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Morphological traits associated with grain plumpness of barley grown in Western Australia

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Abstract

Progeny from crosses between plump grain and narrow grain barleys were evaluated in small plot, field trials during 1999 and 2000. The aim of the study was to identify plant characteristics that are associated with a plump grain size that can be used to improve the selection efficiency for high yielding malting barley with plump grain in Western Australia. Hierarchal cluster analysis of screenings data was used to group the crosses into eight clusters. Plant traits were then related to the cluster analysis.

Results from two distinctly different seasons (non-stressed and stressed) suggest that the following traits are associated with grain plumpness in barley - stem or peduncle length, head length or number of grains per ear, average grain weight, the linear rate of grain filling, stem carbohydrates per grain, ability to maintain green leaf colour during grain filling and time to awn emergence.

A restricted data set from the 2000 season looked within a group of crosses that reached awn emergence at a similar time after the variety Stirling. This was done to remove any over riding effect maturity may have on grain plumpness in a very dry season. Within this narrow range of flowering dates, lines with high rates of grain filling, fewer grains per ear and high average grain weights were found in the plumper clusters. In this maturity group, stem and peduncle length were not associated with grain plumpness, whilst there was a weak association with the ratio of green leaf area per grain.

Introduction

Since it's release in 1983, the malting barley variety Stirling has been a benchmark variety for it's ability to produce plump grain under a wide range of conditions in Western Australia. In the higher rainfall areas (> 400 mm annual rainfall), improvements in grain yield have resulted from the release of later maturing, feed barley varieties such as Onslow, Skiff and Fitzgerald. Attempts to breed for improvements in malting quality have resulted in the release of Franklin and Gairdner. These varieties lack the grain plumpness of Stirling and the ability to maintain grain plumpness under a range of environmental stresses. The propensity of crosses using European or Canadian malting germplasm to produce small grain in Western Australia is a major hurdle for barley breeding in the long term.

This poses several questions. Is the tendency to produce small grain linked to plant traits such as the semi-dwarf character or is it possible to breed short strawed, high yielding varieties that are reliably plump? What plant traits do varieties such as Stirling have that allows them to produce plump grain under a range of environmental and management conditions? Is it possible to identify combinations of characteristics that can be used to improve the selection efficiency for high yielding malting barley with plump grain?

The aim of this study was to identify the plant traits common to the plump grained progeny in a range of crosses between plump and narrow grained parents.

Materials and Methods

Evaluation of grain plumpness crosses

During 1997 and 1998, progeny of crosses between plump grained and narrow grained varieties were selected on the basis of time to awn emergence, plant height, penultimate leaf dimensions and grain size in un-replicated, single rows (2m long) at Esperance. Control plots were sown every fifth plot.

Sources of grain plumpness used were from four different backgrounds - Australian (VB9104), Japanese (Kinukei 19, Kinukei 20, Kinukei 22, Unicorn, Nasu Nijo, Kino Nijo 7), winter (85S:328-56-15) and international nurseries (Yagan, Arupo). Where possible lines were chosen from doubled haploids or genetically stable selections from crosses to narrow grained varieties (Franklin, Chariot, Harrington and Skiff) (Table 1). Control varieties included Stirling, Skiff, Harrington, Chariot, Fitzgerald and Franklin.

In 1999, lines intermediate in maturity between Stirling and Fitzgerald were sown in small plots (5m long x 5 rows) at Wongan Hills. Lines were sown in a fully randomised block design with 2 replications (6 banks per replicate and 30 plots per bank). Plots were sown on 20th May and 17th June. Plant traits measured included early growth habit, time to awn emergence, linear rate of grain fill, stem carbohydrates at beginning of linear grain filling phase, stem and peduncle length and width, penultimate leaf length and width, head shape and length, grain number per ear, grain yield and physical grain quality.

In 2000, a reduced number of lines were sown in small plots (5m long x 5 rows) at Wongan Hills in a fully randomised block design with 2 replications (6 banks per replicate and 14 plots per bank). Plots were sown on 26th May, 22nd June and 13th

July. A number of elite lines from both the West Australian (WABAR2098, WABAR2104, WABAR2109, WABAR2110, WABAR2076 and WABAR2080) and South Australian (WI3073 and WI3102) barley breeding programs were also included in the study. In addition to the plant traits measured in 1999 a measure of leaf greenness during grain filling was also made with a Minolta SPAD meter.

Table 1. Pedigrees studied and the number of lines evaluated for grain plumpness.

Pedigree	1997	1998	1999	2000
85S:328-56-15/Skiff	-	21	16	7
Chariot/85S:328-56-15	-	17	11	6
Franklin/Kinukei 20	27	4	4	3
Franklin/Unicorn	68	8	6	2
Franklin/Kinukei 22	27	15	11	7
Skiff/Harrington//Kinukei 19	16	3	3	2
Skiff/Harrington//Unicorn	32	16	14	12
Skiff/Unicorn	29	6	6	-
Skiff/Nasu Nijo	-	21	11	3
Kino Nijo 7/Skiff	-	9	7	1
Unicorn/VB9104	21	5	4	-
VB9104/Chariot	-	170	60	18
Arupo/Unicorn	37	8	7	7
Controls	2	7	12	13
Total number of lines evaluated	259	310	172	81

In addition, small plot trials (`breeders' trials) of the same design as that sown at Wongan Hills in 2000 were repeated at nine other locations around Western Australia (Mingenew, Badgingarra, Wilgoyne, Yilliminning, Gairdner River, Neridup, Katanning, Newdegate and Lake King) to test for the stability of grain size. These sites were chosen to represent a broad spectrum of rainfall zones and soil types. At these nine locations, the only measurements were grain yield and physical grain quality.

Seasonal conditions

At Wongan Hills in 1999 and 2000, maximum, minimum and daily air temperatures, solar radiation, relative humidity and daily rainfall were recorded. Contrasting seasons were experienced between 1999 and 2000. The 1999 season was characterised by little or no moisture deficit. During 2000, plots underwent moisture stress during grain filling. At the other nine locations in 2000, lack of spring rain put all lines under moderate to severe moisture stress during the grain filling period.

Statistical analysis

General statistical analysis was conducted in GENSTAT (Payne *et al.* 1998). Grain yield (kg/ha) and screenings (% < 2.5 mm) data were spatially analysed by a multiplicative mixed model, which allowed for a separate covariance structure and error variance at each location and heterogeneity of the genotype by environment variance (ASREML, NSW Department of Agriculture). Ward hierarchical cluster analysis was performed in JMP (SAS Institute, USA) with a location by screenings data matrix from the 2000 season (12 locations). The morphological traits of lines clustering in the same cluster were averaged (with standard errors) to summarise the performance of similarly clustering lines.

Table 2. Average screenings, number of lines and average yield of each screenings cluster

Cluster Number	Number of lines per cluster	Average screenings (% < 2.5 mm ± s.e.)	Average grain yield (kg/ha ± s.e.)
1	15	50.1 ±0.6	1,840 ± 57
2	7	29.5 ± 0.2	2,090 ± 53
3	16	42.1 ± 0.6	1,878 ± 44
4	5	59.6 ± 1.2	1,861 ± 47
5	3	17.7 ± 2.3	2,097 ± 160
6	15	36.3 ± 0.6	1,854 ± 42
7	9	32.2 ± 0.7	2,149 ± 78
8	11	26.1 ± 0.6	2,037 ± 81

Results and Discussion

Cluster analysis of screenings from 2000 season

A large range of screenings (% < 2.5 mm) was observed across the twelve locations sown in 2000. The overall average screenings was 38.3 ± 1.2 % and ranged across locations from 18.1% at Neridup to 58.5% at Yilliminning.

Table 3. Lines of lower or similar screenings to Stirling identified from cluster analysis.

Cross	Pedigree	Screenings (%<2.5mm)	Cross	Pedigree	Scree (%<2
Cluster 2			**Cluster 8**		
42-18	Franklin/Kinukei 20	28.9	52-15	Arupo/Unicorn	28
47-25	Skiff/Harrington//Unicorn	28.8	WADH11787	Chariot/85S328-56-15	27
47-31	Skiff/Harrington//Unicorn	29.1	45-6	Franklin/Kinukei 22	27
WABAR2104	Stirling/Harrington	30.0	43-42	Franklin/Unicorn	28
94T059M-173-3	VB9104/Chariot	30.3	WADH11513	Skiff/Nasu Nijo	23
WI3102	WI2828//Skiff/Haruna Nijo	29.3	WABAR2109	Stirling/Harrington//Yagan	26
Stirling		30.0	94T059M-263-2	VB9104/Chariot	23
Cluster 5			94T059M-263-3	VB9104/Chariot	24
52-2	Arupo/Unicorn	20.8	94T059M-108	VB9104/Chariot	24
WABAR2110	Stirling/Harrington//Yagan	13.3	94T059M-168-3	VB9104/Chariot	26
WABAR2098	Yagan/Natasha	19.0	94T059M-121-4	VB9104/Chariot	28

Lines were grouped into eight clusters using the Ward hierarchical cluster analysis of screenings. Screenings of the eight clusters ranged from 17.7% to 59.6% (Table 2). The plumper groups (clusters 2, 5, 7 and 8) out-yielded the narrower clusters by around 10% (average grain yield difference of 235 kg/ha). Two clusters (clusters 5 and 8) were identified as having lower screenings and superior screenings stability than Stirling (Tables 2 and 3). The best cluster (cluster 5) included two elite lines from the West Australian breeding program that derive their grain plumpness from Yagan and one cross with two plump parents, Arupo and Unicorn. The plumpest line of those evaluated was WABAR2110 in cluster 5, with an average screenings level of 13.3% relative to Stirling, 30.0%. The second best group (cluster 8), included selections from all of the plump grained parents. Stirling was grouped in cluster 2 with progeny of VB9104 and a number of lines with Japanese parents. A high yielding semi-dwarf from the South Australian program, WI3102, was included in this group. Narrow grained parents, Skiff (46.6% screenings) clustered in the group with the second highest level of screenings (cluster 1), whilst Fitzgerald (43.0%), Chariot (41.8%) and Harrington (42.0%) grouped in the third highest screenings cluster (cluster 3).

Plant traits and grain plumpness

The plumpness (as indicated by % screenings) of each cluster observed at Wongan Hills (average of three times of sowing) in 2000 was highly correlated to their average performance at nine other locations sown in 2000 (`breeders') and the two dates of seeding sown at Wongan Hills in 1999 (Figure 1). Plant traits measured at Wongan Hills in both 1999 and 2000 were therefore used to represent the morphological traits of each cluster.

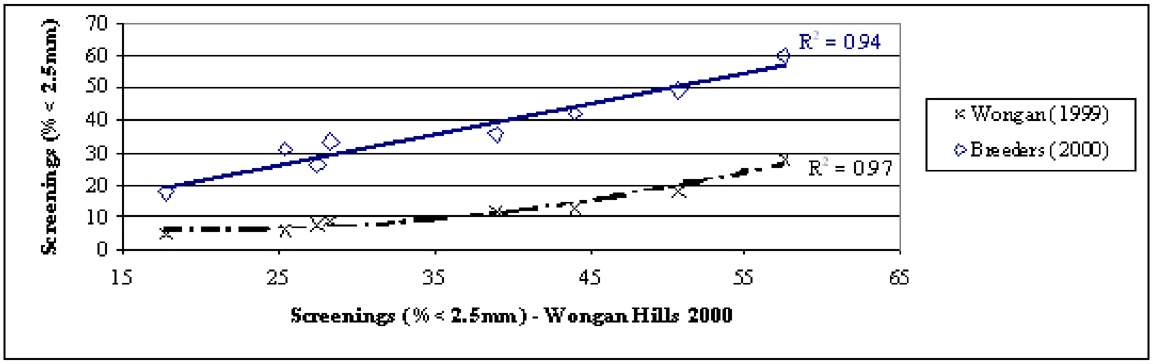

Figure 1. Relationship between average screenings of the eight clusters from Wongan Hills in 2000 (average 3 dates of seeding) versus their screenings at Wongan Hills in 1999 (average 2 dates of seeding) and at nine other sites around Western Australia in 2000 (`breeders').

Linear regression of plant trait data (1999 and 2000) indicated clusters with lower screenings were:

a) taller with a long peduncle (but ratio of peduncle to stem length similar to narrow clusters),

b) had shorter ears with less grains per ear (Figure 2) (but not more densely packed),

c) higher average grain weights,

d) faster rates of grain filling (Figure 2),

e) more stem carbohydrates per grain,

f) took fewer GDD to reach awn emergence than Fitzgerald,

g) maintained higher levels of green leaf area until mid grain filling and

h) had a higher ratio of green leaf area per grain at the middle of grain filling.

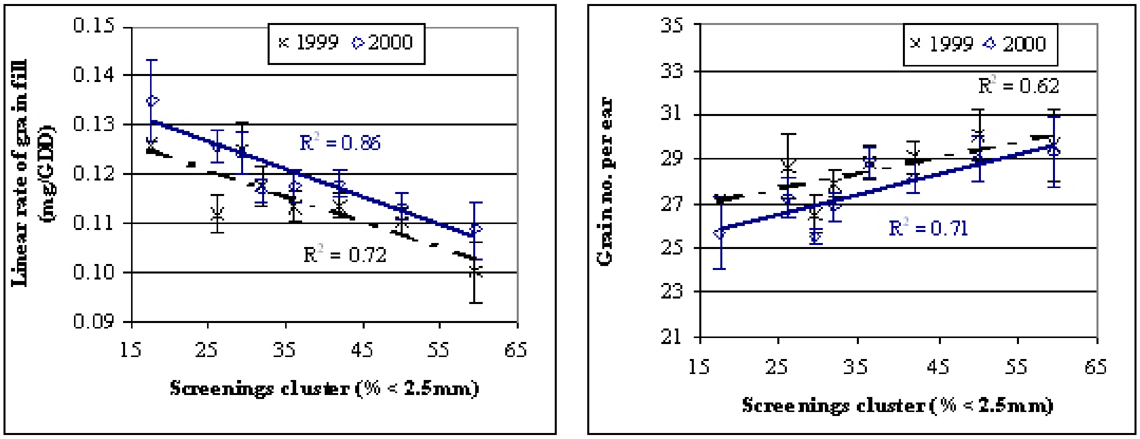

Figure 2. Relationship between average screenings of a cluster and a) average rate of grain filling during linear phase (mg/GDD) and b) average grain number per ear of the cluster.

Plant traits such as early growth habit (prostrate versus erect seedling habit), length and maximum width of the penultimate leaf, leaf area of penultimate leaves, basal stem width and peduncle width were found to bear no significant relationship to the group in which a line clustered.

Given the very dry conditions experienced in 2000 during the grain filling period, it is possible that early maturity may have had an over riding effect and that the correlation of all other traits to grain plumpness may be coincidental. To test this, lines that reached awn emergence in a narrow range (between 50 to 110 GDD after Stirling) were selected from all three sampling dates. This set included some data from the narrow grained parental lines Skiff, Harrington, Chariot and Fitzgerald.

This analysis from a narrow range of flowering dates showed that clusters 2, 5 and 8 were still the plumpest clusters. Linear regression showed that clusters with lower screenings had:

a) shorter ears with less grains per ear (but not more densely packed),

b) higher average grain weights,

c) started the linear phase of grain filling sooner after awn emergence and,

d) achieved faster rates of grain filling.

Within this maturity group, stem and peduncle length were not associated with grain plumpness. There was also only a weak association with ratio of green leaf area per grain at the middle of grain filling.

These results confirm the findings of a similar research project in south-eastern Australia. Moody (2001) observed that high rates of grain filling and the ability to transfer stem carbohydrates to the grain were important for barley growing in that region. Early maturity (especially short basic vegetative phase) and long peduncles were also found to be associated with grain plumpness.

Conclusion

A number of plant traits have been identified as being important to the ability of a barley plant to produce plump grain - probably none more than a high rate of grain filling. We also observed a high correlation between stem carbohydrates per grain and rate of grain filling. This suggests that high level of stem carbohydrate per grain may be important in buffering against reductions in photosynthesis during grain filling. As the rate of grain filling is difficult to measure in a breeding program it is probably a good example for where marker assisted selection could be of its greatest value.

Other traits such as fewer grains per ear and longer peduncles can be measured in the field. The `stay-green' character observed in 2000 is interesting and is being explored again in 2001. It is has been reported in other crops (*i.e*. maize and durum wheat) and there is a suggestion in the data generated to date that it may also be important in barley.

Acknowledgments

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References

1. Moody D. (2001) Improved grain size for barley varieties in south-eastern Australia. Final report submitted to the Grains Research and Development Corporation. Project No. DAV325.
2. Payne R.W., Lane P.W., Daird D.B., Gilmour A.R., Harding S.A., Morgan G.W., Murray D.A., Thompson T., Todd A.D., Tunnicliffe-Wilson G., Webster R., Welham S.J. and White R.P. (1998) Genstat 5 Release 4.1 Reference Manual supplement. (Numerical Algorithms Group: Oxford, UK).