Survey of White Salted Noodle Quality Characteristics in Wheat Landraces

C. K. Black,[1,2] J. F. Panozzo,[1] C. L. Wright,[3] and P. C. Lim[1]

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ABSTRACT

The introduction of novel quality characteristics from wheat (*Triticum aestivum* L.) landraces can enhance the genetic diversity of current wheat breeding programs. The composition of starch and protein in wheat is important when determining the end-product quality, particularly for white salted noodles (WSN). Quality characteristics that contribute to the production of improved WSN include high starch pasting peak viscosity, low amylose content, high proportion of A-type granules, low protein content, soft grain texture, and high protein quality as measured by SDS sedimentation volume. A survey of 133 wheat landraces from Afghanistan, China, Egypt, Ethiopia, India, Iran, Syria, and Turkey was conducted to examine the genetic variability of starch and protein quality characteristics. Two wheat cultivars, Rosella and Meering, were used as the quality controls. The variation in starch pasting peak viscosities observed among the wheat landraces had a range of 175–295 Rapid Visco Analyser units (RVU), where 52 of the landraces were not significantly different from Rosella, a commercial soft grain wheat with high pasting properties. The amylose content of the landrace population was 23.4–30.2%, where 17 landraces had significantly lower values than Rosella. The proportion of A-type granules was 60.5–73.9%, where 112 landraces had significantly higher values than Rosella. The grain texture hardness score was 28.0–99.3, the total protein content was 8.0–15.1%, and the adjusted SDS sedimentation volume (SDS/protein) was 1.6–7.0 mL/%P. The landrace AUS4635 had high starch pasting peak viscosity, high breakdown, low amylose content, low protein content, soft grain texture, and high protein quality flour. This wheat is an ideal parent to use in a breeding program that increases the genetic variation available to develop cultivars with high-quality WSN characteristics.

The genetic diversity of wheat breeding programs is relatively narrow when compared with the genetic resources available (Moghaddam et al 1997). There is a need to produce improved quality wheats to meet the demands of targeted markets such as that for white salted noodles (WSN). Wild relatives of wheat and wheat landraces may hold the key to increasing the genetic diversity of quality characteristics available to wheat breeders.

Landraces are cultivated in traditional wheat growing areas such as Africa, the Middle East, Asia, and Russia. Zeven (1998) defined an autochthonous landrace as one that has been grown over a long period in a farming system, and that continuously adapts itself as the environment changes. Due to the nonuniformity and instability of landrace characteristics, they can exhibit a substantial amount of genetic variation. In the past, researchers have found variation in landraces for traits such as disease resistance (Negassa 1986), morphology (Poiarkova and Blum 1983), yield improvement (Jaradat 1991), agronomic properties (Moghaddam et al 1997), starch pasting characteristics (Bhattacharya and Corke 1996, Bhattacharya et al 1997), and protein quality (Ereifej and Shibi 1993).

A survey was conducted on landraces from Africa, the Middle East, and Asia. Quality characteristics investigated included grain texture, grain weight, protein content, SDS sedimentation volume, starch amylose content, starch granule size distribution, and starch pasting properties. The aim of this survey was to identify germ plasm with novel quality characteristics that would be of value in producing new wheat cultivars with quality traits suitable for the WSN market.

MATERIALS AND METHODS

Wheat Samples

Seed of 133 wheat landraces from Afghanistan, China, Egypt, Ethiopia, India, Iran, Syria, and Turkey was obtained from the Australian Winter Cereals Collection at Tamworth, Australia. In this study, Australian commercial cultivars Rosella and Meering were used as controls. Rosella is a soft grain wheat with high pasting properties that is used in the production of Japanese WSN. Meering is a hard grain wheat with extensible and intermediate-to-strong dough properties that is used by the Australian bread industry. The landraces were grown at Horsham, Australia, in 1995 and 1996 in resolvable incomplete block designs with two replicates.

Sample Preparation

Grain weight, moisture, and grain texture were determined using a single kernel characterization system (SKCS 4100, Perten, Reno, NV) (Martin et al 1993). The flour was produced by conditioning the grain to 14.5% moisture and milling to flour (Quadrumat Jr., Brabender, Duisberg, Germany). Nitrogen percentages were determined on flour by near-infrared reflectance (NIR) analysis (Inframatic 8100, Perten) calibrated against the Kjeldahl nitrogen procedure based on Approved Method 46-16 (AACC 2000).

The SDS sedimentation volume was determined on the flour using the procedure developed by Axford et al (1979). The SDS sedimentation volume was expressed per unit of protein content to remove the effect of total protein.

Starch was isolated and the granule size distribution was determined according to Panozzo and Eagles (1998). Starch was separated from flour using a Glutamatic 2200 (Falling Number, Sweden AB). The granule size distribution of the isolated starch was measured using a laser diffraction particle size analyzer (model 2600, Malvern Instruments Ltd., Worscestershire England). Duplicate analyses were performed on the wet prime starch isolate dispersed in distilled water. The wet prime starch was purified for amylose determination by extensive washing and centrifugation and then air-dried.

Amylose Analysis

The amylose content was determined by a modified iodometric method (Morrison and Laignelet 1983). The starch lipid was removed using 85% (v/v) methanol at 65°C, followed by solubilization with urea dimethyl sulfoxide (DMSO) at 100°C. Iodine solution (0.2% I, 2% KI) was added to 8 mL of starch urea DMSO solution. The absorbance was recorded at 620 nm. The recorded values were converted to percent of amylose by reference to a standard curve prepared with amylose from potato and amylopectin from corn (ICN Biochemicals, Inc., Costa Mesa, CA).

A Rapid Visco Analyser model 3D (RVA) (Newport Scientific Pty. Ltd., Narrabeen Australia) was used to measure pasting properties of starch (Panozzo and Eagles 1998). Starch (3.0 g) was added to a disposable aluminum canister containing 25 mL of

[1] Agriculture Victoria – Horsham, Victorian Institute for Dryland Agriculture, Private Bag 260, Horsham Vic 3401 Australia.
[2] Corresponding author. E-mail: cassandra.black@nre.vic.gov.au Phone: +61 3 53622130.
[3] Northern Territory Department of Primary Industry and Fisheries, Berrimah Farm, GPO Box 990, Darwin, NT 0801, Australia.

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distilled water at 20°C, mixed, and placed in an RVA heating block. A Thermocline software program controlled the heating and cooling cycles. The programmed cycle was held at 50°C for 1 min, ramped to 95°C for 3.7 min, held at 95°C for 2.5 min, ramped to 50°C for 3.8 min, and held at 50°C for 2 min. The peak pasting, final, breakdown, and setback viscosities were recorded, in Rapid Visco Analyser units (RVU), along with the gelatinization temperature.

Statistical Analyses

The data from this study were analyzed using the spatial techniques of Cullis and Gleeson (1991) and Gilmour et al (1997). Spatial analysis was used to minimize variation due to extraneous trends such as trial management, and natural trends in the field including soil fertility, moisture, and soil structure (Cullis et al 1996a,b). These analyses were conducted using the statistical programs ASREML (Gilmour et al 1996) and S-PLUS (Becker et al 1988). The correlation coefficients were calculated using Genstat for Windows Release 5.4.1 (Lawes Agricultural Trust, Rothamsted, UK).

RESULTS AND DISCUSSION

Although 133 landrace wheats were surveyed in this study, only those with quality characteristics statistically identical or greater than the commercial cultivars Rosella and Meering are discussed in this study.

Variation in Pasting Properties

The identification of genotypes with a high paste viscosity is desirable because of the established relationship between eating quality of Japanese WSN and the pasting properties of starch (Oda et al 1980, Konik et al 1992, Batey et al 1997, Jun et al 1998). High peak viscosity, high breakdown, low setback, and low final viscosity are properties related to the high eating quality of Japanese WSN. The differences in the starch pasting profiles of Rosella and Meering were used to classify the landraces by pasting properties (Fig. 1A). In Australia and Japan, Rosella is a commercial cultivar used to produce Japanese WSN with optimal texture and organoleptic properties. The mean peak viscosity of

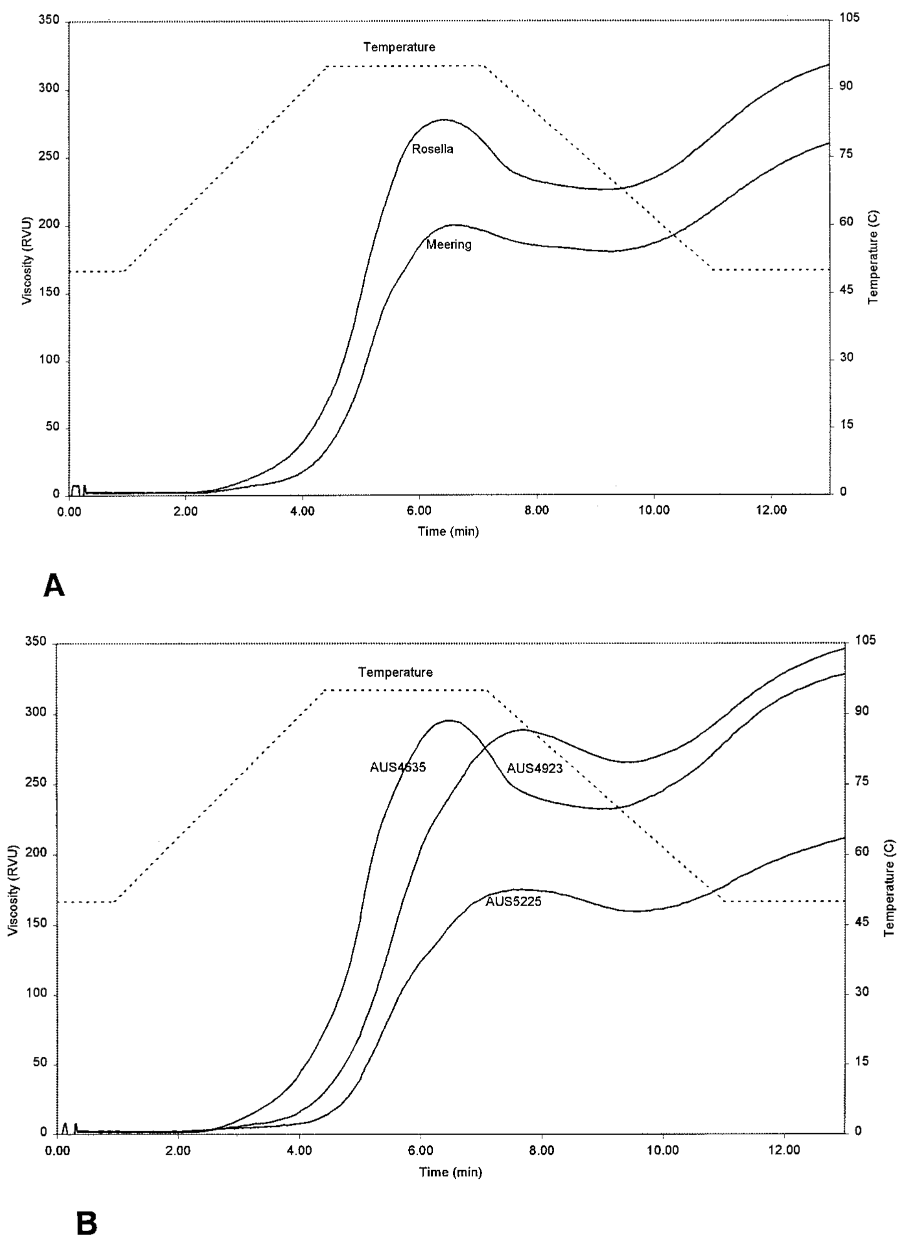

Fig. 1. Temperature program and starch pasting viscosities of (**A**) two Australian commercial wheats (Rosella and Meering) and (**B**) three wheat landraces (AUS4635, AUS4923, and AUS5225).

the commercial cultivars ranged from 198 RVU for Meering to 278 RVU for Rosella (Table I). Rosella had the highest mean peak viscosity and the highest breakdown among commercial cultivars. The paste characteristics exhibited by Rosella in this study are desirable for producing high-quality WSN.

The pasting profiles varied among landraces; some were notably different from the commercial cultivars (Fig. 1B). The peak viscosity range within the landraces was 175–295 RVU, with an average of 254 RVU. The population distribution for peak viscosity of the landraces was bimodal (Fig. 2). Possibly, landraces with higher pasting viscosity were null at the *Wx-B1* locus that codes for granule-bound starch synthase (Yamamori et al 1994, Panozzo and Eagles 1998), while those with lower peak viscosities contained a functional allele. Alternatively, other waxy genes could have been involved (Yamamori et al 1994); this will be investigated in the next stage of this work.

Fifty-two landraces had peak viscosity values not significantly different from Rosella (data not shown), however none was significantly higher ($P < 0.05$) than Rosella. Of these 52 landraces, three had a significantly higher breakdown ($P < 0.05$) and seven had a significantly lower setback ($P < 0.05$) values than Rosella (Table I). Landraces that produce starch viscosity profiles different from current commercial cultivars such as Rosella should be investigated further to determine whether these starch properties influence other noodle characteristics such as noodle texture and cooking quality.

TABLE I
Pasting Properties of Starch from Wheat Landraces and Commercial Cultivars

	Country of Origin	Viscosity (RVU)			
		Peak	Breakdown	Final	Setback
Cultivar					
Rosella		278	50	321	90
Meering		198	21	273	78
Landrace					
AUS4045	Ethiopia	267	24	316	75
AUS4671	India	275	26	318	70
AUS4718	India	275	24	321	75
AUS4687	India	277	22	329	79
AUS4151	Syria	278	57	315	93
AUS4847	India	283	59	311	94
AUS4721	India	285	29	329	70
AUS4669	India	288	35	327	79
AUS4719	India	290	27	339	77
AUS4635	India	295	63	330	96
LSD[a]		19	7	24	11

[a] Least significant difference ($P < 0.05$) for Rosella.

Amylose Content

The major components of starch are amylose and amylopectin. For nonwaxy wheat, the amylose content of starch was 21–30%. The amylose content of the landraces was 23.4–30.2%, with an average of 27.9%, while the amylose content of the two commercial cultivars was 27.9–29.9% (Table II). Seventeen landraces were significantly lower ($P < 0.05$) in amylose content than Rosella, with a mean amylose content of <26.5%. Thirteen of the 17 landraces were significantly lower in amylose and were comparable in peak viscosity to Rosella (Table II). Zeng et al (1997) reported that the amylose content of wheat contributes to starch pasting and gelatinization properties. Eating quality of Japanese WSN was

TABLE II
Amylose Content Peak Viscosity of Starch from Wheat Landraces

	Country of Origin	Amylose Content (%)	Peak Viscosity (RVU)
Cultivar			
Rosella		27.9	278
Meering		29.9	198
Landrace			
AUS5215	Iran	23.5	241
AUS4721	India	25.0	285
AUS4719	India	25.3	290
AUS4692	India	25.3	281
AUS4672	India	25.4	280
AUS4142	Syria	25.6	273
AUS4686	India	25.8	274
PBI.1190124	India	25.9	272
PBI.1190020	India	26.2	275
AUS4764	India	26.2	281
AUS4141	Syria	26.2	282
AUS4669	India	26.2	288
PBI.1190295	Turkey	26.3	286
AUS4685	India	26.4	276
AUS4635	India	26.8	295
LSD[a]		1.4	19

[a] Least significant difference ($P < 0.05$) for Rosella.

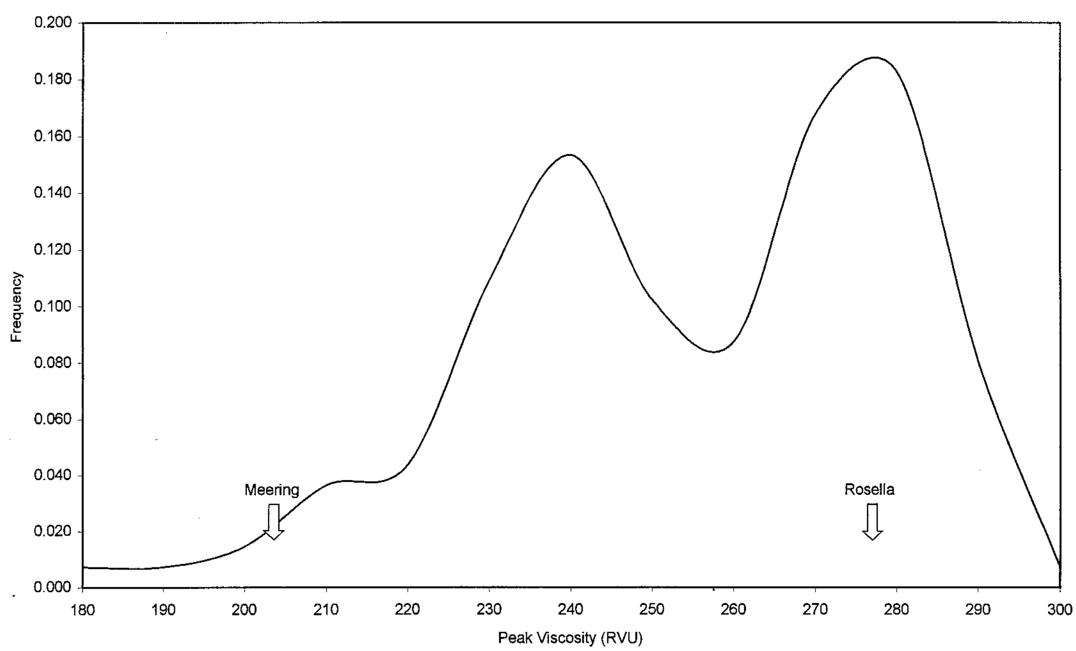

Fig. 2. Population distribution for starch pasting viscosity of wheat landraces and commercial cultivars.

negatively correlated to starch amylose content and positively correlated to starch amylopectin content (Oda et al 1980, Yamamori et al 1994).

There was a negative correlation ($P < 0.001$) between amylose content, peak viscosity, and breakdown (Table III). This has been supported by other researchers (Moss 1980, Oda et al 1980, Zeng et al 1997) who also found a significant relationship between low amylose content and high setback; this was not observed in this study. The correlation between peak viscosity and amylose content (–0.504, $P < 0.001$) substantiated the view of Panozzo and Eagles (1998) that amylose content per se may not be the sole determinant of pasting viscosity. In this study, the peak viscosity and final viscosity were positively correlated and a negative correlation was found between final viscosity and amylose content for the landrace population. This relationship has not been reported previously.

Starch Granule Distribution

Wheat grain contains three types of starch granules: 1) the large and lenticular-shaped A-type granules with diameters >9.9 µm; the smaller more spherical-shaped B-type granules with diameters of 2.8–9.9 µm; and the very small (<2.8 µm diameter) C-type granules (Raeker et al 1998). The range in the proportion of A-type granules within the landrace population was 60.5–73.9%, with an average of 66.7%. There were 112 landraces that had a significantly higher ($P < 0.05$) proportion of A-type granules than Rosella. Of these 112 landraces, 44 had a peak viscosity similar to that of Rosella, and 13 had an amylose content significantly lower ($P < 0.05$) than that of Rosella.

The relative proportions of these starch granules in the wheat landraces may result in differences in chemical composition that affect the functionality of the starch (Karlsson et al 1983, Morrell et al 1995, Stoddard 1999). Therefore, starch granule size distribution influences the pasting properties of starch, which may affect the eating quality of noodles. Raeker et al (1998) found a correlation between high amylose content and a high proportion of A-type granules; this relationship was not observed in this study (Table III). Correlations were observed between landraces with a high percentage of A-type granules and an increase in high peak viscosity ($P < 0.05$), final viscosity ($P < 0.01$), and pasting temperature ($P < 0.01$).

Grain Texture

The known differences in grain texture of Rosella and Meering were used to classify the landraces. The grain hardness scores of the landrace wheat samples were 28.0–99.3, with a mean of 67.9. The grain hardness scores of Meering and Rosella were 83.4 and 32.6, respectively (Table IV). Four landrace wheats not significantly different ($P < 0.05$) in texture from Rosella were AFGHAN.14444, AUS4635, AFGHAN.13691, and PBI.1190322 (Table IV). None of the landrace wheats were significantly ($P < 0.05$) softer than Rosella. Grain texture affects the milling performance of the wheat and hence flour quality (Anjum and Walker 1991, Carver 1994). Hard grains require more force to fracture kernels, sieve more easily, and have a higher proportion of damaged starch (Anjum and Walker 1991). Konik et al (1992) found that flour from softer wheat kernels produce noodles of improved eating quality.

Protein Quantity and Quality

Protein quality is determined by the gluten storage proteins present in the wheat that are responsible for the viscoelastic behavior and strength of the dough (Moonen et al 1982). This functional quality is correlated with the SDS sedimentation volume (Axford et al 1978). This simple procedure assists in assessing early generation wheat cultivars for suitability in products such as cookies and pan breads. It has been reported that SDS sedimentation volume can be used to indicate Japanese noodle texture (Konik et al 1992, Baik et al 1994, Jun et al 1998).

The protein concentration of the landrace population was 8.0–15.1%, with a mean of 10.6%. The protein concentration of the commercial wheat cultivars was 9.6% for Rosella and 11.4% for Meering. The adjusted SDS sedimentation volumes of the landrace wheats were largely independent from the total protein content (data not shown) and had a range of 1.6–7.0. The adjusted SDS sedimentation volume of the commercial cultivars was 5.5–6.5. Twenty-eight landraces were comparable to Rosella in total protein content; one landrace was significantly higher in adjusted SDS sedimentation volume. From the population, 13 of the landraces were comparable to Rosella in adjusted SDS sedimentation volume.

When compared to Rosella, landrace AUS4635 was significantly higher in adjusted SDS sedimentation volume, significantly lower in amylose content, and similar in grain texture and protein content

TABLE IV
Total Protein, Grain Texture, Grain Weight, and Protein Quality of Wheat Landraces and Commercial Cultivars

	Country of Origin	Protein (%)	Texture (SKCS units)	Grain Weight (mg)	Adjusted SDS (mL/% P)
Cultivar					
Meering		11.4	83.4	35.6	5.8
Rosella		9.6	32.6	38.5	6.5
Landrace					
AUS4635	India	9.6	30.7	38.6	7.0
AUS4357	Syria	9.6	42.0	36.7	6.3
AUS23892	China	9.6	66.4	39.7	6.7
AUS4059	Afghanistan	9.8	86.2	32.0	6.6
AUS4106	Afghanistan	10.0	81.7	42.0	6.5
AFGHAN.13691	Afghanistan	9.7	33.6	37.0	4.8
AFGHAN.14444	Afghanistan	9.4	28.0	34.9	5.3
PBI.1190322	China	10.5	34.6	37.2	5.0
LSD[a]		0.7	6.8	2.5	0.5

[a] Least significant difference ($P < 0.05$) for Rosella.

TABLE III
Correlation Coefficients (r)[a] of Quality Traits for Wheat Landraces

	Amylose	Peak Viscosity	A-Type Granules	Grain Weight	Adjusted SDS	SDS	Grain Texture	Protein Content	Breakdown	Final Viscosity	Setback
Peak viscosity	–0.504***										
A-type granules	0.070	0.170*									
Grain weight	0.184*	–0.150	–0.053								
Adjusted SDS	0.203*	–0.020	–0.187*	0.067							
SDS	0.210*	–0.054	–0.133	–0.022	0.900***						
Grain texture	0.054	–0.272**	0.205*	–0.073	–0.395***	–0.150					
Protein content	–0.064	–0.042	0.228**	–0.203*	–0.521***	–0.119	0.614***				
Breakdown	–0.370***	0.613***	–0.114	–0.054	0.078	–0.098	–0.400***	–0.347***			
Final viscosity	–0.381***	0.913***	0.261**	–0.098	0.087	0.050	–0.263**	–0.098	0.430***		
Setback	–0.075	0.429***	0.109	0.060	0.362***	0.166*	–0.393***	–0.515***	0.449***	0.650***	
Pasting temp.	–0.033	0.042	0.220**	–0.110	–0.403***	–0.146	0.390***	0.640***	–0.454***	–0.067	–0.706***

[a] ***, **, * = $P < 0.001$, 0.01, and 0.05, respectively; $n = 136$.

($P < 0.05$). AUS4635 would be a useful parent to use in a breeding program aimed at developing wheat cultivars with quality attributes suitable for WSN markets.

CONCLUSIONS

A wide range of physical and chemical characteristics were observed among the 133 wheat landraces. AUS4635 contained a combination of characteristics indicating possible suitability for the production of WSN. It is apparent from this study that landrace wheats offer variation in quality characteristics that are of value to a wheat breeding program where the interest is to produce high-quality WSN wheats.

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