an entire year, a combined file of all micromalts is made (columns A–F, Fig. 1). Using the query process, all lines with greater than some set malt quality total or all lines in the top specified percentage of malt quality totals will be selected.

Other computer programs for selection of wheat quality (Gilles et al 1965, Dick and Shuey 1976, Nolte et al 1985) have used the Statistical Analysis System, SAS (Barr et al 1981). These programs used a maximum quality rating of 4 and subtracted points for faults that were determined by deviation from the average values obtained for standard varieties. Using this type of evaluation, it is not possible to specify an acceptable range of values, excluding values that fall above or below it as unacceptable, or to give a premium for exceeding the quality of standard varieties. This is not important when identifying samples that meet some minimum standard for quality control purposes but is a definite disadvantage to a breeder trying to identify superior genetic material. SAS has the capability to be used in the same manner as Lotus 1-2-3 is used here.

This program has been used for three years to evaluate over 3,000 lines. It has been necessary to adjust only the plump kernel percentage, which is the characteristic most influenced by annual weather fluctuations. However, the selection criteria statements and the query criteria are easily changed to suit specific goals. The lines can be reselected for different criteria any number of times in just minutes. A breeder might decide to put extra pressure on a particular trait by increasing the potential points or changing the levels specified in the selection formulas. Breeding lines that are outstanding in one particular trait could be selected for parent building and crossing purposes by listing that trait in the query criteria.

This computer program allows breeders the ability to objectively evaluate new malting barley lines and to more concisely discuss quality among themselves. It may also be used by individual breeders to select lines to meet specific goals of their program. This basic format could easily be adapted to select for different quality traits in other crops or to select for nearly any kind of quantitative breeding objective.

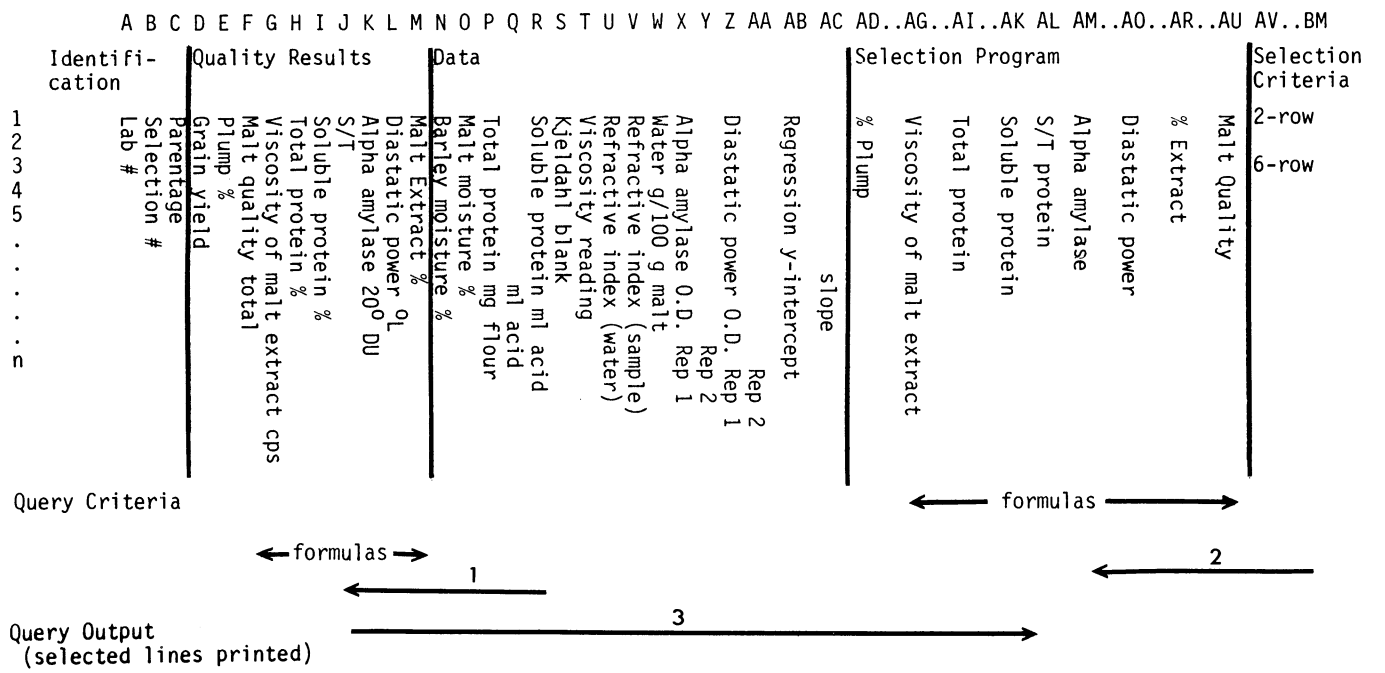

Fig. 1. Lotus spreadsheet selection program for quality analysis and selection of malted barley lines. The arrows indicate order and direction of information flow. **1,** Data are converted into quality results. **2,** Either the two- or six-rowed selection criteria are moved into the selection program depending on the type being selected. **3,** The quality results are then analyzed by the selection program giving a malt quality total value.

TABLE II
Printout of Test Results and Selections Made from a Micromalt of Two-rowed Barley Lines

Lab No.	Selection	Parentage	Test Results: Yield (bu/a)	Plump (%)	Malt Total	Visc. (cps)	Total Prot. (%)	Soluble Prot. (%)	S/T[a]	AA[b] (20U)	DP[c] (°L)	Extract (%)
0	CMorex	Assay check	···	95	21	1.56	12.29	5.18	0.422	47	185	79.2
468	CMorex	Lab check	···	95	28	1.62	12.28	5.25	0.427	49	207	84.0
469	11869	10698-76 × Sunbar 550	69	86	20	1.63	12.50	4.70	0.376	48	169	82.2
470	11895	10698-76 × Sunbar 550	80	96	6	1.88	13.34	4.43	0.332	33	108	78.2
471	11899	10698-76 × Sunbar 550	84	94	7	1.88	9.48	4.34	0.458	37	101	79.8
472	11905	10698-76 × Sunbar 550	81	94	17	1.70	11.56	4.18	0.362	44	121	82.3
473	11910	10698-76 × Sunbar 550	76	95	16	1.86	11.61	4.16	0.358	48	122	81.0
474	11917	10698-76 × Sunbar 550	97	98	9	1.85	12.58	4.51	0.358	32	117	77.4
475	11926	10698-76 × 9044-75	72	95	20	1.67	13.00	5.12	0.394	50	180	79.2
476	11928	10698-76 × 9044-75	75	94	18	1.77	13.62	5.38	0.395	52	200	80.4
477	11932	10698-76 × 9044-75	82	95	26	1.75	12.49	5.29	0.423	56	186	81.7
478	11952	10698-76 × 9044-75	70	93	25	1.72	11.97	5.08	0.424	55	162	81.1
499	12107	Pirouette × 9390-80	80	94	21	1.77	13.44	5.45	0.405	51	176	80.8
508	12186	8892-78 × Mt. 41918	68	96	20	1.79	12.66	4.39	0.347	53	175	81.4
509	12192	8892-78 × Mt. 41918	103	93	15	2.13	12.03	4.30	0.357	49	168	79.5
510	12214	8892-78 × Mt. 41918	77	96	17	1.78	10.74	4.15	0.387	52	165	84.5
511	12217	8892-78 × Mt. 41918	66	99	16	1.96	13.15	4.90	0.372	49	208	80.3
512	12218	8892-78 × Mt. 41918	60	95	16	1.88	12.67	4.50	0.355	56	201	79.7
513	12227	8892-78 × Mt. 41918	89	97	13	1.89	13.03	4.87	0.374	50	189	77.8
514	12229	8892-78 × Mt. 41918	66	96	17	1.77	13.23	4.65	0.351	54	186	81.6
515	CMorex	Lab check	···	95	20	1.70	12.42	4.91	0.395	54	211	80.1
0	CMorex	Assay check	···	95	21	1.57	13.26	5.23	0.395	50	200	78.7
Query criteria												
*	~C*			+$F9> = 20								
Query output												
469	11869	10698-76 × Sunbar 550	69	86	20							
475	11926	10698-76 × 9044-75	72	95	20							
477	11932	10698-76 × 9044-75	82	95	26							
478	11952	10698-76 × 9044-75	70	93	25							
499	12107	Pirouette × 9390-80	80	94	21							
508	12186	8892-78 × Mt. 41918	68	96	20							

[a] S/T = Ratio of soluble to total protein.
[b] AA = α-Amylase.
[c] DP = Diastatic power.

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