PROJECT REPORT No. 174

EXPLOITATION OF VARIETIES FOR UK CEREAL PRODUCTION (VOLUME V)

VARIETAL TYPING TRIALS AND NIAB ADDITIONAL CHARACTER ASSESSMENTS

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(VOLUME V)

PART 1. VARIETY TYPING TRIALS
by

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PART 2. NIAB ADDITIONAL CHARACTER ASSESSMENTS
by

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Summary

VARIETY TYPING TRIALS

Variety trials were established in four site-seasons, ADAS Rosemaund 1993-4, ADAS Boxworth 1993-4, ADAS Rosemaund 1994-5 and Sutton Bonington 1994-5, for the purpose of i) defining the extent of varietal variation for key traits, ii) examining the consistency of the varietal ranking order across different sites and seasons and iii) testing methodologies for precision and rapidity in relation to field trials with large numbers of plots. Varieties were selected so as to include all eighteen tested in individual Sub-Project experiments plus additional varieties chosen to extend the range of developmental rate and date of introduction. The traits assessed and respective varietal ranges were : i) Kpar extinction coefficient (0.44 – 0.66), ii) fertile shoot number per m^2 at GS 31 (873 – 1281) and GS 61 (390 – 625), iii) canopy N requirement (ratio of N in the canopy to its green surface area, g/m^2) (2.29 – 3.62), iv) stem soluble carbohydrate at GS61+75°Cd (g/m^2) (254 – 447), v) harvest above-ground biomass (g/m^2) (1386 – 1574) and harvest total crop N offtake (kg/ha) (184 – 208). For all traits examined there were statistically significant differences amongst varieties which, at the extremes of the varietal range, were consistently expressed across the individual site-seasons. For stem soluble carbohydrate, the varietal ranking order across site-seasons was particularly consistent and the site-season/variety interaction was non-significant. There was a trend for greater accumulation of stem reserves for the modern, semi-dwarfs with higher yield potential. There was also a trend for great harvest above-ground biomass for more modern varieties with later dates of introduction. With regard to the feasibility and rapidity of field assessments, measurements of : i) dates of GS 31 and GS 61, ii) fertile shoot number at GS 31 and GS 61, iii) stem soluble carbohydrate reserves at GS61+75°Cd, iv) harvest above-ground biomass and v) harvest crop N offtake were shown to be practical in field programmes testing large numbers of varieties. In future work, UK variety testers might include some of these assessments on a permanent basis in their RL trials.

NIAB ADDITIONAL CHARACTER ASSESSMENTS

Some promising traits were known at the mid-term stage of the Project and were put forward as of immediate potential use to testers. These were measured in NIAB RL trials in 1994-5 and 1995-6 as additional character assessments. This allowed proposed methodologies to be examined by variety testers and the most recent candidate varieties, not included in other Project experiments, to be characterised. In 1994-5, additional characters were measured in winter wheat RL trials at five sites (Bridgets , Rosemaund, Harper Adams, Headley Hall and Cockle Park) and at three sites in 1995-6 (Bridgets, Harper Adams and Headly Hall). The traits assessed in 1994-5 and 1995-6 were : i) dates of GS 31 and GS 61, ii) fertile shoot number at GS 31 and GS 61, iii) soluble stem carbohydrate at GS 61+75°Cd, iv) harvest index (allowing for the calculation of above-ground biomass) and v) nitrogen harvest index (allowing for the calculation of total N offtake). For common varieties in Typing Trials and NIAB trials, the variety ranking order and overall variety ranges were broadly consistent in the two data sets. Thus, the range for stem reserves of c. 200 - 400 g/m^2 in NIAB assessments corroborated that in the Typing Trials and similarly the ranges for harvest dry mass of 1270 - 1500 g/m^2 and crop N offtake of 149 - 171 kg/ha were of the same order of magnitude to those in the variety Typing Trials. The feasibility of measuring the above traits was demonstrated in NIAB winter wheat RL trials. As a result of Project work the assessment of stem soluble carbohydrate at GS 61+75°Cd has been added to the list of agronomic characters

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Part 1 : VARIETY TYPING TRIALS

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1. INTRODUCTION

Variety trials were established in four site-seasons, ADAS Rosemaund 1993-4, ADAS Boxworth 1993-4, ADAS Rosemaund 1994-5 and Sutton Bonington 1994-5, specifically for the purpose of recording key indicative physiological characteristics. The objectives of assessing physiological traits in these experiments were :

- To define the extent of varietal variation for candidate characteristics over as wide a range of genotypes as possible.
- To examine the consistency of the varietal ranking order for traits across different sites and seasons.
- To measure physiological characteristics for those eighteen varieties selected for testing in the individual Sub-Project experiments concurrently in a parallel experimental exercise.
- To test associations between physiological traits and descriptors of crop growth at the whole crop level, e.g. green area index.
- To gain information on varieties under test in the individual Sub-Project experiments which was not available at the outset of the Project from existing data sets.
- To test methodologies in relation to precision and rapidity.

2. MATERIALS AND METHODS

2.1. Experimental design and treatments

In each site-season the design was a completely randomised block design testing one factor, variety, and there were four replicates. Plot sizes were as follows: RM 93-4, 2.25 x 25 m; BX 93-4, 2.25 x 24 m; RM 94-5, 2.25 x 24 m; and SB 94-5, 3.30 x 18 m.

Varieties were chosen so as to include all eighteen tested in individual Sub-Project experiments plus additional varieties selected to extend the varietal range in terms of i) developmental rates and ii) dates of introduction. Thus, Avital (an early developing, French-bred variety) and Zentos (a slow developing, German-bred variety) were included in experiments to stretch development rates. Similarly, Holdfast and M. Huntsman introduced in *c.* 1930 and *c.* 1969, respectively, were included to stretch the range of partitioning across genotypes with differing dates of introduction.

Table 2.1 Varieties tested in Variety Typing Trials in four site-seasons

	RM 93-4	BX 93-4	RM 94-5	SB 94-5
Ami[1]			✓	
Apollo[1]	✓	✓	✓	✓
Avalon	✓	✓	✓	✓
Avital[1]	✓	✓	✓	✓
Barouder[1]	✓	✓		
Beaver	✓	✓	✓	✓
Brigadier	✓	✓	✓	✓
Cadenza	✓	✓	✓	✓
Contra[1]	✓	✓		
Florin[1]			✓	✓
Haven	✓	✓	✓	✓
Hereward	✓	✓	✓	✓
Holdfast[2]			✓	✓
Hunter	✓	✓	✓	✓
Konsul[1]	✓	✓		✓
Little Joss[2]			✓	✓
Longbow	✓	✓	✓	✓
Lynx	✓	✓	✓	✓
M. Huntsman	✓	✓	✓	✓
Mercia	✓	✓	✓	✓
Obelisk[1]	✓	✓		
Piko[1]			✓	
Rascal	✓	✓		
Rialto	✓	✓	✓	✓
Riband	✓	✓	✓	✓
Rossini[1]	✓	✓		
Scipion[1]			✓	
Sideral[1]	✓	✓		✓
Soissons	✓	✓	✓	✓
Spark	✓	✓	✓	✓
Sq'hds Master[2]			✓	✓
Zentos[1]	✓	✓	✓	✓

[1] = Continental non-UK bred winter wheat variety; [2] = Very old variety first introduced pre-1940.

✓ = variety included in trial.

Table 2.2. Varieties tested in Variety Typing Trials categorised for Rht dwarfing genes, 1BL/1RS rye chromosome translocation, photoperiod insensitivity, country cultivated and approximate year of release.

	Rht	1B/1R	Photoperiod sensitivity	Counrty cultivated	Approximate year of release
Ami	n/a	No	I	France	1991
Apollo	1	Yes	S	Germany/UK	1985
Avalon	2	No	S	UK	1977
Avital	No	No	I	France	1989
Baroudeur	1	No	n/a	France	n/a
Beaver	2	Yes	S	UK	1987
Brigadier	2	Yes	S	UK	1990
Cadenza	No	No	S	UK	1991
Contra	1	No	S	Germany	1990
Florin	n/a	No	n/a	France	n/a
Haven	2	Yes	S	UK	1987
Hereward	2	No	S	UK	1988
Holdfast	No	No	S	UK	1930
Hunter	2	Yes	S	UK	1990
Konsul	2	No	S	Germany	n/a
Little Joss	No	No	S	UK	1910
Longbow	2	No	S	UK	1979
Lynx	2	Yes	S	UK	1991
Maris Huntsman	No	No	S	UK	1969
Mercia	No	No	S	UK	1983
Norman	2	No	S	UK	1979
Obelisk	No	No	S	Germany	1987
Piko	n/a	No	n/a	Germany	n/a
Rascal	No	No	n/a	UK	n/a
Rialto	2	Yes	S	UK	1992
Riband	2	No	S	UK	1986
Rossini	n/a	No	n/a	France	n/a
Scipion	n/a	No	n/a	France	n/a
Sideral	n/a	No	n/a	France	1990
Soissons	1	No	I	France/UK	1988
Spark	No	No	S	UK	1990
Square's Master	No	No	S	UK	1890
Zentos	No	No	S	Germany	1989

n/a = not available. 1 = Rht1, 2 = Rht2. I = photoperiod insensitive, S = photoperiod sensitive.

2.2. Plot management and soil type

Full details of site information, husbandry inputs and weather data for all sites are given in Appendix Tables 1 and 2. The soil type at ADAS Rosemaund (Bromyard Series, normal phase) was a silt loam to 50 cm over silty clay loam with AWC of *c.* 225 mm. The soil type at ADAS Boxworth was a clay to 80 cm overlying clay with chalk stones (Hanslope series) with AWC of *c.* 200 mm. The soil type at Sutton Bonington was a light medium loam to 80 cm over clay (Dunington Heath series) with AWC of *c.* 180 mm.

2.3. Experimental measurements

Assessments were taken in three replicates unless otherwise stated. All experimental measurements, with the exception of those described below, were undertaken following protocols outlined in the general methods section (see Vol. I, Part 1, section 6.2).

2.3.1. Fractional interception of photosynthetically active radiation (F_{PAR})

Using a Delta T instruments ceptometer, two consecutive readings were taken, one above the canopy and one below the canopy at ground level. This process was then repeated ten times per plot. On each occasion PAR assessments were undertaken, readings were taken as far as possible at the same time during the day between 11.00 and 13.00. Operators stood facing towards the sun, with the same orientation for all readings. The respective ten readings per plot were averaged and the fractional PAR interception (F_{PAR}) calculated as :

$$F_{PAR} = 1 - (PAR_{below}/PAR_{above})$$

3. RESULTS

3.1. Developmental stages

Table 3.1 Dates of GS 31 and GS 61 in Variety Typing Trials in 1993-4 and 1994-5.

	RM 93-4		RM 94-5		SB 94-5		Mean	
	GS 31	GS 61	GS 31	GS 61	GS 31	GS 61	GS 31	GS 61
Ami	-	-	24-Mar	1-Jun	-	-	-	-
Apollo	25-Apr	20-Jun	6-Apr	14-Jun	11-Apr	10-Jun	14-Apr	14-Jun
Avalon	24-Apr	19-Jun	3-Apr	10-Jun	11-Apr	10-Jun	12-Apr	13-Jun
Avital	23-Apr	11-Jun	20-Mar	30-May	1-Apr	31-May	04-Apr	03-Jun
Barouder	20-Apr	14-Jun	-	-	-	-	-	-
Beaver	03-May	23-Jun	16-Apr	16-Jun	25-Apr	16-Jun	24-Apr	18-Jun
Brigadier	03-May	21-Jun	6-Apr	15-Jun	15-Apr	13-Jun	18-Apr	16-Jun
Cadenza	03-May	21-Jun	10-Apr	14-Jun	15-Apr	13-Jun	19-Apr	16-Jun
Contra	23-Apr	20-Jun	-	-	-	-	-	-
Florin	-	-	6-Apr	12-Jun	5-Apr	8-Jun	-	-
Haven	25-Apr	24-Jun	16-Apr	15-Jun	18-Apr	15-Jun	19-Apr	18-Jun
Hereward	24-Apr	22-Jun	10-Apr	14-Jun	8-Apr	11-Jun	14-Apr	15-Jun
Holdfast	-	-	16-Apr	18-Jun	15-Apr	17-Jun	-	-
Hunter	23-Apr	24-Jun	14-Apr	16-Jun	15-Apr	15-Jun	17-Apr	18-Jun
Konsul	24-Apr	22-Jun	-	-	12-Apr	14-Jun	-	-
Little Joss	-	-	16-Apr	19-Jun	12-Apr	18-Jun	14-Apr	18-Jun
Longbow	03-May	23-Jun	16-Apr	13-Jun	11-Apr	12-Jun	20-Apr	16-Jun
Lynx	25-Apr	22-Jun	10-Apr	15-Jun	15-Apr	14-Jun	16-Apr	17-Jun
M. Huntsman	03-May	22-Jun	10-Apr	12-Jun	15-Apr	11-Jun	19-Apr	15-Jun
Mercia	24-Apr	18-Jun	6-Apr	11-Jun	8-Apr	10-Jun	12-Apr	13-Jun
Norman	-	-	6-Apr	12-Jun	8-Apr	11-Jun	-	-
Obelisk	20-Apr	23-Jun	-	-	-	-	-	-
Piko	-	-	14-Apr	18-Jun	-	-	-	-
Rascal	20-Apr	16-Jun	-	-	-	-	-	-
Rialto	20-Apr	21-Jun	3-Apr	13-Jun	4-Apr	13-Jun	09-Apr	15-Jun
Riband	23-Apr	20-Jun	12-Apr	14-Jun	18-Apr	11-Jun	17-Apr	15-Jun
Rossini	23-Apr	14-Jun	-	-	-	-	-	-
Scipion	-	-	16-Mar	4-Jun	-	-	-	-
Sideral	20-Apr	13-Jun	-	-	1-Apr	4-Jun	-	-
Soissons	20-Apr	13-Jun	24-Mar	4-Jun	4-Apr	7-Jun	05-Apr	08-Jun
Spark	03-May	23-Jun	14-Apr	18-Jun	25-Apr	17-Jun	24-Apr	19-Jun
S. Master	-	-	14-Apr	19-Jun	18-Apr	18-Jun	-	-
Zentos	03-May	25-Jun	16-Apr	19-Jun	25-Apr	18-Jun	24-Apr	20-Jun
Mean	25-Apr	19-Jun	8-Apr	12-Jun	12-Apr	12-Jun		

Measurements of dates of GS 31 and GS 61 were only undertaken in three of the four site-seasons.

3.1.1. GS 31

The varietal range for GS 31 was 20 April - 3 May at RM 93-4, 20 March - 16 April at RM 93-4 and 1 - 15 April at SB 93-4 (Table 3.1). The generally later phasing of GS 31 at RM 93-4 compared to the other two site-seasons was associated with a later sowing date of 11 November (emerged 30 December) compared to 12 October (emerged 28 October) and 13 October (emerged 28 October) at RM 94-5 and SB 94-5, respectively.

For the eighteen common varieties in Typing Trials, the varietal ranking order was generally consistent across sites-seasons. At each site-season, Avital, Rialto and Soissons were the three earliest varieties to GS 31 and conversely Zentos and Spark amongst the latest. There were some changes in rank across site-seasons, however; for example, Longbow was relatively earlier at SB 94-5 compared to other site-seasons and Mercia later at RM 93-4 compared to the two other site-seasons. This effect for Mercia may have been due to Mercia's weak photoperiod sensitivity (Worland *et al.*, 1994) compared to other UK-bred genotypes.

3.1.2. Date of GS 61

The varietal range in date of GS 61 was 11 - 24 June, 30 May - 19 June and 3 - 18 June at RM 93-4, RM 94-5 and SB 94-5, respectively (Table 3.1). Again, the generally later phasing of development in 1993-4 related to the later sowing date. The range for varieties reaching GS 61 was slightly longer at RM 94-5 (20 days) than at SB 94-5 (15 days). This was due to the earliest varieties flowering relatively earlier at RM 94-5; the latest flowering varieties flowered on a similar calendar date of about 18 June at both site-seasons. This suggested that the late varieties, e.g. Spark and Zentos, had a strong photoperiod response predominantly controlling their time of flowering.

For the eighteen common varieties, the ranking order for GS 61 was broadly consistent from experiment to experiment, and more consistent than for GS 31. As expected, the photoperiod insensitive varieties, Soissons and Avital, were the most rapid to GS 61 at all site-seasons and those varieties with a strong photoperiod response, e.g. Spark and Zentos, the latest. Generally in comparison with GS 31, the mean ranking order of the varieties across experiments was very similar, with the exception of Rialto; Rialto was the third earliest variety to GS 31 but only equal sixth earliest with four other varieties to GS 61. When date of flowering was examined for some of the very old varieties in 1994-5, their later flowering of *c.* one week later than the average for currently grown varieties was in agreement with Austin *et al.* (1980) who reported that flowering had been brought forward about 4 - 5 days since the early decades of the century through breeding.

3.2. Extinction coefficient

The PAR extinction coefficient describes the exponential relationship between GAI and fractional interception of photosynthetically active incident radiation (F_{PAR}). Canopies with more erect, upright leaves tend to have lower extinction coefficients, intercepting a smaller proportion of incident radiation per unit increase in GAI.

Table 3.2 Extinction coefficient (K_{PAR}) for varieties tested in Typing Trials in 1993-4 and 1994-5

	RM 93-4	RM 94-5	SB 94-5	Mean
Ami	-	0.52	-	-
Apollo	0.45	0.44	0.53	0.47
Avalon	0.77	0.50	0.57	0.61
Avital	0.62	0.67	0.70	0.66
Baroudeur	0.77	-	-	-
Beaver	0.74	0.56	0.46	0.61
Brigadier	0.56	0.45	0.46	0.49
Cadenza	0.75	0.56	0.62	0.64
Contra	0.54	-	-	-
Florin	-	0.55	0.64	-
Haven	0.67	0.56	0.42	0.55
Hereward	0.61	0.47	0.54	0.54
Holfast	-	0.52	0.53	
Hunter	0.35	0.54	0.44	0.44
Konsul	0.43	-	0.48	-
Little Joss	-	0.65	0.49	-
Longbow	0.60	0.62	0.52	0.63
Lynx	0.47	0.47	0.43	0.46
Maris Huntsman	0.76	0.45	0.54	0.58
Mercia	0.57	0.53	0.57	0.56
Norman	-	0.29	0.53	-
Obelisk	0.75	-	-	-
Piko	-	0.45	-	-
Rascal	0.74	-	-	-
Rialto	0.66	0.34	0.52	0.49
Riband	0.51	0.63	0.49	0.55
Rossini	0.69	-	-	-
Scipion	-	0.50	-	-
Sideral	0.62	-	0.63	-
Soissons	0.63	0.37	0.68	0.56
Spark	0.77	0.44	0.50	0.56
Squareheads Master	-	0.65	0.51	-
Zentos	0.80	0.55	0.51	0.62
Mean	0.63	0.51	0.53	
S.E.D. Var.	0.117	0.079	0.077	0.043
Prob.	0.007	<0.001	0.003	0.045
S.E.D. Site-season				0.058
Prob.				0.002
S.E.D. Site-s'n/Var.				0.107
Prob.				0.008
D.F. residual	48	50	48	102

Overall, across the three site-seasons, there were significant varietal differences in the range 0.47 to 0.66 ($P < 0.05$) (Table 3.2). As expected there was a tendency for varieties with larger, more recurved flag leaves, such as Avalon (0.61), M. Huntsman (0.58) and Zentos (0.62) to have greater extinction coefficients than those with more erect, upright flag leaf attitudes, such as Hunter (0.44), Rialto (0.49) and Brigadier (0.49). Using the variety data from all site-seasons, the fitted curve confirmed the expected exponential relationship described by Monsi and Saeki (1953) of the form (Fig. 3.4):

$$F = 1 - e^{-KL},$$

Where F = fractional interception, K = extinction coefficient and L = green area index,

and this fitted curve accounted for 70% of the variation in present data. It was noticeable that the greatest deviations from the exponential curve of GAI on F_{PAR} related to known differences in flag leaf attitude. For example, in Fig. 3.4 the greatest deviation was for Rialto, know to have an erect, upright flag leaf attitude (NIAB, 1996b). It follows that a knowledge of varietal variation in K may increase the scope for using intercepted radiation data (from ceptometer readings) as a surrogate for the more time-consuming measurement of green area index. This possibility would seem to justify further work in this area. From the cross site-season analysis of variance, the effect of site-season on K_{PAR} was significant ($P < 0.01$) with higher coefficients at RM 93-4 than the other two site-seasons. A part of the explanation for this was that RM 93-4 assessments were undertaken at GS 31 compared to GS 39 for the other two site-seasons. The site-season/variety interaction was significant ($P < 0.001$), indicating that ascribing values of K_{PAR} to crops in particular sets of field circumstances ideally should take into account likely variation due to both variety and environment.

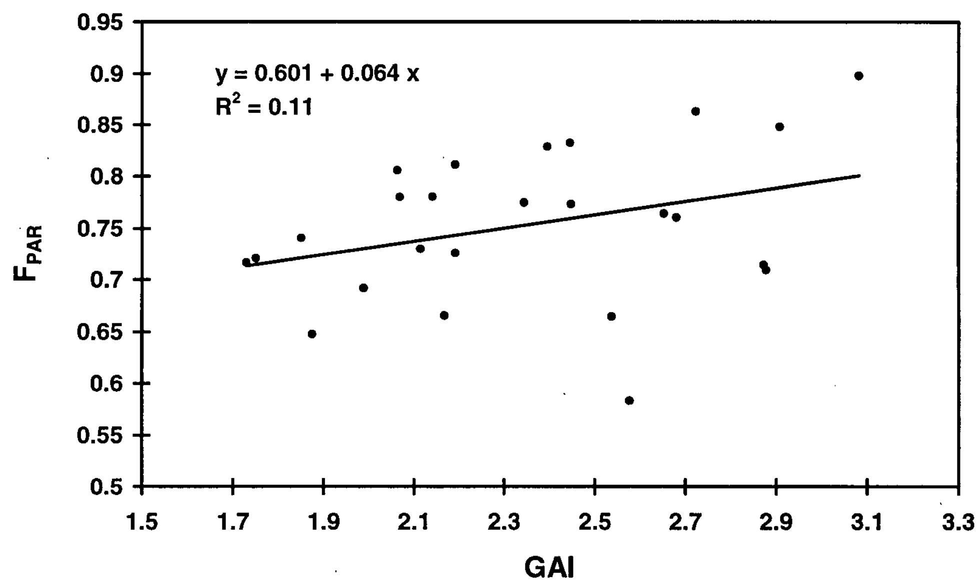

Fig. 3.1 GAI versus fractional PAR interception at GS 31 for RM 93-4

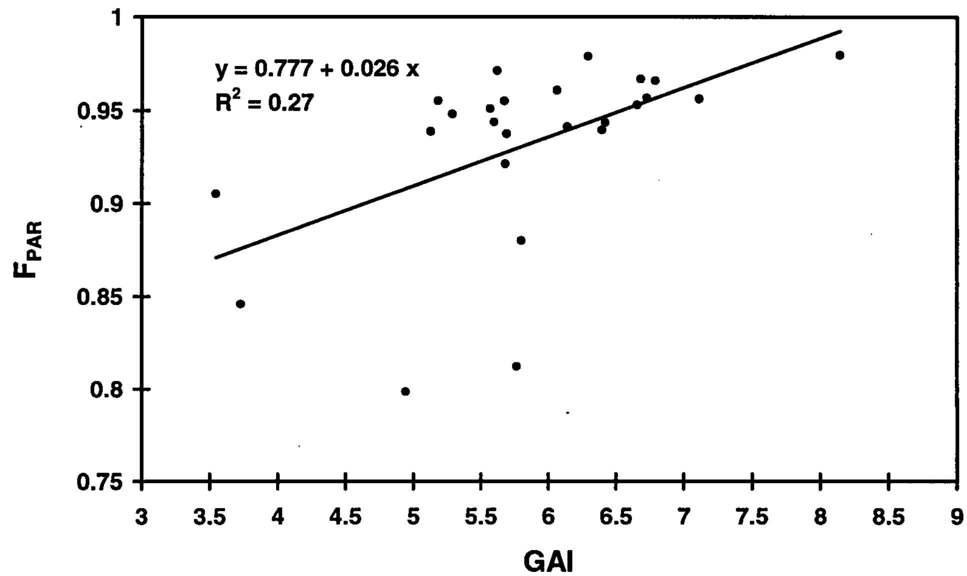

Fig. 3.2 GAI versus fractional PAR interception at GS 39 for RM 94-5

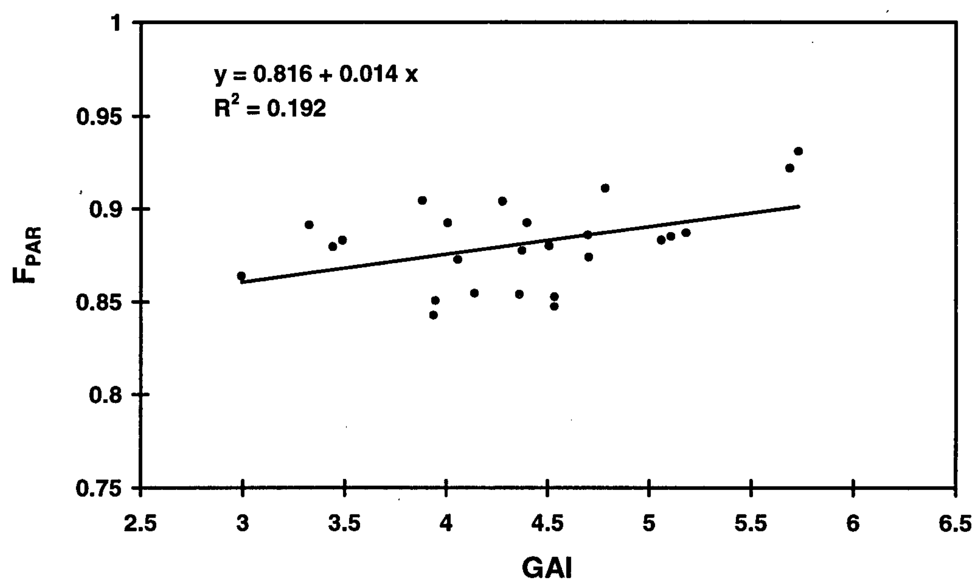

Fig. 3.3 GAI versus fractional PAR interception at GS 39 for SB 94-5

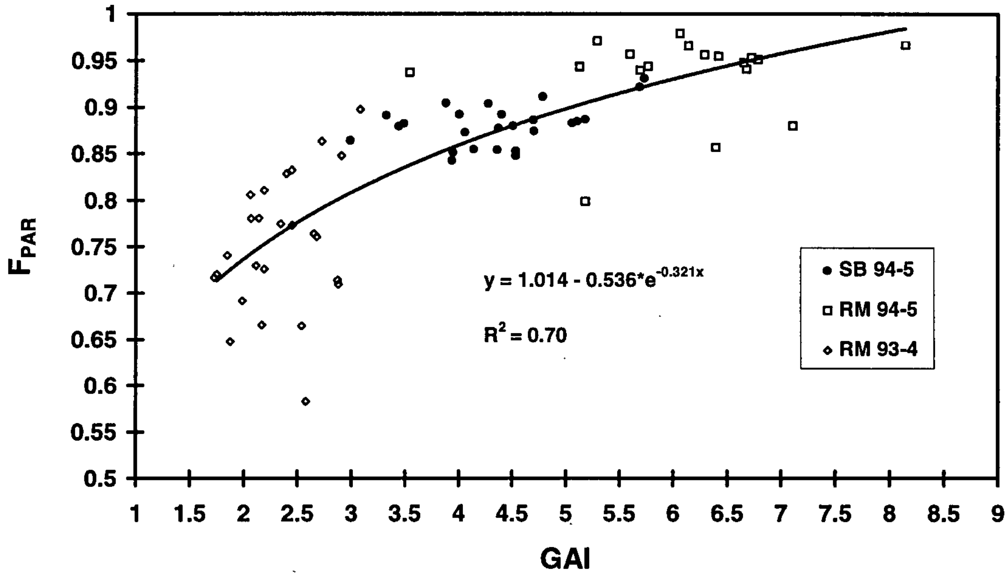

Fig. 3.4 GAI versus fractional PAR interception at GS 31 for RM 93-4, and GS39 for RM 94-5 and SB 94-5.

3.3. Shoot numbers

Table 3.3 Potentially fertile shoots per m² at GS 31 and harvest for varieties tested in Typing Trials 1993-4 and 1994-5.

	Shoots per m^2 at GS 31				Shoots per m^2 at harvest				
	RM 93-4	RM 94-5	SB 94-5	Mean	BX 93-4	RM 93-4	RM 94-5	SB 94-5	Mean
Ami	-	603	-	-	-	-	592	-	-
Apollo	1309	800	1134	1081	431	537	478	493	485
Avalon	731	765	1050	849	396	410	492	465	440
Avital	1048	448	1038	845	420	49	557	507	494
Baroudeur	1147	-	-	-	485	525	-	-	-
Beaver	1172	891	1302	1123	448	581	527	452	503
Brigadier	1516	1101	1182	1266	479	563	556	496	523
Cadenza	959	1011	673	881	413	448	505	449	456
Contra	1357	-	-	-	470	525	-	-	-
Florin	-	708	1178	-	-	-	499	465	-
Haven	1327	1108	1273	1236	400	508	444	411	440
Hereward	1050	740	849	879	410	486	494	444	458
Holfast	-	880	950	-			605	460	-
Hunter	1607	989	1174	1281	439	578	548	482	512
Konsul	1734	-	1231	-	435	525	-	459	-
Little Joss	849	843	1140	-	-	-	458	382	-
Longbow	854	637	1121	873	394	430	431	360	399
Lynx	1383	927	1158	1150	439	487	549	454	481
M. Huntsman	955	975	1090	1007	398	384	428	354	390
Mercia	1092	612	1043	915	525	607	522	516	542
Norman	-	617	922	-	-	--	391	399	-
Obelisk	1079	-	-	-	428	533	-	-	-
Piko	-	826	-	-	-	-	563	-	-
Rascal	1200	-	-	-	416	492	-	-	-
Rialto	1289	769	1263	1107	395	481	471	467	454
Riband	1119	1040	1028	1062	396	422	427	485	435
Rossini	813	-	-	-	387	410		-	-
Scipion	-	475	-	-	-	-	495	-	-
Sideral	1067	-	917	-	440	499		538	-
Soissons	996	1104	1045	1048	529	550	645	555	570
Spark	977	1231	1452	1220	598	593	682	626	625
S'heads Master	-	768	1186	-	-	-	490	438	-
Zentos	1042	1164	1122	1109	368	381	534	461	436
Mean	1141	847	1101		437	498	515	467	
S.E.D. Var.	135.1	134.6	138.5	82.9	19.59	37.62	55.01	34.67	20.13
Prob.	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001
S.E.D. S-season				33.1					17.58
Prob.				<0.001					0.013
SED S-s'n/Var.				143.4					39.65
Prob.				<0.001					<0.001
D.F.	48	50	48	102	48	50	48	48	161

Shoot numbers at GS 31 are close to the maximum, which is attained at about the double ridge stage of apical development (Hay & Kirby, 1991). The variety effect was significant at GS 31 in each site-season ($P < 0.01$) (Table 3.3). From the cross site-season analysis of variance for the 18 common varieties, the overall varietal range was 845 to 1266 shoots per m^2. There were varietal differences in shoot numbers which were consistently expressed across all site-seasons. Thus, Spark (1220 per m^2), Haven (1236 per m^2) and

Brigadier (1266 per m^2) had consistently high shoot numbers and conversely Avalon (849 per m^2) and Mercia (915 per m^2) low shoot numbers within the overall varietal range. As expected, there was a tendency for the slower developing varieties, e.g. Spark, Haven and Beaver (Table 3.1) to have more shoots than the more rapid developing varieties, e.g. Avital, Avalon, Mercia and Soissons. This is due to earlier onset of stem extension for the more rapid varieties at which point further development of tiller buds into tillers is suppressed by competition for assimilate from extending stems. The site-season/variety interaction was significant (P< 0.001) with certain varieties changing their ranking order across experiments: for example Avital and Riband ranked relatively higher and lower, respectively, compared to other varieties at RM 94-5 than at other site-seasons.

Final shoot number was recorded at four site-seasons, whereas shoot number at GS 31 was only assessed at three site-seasons. There were significant differences amongst varieties in all site-seasons (P< 0.01) (Table 3.3). Overall differences were significant in the range 390 - 625 shoots per m^2 (P< 0.001). There were consistently expressed effects for some varieties, for example Spark (625 per m^2), Soissons (570 per m^2), Mercia (542 per m^2) and Brigadier (523 per m^2) showed high final shoot numbers in all site-seasons and the converse for M. Huntsman (390 per m^2), Longbow (399 per m^2), Riband (435 per m^2) and Avalon (440 per m^2). The site-season/variety interaction was significant (P< 0.001), however, indicating that the rank order for some varieties changed across environments.

For the three site-seasons where both GS 31 and final shoot populations were estimated, it was possible to calculate for the eighteen common varieties an estimate of the economy of tillering : defined as the difference between shoot numbers at GS 31 and harvest. The varietal range was 393 - 789 aborted shoots per m^2. The most efficient varieties were Mercia (367 per m^2), Avalon (393 per m^2), Hereward (404 per m^2), Cadenza (464 per m^2) and Soissons (465 per m^2) with less efficient tillering for Haven (781 per m^2), Brigadier (727 per m^2), Lynx (650 per m^2), Zentos (650 per m^2) and Rialto (634 per m^2). The especially inefficient economy of tillering for Brigadier and efficient tillering for Soissons was corroborated in the Rotational Position Sub-Project (Vol. II, Part 2). In that Sub-Project, the varietal range for the dry mass lost in aborted shoots was *c.* 1.5 - 2.5 t/ha. The timing of tiller death will influence the amount of water uptake and radiation interception lost in tillers destined to die, earlier tiller death tending to minimise wasted resources. The number of aborted shoots itself is not a definitive indicator of these wasted resources, and thus economy of tillering, as currently defined, should be treated with some caution and ideally qualified with reference to the average size of the aborted tillers at the time of tiller death.

3.4. Canopy N requirement

Table 3.4. Canopy Nitrogen Requirement (g/m²) for varieties tested in Typing Trials 1993-4 (GS 59) and 1994-5 (GS 39)

	RM 93-4	RM 94-5	SB 94-5	Mean
Ami	-	2.65	-	-
Apollo	2.24	2.52	3.31	2.69
Avalon	2.57	2.57	2.72	2.62
Avital	2.35	3.46	2.75	2.85
Baroudeur	2.10	-	-	-
Beaver	3.62	2.98	4.27	3.62
Brigadier	2.23	2.95	3.13	2.77
Cadenza	2.16	2.94	2.92	2.67
Contra	1.74	-	-	-
Florin	-	2.51	2.69	-
Haven	3.57	2.60	3.87	3.35
Hereward	2.54	2.92	3.59	3.02
Holfast	-	2.15	3.56	-
Hunter	1.85	2.47	2.55	2.29
Konsul	2.08	-	2.81	-
Little Joss	-	3.09	3.03	-
Longbow	2.30	2.94	3.35	2.84
Lynx	2.31	2.60	3.14	2.68
Maris Huntsman	2.39	2.79	2.49	2.58
Mercia	1.74	3.06	2.37	2.39
Norman	-	3.38	3.24	-
Obelisk	2.10	-	-	-
Piko	-	3.14	-	-
Rascal	2.12	-	-	-
Rialto	2.25	2.97	3.92	3.05
Riband	2.13	2.75	3.02	2.63
Rossini	2.67	-	-	-
Scipion		2.87	-	-
Sideral	2.25	-	2.49	-
Soissons	2.42	2.58	3.17	2.72
Spark	3.51	2.48	4.07	3.35
Squareheads Master	-	2.72	3.18	-
Zentos	2.32	2.91	3.50	2.91
Mean	2.38	2.81	3.17	2.83
S.E.D. Var.	0.423	0.322	0.439	0.247
Prob.	< 0.001	0.003	<0.001	<0.001
S.E.D. Site-season				0.082
Prob.				<0.001
S.E.D. Site-s'n/Var.				0.423
Prob.				0.014
D.F. residual	48	50	48	102

Canopy Nitrogen Requirement, the ratio of N taken up in shoots (g/m²) to green surface area (m² per m² ground area) was measured at GS 59 in 1993-4 and GS 39 in 1994-5. The most telling time to measure CNR is at GS 39 when green leaf expansion is complete. Assessments were taken slightly later than this in 1993-4 because of reasons relating to staff availability at around the time of GS 39. There were significant differences amongst varieties in each site-season ($P < 0.01$) (Table 3.4). The varietal ranges of 1.74 - 3.62 g/m², 2.15 - 3.38 g/m² and 2.29 - 3.62 g/m² at RM 93-4, RM 94-5 and SB 94-5, respectively, were broadly similar, but when data for the eighteen common varieties were analysed across site-seasons, the site-season effect was significant ($P < 0.001$). CNR at SB 94-5

(3.17 g/m^2) was greater than at RM 94-5 (2.81 g/m^2) which was, in turn, greater than at RM 94-5 (2.38 g/m^2). Overall across experiments, the variety effect was significant (P< 0.001) in the range 2.39 - 3.62 g/m^2. There was a tendency for the most recently introduced varieties (e.g. Haven, Rialto, Spark and Beaver) to have greater CNR than some older genotypes (e.g. Avalon and M. Huntsman), but there were exceptions to this: for example, the low CNR for Hunter (introduced 1990) and Cadenza (introduced 1991). Indeed, the regression of CNR on year of introduction was not significant. The site-season/variety interaction was significant (P< 0.05), indicating that the ranking order changed for some varieties across site-seasons. This was particularly noticeable for Mercia which had greater CNR at RM 94-5 than at other site-seasons and also for Spark for which the converse occurred.

3.5. Soluble stem carbohydrate

Table 3.5. Soluble carbohydrate content of stems (g/m² 100% DM) at GS 61+75°Cd and harvest for varieties tested in Typing Trials 1993-4 and 1994-5

	GS 61+75°Cd				HARVEST			
	RM 93-4	RM 94-5	SB 94-5	Mean	RM 93-4	RM 94-5	SB 94-5	Mean
Ami	-	241	-	-	-	6	-	-
Apollo	377	338	324	346	5	9	27	15
Avalon	242	313	244	262	2	8	27	13
Avital	-	227	209	-	2	9	22	-
Baroudeur	.51	-	-	-	2	-	-	-
Beaver	373	326	337	345	4	7	19	7
Brigadier	355	414	309	361	4	6	23	12
Cadenza	319	393	289	336	2	8	27	14
Contra	.95	-	-	-	3	-	-	-
Florin	-	399	301	-	-	9	23	-
Haven	369	324	342	345	4	9	18	10
Hereward	185	326	250	254	2	11	34	17
Holdfast	-	211	232	-	-	35	34	-
Hunter	211	380	321	304	3	8	27	14
Konsul	196	-	295	-	8	-	29	-
Little Joss	-	259	269	-	-	9	43	-
Longbow	251	356	306	311	3	9	15	10
Lynx	363	416	295	360	4	11	20	13
M. Huntsman	262	292	318	291	4	9	20	8
Mercia	291	267	312	290	3	6	29	13
Norman	-	334	305	-	-	5	22	-
Obelisk	191	-	-	-	5	-	-	-
Piko	-	291	-	-	-	9	-	-
Rascal	161	-	-	-	2	-	-	-
Rialto	492	487	374	447	6	13	49	24
Riband	277	298	251	284	2	6	26	12
Rossini	311	-	-	-	3	-	-	-
Scipion	-	294	-	-	-	5	-	-
Sideral	2.41	-	269	-	3	-	25	-
Soissons	3.46	407	289	348	4	15	24	16
Spark	2.46	302	265	271	2	9	31	15
Squ'ds Master	-	255	251	-	-	6	27	-
Zentos	2.76	348	268	297	4	6	13	19
Mean	2.87	327	2.89		3	9	26	
SED Var.	57.0	46.6	34.2	27.9	1.9	5.7	8.7	3.5
Prob.	< 0.001	< 0.001	0.004	<0.001	0.354	< 0.001	0.310	0.001
SED Site-season				9.0				1.8
Prob.				0.002				<0.001
SED S-s'n/Var.				47.7				6.1
Prob.				0.083				0.015
D.F.	48	50	48	93	48	50	48	93

From about GS 33 onwards soluble carbohydrate, mostly in the form of fructans, accumulates in the upper internodes of the stem and the peduncle reaching maximum amounts about one week after the onset of anthesis (Austin *et al.*, 1977). These reserves can be retranslocated to grains during the mid-to-latter stages of grain fill to compensate for any shortfall in current assimilate production, for example when premature senescence occurs in response to late season drought. Varieties differed significantly in the amount of stem reserves amassed at GS 61+75°Cd (*c.* 5 days after GS 61) in each experiment ($P <$ 0.01) (Table 3.5). The range was *c.* 200 g/m² in each experiment from about 250 to 450 g/m^2. For the 17 common varieties for which stem reserves were assessed, there were variety differences overall in the range 251 - 447 g/m^2 (P< 0.001). Reserves were consistently greater for Rialto (447 g/m^2), Brigadier (361 g/m^2) and Lynx (360 g/m^2) than for Spark (271 g/m^2), Hereward (254 g/m^2) and Riband (284 g/m^2) (P< 0.05). There was also a tendency for reserves to be greater for varieties possessing the semi-dwarf genes, *Rht1* or *Rht2* (e.g. Rialto, Haven, Brigadier, Beaver, Hunter, Longbow and Lynx) (Tables 2.2 and 3.5) compared to tall, non-dwarf genotypes (e.g. Spark, Mercia and M. Huntsman), although there were occasional exceptions to this : for example, Riband (*Rht2*) had consistently low-to-moderate stem reserves. There was a significant positive linear regression (R^2 =0.425, P < 0.05; Fig. 3.5) between amount of stem reserves at GS 61+75°Cd and grain yield, with the more modern varieties of higher yield potential amassing greater amounts.

The varietal ranking order was generally consistent with and corroborated differences detected in the Moisture Availability (Vol. II, Part 1) and Rotational Position (Vol. II, Part 2) Sub-Projects. Thus, the low stem reserves for Mercia, Spark and Riband in those Sub-Project experiments was corroborated by the Typing Trials data set as was the high amounts for Rialto, Lynx and Soissons. This would indicate that the influence of environment on the variety ranking order was not great for this trait and less than that for some other traits characterised, e.g. canopy N requirement. This was confirmed by the cross site-season ANOVA. There were differences amongst the three site-seasons in the range 287 - 327 g/m^2 (P< 0.01), but the site-season/variety interaction was not significant, suggesting that the overall variation in stem reserves was influenced more by genotype than environment.

The amount of soluble stem carbohydrate remaining at harvest was low in all site-seasons averaging only 3, 9 and 26 g/m^2 at RM 93-4, RM 94-5 and SB 94-5, respectively (Table 3.5). Although there were significant varietal differences at harvest in the range 10 - 24 g/m^2 (P< 0.001), these differences were small and probably not meaningful in relation to differences in buffering capacity which would be overwhelmingly determined by the maximum amount of stem sugars accumulated shortly after anthesis.

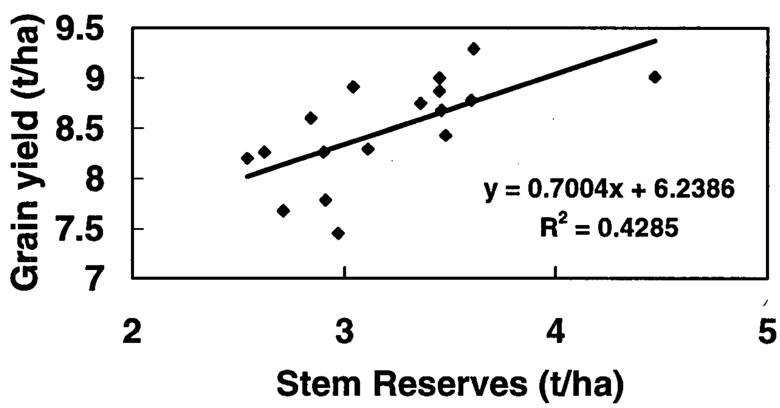

Fig 3.5. Regression of grain yield (t/ha 85% DM) on stem reserves (t/ha 100% DM) at GS 61 +75°Cd for 17 common varieties tested at RM 93-4, RM 94-5 and SB 94-5.

3.6. Harvest above-ground dry mass and harvest index

Table 3.6. *Harvest above-ground dry mass (g/m² 100% DM) and harvest index for varieties tested in Typing Trials in 1993-4 and 1994-5*

	BIOMASS t/ha					HARVEST INDEX				
	RM 93-4	BX 93-4	RM 94-5	SB 94-5	MEAN	RM 93-4	BX 93-4	RM 94-5	SB 94-5	MEAN
Ami	-	-	1218	-	-	-	-	0.52	-	-
Apollo	1544	1407	1555	1484	1507	0.53	0.47	0.50	0.45	0.49
Avalon	1364	1353	1459	1549	1431	0.54	0.49	0.50	0.45	0.49
Avital	1354	1399	1337	1455	1386	0.57	0.51	0.53	0.47	0.52
Baroudeur	1262	1367	-	-	-	0.55	0.49	-	-	-
Beaver	1618	1394	1596	1476	1525	0.54	0.50	0.51	0.47	0.50
Brigadier	1628	1475	1424	1600	1530	0.56	0.51	0.54	0.46	0.52
Cadenza	1387	1424	1724	1611	1537	0.56	0.48	0.49	0.42	0.49
Contra	1507	1447	-	-	-	0.54	0.50	-	-	-
Florin	-	-	1526	1557	-	-	-	0.47	0.46	-
Haven	1590	1368	1459	1418	1459	0.54	0.51	0.51	0.51	0.52
Hereward	1357	1329	1479	1486	1413	0.54	0.48	0.50	0.47	0.49
Holfast	-	-	1387	1492	-	-	-	0.36	0.35	-
Hunter	15.80	1398	1575	1545	1523	0.52	0.49	0.51	0.46	0.50
Konsul	14.82	1385	-	1543	-	0.52	0.48	-	0.45	-
Little Joss	-	-	1336	1416	-	-	-	0.35	0.34	-
Longbow	1417	1370	1440	1315	1386	0.54	0.50	0.51	0.48	0.51
Lynx	1484	1401	1522	1496	1470	0.54	0.51	0.51	0.47	0.51
M. Huntsman	1340	1325	1571	1341	1388	0.53	0.45	0.47	0.45	0.48
Mercia	1373	1401	1506	1541	1471	0.54	0.47	0.49	0.43	0.48
Norman	-	-	1329	1554	-	-	-	0.52	0.47	-
Obelisk	1482	1406	-	-	-	0.50	0.44	-	-	-
Piko	-	-	1379	-	-	-	-	0.45	-	-
Rascal	1302	1363	-	-	-	-	-	0.53	0.44	-
Rialto	1614	1458	1599	1612	1574	0.52	0.47	0.50	0.47	0.49
Riband	1385	1356	1373	1613	1432	0.58	0.51	0.52	0.44	0.51
Rossini	1251	1330	-	-	-	0.56	0.44	-	-	-
Scipion	-	-	1215	-	-	-	-	0.52	-	-
Sideral	1284	1373	-	1429	-	0.55	0.50	-	0.47	-
Soissons	1311	1385	1573	1526	1449	0.55	0.49	0.47	0.48	0.50
Spark	1367	1441	1405	1541	1438	0.52	0.44	0.46	0.41	0.46
Square's Master	-	-	1262	1516	-	-	-	0.36	0.33	-
Zentos	1408	1412	1295	1585	1425	0.51	0.42	0.46	0.40	0.45
MEAN	1428	1391	1444	1508		0.54	0.48	0.48	0.44	
S.E.D. Var.	69.5	29.4	110.8	103.7	40.9	0.013	0.007	0.017	0.048	0.007
Prob.	< 0.001	<0.001	< 0.001	0.298	< 0.001	<0.001	<0.001	<0.001	<0.001	< 0.001
S.E.D. S-season					0.496					0.008
Prob.					0.126					< 0.001
S.E.D S-s'n/Var.					0.937					0.015
Prob.					< 0.001					<0.001
D.F.	72	72	72	72	204	72	72	72	72	204

In three of the four site-seasons, differences amongst varieties were significant for harvest above-ground dry mass ($P< 0.001$) (Table 3.6). From the cross site-season analysis of variance for the 18 common varieties, differences amongst site-seasons were not significant in the range 1391 -1508 g/m^2, but differences amongst varieties overall were ($P< 0.001$) in the range 1386 - 1574 g/m^2. Some genotypes showed consistent effects for high or low biomass across all experiments : for example, greater and smaller harvest dry mass for Rialto and Avital, respectively. Overall there was a positive linear regression between date of introduction of variety and harvest dry mass ($P< 0.05$) (Fig. 3.6). This between date of introduction of variety and harvest dry mass ($P< 0.05$) (Fig. 3.6). This indicated that yield improvement during the last two decades may have come about through improvements in total biomass production in addition to those for harvest index. It is possible that the introduction of UK varieties containing the 1BL/1RS translocation since 1987 (Table 2.2) (Zeller & Hsam, 1983) could, in part, be associated with this improvement in harvest dry mass. The site-season/variety interaction was significant ($P< 0.001$), indicating that the ranking order for some varieties changed across environments. For example, M. Huntsman had relatively greater dry mass at RM 94-5 than in other site-seasons and Soissons greater dry mass in the two site-seasons in 1994-5 compared to the two site-seasons in 1993-4.

Harvest index overall varied amongst varieties in the range 0.46 - 0.52 ($P< 0.001$) (Table 3.6). There were relatively large differences amongst site-seasons ($P< 0.001$), the extremes being represented by RM 93-4 (0.54) and Sutton Bonington 94-5 (0.44). The late sowing date in RM 93-4 may have contributed to its large harvest index and drought at SB 94-5 to the low harvest index. As expected, there was a clear trend for greater harvest index for *Rht* semi-dwarf varieties compared to tall non-dwarf varieties (Gale & Youseffian, 1985; Austin *et al.*, 1989) (Tables 2.2 and 3.6). The site-season/variety interaction was significant ($P< 0.001$) showing an influence of environment on relative varietal performance for at least some of the varieties examined : for example, Soissons had relatively higher harvest index at RM 93-4 compared to its performance in the three other sites seasons. Again, this may have been associated with the late sowing date at RM 93-4 truncating the vegetative phase of growth for the slower developing varieties and reducing potential differences in the ratio between vegetative and reproductive crop dry matter growth.

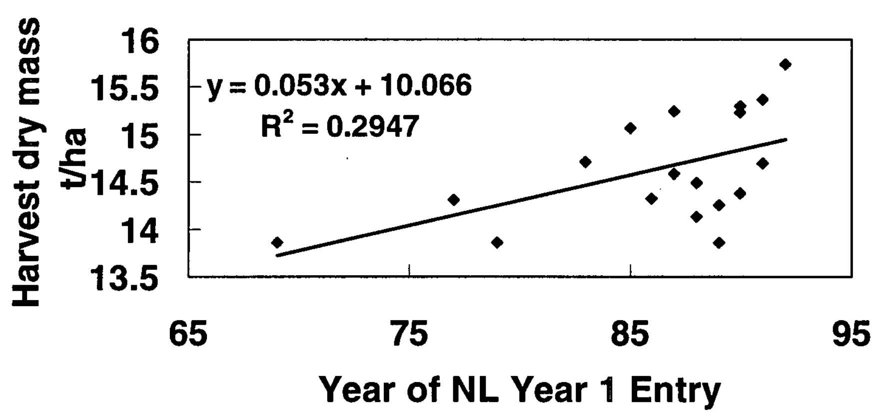

Fig 3.6. Regression of year of introduction on harvest dry mass (t/ha) for 18 common varieties tested at four site-seasons in 1993-4 and 1994-5

3.7. Harvest N offtake and nitrogen harvest index (NHI)

Table 3.7. Harvest crop N offtake (kg/ha) and nitrogen harvest index for varieties tested in Typing Trials 1993-4 and 1994-5.

	N OFFTAKE Kg/ha					N HARVEST INDEX				
	RM 93-4	BX 93-4	RM 94-5	SB 94-5	MEAN	RM 93-4	BX 93-4	RM 94-5	SB 94-5	MEAN
Ami	-	-	196.9	-	-	-	-	0.79	-	-
Apollo	195.0	159.1	236.0	204.8	199.7	0.79	0.80	0.81	0.75	0.79
Avalon	182.4	158.6	231.2	224.8	199.6	0.78	0.81	0.79	0.74	0.78
Avital	180.3	169.9	211.4	206.0	191.9	0.80	0.80	0.80	0.74	0.79
Baroudeur	158.4	165.3	-	-	-	0.79	0.79	-	-	-
Beaver	211.2	158.3	240.4	201.9	203.9	0.77	0.79	0.78	0.74	0.77
Brigadier	210.5	176.0	229.7	218.9	208.4	0.78	0.79	0.82	0.73	0.78
Cadenza	164.6	171.9	262.7	224.8	206.0	0.81	0.80	0.77	0.71	0.77
Contra	194.3	169.2	-	-	-	0.77	0.78	-	-	-
Florin	-	-	232.8	222.1	-	-	-	0.78	0.74	-
Haven	203.3	156.9	219.2	220.3	200.5	0.79	0.79	0.79	0.74	0.78
Hereward	178.6	155.4	228.9	220.9	195.9	0.78	0.77	0.81	0.74	0.77
Holfast	-	-	201.5	200.0	-	-	-	0.69	0.64	-
Hunter	199.3	157.4	238.4	220.8	204.1	0.75	0.78	0.80	0.75	0.77
Konsul	188.4	164.1	-	218.4	-	0.77	0.78	-	0.74	-
Little Joss	-	-	183.3	193.7	-	-	-	0.69	0.64	-
Longbow	175.6	159.3	212.4	190.5	184.2	0.80	0.78	0.80	0.75	0.79
Lynx	193.2	174.6	235.4	213.8	203.7	0.79	0.79	0.80	0.75	0.78
M. Huntsman	180.2	162.5	232.7	183.3	189.4	0.78	0.76	0.77	0.73	0.76
Mercia	176.9	169.5	230.3	210.6	199.0	0.80	0.75	0.79	0.71	0.76
Norman	-	-	204.1	213.5	-	-	-	0.80	0.76	-
Obelisk	199.2	165.3	-	-	-	0.73	0.77	-	-	
Piko	-	-	207.2	-	-	-	-	0.76	-	-
Rascal	166.6	163.3	-	-	-	0.81	0.78	-	-	-
Rialto	203.3	167.0	239.2	218.7	205.8	0.78	0.78	0.80	0.72	0.77
Riband	170.8	161.8	209.4	211.6	190.1	0.80	0.78	0.80	0.75	0.77
Rossini	166.5	162.5	-	-	-	0.79	0.80	-	-	-
Scipion	-	-	197.6	-	-	-	-	0.79	-	-
Sideral	172.4	168.8	-	218.9	-	0.80	0.82	-	0.76	-
Soissons	176.3	170.4	229.6	216.7	198.2	0.81	0.77	0.79	0.76	0.78
Spark	156.8	166.9	206.7	206.9	184.7	0.79	0.75	0.78	0.71	0.76
S'heads Master	-	-	173.7	194.2	-	-	-	0.73	0.70	-
Zentos	175.0	171.5	195.5	207.5	187.4	0.78	0.75	0.77	0.73	0.76
			-	-						
Mean	183.1	165.0	219.6	210.5		0.79	0.78	0.78	0.73	
S.E.D. Var.	15.16	5.89	16.78	14.97	6.93	0.020	0.018	0.020	0.026	0.010
Prob.	0.005	<0.01	< 0.001	0.271	0.002	0.123	0.027	< 0.001	< 0.001	< 0.001
S.E.D. S-season					5.12					0.010
Prob.					< 0.001					< 0.034
S.E.D S-s'n/Var.					14.41					0.021
Prob.					0.012					0.301
D.F.	72	72	72	72	204	72	72	72	72	204

In three of the four site-seasons there were significant differences amongst varieties in crop N offtake at harvest ($P< 0.01$), but not at SB 94-5 (Table 3.7). Overall, for common varieties across site-seasons, there were varietal differences in the range 184 - 208 kg N/ha ($P< 0.001$). There was a tendency for greater N offtakes for the more recently introduced varieties (Fig. 3.7) and the linear regression of Nofftake on year of introduction was significant at the 10% significance level. For example, there were consistently lower offtakes for the older varieties M. Huntsman (189 kg/ha, introduced 1969) and Longbow

(184 kg/ha, introduced 1979) and greater offtakes for the more recent varieties Brigadier (208 kg/ha, 1990) and Rialto (206 kg/ha, 1992) compared to most other genotypes. There were, however, exceptions to this, e.g. the modern variety Spark (introduced 1990) had a low N offtake of 187 kg/ha.

Nitrogen harvest index, from the cross site-season analysis of variance, differed significantly amongst varieties ($P< 0.001$). Varieties with consistently high NHI were Apollo (0.79), Avital (0.79) and Longbow (0.79) and low values for M. Huntsman (0.76), Mercia (0.76), Zentos (0.76) and Spark (0.76). Although there were differences the range was relatively narrow at 0.76 - 0.79, and except at the varietal extremes it seems unlikely that this variation would influence varietal performance significantly in environments differing in N availability. The site-season/variety interaction was non-significant (P=0.301) indicating that varietal differences were consistently expressed across the different test environments (Table 3.7).

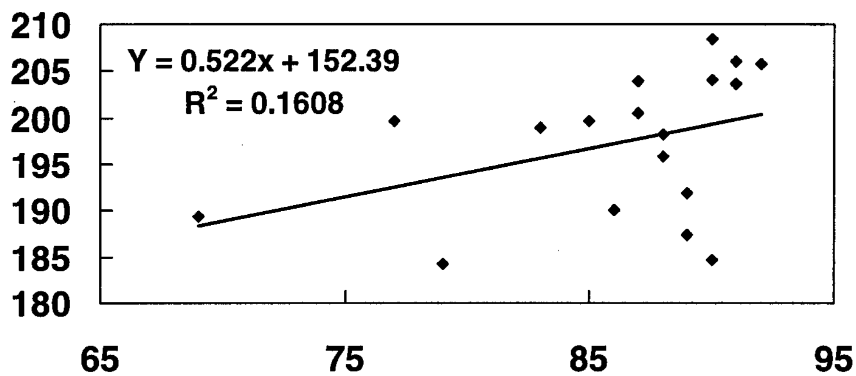

Fig 3.7. Regression of year of introduction on crop N offtake (kg/ha) at harvest for 18 common varieties tested at four site-seasons in 1993-4 and 1994-5

Table 3.8. Grain yield, grains per ear and thousand grain weight for varieties tested in Typing Trials in 1993-4 and 1994-5.

	GRAIN YIELD 85% DM					TGW 85% DM					GRAINS PER EAR				
	BX 93-4	RM 93-4	RM 94-5	SB 94-5	MEAN	BX 93-4	RM 93-4	RM 94-5	SB 94-5	MEAN	BX 93-4	RM 93-4	RM 94-5	SB 94-5	MEAN
Ami	-	-	6.46	-	-	-	-	41.96	-	-	-	-	27.85	-	-
Apollo	7.81	9.62	9.45	7.84	8.68	42.71	50.32	46.23	41.85	45.28	42.57	36.21	43.44	38.22	40.11
Avalon	7.75	8.50	8.54	8.24	8.26	47.79	52.60	48.04	46.76	48.80	41.16	40.22	35.95	38.37	38.94
Avital	8.38	9.04	8.32	8.05	8.45	47.33	56.26	51.57	49.30	51.12	42.50	32.94	26.96	32.25	34.34
Baroudeur	7.82	8.15	-	-	-	46.01	50.74	-	-	-	35.40	30.74	-	-	-
Beaver	8.14	10.34	9.48	8.06	9.00	41.27	49.52	46.23	41.12	44.21	44.13	36.61	39.31	42.20	41.12
Brigadier	8.87	10.71	8.96	8.61	9.29	42.51	48.62	43.98	42.46	44.39	43.89	39.26	35.63	40.97	39.95
Cadenza	8.11	9.08	9.87	7.95	8.75	43.77	49.03	48.15	48.05	47.25	45.11	42.16	39.67	36.93	40.93
Contra	8.45	9.50	-	-	-	41.15	48.49	-	-	-	43.79	37.49	-	-	-
Florin	-	-	8.38	8.45	-	-	-	49.30	48.98	-	-	-	34.01	37.18	-
Haven	8.23	10.15	8.78	8.35	8.87	45.25	53.50	47.47	45.13	47.87	45.55	37.70	42.66	44.96	42.68
Hereward	7.44	8.55	8.64	8.16	8.20	39.36	44.21	43.80	42.35	42.43	46.34	40.00	40.01	43.74	42.52
Holfast	-	-	5.83	6.11	-	-	-	36.24	37.79	-	-	-	28.99	35.27	-
Hunter	8.10	9.67	9.43	8.42	8.91	40.88	44.76	45.19	45.07	43.97	45.18	37.71	39.16	38.74	40.20
Konsul	7.81	9.00	-	8.32	-	38.36	45.21	-	42.04	-	47.01	38.00	-	43.36	-
Little Joss	-	-	5.42	5.68	-	-	-	41.58	41.68	-	-	-	29.34	35.53	-
Longbow	8.03	9.13	8.72	7.36	8.29	45.10	51.21	47.61	51.01	48.50	45.31	41.69	43.01	39.85	43.04
Lynx	8.35	9.46	9.09	8.23	8.78	42.14	54.37	45.79	41.16	46.01	45.26	35.71	35.85	44.26	40.23
Maris Huntsman	7.05	8.26	8.65	7.27	7.78	45.65	55.84	50.88	53.59	51.52	39.03	38.58	37.79	37.77	38.24
Mercia	7.68	8.66	8.70	7.54	8.26	39.52	45.19	42.78	41.42	42.54	37.08	31.66	39.72	36.01	36.46
Norman	-	-	8.20	8.67	-	-	-	48.04	48.23	-	-	-	45.18	45.10	-
Obelisk	7.34	8.92	-	-	-	39.53	44.72	-	-	-	43.42	37.86	-	-	-
Piko	-	-	7.35	-	-	-	-	35.91	-	-	-	-	35.81	-	-
Rascal	7.08	8.11	-	-	-	45.85	45.01	-	-	-	37.16	36.68	-	-	-
Rialto	8.12	9.89	9.29	8.69	9.01	45.85	49.33	45.58	44.68	46.28	44.86	42.23	42.61	42.60	42.94
Riband	8.21	9.37	8.47	8.37	8.60	44.17	51.52	45.50	44.72	46.48	47.12	43.54	48.17	39.23	44.47
Rossini	8.40	8.30	-	-	-	54.63	59.73	-	39.68	-	-	34.22	-	-	-
Scipion	-	-	7.42	-	-	-	-	47.72	-	-	-	-	30.11	-	-
Sideral	8.12	8.24	-	7.93	-	47.02	49.95	-	45.89	-	39.43	33.38	-	32.19	-
Soissons	8.01	8.50	8.58	8.65	8.43	43.12	46.47	45.24	44.90	44.93	35.15	34.26	29.77	34.78	33.49
Spark	7.42	8.36	7.54	7.41	7.68	34.90	38.59	37.16	33.27	35.97	35.85	35.61	33.14	35.73	35.04
S'heads Master	-	-	5.59	5.85	-	-	-	38.12	38.85	-	-	-	33.05	34.45	-
Zentos	7.05	8.40	6.98	7.39	7.45	40.50	49.04	42.85	44.39	44.20	47.45	45.02	31.90	36.12	40.17
Mean	7.91	9.04	8.16	7.82		43.4	49.4	44.7	44.0		42.5	37.6	36.5	38.6	
S.E.D. Var	0.108	0.349	0.627	0.487	0.226	0.834	1.285	2.148	0..942	0.747	1.884	2.351	3.708	1.943	1.222
Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
S.E.D. S-season					0.231					0.575					1.176
Prob.					<0.001					<0.001					0.006
S.E.D S-s'n/var					0.497					1.562					2.649
Prob.					0.011					<0.001					<0.001
D.F.	72	72	72	72	204	72	72	72	72	204	72	72	72	50	161

3.8. Grain yield and yield components

Although grain yield and to a lesser extent components of grain yield are not strictly physiological traits in the same way, for example, that canopy N requirement could be considered a trait, they are included here in order to put the test environments into context. Yield structure also has direct physiological connotations, in that they are determined sequentially during different development phases and specific yield structures may indicate suitabilities to particular aspects of environment and husbandry.

As expected, there were significant differences amongst varieties at all site-seasons ($P < 0.001$) for grain yield (Table 3.8). The more modern varieties generally expressed their higher yield potential at all site-seasons. For the eighteen common varieties, the site-season effect was significant ($P < 0.001$) with lower yields for the two site-seasons in 1994-5 compared to the two site-seasons in 1993-4, probably related to the occurrence of more extended drought in the later season. The higher AWC of Rosemaund compared to Boxworth in 1993-4 may have contributed to its greater yield than Boxworth in this season.

The regression of grain yield on year of introduction for the eighteen common varieties showed a linear rate of yield improvement of 41 kg/ha per year. This reflected the contribution of genotype to yield improvement over the period, 1969 - 1992 (Fig. 3.7). This rate of improvement was broadly in line with the estimate of Silvey (1986) of *c.* 60 kg/ha per year for the period 1947 to 1983, suggesting that yield improvement has progressed at similar rates in the last ten to fifteen years to that in previous decades. The regression was significant at the 5% significance level. The yield differential between the quality and feed varieties was evident, with greater yields for the feed varieties, Brigadier, Beaver and Hunter, compared, for example, to the bread-making varieties, Spark and Hereward.

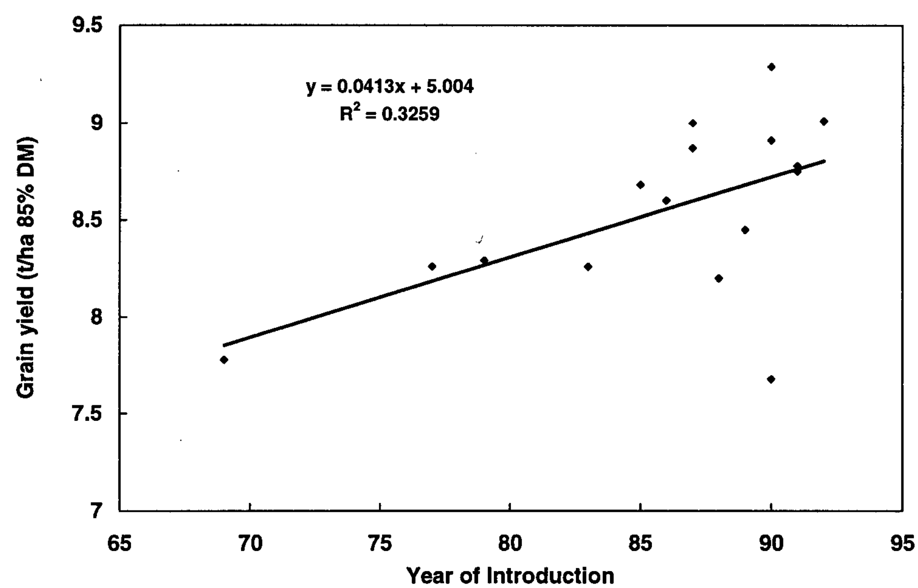

Fig. 3.8 Regression of year of introduction on grain yield (t/ha 85% DM) at harvest for 18 common UK-bred varieties tested at Typing Trials in 1993-4 and 1994-5

For grains per ear, there were differences amongst varieties in each site-season ($P < 0.001$) (Table 3.8). Grains per ear for the 18 common varieties, averaged across site-seasons, differed in the range 33.5 - 44.5 ($P < 0.001$). Consistent with previous reports, there was a tendency for the semi-dwarf varieties to have more grains per ear than tall non-dwarf types (Gale & Youseffian, 1985): cf. the semi-dwarfs Riband (44.5), Rialto (42.9), Haven (42.7) with the non-dwarfs M. Huntsman (38.2), Mercia (36.5) and Spark (35.0). The varieties with smaller ears were generally those with lower yield potential, and these comprised chiefly the older feed wheat varieties, such as M. Huntsman, together with the modern bread wheat varieties, such as Spark.

There were significant differences amongst site-seasons, with average grain number per ear being about five more at BX 94-5 than in other site-seasons. The site-season/variety interaction was significant ($P< 0.001$) with some of the continental winter wheats changing ranking order across environments, for example Zentos and Avital had relatively fewer grains per ear at RM 94-5 compared to BX 94-5.

Grain size, as indicated by 1000 grain weight, differed amongst varieties at all site-seasons ($P< 0.001$) (Table 3.8). Overall, the varietal range was 36.0 (Spark) to 51.5 (M. Huntsman) g. Fourteen of the eighteen common varieties, however, lay within the narrower range of 42.0 to 48.0 g and the variation for this component amongst varieties was less than that for either ears per m^2 (Table 3.3) or grains per ear (Table 3.8). Both the site-season effect and the site-season/variety interaction were significant ($P< 0.001$). The heavier grains at RM 93-4 compared to other test environments ($P< 0.05$) may have related to the effect of less drought here than in the other three site-seasons.

4. DISCUSSION

The main objectives of the Typing Trials were to i) quantify the extent of varietal variation for traits examined, ii) test for consistency of varietal differences across a range of differing environmental conditions, iii) compare trait expression for all varieties in Sub-Project experiments concurrently in the same environment and iv) assess the feasibility and rapidity of assessment methods.

4.1. Varietal variation for traits

Table 4.1 shows that amongst the 18 common varieties in Typing Trials there were differences for all traits measured ($P< 0.05$). Of more interest is the quantitative extent of the varietal range in each case. The ranges for K_{PAR}, harvest index, grain yield and components of grain yield were already, in large part, known at the outset of the current work (NIAB 1996a and previous publications, Kirby 1994, Gale & Youseffian, 1985) and reported results broadly confirm these previous findings. Previous work had, however, attributed yield potential improvement solely to increases in harvest index (largely associated with more grains per ear (Austin *et al.*, 1989). Current results show that newer varieties had a trend for greater harvest biomass, and, indeed, even amongst the more modern wheat varieties (introduced after 1985) there were differences in harvest dry mass of about 150 g/m^2 at the extremes. These differences were large enough to be meaningful in terms of differing demand for environmental resources amongst varieties and may have implications in late-season stress environments where resource supply, e.g. water, is limited. A knowledge of these differences would thus be of value to agronomists when attempting to predict performance in particular growing conditions, e.g. drought-prone soil types or the second wheat environment. More generally, it can be stated that for those varieties currently examined genetic improvement for the modern varieties compared to their predecessors has been partly due to improvements in harvest dry mass alongside those for harvest index.

For shoot numbers, within the overall range at GS 31 of 873 to 1281 per m^2 and at final harvest of 390 to 625 per m^2, varietal patterns in tiller production and survival detected in individual Sub-Project experiments were corroborated. Thus, the later developing varieties, such as Spark (1220 per m^2), Haven (1236 per m^2) and Beaver (1123 per m^2) generally had more shoots at GS 31 compared to the early developing varieties such as Avital (845 per m^2), Avalon (849 per m^2) and Soissons (1048 per m^2). Similarly, the high tiller survival for Soissons and Mercia observed in the Moisture Availability Sub-Project (see Vol. II, Part 1) was reflected in high harvest ear numbers of 570 and 542 per m^2, respectively, in Typing Trials. The high final ear number of Spark (625 per m^2) was associated with high tiller production and average tiller survival, corroborating this tillering pattern as observed in the Rotational Position Sub-Project (see Vol. II, Part 2). In summary, findings in the Typing Trials generally re-enforced the patterns of tiller production and survival detected in the individual Sub-Project experiments. The implications of these differences for environmental suitabilties are discussed in more detail in the Sub-Project report discussions (see Vol. II). In brief, excessive production of tillers, which are subsequently lost, wastes water resources, since the dry matter production in dead tillers is not effectively redistributed through the plant. Thus, the presence of shoots destined to die is especially deleterious in growing conditions where water uptake is restricted, as is the case in drought-prone soil types or second and subsequent wheats. The most economic tillering varietal type is therefore likely to relate to low tiller production coupled with high tiller survival as exemplified, for example, by Soissons (Spink *et al.*, 1996).

Table 4.1 Varietal ranges, means and statistical significances for physiological traits for the 18/17 common varieties measured in Typing Trials in 1993-4 and 1994-5.

Physiological trait	Site-seasons	Varieties	Var. range	Var. mean	Significance: Variety	Site-season	V./S-s'son
K_{PAR}	3	18	0.44 - 0.66	0.56	<0.05	<0.01	<0.01
Max shoots/ m^2	3	18	873 - 1281	1052	<0.001	<0.001	<0.001
Final shoots/m^2	4	18	390 - 625	480	<0.001	0.013	<0.001
CNR g/m^2	3	18	2.29 - 3.62	2.83	<0.001	<0.001	<0.05
Stem CHO (GS61+75°Cd g/m^2)	3	17	254 - 447	3.21	<0.001	<0.01	NS
Harvest biomass g/m^2	4	18	1386 - 1574	1460	<0.001	0.01	<0.001
HI	4	18	0.45 - 0.52	0.50	<0.001	NS	<0.001
Harvest crop N offtake kg/ha	4	18	184 - 208	197	<0.01	<0.001	<0.05
Nitrogen harvest index	4	18	0.76 - 0.79	0.77	<0.001	<0.05	NS
Grain yield g/m^2	4	18	745 - 929	848	<0.001	<0.01	<0.001
Grains per ear	4	18	33.4 - 44.5	39.7	<0.001	<0.01	<0.001
Thousand grain weight g	4	18	36.0 - 51.5	45.7	<0.001	<0.001	<0.001

The varietal range for stem reserves was from *c.* 2.5 to 4.5 t/ha. Again this difference was relatively large and has meaningful implications for performance in situations where premature canopy senescence occurs, for example due to drought or take-all root loss in second wheats. Buffering of grain filling from stem reserves can offset the shortfall of photosynthate from current assimilate and help to maintain yield in these late-season stress environments. The varietal ranking order for stem reserves observed was broadly similar to that detected in the Moisture Availability and Rotational Position Sub-Projects (see Vol. II, Parts 1 and 2) corroborating findings in those investigations. Thus, lower amounts of stem reserves at GS61+75°Cd were found for Mercia, Spark, M. Huntsman and Riband with higher amounts for Rialto, Haven and Soissons.

The canopy N requirement varied in the range 2.3 - 3.6 g/m^2 amongst varieties with an average of 2.83 g/m^2, close to the value of 3.0 g/m^2 reported by Sylvester-Bradley *et al.* (1991) for Avalon. The fact that there were significant differences amongst varieties and that these appeared to be relatively large at the varietal extremes may have implications for fertilzer N inputs, i.e. when targeted to build an optimum canopy size of *c.* GAI 5 (assuming 30 kg/ha of N uptake = 1.0 GAI unit of green canopy area) (see HGCA Final Project Report 159; HGCA, 1998).

In addition to the trend for greater harvest total biomass for more modern varieties, there was a positive linear regression of harvest crop N offtake on date of introduction of variety at the 10% significance level. This trend for greater harvest N offtake for more modern varieties was also detected in an independent analysis of Levington Agriculture variety/fertilizer N trials 1982-92 (Foulkes *et al.*, 1998). The range currently reported was from 184 kg/ha N for Longbow (introduced in 1979) to 208 kg/ha N for Brigadier (introduced in 1992). Evidence for differences between currently commercial modern varieties in N offtake was less easily discernible, although Riband did have generally lower N offtakes than most other contemporary varieties. However, from current findings it could not be concluded that the requirement for N was shown to differ consistently amongst the group of most recent currently commercial varieties tested, other than the already known distinctions relating to quality and feed wheats (MAFF, 1994).

The N harvest index did vary significantly amongst varieties in the range 0.76 - 0.79, but differences were small in absolute terms and it is doubtful whether they had implications for environmental performance. The low N harvest index for the older variety M. Huntsman of 0.76 compared to more modern genotypes is consistent with the trend for small improvements in NHI through breeding from the late 1960s through to the late 1970s reported by Austin *et al.* (1977).

Ranges for traits examined in Table 4.1 refer to both UK-grown varieties and some continental winter wheats, e.g. Avital and Zentos, sown in Typing Trials. Continental varieties, other than Soissons, are not grown to any appreciable extent in the UK. It could be argued that applying these ranges to the UK environment may artificially exaggerate the importance of target traits for performance in the UK in different growing conditions. For all traits studied, however, only Zentos (lowest harvest index and grain yield) and Avital (lowest shoot number at GS 31, and then only by five shoots per m^2 compared to Avalon) acted to define the extremes of the varietal ranges. Thus the ranges in Table 4.1 relate, with these few exceptions, to UK-grown varieties and therefore are relevant in terms of their implications for varietal choice in particular environmental conditions.

4.2 Consistency of varietal trait expression across different environments

For a trait to be of maximum use to variety testers and breeders it is important that the varietal ranking order for the trait shows a high degree of consistency from site to site and from season to season. Such consistency is useful to testers because it reduces the number of site-seasons over which varieties must be characterised in order to describe trait differences with confidence. It also confirms that trait expression should consistently relate to performance, in that trait expression will not be unduly coloured by particular sets of seasonal weather patterns. For the breeder, consistency of trait ranking is useful since it confirms a high degree of heritibility and therefore the suitability of the trait for inclusion in breeding programmes.

For all characteristics examined, the site-season/variety interaction was significant ($P< 0.05$), with the exceptions of stem reserves at GS61+75°Cd and nitrogen harvest index (Table 4.1). From this it follows that varietal differences for these two traits were particularly consistently expressed and could be determined with confidence over relatively few site-seasons. For the other traits, where there was a significant G x E interaction, there were consistencies within the varietal range usually at the extremes, so that some varieties were consistently high or low. In these situations, it would be important for testers' to identify the consistencies within the overall range and to highlight these to growers in their publications to provide intelligence on potential environmental suitabilities.

4.3 Feasibility and rapidity of assessment methodologies

In terms of the general rapidity and feasibility of the methods used, they all would represent an increase in labour requirement compared to the existing range of agronomic characters routinely recorded by testers in RL trials. For NIAB regional centres to add all the above characters examined to their existing protocols would probably be unrealistic. However, there may be scope for introducing a limited sub-set of additional traits. Tillering characteristics and stem reserves could be measured with relatively little additional requirement for laboratory facilities or extra oven-space in relation to drying samples to constant weight. These characters were tested for their feasibility in 1996-7 at three NIAB regional centres (see discussion Part 2, this Vol.), where the extra workload was found to be generally manageable in relation to existing work schedules. There would, however, be a direct cost of submitting stem samples for chemical analysis to determine water soluble carbohydrate percentage, currently *c.* £12 per sample.

The canopy N requirement, however, may be an impractical trait to assess over large numbers of testers' plots because, in addition to the cost of chemical analysis, it necessitates recording both green canopy area and dry mass per unit area. This would involve considerable labour in relation to handling samples. Similarly, the extinction coefficient cannot be measured rapidly. Fractional PAR interception can be assessed relatively quickly using hand-held ceptometers, although there is a requirement for undertaking assessments during particular times of the day. Estimating green canopy area concurrently, however, would entail some of the same problems in relation to labour input referred to above for the canopy N requirement. Harvest characteristics, e.g. harvest index, harvest dry mass, and components of grain yield, were shown to be reasonably rapid, with the fact that the material is at low moisture content and therefore can be stored without deteriorating assisting in the scheduling of the workload. For this reason, these traits can feasibly be assessed over large numbers of testers' field plots (see discussion Part 2, this Vol.).

4.4 Conclusions and future work

- For all traits examined there were statistically significant differences in varietal expression which, at the extremes of the varietal range, were consistently expressed across site-seasons.

- Regressions of F_{PAR} on GAI were significant, and there were significant varietal differences in K_{PAR} in the range 0.47 to 0.66. Future work could concentrate on typing varieties for K_{PAR} to allow field walkers to more accurately estimate green area index from in-field ceptometer measurements of F_{PAR} for crops on a variety specific basis.

- There was a tendency for the slower developing varieties, e.g. Spark, Haven and Beaver to have more shoots at GS 31 than the more rapid developing varieties, e.g. Avital, Avalon, Mercia and Soissons. The varietal range for the number of aborted shoots was 393 to 789 per m^2. This range corresponds broadly to a varietal range for dry mass lost in aborted tillers of *c.* 1.5 - 2.5 t/ha (see Rotational Position Sub-Project, Vol. II, Part 2). More work is needed to quantify the relationship between the number of shoots lost between GS 31 and GS 61 and the dry matter loss associated with these destined-to-die shoots.

- There were significant varietal differences in soluble stem carbohydrate at GS61+75°Cd in the range 2.5 to 4.5 t/ha. Differences were large enough to have meaningful implications for yield performance in environments with late-season stress. Varietal differences were consistently expressed across environments, indicated by the non-significance of the G x E interaction.

- There were significant varietal differences in canopy N requirement in the range 2.3 to 3.6 g/m^2, implying that the amount of N required to generate optimal canopy size of *c.* GAI 5 differs for varieties. Future work might concentrate on testing the principles of Canopy N Management (see HGCA Final Project Report 159 (HGCA, 1998)) across a wide range of varieties contrasting for CNR.

- There were significant differences amongst varieties in harvest above-ground dry mass. Newer varieties showed a tendency for greater biomass. This appeared to be associated with the possession of the 1B/1R rye chromosome translocation, cited by breeders as conferring a 'stay green' effect on the lower canopy during senescence.

- In terms of feasibility and rapidity of assessments, there is scope for introducing :

  ⇒ dates of GS 31 and GS 61,
  ⇒ shoot number at GS 31 and GS 61 and
  ⇒ stem reserves at GS61+75°Cd

  into field programmes testing large numbers of varieties.

- In future work, NIAB might include some of these assessments on a permanent basis in their RL trials (see Part 2, this Vol.).

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Appendix table 1 - Weather data

A 1.1. Boxworth 1993-4

	Monthly mean air T°C	Monthly total Rainfall (mm)	Mean Irradiance sun hrs per day
October	8.9	84	3.6
November	4.6	60	2.0
December	5.4	79	1.2
January	5.0	61	2.3
February	3.2	28	2.4
March	7.4	42	4.1
April	8.1	72	5.8
May	10.8	58	4.9
June	15.1	24	8.3
July	18.9	26	8.2
August	16.7	62	5.9
September	13.2	78	3.6

A.1.2. Rosemaund 1993-4

	Monthly mean air T°C	Monthly total Rainfall (mm)	Mean solar rad. $MJ/m^2/day$
October	9.3	97	6.5
November	4.5	62	2.5
December	5.5	92	2.1
January	5.4	59	2.9
February	3.0	80	4.0
March	8.0	34	8.9
April	8.2	34	14.4
May	11.5	61	19.3
June	14.2	17	19.4
July	17.8	32	19.1
August	15.8	45	14.4
September	12.5	120	9.2

A.1.3. Rosemaund 1994-5

	Monthly mean air T°C	Monthly total Rainfall (mm)	Mean solar rad. MJ/m^2/day
October	9.5	68	6.5
November	10.0	58	2.4
December	6.4	99	1.7
January	4.9	116	2.2
February	6.4	61	4.3
March	5.5	15	10.3
April	9.0	15	16.0
May	11.3	59	13.5
June	14.0	12	20.7
July	18.3	6	17.9
August	19.1	18	18.2
September	13.3	81	10.6

A 1.4. Sutton Bonington 1994-5

	Monthly mean air T°C	Monthly total Rainfall (mm)	Mean solar rad. MJ/m^2/day
October	9.7	42	5.9
November	9.8	67	2.6
December	6.3	94	1.9
January	4.7	105	2.3
February	3.4	55	4.5
March	5.5	35	9.3
April	8.9	13	13.3
May	11.7	23	16.6
June	14.3	12	16.6
July	18.9	11	16.5
August	18.6	6	16.1
September	13.6	83	8.8

Appendix table 2 Site Details

A.2.1.

Boxworth 1993-4

Soil series		Hanslope
Soil texture		Clay
Soil analysis	pH	8.1
	P	22 mg/l
	K	295 mg/l
	Mg	98 mg/l
	Organic matter (%)	3.5
Sowing date		1 November1993
Seed rate		325 seeds/m^2
Drainage		Good
Previous crop	1993	Winter oilseed rape
	1992	Winter wheat
	1991	Winter wheat
Cultivations	4 August	Ploughed
	5 August	Mashio
	22 September	Vaderstad
	20 October	Harrowed
Fertilizer	21 February	40 kg/ha N (as ammonium nitrate prill)
	19 April	50 kg/ha N (as ammonium nitrate prill)
	10 May	55 kg/ha N (as ammonium nitrate prill)
Herbicide	10 February	Arelon 2.9 l/ha
	10 February	Panther 1 l/ha
	7 April	Starane 0.75 l/ha
	7 April	Ally 15 g/ha
Fungicide	9 May	Sportak 45 1.25 l/ha
	9 May	Patrol 0.5 l/ha
	25 May	Folicur 1 l/ha
	25 May	Patrol 0.75 l/ha
	28 May	Silvacur 1 l/ha
Pesticide	18 October	Draza 5.5 kg/ha
	17 June	Hostathion 0.84 l/ha
Growth regulator	None	
Trace elements	None	
Harvest date		9 August

A. 2.2.

Rosemaund 1993-4

Soil series		Bromyard
Soil texture		Silty clay loam
Soil analysis	pH	7.1
	P index	4
	K index	3
	Mg index	3
Sowing date		11 November 1993
Seed rate		375 seeds/m^2
Drainage		Good
Previous crop	1993	Forage Maize
	1992	Grass
	1991	Grass
Cultivations	11 November	Ploughed
	11 November	Power harrowed
Fertilizer	14 March	40 kg/ha N (as ammonium nitrate prill)
	25 April	63 kg/ha N (as ammonium nitrate prill)
Herbicide	11 March	Panther 2.0 l/ha
Fungicide	29 April	Sportak 45 0.9 l/ha
	29 April	Ternç 750 EC 0.75 l/ha
	27 May	Folicur 1 l/ha
	24 June	Silvacur 0.75 l/ha
Pesticide	17 November	Draza 5.5 kg/ha
	28 June	Aphox 280 g/ha
Growth regulator	22 April	Chlomequat 70% 1.65 l/ha
	27 May	Terpal 1 l/ha
Trace elements	None	
Harvest date		26/27 August

A. 2.3.

Rosemaund 1994-5

Soil series		Bromyard
Soil texture		Silty clay loam
Soil analysis	pH	7.2
	P index	3
	K index	2
	Mg index	2
Sowing date		12 October 1993
Seed rate		375 seeds/m^2
Drainage		Good
Previous crop	1994	Linseed
	1993	Winter wheat
	1992	Winter wheat
Cultivations	11 October	Ploughed
	11 October	Power harrowed
Fertilizer	14 March	64 kg/ha N (as ammonium nitrate prill)
	25 April	148 kg/ha N (as ammonium nitrate prill)
	6 May	40 kg/ha N (as foliar urea)
Herbicide	17 November	Panther 2.0 l/ha
Fungicide	GS31[1]	Sportak 45 0.9 l/ha
	GS31[1]	Ternc 750 EC 0.75 l/ha
	18 May	Folicur 1 l/ha
	16 June	Silvacur 0.75 l/ha
Pesticide	28 October	Draza 5.5 kg/ha
	17 November	Cyperkill 0.2 l/ha
	26 June	Phantom 0.1 l/ha
Growth regulator	GS31[1]	Chlomequat 70% 1.65 l/ha
Trace elements	None	
Harvest date		8 August

[1] GS31: 30 March for Ami, Avital, Florin, Rialto, Scipion, Soissons; 8 April for Apollo, Avalon, Brigadier, Cadenza, Haven, Hereward, Lynx, M. Huntsman, Mercia, Norman and Riband and 21 April for Beaver, Holdfast, Hunter, Little Joss, Longbow, Piko, Spark, Squareheads Master and Zentos.

A.2.4.

Sutton Bonington 1994-5

Soil series		Dunnington Heath
Soil texture		Stony medium loam over clay
Soil analysis	Ph	6.2
Sowing date		13 October 1995
Emergence date		24 October 1995
Seed rate		350 seeds per m^2
Drainage		Good
Previous crop	1993/4	Winter Oats
Cultivations	11 October	Ploughed and pressed and power harrowed
Fertilizer	21 March	30 kg/ha N (as ammonium nitrate prill)
	25 April	150 kg/ha N (as ammonium nitrate prill)
Herbicide	11/3/95	Panther (2 l/ha).
	11/3/95	Duplosan (2.3 l/ha)
Fungicide		
	21 April	Sportak 45 (0.9 l/ha)
	21 April	Patrol (1 l/ha)
	15 June	Folicur (1 l/ha)
Pesticide	22 June	Aphox (280 g/ha)
Growth regulator	9 April	Chlormequat 70 (1.15 l/ha)
	21 April	Chlormequat 70 (1.15 l/ha)
Trace elements	None	
Harvest date	5 August 1995	

Contents

Part 2 : NIAB ADDITIONAL CHARACTER ASSESSMENTS

Part 2 : NIAB ADDITIONAL CHARACTER ASSESSMENTS

1. INTRODUCTION

At the outset of the current Project, there were existing standard NIAB tests for vernalization requirement, winter hardiness, shattering and sprouting, and for resistance to six wheat diseases. The objective of this element of the Project was to provide NIAB testers with the opportunity to test candidate indicative physiological traits developed in Project work at an early stage in their own RL trials. Some promising characters were already known at the mid-term stage of the Project and were put forward as of immediate potential use to testers, e.g. dates of GS 31 and GS 61 (indicative of suitability to sowing date, drought and non-first wheat environments) and amount of stem soluble carbohydrate reserves at GS 61+75°Cd (indicative of suitabilities to drought and non-first wheats). NIAB Additional Character Assessments also allowed proposed methodologies to be examined in RL trials incorporating large numbers of plots. Furthermore, they allowed the most recent candidate varieties, not included in other Project experiments, to be characterised. Two additional varieties were included in RL trial sites where additional characters were assessed, Avital (a French-bred, photoperiod insensitive, early developing variety) and Maris Huntsman (an older, tall, non-semi dwarf UK-bred variety). This stretched genotype differences in relation to development and stem partitioning, so providing an opportunity for corroboration of effects detected in Sub-Project experiments. The aim was to examine traits with relatively straightforward methodologies in 1994-5 over five test sites, but in 1995-6 to examine traits with slightly more involved assessment methodologies over a restricted number of three sites.

The objectives of the NIAB Additional Character Assessments were thus to :

- Examine feasibility of methodologies for assessing traits in testers' trials with large numbers of plots.
- Characterise newest candidate varieties in RL trials for important indicative traits.
- Corroborate varietal ranges for traits established in Typing Trials and individual Sub-Project experiments.

2. MATERIALS AND METHODS

2.1. 1994-5

2.1.1 Selected sites

In 1994-5, additional character assessments were measured in two fungicide-treated replicates in winter wheat RL trials at five sites, namely :

1. Bridgets
2. Rosemaund
3. Harper Adams
4. Headley Hall
5. Cockle Park.

Details of sowing date, N fertilizer applications, soil type and previous cropping are given in Appendix Table 1. Disease and pest control were according to the standard NIAB RL Protocol. Seed rate was according a standard weight of seed per m^2 for all varieties.

2.1.2. Crop measurements

The additional characters assessed in 1994-5 were :

- Date of GS 31,
- Date of GS 61,
- Harvest index (allowing for the calculation of above-ground harvest dry mass) and
- N Harvest index (allowing for the calculation of total harvest N offtake).

2.1.2.1. Dates of GS 31 and GS 61

Dates of GS 31 and GS 61 were recorded in two-fungicide-treated replicates as described in 'How to run a reference crop', Vol. II (of III), Project Report No. 151, 'Predictive information on plant development in relation to eventual yield and quality' (HGCA, 1998).

2.1.2.2. Harvest dry mass, harvest index, havest N offtake and N harvest index.

Harvest dry mass, harvest index, havest N offtake and N harvest index were assessed in two fungicide-treated replicates by taking pre-harvest grab samples in each plot and subsequently performing growth analysis as described in 'How to run a reference crop', Vol. II (of III), Project Report No. 151, 'Predictive information on plant development in relation to eventual yield and quality' (HGCA, 1998).

2.2. 1995-6

2.2.1. Selected sites

In 1995-6, additional character assessments were measured in two fungicide-treated replicates in winter wheat RL trials at three sites, namely : -

1. Bridgets
2. Harper Adams
3. Headley Hall.

Details of sowing date, N fertilizer applications, soil type and previous cropping are given in Appendix Table 2. Disease and pest control were according to the standard NIAB Protocol. Seed rate was adjusted for each variety according to 1,000 grain weight to sow a standard number of seeds per m^2 of 275.

2.2.2. Crop measurements

The additional characters assessed in 1995-6 were :

- Date of GS 31,
- Date of GS 61,
- Fertile shoot number at GS 31 and GS 61 and
- Stem soluble carbohydrate dry mass at GS 61+75°Cd and harvest.

2.2.2.1. Dates of GS 31 and GS 61

Dates of GS 31 and GS 61 were recorded in two-fungicide-treated replicates as described in 'How to run a reference crop', Vol II (of III), Project Report No. 151, 'Predictive information on plant development in relation to eventual yield and quality' (HGCA, 1998).

2.2.2.2. Potentially fertile shoot numbers per m^2

Shoot numbers were assessed in two fungicide-treated replicates as described in the section 'How to run a reference crop', Vol. II (of III) , Project Report No. 151, 'Predictive information on plant development in relation to eventual yield and quality' (HGCA, 1998) except that a 10% sub-sample from the 0.72 m^2 quadrat was used and the sub-sample was related to the whole sub-sample on the basis of fresh weight rather than dry weight.

2.2.2.3. Stem soluble carbohydrate at GS 61 and pre-harvest.

Soluble stem carbohydrate content was assessed in two fungicide-treated replicates at GS61+75°Cd (base temperature 0°C) and harvest as described in 'How to run a reference crop', Vol. II (of III), Project Report No. 151, 'Predictive information on plant development in relation to eventual yield and quality' (HGCA, 1998).

3. RESULTS

3.1. DEVELOPMENT RATE

3.1.1. Date of GS 31

Table 3.1. Date of GS 31 at five NIAB RL sites 1994-5: Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RM	BT	Mean
Sow. date.	29 Sep	27Oct	28 Sep	13 Oct	5 Oct	
Avital	21-Mar	11-Apr	30-Mar	28-Mar	12-Mar	26-Mar
Soissons	30-Mar	13-Apr	4-Apr	31-Mar	24-Mar	1-Apr
Buster	7-Apr	13-Apr	4-Apr	6-Apr	29-Mar	5-Apr
Rialto	5-Apr	13-Apr	4-Apr	6-Apr	7-Apr	7-Apr
Caxton	12-Apr	15-Apr	3-Apr	7-Apr	29-Mar	7-Apr
Hereward	8-Apr	15-Apr	3-Apr	5-Apr	4-Apr	7-Apr
Mercia	10-Apr	15-Apr	4-Apr	7-Apr	4-Apr	8-Apr
Chianti	9-Apr	13-Apr	10-Apr	9-Apr	7-Apr	9-Apr
Genesis	11-Apr	15-Apr	12-Apr	7-Apr	4-Apr	9-Apr
Magellan	9-Apr	15-Apr	10-Apr	7-Apr	4-Apr	9-Apr
Turpin	12-Apr	15-Apr	10-Apr	7-Apr	4-Apr	9-Apr
Flame	11-Apr	15-Apr	10-Apr	8-Apr	7-Apr	10-Apr
Reaper	10-Apr	15-Apr	10-Apr	7-Apr	12-Apr	10-Apr
Prophet	9-Apr	15-Apr	15-Apr	8-Apr	4-Apr	10-Apr
Cadenza	8-Apr	21-Apr	12-Apr	7-Apr	7-Apr	11-Apr
Charger	13-Apr	15-Apr	8-Apr	9-Apr	10-Apr	11-Apr
Beaufort	10-Apr	15-Apr	12-Apr	7-Apr	15-Apr	11-Apr
Encore	9-Apr	19-Apr	12-Apr	7-Apr	12-Apr	11-Apr
Hussar	10-Apr	17-Apr	11-Apr	8-Apr	10-Apr	11-Apr
Brigadier	13-Apr	17-Apr	12-Apr	8-Apr	10-Apr	12-Apr
Hunter	11-Apr	17-Apr	11-Apr	11-Apr	15-Apr	13-Apr
Dynamo	11-Apr	21-Apr	13-Apr	16-Apr	10-Apr	14-Apr
M. Huntsman	16-Apr	17-Apr	15-Apr	11-Apr	12-Apr	14-Apr
Riband	14-Apr	17-Apr	20-Apr	12-Apr	15-Apr	15-Apr
Consort	8-Apr	21-Apr	20-Apr	14-Apr	18-Apr	16-Apr
Haven	11-Apr	19-Apr	19-Apr	17-Apr	22-Apr	17-Apr
Spark	14-Apr	21-Apr	20-Apr	16-Apr	15-Apr	17-Apr
Raleigh	17-Apr	24-Apr	21-Apr	9-Apr	22-Apr	18-Apr
Beaver	17-Apr	21-Apr	25-Apr	17-Apr	22-Apr	20-Apr
Varietal range (d)	27	13	26	20	41	25
Mean	9-Apr	16-Apr	11-Apr	8-Apr	8-Apr	10-Apr

In 1995 development was generally faster to GS 31 than in 1996 associated with cooler March temperatures in the latter season (Appendix Table 1). The sowing dates in the two seasons were broadly similar : CP 94-5 (29 Sep), HH 94-5 (27 Oct), HA 94-5 (28 Sep), RM 94-5 (13 Oct), BT 94-5 (5 Oct), HH 95-6 (9 Oct), HA 95-6 (2 Oct) and BT 95-6 (11 Oct). In 1995, date of reaching GS 31 was later at Headley Hall compared to other sites due mainly to a later sowing date of 27 October. Late sowing date at this site also restricted the varietal range to 13 d compared with the average of 25 d. At the most southerly site at Bridgets the range was greatest (41 d), associated with the photoperiod insensitive varieties (Avital and Soissons) being relatively more advanced at this site compared to other locations.

The varietal range for GS 31, meaned across the five sites in 1995, was 26 March - 20 April (25 d) and across the three sites in 1996 12 - 29 April (17 d) (Tables 3.1 and 3.2). Generally in 1995, the variety ranking order was consistent across sites, with Avital, Soissons, Rialto, Mercia, Caxton, Buster and Hereward being amongst the earliest and Spark, Beaver, Haven and Raleigh amongst the latest to reach GS 31. In 1996, assessments were only carried out at three sites, but the same broad varietal differences were detected. Avital was on average 6 d earlier than any other variety in 1995 but only 1 d earlier than the next earliest variety in 1996, Soissons in each case. Presumably, Soissons's higher vernalization requirement compared to Avital (Worland, Pers. Comm.) and the generally cold autumn temperatures (and lack of vernalizing days) in 1995 checked Soissons relatively more than Avital in this season.

3.1.2. Date of GS 61

The varietal range for GS 61 averaged across sites was 3 - 19 June (16 d) in 1995 and 13 - 26 June (13 d) in 1996 (Tables 3.2 and 3.3). In calendar days, the range was narrower at GS 61 than it was at GS 31 in both seasons. This confirmed the general telescoping of developmental differences at sequential stages through the season widely reported for wheat elsewhere, e.g. Hay & Kirby (1991). In 1995, there was a broad consistency in varietal ranking order across sites with Avital, Soissons and Caxton amongst the earliest flowering varieties and Haven, Spark and Raleigh amongst the latest at all sites. In 1996, the same varietal differences were generally observed. Excluding, the two French-bred, photoperiod insensitive varieties (Avital and Soissons) the range for date of GS 61 was noticeably narrower in both seasons, 11 - 19 June (8 d) in 1995 and 16 - 26 June (10 d) in 1996. Within UK-bred varieties, Caxton was 2 and 3 d earlier than any other variety in 1995 and 1996, respectively.

In general, the varietal ranking order corresponded closely to that observed at GS 31, with few varieties speeding up or slowing down relative to others in the period between GS 31 and GS 61 (Table 3.3). Rialto, Buster and Encore, however, were exceptions, and were relatively earlier to GS 31 than they were to GS 61.

Table 3.2. Date of GS 61 at five NIAB RL sites in 1994-5 : Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RM	BT	Mean
Sow date.	29 Sep	27Oct	28 Sep	13 Oct	5 Oct	
Avital	07-Jun	12-Jun	01-Jun	30-May	28-May	03-Jun
Soissons	14-Jun	15-Jun	06-Jun	01-Jun	30-May	07-Jun
Caxton	21-Jun	17-Jun	12-Jun	06-Jun	02-Jun	11-Jun
Mercia	24-Jun	19-Jun	12-Jun	07-Jun	05-Jun	13-Jun
Prophet	24-Jun	17-Jun	14-Jun	07-Jun	05-Jun	13-Jun
Buster	27-Jun	19-Jun	12-Jun	07-Jun	09-Jun	14-Jun
Charger	22-Jun	19-Jun	14-Jun	08-Jun	09-Jun	14-Jun
Chianti	22-Jun	19-Jun	12-Jun	10-Jun	09-Jun	14-Jun
Cadenza	26-Jun	21-Jun	15-Jun	11-Jun	05-Jun	15-Jun
Genesis	26-Jun	19-Jun	15-Jun	10-Jun	07-Jun	15-Jun
Hereward	24-Jun	21-Jun	15-Jun	10-Jun	09-Jun	15-Jun
Rialto	19-Jun	19-Jun	17-Jun	11-Jun	12-Jun	15-Jun
Riband	26-Jun	19-Jun	16-Jun	11-Jun	07-Jun	15-Jun
Brigadier	27-Jun	21-Jun	15-Jun	10-Jun	09-Jun	16-Jun
Dynamo	27-Jun	19-Jun	15-Jun	12-Jun	09-Jun	16-Jun
Hussar	27-Jun	19-Jun	16-Jun	12-Jun	07-Jun	16-Jun
Magellan	27-Jun	19-Jun	16-Jun	11-Jun	09-Jun	16-Jun
M. Huntsman	27-Jun	19-Jun	16-Jun	13-Jun	07-Jun	16-Jun
Turpin	26-Jun	21-Jun	16-Jun	11-Jun	09-Jun	16-Jun
Beaufort	28-Jun	21-Jun	15-Jun	12-Jun	09-Jun	17-Jun
Flame	24-Jun	23-Jun	17-Jun	11-Jun	09-Jun	17-Jun
Reaper	27-Jun	21-Jun	16-Jun	12-Jun	12-Jun	17-Jun
Consort	27-Jun	21-Jun	18-Jun	14-Jun	12-Jun	18-Jun
Hunter	27-Jun	21-Jun	17-Jun	14-Jun	12-Jun	18-Jun
Beaver	27-Jun	23-Jun	18-Jun	14-Jun	16-Jun	19-Jun
Encore	28-Jun	23-Jun	16-Jun	14-Jun	14-Jun	19-Jun
Haven	26-Jun	23-Jun	19-Jun	14-Jun	14-Jun	19-Jun
Spark	28-Jun	22-Jun	19-Jun	16-Jun	14-Jun	19-Jun
Raleigh	28-Jun	23-Jun	18-Jun	16-Jun	16-Jun	20-Jun
Varietal range (d)	19	11	17	17	19	17
Mean	24-Jun	19-Jun	14-Jun	10-Jun	8-Jun	15-Jun

Table 3.3. Date of GS 31 and GS 61 in NIAB RL trials at Headley Hal (HH), Harper Adams (HA) and Bridgets (BT) 1996

	GS 31					GS 61			
	HH	HA	BT	Mean		HH	HA	BT	Mean
Sow date	9 Oct	2 Oct	11 Oct			9 Oct	2 Oct	11 Oct	
Avital	22-Apr	08-Apr	06-Apr	12-Apr	Avital	18-Jun	13-Jun	09-Jun	13-Jun
Soissons	23-Apr	08-Apr	09-Apr	13-Apr	Caxton	20-Jun	17-Jun	13-Jun	16-Jun
Rialto	20-Apr	21-Apr	15-Apr	18-Apr	Soissons	22-Jun	16-Jun	13-Jun	17-Jun
Abbot	25-Apr	22-Apr	15-Apr	20-Apr	Cadenza	23-Jun	19-Jun	16-Jun	19-Jun
Brigadier	25-Apr	22-Apr	18-Apr	21-Apr	Charger	22-Jun	19-Jun	16-Jun	19-Jun
Caxton	25-Apr	21-Apr	18-Apr	21-Apr	Mercia	22-Jun	19-Jun	21-Jun	19-Jun
Reaper	26-Apr	21-Apr	18-Apr	21-Apr	Riband	23-Jun	20-Jun	16-Jun	19-Jun
Beaufort	25-Apr	22-Apr	21-Apr	22-Apr	Abbot	24-Jun	21-Jun	16-Jun	20-Jun
Buster	03-May	22-Apr	15-Apr	23-Apr	M. Huntsman	24-Jun	21-Jun	17-Jun	20-Jun
Chianti	26-Apr	23-Apr	21-Apr	23-Apr	Rialto	24-Jun	20-Jun	16-Jun	20-Jun
Equinox	26-Apr	20-Apr	24-Apr	23-Apr	Beaufort	24-Jun	21-Jun	20-Jun	21-Jun
Encore	25-Apr	23-Apr	24-Apr	24-Apr	Dynamo	26-Jun	22-Jun	16-Jun	21-Jun
Hereward	01-May	21-Apr	21-Apr	24-Apr	Genesis	23-Jun	23-Jun	17-Jun	21-Jun
Hussar	24-Apr	22-Apr	28-Apr	24-Apr	Hereward	26-Jun	22-Jun	16-Jun	21-Jun
M. Huntsman	27-Apr	21-Apr	24-Apr	24-Apr	Hussar	24-Jun	21-Jun	20-Jun	21-Jun
Mercia	01-May	21-Apr	21-Apr	24-Apr	Brigadier	23-Jun	23-Jun	20-Jun	22-Jun
Cadenza	03-May	22-Apr	21-Apr	25-Apr	Chianti	25-Jun	21-Jun	20-Jun	22-Jun
Charger	23-Apr	22-Apr	30-Apr	25-Apr	Buster	26-Jun	20-Jun	24-Jun	23-Jun
Crofter	25-Apr	22-Apr	30-Apr	25-Apr	Harrier	24-Jun	22-Jun	23-Jun	23-Jun
Genesis	01-May	22-Apr	24-Apr	25-Apr	Madrigal	24-Jun	23-Jun	23-Jun	23-Jun
Hunter	23-Apr	22-Apr	30-Apr	25-Apr	Reaper	27-Jun	23-Jun	20-Jun	23-Jun
Magellan	29-Apr	22-Apr	24-Apr	25-Apr	Spark	25-Jun	23-Jun	23-Jun	23-Jun
Raleigh	25-Apr	22-Apr	30-Apr	25-Apr	Consort	27-Jun	23-Jun	23-Jun	24-Jun
Harrier	29-Apr	23-Apr	30-Apr	27-Apr	Crofter	29-Jun	23-Jun	21-Jun	24-Jun
Madrigal	29-Apr	24-Apr	30-Apr	27-Apr	Drake	27-Jun	25-Jun	21-Jun	24-Jun
Consort	01-May	23-Apr	30-Apr	28-Apr	Encore	27-Jun	23-Jun	21-Jun	24-Jun
Drake	03-May	23-Apr	30-Apr	28-Apr	Equinox	28-Jun	21-Jun	23-Jun	24-Jun
Dynamo	03-May	24-Apr	28-Apr	28-Apr	Hunter	28-Jun	23-Jun	23-Jun	24-Jun
Riband	03-May	24-Apr	28-Apr	28-Apr	Raleigh	29-Jun	24-Jun	23-Jun	25-Jun
Spark	03-May	25-Apr	30-Apr	29-Apr	Magellan	27-Jun	25-Jun	27-Jun	26-Jun
Varietal range (d)	13	17	24	17		9	12	18	13
Mean	27-Apr	21-Apr	23-Apr	23-Apr		24-Jun	21-Jun	19-Jun	21-Jun

3.2. Harvest assessments

Above-ground dry mass, harvest index, harvest N offtake and N harvest index were only measured in 1994-5.

3.2.1. Above-ground dry mass

Overall, across the five sites, there were significant differences amongst varieties for above-ground harvest dry mass, with values in the range 12.7 - 15.0 t/ha ($P< 0.001$) (Table 3.4). Thus, Rialto and Reaper showed a consistent pattern for greater dry mass growth compared to most other varieties, and the converse for the rapid developing varieties, Avital and Caxton, and the older variety M. Huntsman, with low dry mass.

For the thirteen common varieties in the Typing Trials (see Part 1, this Vol.) and NIAB assessments in 1994-5, corresponding varietal differences in the two data sets were broadly consistent. For all varieties tested, the respective varietal ranges were 13.9 - 15.7 t/ha in the Typing Trials and 12.7 - 15.0 t/ha in the NIAB Assessments. The linear regression of the varietal means in Typing Trials on those in NIAB RL trials for common varieties was significant ($P< 0.05$) (Fig. 3.1). Two varieties, Spark and Haven, showed evidence of differential relative rankings, but the general trend was for consistency between data sets. A part of the explanation for the deviation for Spark and Haven may have been due to different seed rate management in the two sets of experiments. In the Typing Trials, a standard number of seeds per m^2 (generally about 325 per m^2) was sown for all varieties to establish a target spring plant population of 275 plants per m^2. In the NIAB RL trials in 1994-5, a standard weight of seed per m^2 was sown for all varieties. Thus, Spark, with the lowest thousand grain weight on the current RL, was sown at a higher number of seeds per m^2 than other varieties and this may have contributed to its relatively greater harvest dry mass in the NIAB trials.

There were significant site differences for above-ground dry mass in NIAB trials in 1994-5 ($P< 0.01$), and the site/variety interaction was also significant ($P< 0.01$) (Table 3.4). Although the variety ranking order changed from site to site (for example, the relatively greater dry mass for Mercia compared to other varieties at Harper Adams), at the varietal extremes there were consistent effects observed across all sites. Thus, the greater dry mass for Reaper and Rialto and the smaller dry mass for Avital and Caxton compared to other genotypes were consistently expressed across all sites.

3.2.2. Harvest index

The expected varietal differences in harvest index were generally observed in the range 0.47 - 0.54 ($P< 0.001$) (Table 3.5). The tall, non-dwarf varieties, such as Spark (0.47), M. Huntsman (0.49) and Cadenza (0.49), all had lower harvest indices than the majority of the shorter semi-dwarf varieties, such as, for example, Riband (0.54), Buster (0.54), Raleigh (0.54) and Brigadier (0.53). Similarly, there was a trend for the lower yield potential bread wheat varieties, e.g. Mercia (0.49), Spark (0.47) and Hereward (0.49), to have lower indices than most higher yield potential, modern feed wheat varieties, e.g Riband (0.54), Consort (0.54) and Raleigh (0.54). In general, there was good agreement between varietal means for harvest index obtained in the Typing Trials (Part1, this Vol.) and the NIAB RL assessments 1994-5. There were significant differences amongst sites ($P< 0.001$) and the site/variety interaction was also significant ($P< 0.05$). Since thirty one varieties were examined it is, perhaps, not surprising that at least some of them changed their ranking significantly amongst sites. However, this should not detract from the main observation that for the majority of varieties there were distinct differences in harvest index which were consistently expressed across all test sites.

3.2.3. Nitrogen offtake

Overall, across the five sites, varietal differences were significant, with values in the range 149 - 171 kg/ha ($P< 0.001$) (Table 3.6). This compares with the overall range of 184 - 208 kg/ha in the Typing Trials (Part 1, this Vol.). As in the Typing Trials, there was a tendency for greater offtakes for i) more recently introduced varieties compared to older varieties and ii) more rapid developing compared to slower developing varieties; for example, lowest offtakes were observed for two of the more rapid developing genotypes Avital (149 kg/ha)) and Mercia (151 kg/ha) and one of the older varieties M. Huntsman (151 kg/ha). There were, however, exceptions to these trends, with low N offtakes being found for some modern varieties, e.g. Raleigh (155 kg/ha) and Prophet (154 kg/ha). For the thirteen varieties common to the Typing Trials and NIAB assessments 1994-5, the regression of variety means from Typing Trials on those from NIAB RL 1994-5 assessments was significant (P< 0.05). The correlation between the data sets was not, however, as strong as for harvest dry mass (Fig. 3.2). There was no trend with regard to bread and feed wheat categories apparent in the data, similar offtakes being observed for both categories.

The site effect (*P*< 0.001) and the variety/site interaction (*P*< 0.001) were both significant. The site mean at Harper Adams of 104 kg/ha was in the order of 50 kg/ha lower than at any other site. This may have been due to the lower available water capacity at this site (see Foulkes *et al.*, 1993) leading to greater water stress in this dry season at this site (Appendix Table 2). This could have restricted fertiliser N uptake during stem extension.

3.2.4. N harvest index

There were significant differences amongst varieties in the range 0.76 - 0.79 (*P*< 0.05) (Table 3.7). As in the Typing Trials, the range was relatively small and proportionately less than that for dry mass harvest index. The varietal ranking order was broadly the same as that observed in the Typing Trials for the thirteen common varieties, although Cadenza and Rialto appeared to have relatively higher indices in the Typing Trials and the converse for Soissons. There were no discernible trends in relation to age of variety or for the bread wheat category versus the feed wheats. There were differences amongst sites (*P*< 0.001) but the site/variety interaction was not significant, indicating consistency of varietal effects across environments. The extremes of the range amongst sites were represented by Headley Hall (0.87) and Rosemaund (0.75).

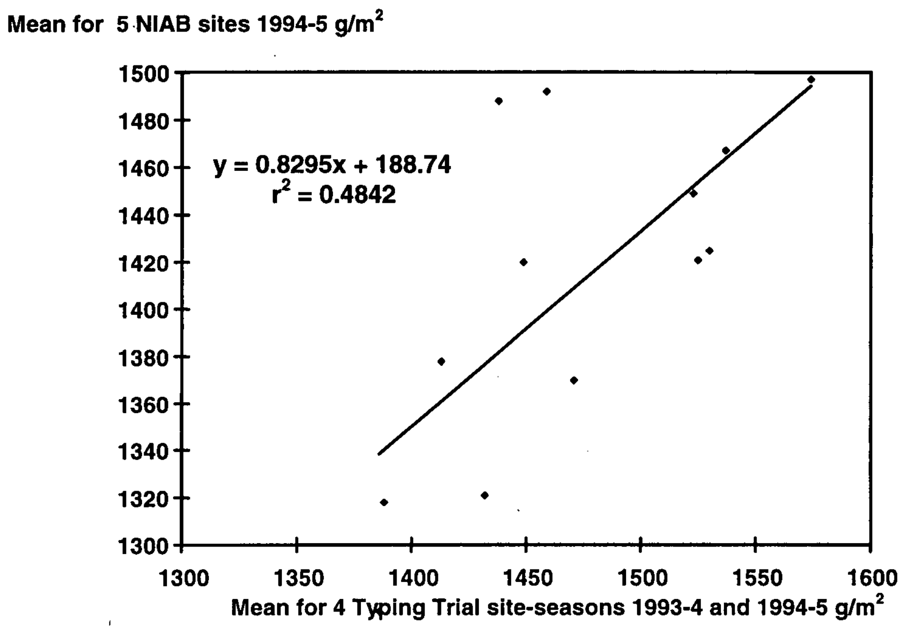

Fig. 3.1 Regression of variety mean for harvest dry mass at five NIAB sites in 1994-5 on variety mean for harvest dry mass at three Typing Trials site-seasons 1993-4 and 1994-5 for thirteen common varieties.

Table 3.4. Harvest above-ground dry mass (g/m² 100% DM) at five NIAB RL sites 1994-5 : Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RM	BT	Mean
Reaper	1699	1317	1004	1683	1799	1501
Rialto	1975	1303	1065	1421	1721	1497
Spark	1792	1351	1164	1367	1811	1496
Haven	1849	1318	1051	1493	1747	1492
Beaufort	1758	1273	1061	1606	1733	1486
Turpin	1779	1349	1088	1474	1715	1481
Hussar	1653	1249	1128	1536	1806	1474
Cadenza	1856	1378	1058	1424	1619	1467
Hunter	1759	1312	1107	1418	1651	1449
Encore	1739	1353	1024	1283	1769	1434
Brigadier	1674	1322	1035	1406	1687	1425
Beaver	1713	1166	1056	1507	1663	1421
Soissons	1724	1295	1037	1285	1757	1420
Charger	1813	1248	1103	1377	1544	1417
Chianti	1747	1241	1009	1346	1699	1408
Raleigh	1665	1207	1043	1344	1725	1397
Dynamo	1720	1281	1094	1424	1455	1395
Consort	1577	1301	1072	1349	1650	1390
Flame	1666	1269	1042	1398	1523	1380
Hereward	1644	1356	1119	1182	1591	1378
Mercia	1588	1277	1131	1354	1498	1370
Magellan	1656	1213	1011	1364	1592	1367
Buster	1681	1297	1023	1272	1517	1358
Genesis	1612	1256	994	1281	1566	1342
Prophet	1640	1262	967	1236	1593	1339
Riband	1537	1259	935	1252	1620	1321
Caxton	1768	1221	966	1258	1383	1319
Maris Huntsman	1589	1138	1014	1325	1523	1318
Avital	1496	1255	937	1305	1366	1272
Mean	1705	1278	1046	1378	1638	1407
SED (D.F. = 29)	86.5	50.63	87.70	127.10	48.13	30.83
Prob.	0.005	0.009	0.660	0.111	< 0.001	<0.001

SED Site 86.32 (DF 5; P=0.003); Site/variety 120.54 (DF 140; P=0.002).

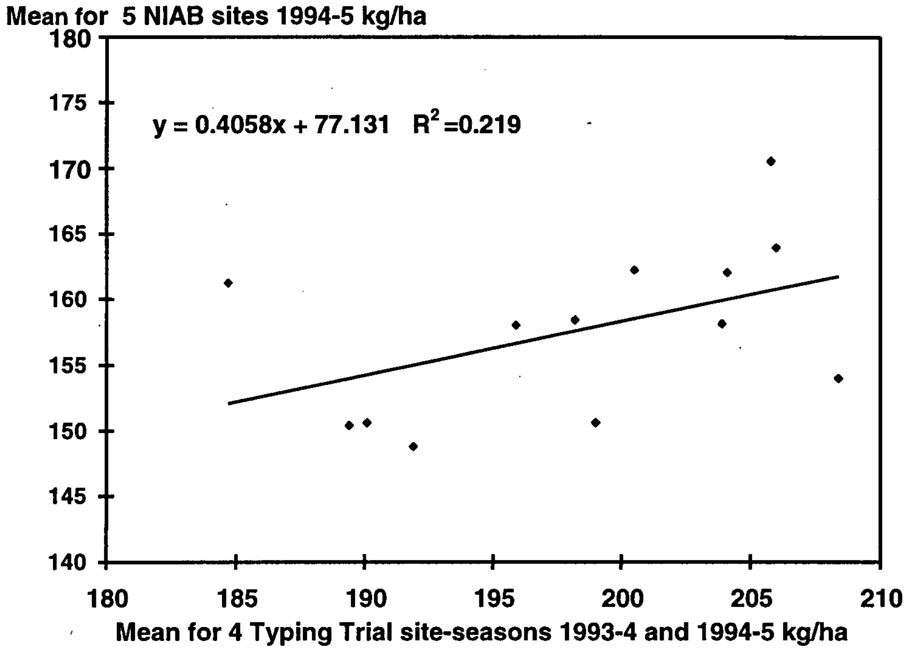

Fig. 3.2 Regression of variety mean for harvest N offtake for five NIAB sites in 1994-5 on variety mean for harvest N offtake in three Typing Trials site-seasons 1993-4 and 1994-5 for thirteen common varieties.

Table 3.5 Harvest index at five NIAB RL sites 1994-5 : Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RM	BT	Mean
Avital	0.51	0.55	0.59	0.42	0.49	0.51
Beaufort	0.54	0.58	0.51	0.40	0.53	0.51
Beaver	0.53	0.57	0.54	0.39	0.54	0.51
Brigadier	0.53	0.57	0.55	0.44	0.56	0.53
Buster	0.52	0.59	0.56	0.47	0.57	0.54
Cadenza	0.48	0.52	0.48	0.42	0.53	0.49
Caxton	0.51	0.58	0.56	0.49	0.55	0.54
Charger	0.53	0.60	0.56	0.47	0.57	0.54
Consort	0.52	0.58	0.59	0.42	0.57	0.54
Chianti	0.50	0.59	0.54	0.46	0.54	0.53
Dynamo	0.53	0.58	0.53	0.42	0.59	0.53
Encore	0.51	0.55	0.55	0.47	0.52	0.52
Genesis	0.51	0.58	0.52	0.46	0.54	0.52
Haven	0.53	0.57	0.55	0.42	0.56	0.53
Hereward	0.49	0.53	0.50	0.46	0.50	0.49
Hunter	0.51	0.57	0.53	0.44	0.54	0.52
Hussar	0.51	0.57	0.53	0.40	0.52	0.51
Flame	0.51	0.56	0.50	0.39	0.55	0.50
Magellan	0.51	0.57	0.57	0.43	0.55	0.53
M. huntsman	0.45	0.54	0.51	0.44	0.52	0.49
Mercia	0.49	0.54	0.52	0.41	0.51	0.49
Reaper	0.53	0.56	0.54	0.37	0.53	0.51
Raleigh	0.53	0.59	0.56	0.46	0.56	0.54
Prophet	0.51	0.57	0.55	0.47	0.51	0.52
Rialto	0.50	0.57	0.53	0.44	0.54	0.52
Riband	0.51	0.58	0.56	0.47	0.58	0.54
Soissons	0.50	0.56	0.52	0.43	0.44	0.49
Spark	0.49	0.52	0.46	0.39	0.50	0.47
Turpin	0.51	0.56	0.53	0.42	0.53	0.51
Mean	0.51	0.57	0.54	0.43	0.54	0.52
S.E.D.,D.F.=29	0.0131	0.0167	0.0293	0.0370	0.0142	0.01151
Prob.	<0.001	<0.001	0.029	0.229	< 0.01	<0.001

S.E.D. Site 0.0049 (DF= 5;P<0.001); Site/variety 0.02577(DF= 140; P= 0.012)

Table 3.6 Harvest crop N offtake (kg/ha) at five NIAB RL sites 1994-5 : Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RM	BT	Mean
Avital	179.3	157.1	103.4	145.7	158.3	148.8
Beaufort	216.8	153.4	108.1	162.0	176.9	163.4
Beaver	214.9	147.6	109.1	156.8	162.1	158.1
Brigadier	187.5	153.6	100.0	160.2	168.8	154.0
Buster	219.0	162.3	102.2	157.1	170.9	162.3
Cadenza	219.2	160.8	102.9	160.1	176.4	163.9
Caxton	217.2	154.1	95.7	152.4	161.5	156.2
Charger	230.0	151.8	106.9	157.7	170.3	163.3
Consort	200.2	150.8	115.1	151.3	167.6	157.0
Chianti	213.3	153.6	88.4	152.3	166.5	154.8
Dynamo	229.4	158.0	107.6	160.8	156.7	162.5
Encore	210.4	159.5	104.5	153.7	175.4	160.7
Genesis	199.7	151.1	103.2	156.6	164.5	155.0
Haven	226.6	158.2	101.6	153.6	171.0	162.2
Hereward	196.9	166.4	111.1	149.1	166.4	158.0
Hunter	218.2	159.7	107.8	160.8	163.5	162.0
Hussar	192.1	147.3	120.1	155.6	174.5	157.9
Flame	202.2	152.9	98.3	151.3	167.4	154.4
Magellan	191.6	146.9	101.3	151.6	171.6	152.6
M. Huntsman	185.2	144.2	103.3	154.4	164.7	150.4
Mercia	195.5	147.6	107.3	145.5	157.0	150.6
Reaper	211.5	155.6	102.9	164.9	175.0	162.0
Raleigh	202.0	143.8	104.6	158.7	165.2	154.9
Prophet	205.7	155.4	93.0	154.4	163.1	154.3
Rialto	242.5	158.9	103.3	160.3	187.7	170.5
Riband	187.0	149.2	98.4	152.1	166.5	150.6
Soissons	208.4	158.4	101.8	147.6	175.8	158.4
Spark	219.9	156.3	107.7	147.6	181.5	162.6
Turpin	206.1	162.2	102.1	157.1	169.9	159.5
Mean	207.9	154.4	103.9	154.9	169.0	157.9
S.E.D.,D.F. = 29	11.44	5.74	8.60	4.59	4.57	3.40

S.E.D. Site 8.89 (DF = 5, P< 0.001); Site/variety 11.61 (DF = 140, P< 0.001).

Table 3.7 Nitrogen harvest index at five NIAB RL 1994-5 : Cockle Park (CP), Headley Hall (HH), Harper Adams (HA), Rosemaund (RM) and Bridgets (BT).

	CP	HH	HA	RO	BT	Mean
Avital	0.83	0.87	0.87	0.70	0.78	0.81
Beaufort	0.84	0.86	0.78	0.68	0.79	0.79
Beaver	0.84	0.86	0.82	0.68	0.80	0.80
Brigadier	0.81	0.86	0.83	0.74	0.80	0.81
Buster	0.83	0.89	0.84	0.78	0.84	0.84
Cadenza	0.83	0.87	0.81	0.77	0.84	0.82
Caxton	0.84	0.87	0.84	0.81	0.82	0.84
Charger	0.83	0.89	0.83	0.80	0.82	0.83
Consort	0.81	0.86	0.87	0.74	0.82	0.82
Chianti	0.80	0.88	0.81	0.78	0.78	0.81
Dynamo	0.86	0.87	0.78	0.70	0.84	0.81
Encore	0.84	0.86	0.86	0.83	0.78	0.83
Genesis	0.84	0.87	0.80	0.77	0.81	0.82
Haven	0.84	0.86	0.82	0.71	0.83	0.81
Hereward	0.82	0.85	0.80	0.81	0.77	0.81
Hunter	0.83	0.87	0.80	0.77	0.79	0.81
Hussar	0.78	0.86	0.80	0.72	0.75	0.78
Flame	0.82	0.87	0.79	0.73	0.80	0.80
Magellan	0.80	0.86	0.85	0.75	0.78	0.81
Maris huntsman	0.76	0.87	0.82	0.79	0.83	0.81
Mercia	0.81	0.87	0.81	0.75	0.80	0.81
Reaper	0.82	0.86	0.81	0.67	0.79	0.79
Raleigh	0.83	0.87	0.82	0.77	0.80	0.82
Prophet	0.82	0.87	0.81	0.80	0.74	0.81
Rialto	0.84	0.89	0.81	0.77	0.83	0.83
Riband	0.81	0.87	0.84	0.76	0.84	0.82
Soissons	0.83	0.87	0.82	0.73	0.71	0.79
Spark	0.83	0.87	0.79	0.79	0.82	0.81
Turpin	0.82	0.85	0.80	0.71	0.79	0.79
Mean	0.82	0.87	0.82	0.75	0.80	0.81
S.E.D., D.F.=29	0.0104	0.0129	0.0384	0.0552	0.0199	0.0154
Prob.	< 0.001	0.494	0.661	0.296	< 0.001	0.012

S.E.D. Site 0.010 (DF = 5; P < 0.001); Site/variety 0.035 (DF = 140; P= 0.086)

3.3 Fertile shoot numbers at GS 31 and GS 61+75°Cd

Table 3.8 Fertile shoot numbers at GS 31 and GS 61+75°Cd in RL trials 1995-6 at Headly Hall (HH), Harper Adams (HA) and Bridgets (BT)

	GS 31					GS 61			
	HH	HA	BR	Mean		HH	HA	BR	Mean
Hereward	847	1129	888	955	Hunter	444	565	553	521
Cadenza	1203	965	707	959	Harrier	512	542	524	526
Caxton	696	1416	846	986	Genesis	489	547	571	536
Buster	1051	1111	867	1010	Flame	-	703	382	537
Avital	1279	1183	676	1046	Raleigh	486	581	603	557
Flame	-	1367	968	1102	Dynamo	498	655	582	579
Beaufort	907	1408	1026	1114	Buster	533	688	568	597
Chianti	778	1586	993	1119	Rialto	569	691	609	623
Mercia	1006	1427	986	1140	M. Huntsman	548	704	623	625
Genesis	976	1483	1048	1169	Mercia	523	719	635	626
Equinox	1144	1391	1015	1184	Hereward	609	684	607	634
Reaper	943	1459	1166	1190	Hussar	576	729	623	643
Abbot	1066	1331	1215	1204	Cadenza	563	716	680	653
Hunter	1142	1503	998	1214	Encore	551	748	662	654
Rialto	1022	1546	1074	1214	Madrigal	572	779	609	654
Charger	921	1593	1184	1233	Caxton	556	748	702	668
Soissons	1119	1433	1148	1234	Soissons	534	778	698	670
Brigadier	1057	1460	1187	1235	Crofter	511	833	674	673
Encore	953	1486	1304	1248	Avital	549	830	653	677
Madrigal	951	1631	1161	1248	Abbot	608	777	654	680
Magellan	1057	1458	1340	1285	Equinox	528	763	753	681
Consort	1163	1565	1145	1291	Brigadier	533	751	762	682
M. Huntsman	1113	1675	1096	1295	Consort	618	769	700	696
Harrier	1250	1507	1315	1357	Chianti	608	878	659	715
Riband	1287	1591	1213	1364	Reaper	625	807	712	715
Hussar	1160	2019	981	1387	Riband	553	955	729	746
Crofter	1411	1670	1164	1415	Charger	-	849	765	759
Dynamo	1433	1784	1097	1438	Magellan	671	841	769	760
Raleigh	1522	1541	1358	1474	Beaufort	613	951	791	785
Spark	1389	2181	1170	1580	Spark	553	1057	828	813
Drake	1426	1974	1406	1602	Drake	784	951	821	852
Mean	1109	1512	1088	1235		563	761	661	662
S.E.D. Var. D.F. = 102				71.0					30.7
Prob.				0.015					<0.001
S.E.D. Site D.F = 102				103.0					24.06
Prob.				<0.00					<0.01
SED Site/var. D.F. = 102				189.6					57.68
Prob.				<0.05					<0.001

Fertile shoot numbers were only measured in 1995-6.

Overall, there were significant varietal differences for shoot numbers at GS 31, with values in the range 955 - 1602 (P< 0.05) (Table 3.8). This compared with the overall range of 845 - 1266 per m^2 at GS 31 in the Typing Trials. For the eleven common varieties, the mean shoot number was 1046 per m^2 in the Typing Trials compared with 1203 per m^2 in the NIAB assessments. Although the site/variety interaction was significant (P< 0.05), there were consistent varietal differences for some varieties at the extremes of the range, e.g. the low shoot numbers for Hereward (955 per m^2), Cadenza (959 per m^2) and Buster (1010 per m^2) and the high shoot numbers for Raleigh (1474 per m^2), Spark (1580 per m^2) and Drake (1602 per m^2). As in the Typing Trials, there was a strong association between date of GS 31 and shoot number at this stage, earlier onset of stem extension correlating with fewer shoots, e.g. Avital and Caxton. The low shoot number for Cadenza, Avital and Hereward at GS 31 observed in Typing Trials was corroborated in the NIAB 1995-6 assessments. Similarly, the low-to-intermediate ranking for Mercia, the intermediate rankings for Rialto and Riband and the high ranking for Spark in Typing Trials were confirmed by NIAB assessments at GS 31. Hunter, however, had relatively fewer shoots in the Typing Trials than in the NIAB assessments.

At GS 61+75°Cd, the varietal range was 521 - 852 shoots per m^2 (P< 0.001). This compared with a range of 390 - 625 per m^2 in the Typing Trials. For the eleven common varieties, the overall mean was 496 per m^2 in Typing Trials and 661 per m^2 in NIAB assessments. The cooler than average spring temperatures in 1996 may have extended the period for rapid fertilizer uptake in 1996 in NIAB trials, which broadly occurs from GS 31 to GS 39 (Sylvester-Bradley, 1993), thus potentially increasing fertilizer N uptake and tiller survival to levels above the norm. At anthesis, high ear numbers for Spark and Brigadier, low numbers for M. Huntsman and intermediate numbers for Cadenza within the range were observed in both the Typing Trials and the NIAB data sets. At the extremes of the range, as at GS 31, there were effects for higher or lower numbers consistently expressed at all sites in the NIAB assessments. Thus, Spark and Drake were observed to have consistently more shoots than other varieties across the range of test environments. At the other end of the spectrum, Hunter and Genesis consistently had fewer shoots compared with most other genotypes examined across the range of test NIAB sites.

Large differences in tiller survival were evident for some varieties. Notable amongst these were Cadenza and Hereward which aborted only 306 and 321 shoots per m^2, respectively, compared to the average of 573 per m^2. In contrast, Drake (750 aborted shoots per m^2), Spark (767 aborted shoots per m^2) and Raleigh (917 aborted shoots per m^2) lost most shoots. The high tiller survival of Cadenza and the poor tiller survival of M. Huntsman was observed in both NIAB and Typing Trials data sets. The high tiller survival of Soissons, observed in the Typing Trials and the Moisture Availability and Rotational Position Sub-Projects (see Part 1, this Vol. & Vol. II, Parts 1 and 2) was not, however, detected in the NIAB assessments in 1995-6.

3.4. Soluble stem carbohydrate at GS 61+75°Cd

3.4.1. GS 61+75°Cd

The total stem dry mass per m^2, the percentage stem water soluble carbohydrate, and the stem water soluble carbohydrate dry mass per m^2 for varieties examined in NIAB trials 1995-6 are shown in Table 3.9. The overall range for stem soluble carbohydrate was 182 - 389 g/m^2 and varietal differences were significant (P< 0.05). For the eleven common varieties in the Typing Trials and the NIAB assessments, the overall means in the two data sets are regressed on each other in Figure 3.2. There was a good agreement in the varietal ranking orders between the two data sets with an R^2 of 0.43, and the overall range of about 200 - 400 g/m^2 was consistent in both data sets. Thus, the high amounts of stem reserves for Brigadier and Rialto, the low-to-intermediate amount for Riband and the low amounts for Spark, Mercia and M. Huntsman were found in both sets of experiments. Of the newer candidate varieties in NIAB RL trials, not included in the Typing Trials exercise, a number showed greater accumulation of reserves than any of the varieties in the Typing Trials, the highest ranking variety in that data set being Rialto. Thus, Drake (389 g/m^2), Encore (382 g/m^2) and Equinox (352 g/m^2) showed slightly greater accumulation of reserves than Rialto (349 g/m^2). Of the more recently introduced varieties, however, some showed a showed a consistent pattern for low accumulation of reserves across sites, e.g. Magellan (269 g/m^2) and Raleigh (280 g/m^2).

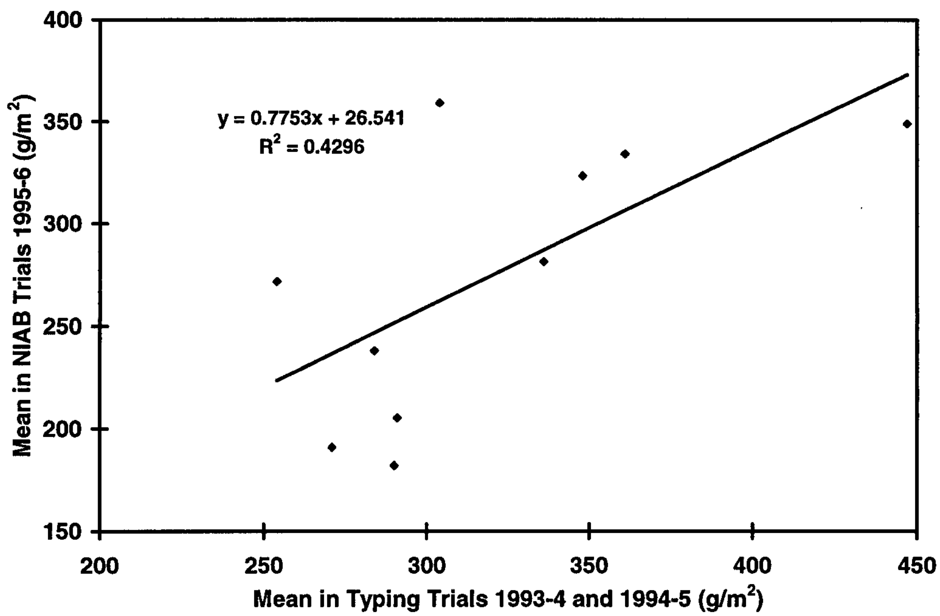

Fig. 3.3 Regression of variety mean for soluble stem carbohydrate (g/m^2) for 3 NIAB sites in 1995-6 on variety mean for soluble stem carbohydrate (g/m^2) in 3 Typing Trials site-seasons 1993-4 and 1994-5.

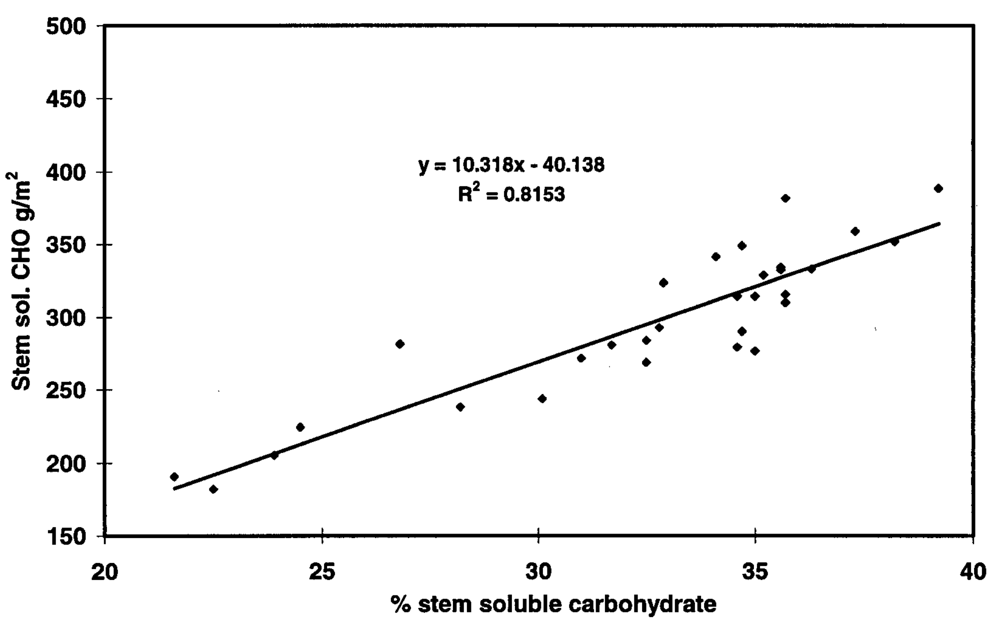

Fig. 3.4 Regression of variety mean for stem soluble carbohydrate (g/m^2) for three NIAB sites in 1995-6 on variety mean for % stem soluble carbohydrate in three NIAB sites in 1995-6 for 30 varieties.

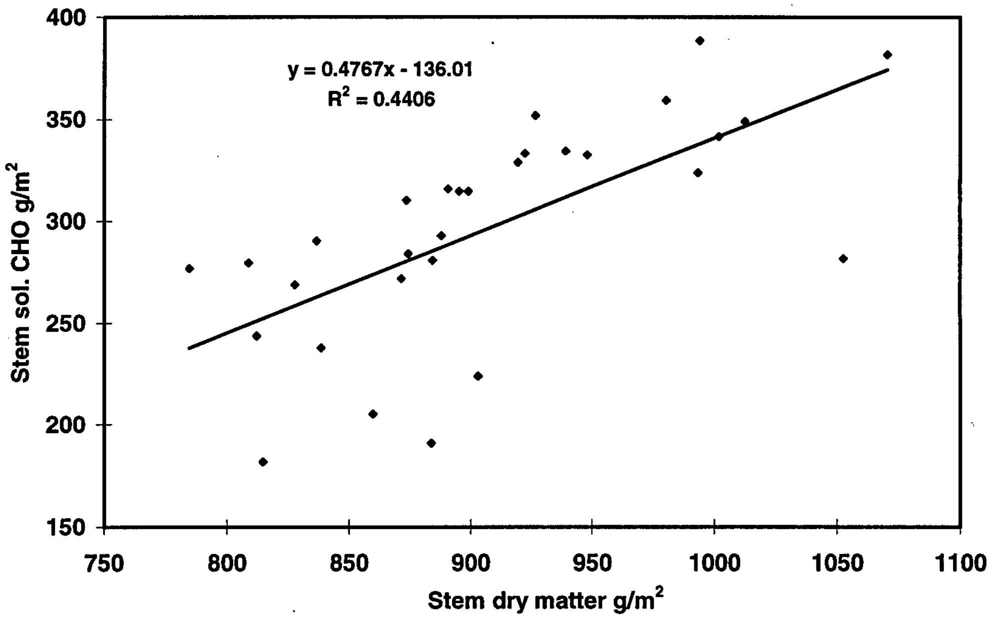

Fig. 3.5 Regression of variety mean for stem soluble carbohydrate (g/m^2) for 3 NIAB sites in 1995-6 on variety mean for stem dry matter (g/m^2) in 3 NIAB sites in 1995-6 for 30 varieties.

The regressions of i) percentage stem soluble carbohydrate and ii) stem dry matter (g/m^2) on stem soluble carbohydrate (g/m^2) are shown in Figs 3.4 and 3.5. Both regressions were significant. The R^2 of 0.82 for the percentage stem soluble carbohydrate regression compared with the R^2 of 0.44 for the stem dry matter regression indicated that the former influences overall variation in reserves more strongly. When assessing varieties for WSC dry matter in the reported range *c.* 200 - 400 g/m^2, it is apparent that satisfactory estimates can only be achieved with an assessment of both i) percentage stem soluble carbohydrate and ii) total stem dry mass. For those varieties at the extremes of the range, however, qualitative differences could be confidently detected by estimating only the percentage soluble stem carbohydrate. A knowledge of stem dry matter alone, on the other hand, appears not be sufficient to distinguish differences in WSC dry matter even at the extremes of the range.

Table 3.9 *Stem soluble carbohydrate (g/m²) at GS61+75°Cd in RL trials 1995-6 at Headly Hall (HH), Harper Adams (HA) and Bridgets (BT).*

	Soluble stem carbohydrate g/m²				Stem dry matter g/m²				% Stem soluble carbohydrate			
	HH	HA	BR	Mean	HH	HA	BR	Mean	HH	HA	BR	Mean
Drake	315.6	459.9	390.4	388.6	809.9	1223.3	948.8	994.0	39.0	37.6	41.1	39.2
Encore	415.1	391.6	338.4	381.7	1087.2	1156.0	968.3	1070.5	38.2	34.0	34.9	35.7
Hunter	371.9	351.3	354.5	359.2	886.5	1169.2	885.2	980.3	42.0	30.1	39.9	37.3
Equinox	361.3	366.3	328.1	351.9	863.5	1023.6	892.7	926.6	41.9	35.8	36.8	38.2
Rialto	336.6	400.9	309.5	349.0	878.0	1197.4	962.3	1012.5	38.3	33.5	32.2	34.7
Genesis	325.3	312.1	387.0	341.5	928.3	956.6	1120.8	1001.9	35.2	32.6	34.6	34.1
Brigadier	378.5	335.0	289.0	334.2	939.0	1020.6	857.6	939.1	40.4	32.6	33.7	35.6
Charger	358.2	296.7	344.2	333.0	842.0	912.7	1012.2	922.3	42.5	32.5	34.0	36.3
Abbot	336.6	288.9	371.8	332.4	785.9	943.2	1114.5	947.9	42.8	30.6	33.4	35.6
Beaufort	450.6	260.0	275.3	328.6	1084.1	850.8	823.7	919.5	41.5	30.7	33.5	35.2
Soissons	306.3	288.9	374.9	323.4	819.2	1050.9	1109.3	993.1	37.3	27.7	33.8	32.9
Madrigal	303.6	333.1	306.3	314.3	798.5	1021.8	876.6	899.0	36.2	32.6	35.1	34.6
Reaper	290.1	369.7	283.1	314.3	773.1	1089.9	822.9	895.3	36.8	33.9	34.3	35.0
Buster	289.1	301.0	356.5	315.5	785.0	987.1	899.9	890.7	37.0	30.5	39.6	35.7
Harrier	244.8	317.3	368.3	310.1	660.3	953.5	1007.0	873.6	37.2	33.3	36.5	35.7
Crofter	302.9	229.2	346.7	292.9	898.3	821.0	944.4	887.9	33.5	28.0	36.8	32.8
Dynamo	270.5	312.2	288.5	290.4	786.8	893.8	829.4	836.7	34.4	34.9	34.9	34.7
Consort	236.3	298.3	317.5	284.1	752.7	969.2	901.4	874.4	31.5	30.8	35.3	32.5
Cadenza	286.0	281.3	277.6	281.6	1017.0	1130.6	1010.2	1052.6	28.1	25.0	27.5	26.8
Caxton	322.4	327.0	181.0	276.8	821.7	960.6	572.0	784.7	39.2	34.1	31.8	35.0
Hereward	214.2	266.0	335.6	271.9	729.2	938.4	946.7	871.4	29.2	28.3	35.5	31.0
Chianti	253.4	224.9	253.5	243.9	786.1	858.9	791.4	812.1	32.2	26.2	31.8	30.1
Hussar	288.5	282.5	271.6	280.9	847.3	914.0	891.5	884.3	34.1	30.8	30.4	31.7
Raleigh	230.5	311.0	297.2	279.6	684.3	921.8	820.5	808.8	33.7	33.7	36.4	34.6
Magellan	299.2	207.2	300.3	268.9	803.9	819.1	860.3	827.8	37.3	25.4	34.9	32.5
Riband	224.2	197.9	292.0	238.0	790.9	780.7	944.2	838.6	28.4	25.2	30.9	28.2
Avital	266.3	182.2	224.0	224.2	897.2	866.6	945.5	903.1	28.8	21.1	23.7	24.5
M. Huntsman	223.5	170.1	221.8	205.1	826.2	759.3	994.2	859.9	27.1	22.4	22.3	23.9
Spark	173.4	197.9	201.2	190.9	804.5	939.0	908.2	883.9	21.7	21.1	22.1	21.6
Mercia	200.6	162.5	183.2	182.1	754.7	875.7	813.6	814.7	26.5	18.6	22.5	22.5
S.E.D. Var. (D.F. = 102)				24.87				61.40				1.207
Prob.				<0.001				<0.01				<0.001
S.E.D. Site (D.F. = 102)				9.11				15.45				0.471
Prob.				0.600				<0.001				<0.01
S.E.D. Site/Var. (D.F. = 102)				43.42				105.95				2.114
				<0.001				<0.01				<0.001

3.4.2 Harvest

Table 3.10 *Stem soluble carbohydrate (g/m^2) at harvest in RL trials 1995-6 at Headly Hall (HH), Harper Adams (HA) and Bridgets (BT).*

	HH	HA	BT	Mean
Drake	7.7	8.6	11.2	9.2
Encore	7.0	9.2	18.7	11.6
Hunter	5.3	10.0	13.7	9.7
Equinox	7.6	5.4	17.9	10.3
Rialto	8.7	9.7	16.7	11.7
Genesis	8.7	4.6	12.7	8.7
Brigadier	5.3	9.4	12.2	9.0
Charger	6.8	9.3	18.2	11.4
Abbot	6.5	5.3	16.9	9.6
Beaufort	7.7	9.7	18.7	12.0
Soissons	8.7	9.1	26.8	14.9
Madrigal	8.3	9.0	12.7	10.0
Reaper	5.7	9.4	12.7	9.3
Buster	6.7	6.3	19.6	10.9
Harrier	4.2	9.4	12.0	8.5
Crofter	11.5	6.7	21.4	13.2
Dynamo	4.7	8.6	9.6	7.6
Consort	9.0	6.8	12.2	9.3
Cadenza	10.4	8.2	13.0	10.5
Caxton	6.3	7.4	8.4	7.4
Hereward	6.5	6.2	16.7	9.8
Chianti	6.3	10.3	15.7	10.8
Hussar	7.5	5.2	19.7	10.8
Raleigh	7.5	7.9	13.5	9.6
Magellan	4.6	6.6	12.7	8.0
Riband	7.7	6.1	12.7	8.8
Avital	6.9	6.6	14.6	9.4
M. Huntsman	9.0	10.2	8.3	9.2
Spark	5.5	11.3	12.6	9.8
Mercia	6.0	8.9	9.8	8.2
	7.1	8.0	14.7	9.9

Table 3.11 Fungicide-treated grain yield (t/ha 85% DM) for RL sites where additional characters were assessed in 1994-5 and 1995-6 and overall mean across all RL sites in 1994-5 and 1995-6.

	1994-5							1995-6			
	Mean all RL sites	CP	HH	HA	RM	BT		Mean all RL sites	HH	RM	HA
Charger	9.67	11.35	8.71	9.59	7.74	10.37	Beaufort	10.48	10.93	11.14	11.86
Brigadier	9.64	10.50	8.74	9.56	7.57	11.11	Equinox	10.45	10.68	10.56	11.35
Reaper	9.64	10.64	8.65	9.43	7.30	11.19	Charger	10.34	10.77	10.06	10.94
Haven	9.63	11.56	8.76	9.47	7.48	11.44	Hunter	10.30	10.77	10.11	10.70
Turpin	9.57	10.91	8.72	8.98	7.43	10.81	Rialto	10.30	10.54	10.69	11.54
Consort	9.55	10.18	8.73	9.53	6.77	11.17	Harrier	10.27	10.89	9.77	11.05
Hussar	9.54	10.47	8.51	9.63	7.44	11.04	Reaper	10.25	10.48	9.91	11.65
Chianti	9.52	10.23	8.50	9.20	7.55	10.83	Raleigh	10.23	10.86	10.00	10.67
Rialto	9.49	11.65	8.58	9.36	7.65	10.93	Brigadier	10.24	11.26	9.07	11.45
Beaufort	9.48	11.46	8.40	9.45	7.48	10.96	Drake	10.22	11.16	10.19	11.03
Raleigh	9.48	10.81	8.13	9.56	7.52	11.30	Madrigal	10.22	11.01	9.72	11.12
Riband	9.32	9.86	8.41	8.71	6.90	11.10	Crofter	10.20	11.05	10.27	10.57
Dynamo	9.27	11.06	8.59	9.15	6.98	7.02	Encore	10.18	10.19	9.95	10.95
Buster	9.29	10.77	8.88	8.70	7.19	10.19	Dynamo	10.14	10.86	10.23	11.48
Encore	9.28	10.81	8.68	9.38	7.30	10.91	Chianti	10.10	11.07	9.66	10.81
Hunter	9.25	10.60	8.66	9.28	7.49	10.37	Consort	10.10	10.86	9.58	10.73
Beaver	9.20	10.89	7.73	9.34	7.00	10.55	Hussar	10.10	10.82	8.98	11.08
Magellan	9.14	10.22	8.09	9.10	7.01	10.28	Riband	10.08	10.67	9.53	10.62
Flame	8.88	10.37	8.33	8.70	6.64	9.88	Buster	10.04	10.86	9.94	11.55
Genesis	8.86	10.32	8.26	8.56	7.03	9.90	Abbot	9.98	10.46	10.72	10.90
Caxton	8.84	10.67	8.22	8.13	7.34	8.90	Caxton	9.84	10.06	10.25	11.15
Prophet	8.75	9.77	8.32	7.89	6.97	9.63	Magellan	9.77	10.56	9.72	10.70
Soissons	8.63	10.30	8.40	8.12	7.05	8.92	Flame	9.77	-	9.84	10.75
Spark	8.58	9.61	7.97	8.08	6.22	10.51	Soissons	9.64	10.62	10.32	10.94
Cadenza	8.57	10.66	8.27	7.45	6.99	10.08	Cadenza	9.50	9.67	9.89	9.91
Hereward	8.54	9.66	8.21	8.49	6.67	9.37	Genesis	9.48	9.64	8.89	9.89
Mercia	8.50	9.23	7.89	8.12	6.65	9.04	Hereward	9.34	9.88	9.96	10.46
							Spark	9.33	9.73	9.53	10.02
							Mercia	9.10	9.83	8.91	10.01
L.S.D. (Pairwise)	0.402	0.606	0.294	0.441	0.320	0.292		0.307	0.601	0.994	0.549

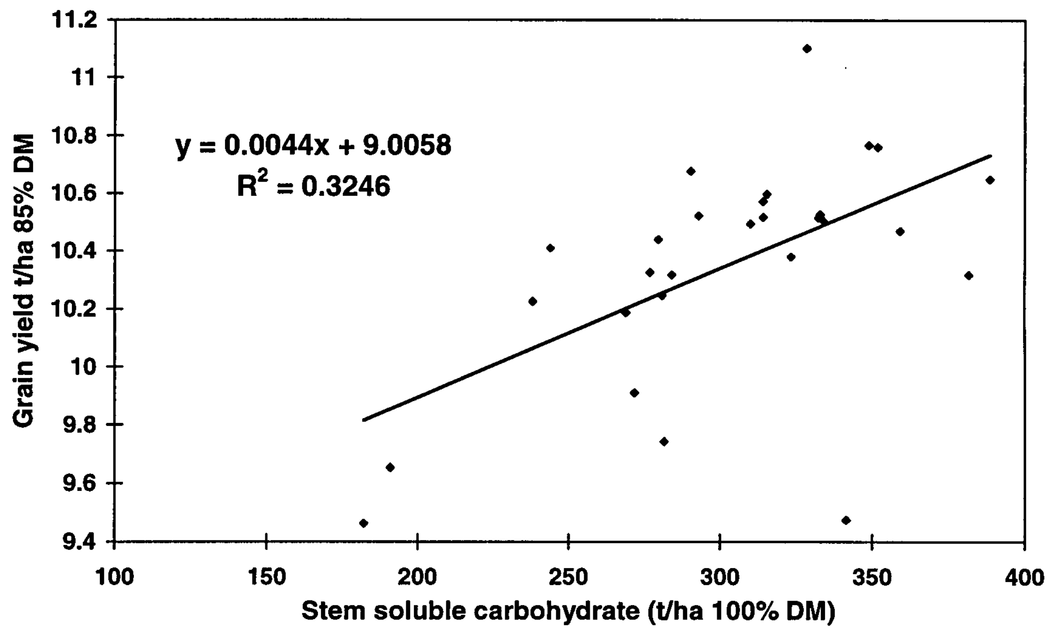

Fig. 3.6 Regression of grain yield at harvest on stem reserves at GS61+75°Cd

4. DISCUSSION

4.1 Date of GS 31 and GS 61

The varietal range for date of GS 31 was 25 d (1995) and 17 d (1996), and for GS 61 17 d (1995) and 13 d (1996). Excluding the continental-bred varieties, Avital and Soissons, the range at GS 31 was 15 and 11 d and at GS 61 9 and 10 d in 1995 and 1996, respectively. These ranges were consistent with the previous literature, e.g. Kirby (1994), and those in the Typing Trials (Part 1, this Vol.). For common varieties, the individual variety differences in NIAB RL trials were generally consistent with those in Typing Trials. The earliness of Soissons and Avital is principally due to their high photoperiod insensitivity (Worland *et al.*, 1994) and the lateness of Spark to its low photoperiod insensitivity (Worland, personal communication). As in the Typing Trials, Rialto showed a distinctive developmental pattern, being amongst the earliest to GS 31 but mid-range at GS 61. Buster also showed this developmental pattern. One of the initial hypotheses proposed in the Moisture Availability and Rotational Position Sub-Projects (Vol. II, Parts 1 and 2) was for early flowering to confer late-season stress escape. The range currently reported for GS 61 of *c.* 10 d for UK-bred varieties (increasing to *c.* 14 d including continental wheats) indicates a potential variation in water uptake up to GS61 of about 25 mm. The consequences of this variation in water use up to GS 61 for drought resistance are discussed more fully in the Moisture Availability Sub-Project (Vol. II, Part 1, Section 4).

The feasibility of assessing date of GS 31 and GS 61 in NIAB RL trials was proved in the current assessments. For GS 31, about ten observation dates (1.5 h operator's time per observation date) were required approximately every 2/3 days starting in early March. For GS 61, about seven observation dates every 2 days were required starting in late May, each observation requiring about 1 h of one operator's time.

4.2 Fertile shoot numbers

The NIAB assessments in 1995-6 generally corroborated tillering patterns observed in Typing Trials and Moisture Availability and Rotational Position Sub-Projects. Within the overall range of 955 - 1602 shoots per m^2 at GS 31, Spark had high and Cadenza, Avital and Hereward low shoot numbers consistent with findings in the Typing Trials. At flowering, high rankings for Spark and Brigadier and low rankings for M. Huntsman again corroborated findings in the Typing Trials. The variety range for economy of tillering (difference between shoot numbers at GS 31 and anthesis) was from 306 per m^2 (Cadenza) to 917 per m^2 (Raleigh). This compared with a range of 393 - 789 per m^2 for aborted shoots in the Typing Trials. The efficient tillering of Cadenza, Hereward, and Avital, the inefficient tillering of Spark and M. Huntsman and the intermediate efficiency of tillering for Mercia was observed in both data sets. Of the newer varieties, Caxton (318 per m^2), Buster (413 per m^2) and Chianti (404 per m^2) had particularly high economy of tillering and the converse for Raleigh (917 per m^2) and Harrier (831 per m^2). In general, for varieties common to both data sets, NIAB assessments re-enforced patterns of tiller production and survival detected in the individual Sub-Project experiments and Typing Trials. The original hypothesis proposed in the Rotational Position Sub-Project (Vol. II, Part 2) was that varieties which aborted fewer shoots perform relatively better with take-all, in that resources wasted in destined-to-die tillers would be minimised. The implications of these different tillering patterns for performance in second wheat environments and under drought are discussed more fully in the separate discussions in the Moisture Availability and Rotational Position Sub-Projects (see discussion sections, Vol. II).

The feasibility of assessing fertile shoot numbers at GS 31 and GS 61+75°Cd in RL trials was demonstrated. Sampling according to growth stage spreads the workload over two to three weeks. There is no requirement for oven facilities. The additional labour input per site required to measure shoot numbers at GS 31 and GS 61 (over and above the labour input to record the date of the growth stages themselves) was in the order of 30 person-hours per site.

4.3 Stem reserves

The varietal range for stem reserves at the end of flowering of *c.* 200 - 400 g/m^2 corroborated findings in Sub-Project experiments (Vol. II) and Typing Trials (Part 1, this Vol.). In this sense, the initial hypothesis as stated in the Moisture Availability and Rotational Position Sub-Projects was further confirmed, in that varietal differences were large enough to confer meaningful differences in tolerance of late-season stress. As in the Typing Trials, there was a trend for the high yield potential modern varieties to have greater stem reserves; the regression of grain yield on stem reserves at GS61+75°Cd for the thirty varieties was significant ($P < 0.05$) (Fig. 3.6). This suggested stem reserves may have a role in maximizing yield in optimal seasons in addition to buffering yield under stress. The influence of stem reserves in conferring stress tolerance is discussed in greater detail in the Moisture Availability and Rotational Position Sub-Projects (see discussion sections, Vol. II). Although the site/variety interaction was significant, there were consistently expressed differences between broad groups of varieties, suggesting the number of sites required to quantify varietal rankings with confidence is considerably less than the *c.* 20 current RL sites. From the significant regressions of i) stem dry mass and ii) % soluble stem carbohydrate on total stem soluble carbohydrate dry mass (Figs 3.4 and 3.5), it is clear that it is necessary to estimate both i) stem dry mass and ii) % soluble stem carbohydrate, and that neither one on its own is sufficient as a surrogate for quantitative estimates of stem soluble carbohydrate dry mass.

The feasibility of measuring stem reserves in RL trials has been demonstrated by the current work. It is important that assessments are taken at an exact thermal increment after GS 61, as the timing of occurrence of the maximum amount is closely correlated with development. This necessitates assessment of date of GS 61 and a daily calculation of thermal increments for respective varieties using maximum and minimum air temperature. A spreadsheet for this purpose was designed and used successfully at the three NIAB RL sites in 1996. The labour input per site to assess thirty varieties (over and above that necessary to record dates of GS 61 and shoot number per m^2 at GS 61, pre-requisites in the calculation) was *c.* 25 person-hours per site. The cost of the chemical analysis was an additional *c.* £12 per sample for the 60 samples per site.

From stem soluble carbohydrate assessments at harvest, in which amounts of reserves remaining were consistently negligible for all varieties at all sites, it can be concluded that assessment of the maximal amount shortly after flowering is sufficient to define potential varietal differences in yield contribution from stem reserves with confidence.

4.4 Harvest above-ground dry mass

The varietal range in harvest dry mass of 1270 - 1500 g/m^2 was significant; as in the Typing Trials there was a tendency for the more recent varieties to have greater dry mass compared to their predecessors and for rapid developing varieties to have smaller dry mass compared to slower developing varieties. It is possible that varieties with greater above-ground dry mass also have greater below-ground dry mass and a resultant greater capacity for water uptake. If so, this could imply that they might perform relatively better in environments where water availability is restricted. However, present NIAB results could not confirm this. In the drought work (Vol. II, Part 1) there was, however, some evidence that varieties with greater biomass showed drought resistance compared to other genotypes.

The feasibility of measuring above-ground harvest dry mass in RL trials was demonstrated. Other than sampling *c.* 100 ear-bearing shoots at harvest per plot, the work can be phased over several weeks subsequent to harvest as samples are of sufficiently low moisture content that they can be stored in dry conditions without deteriorating. The availability of large draught ovens, however, is a requirement for this assessment. The labour required for estimation of harvest dry mass was *c.* 25 person-hours per site.

4.5 N offtake

Within the overall range 149 - 171 kg/ha ($P < 0.001$), there was a tendency for greater offtakes for i) more recently introduced varieties compared to older varieties and ii) varieties with a shorter compared to a longer life cycle. In terms of indicating suitabilities to environment, there was no clear evidence for a relationship between varietal harvest N offtake and relative performance with low or high overwinter soil N availability in the Soil N Availability Sub-Project (Vol. III). Neither was there a clear distinction between bread and feed wheats in their N offtakes. It may be that this characteristic is indicative of a greater requirement for fertilizer N. Recent findings have shown greater N offtakes for more modern varieties compared to their predecessors in varieties introduced during the past two decades, with an increase in N offtake of *c.* 2.1

kg/ha per year (Foulkes *et al.*, 1998). This was associated with an increase in the optimum fertilizer amount of *c.* 2.8 kg/ha per year. In the current exercise, differences were found for harvest N offtake amongst modern cultivars in NIAB trials 1994-5 of *c.* 20 kg/ha, e.g. Rialto (171 kg/ha) compared to Riband (151 kg/ha) and Reaper (151 kg/ha). These differences may reflect different optima. However, further work would be needed to confirm this possibility.

The labour requirement for assessing harvest N offtake is essentially the same as that for harvest dry mass. There is, however, an additional cost of c. £5 per plot for chemical analysis.

4.6 Conclusions

- The varietal range for date of GS 31 was 25 d (1995) and 17 d (1996), and for GS 61 17 d (1995) and 13 d (1996). For common varieties in Typing Trials and NIAB assessments, the individual variety differences reported were broadly consistent. The feasibility of assessing date of GS 31 and GS 61 in NIAB RL trials was demonstrated. For GS 31, this entails a total of *c.* 10 h of one operator's time and for GS 61 c. 7 h.

- The NIAB assessments in 1995-6 generally corroborated tillering patterns observed in Typing Trials (Part 1, this Vol.) and the Moisture Availability (Vol. II, Part 1) and Rotational Position (Vol II, Part 2) Sub-Projects within the overall ranges of 955 - 1602 per m^2 at GS 31 and 521 - 852 shoots per m^2 at GS 61+75°Cd. The feasibility of assessing fertile shoot numbers at GS 31 and GS 61+75°Cd in RL trials was demonstrated. The labour input required at both GS 31 and GS 61 was *c.* 20 person-hours per site.

- The varietal range for stem reserves of *c.* 200 - 400 g/m^2 corroborated findings in Sub-Project experiments and Typing Trials. As in the Typing Trials, there was a tendency for higher yielding modern varieties to have greater stem reserves. From the significant regressions of i) stem dry mass and ii) percentage soluble stem carbohydrate on stem soluble carbohydrate dry mass (Figs 3.4 and 3.5), it is clear that to discriminate for stem soluble carbohydrate amongst varieties with confidence it is necessary to estimate both i) and ii). The feasibility of measuring stem reserves in RL trials has been demonstrated. The labour input to assess thirty varieties (including date of GS 61 and shoot number assessments) was *c.* 80 person-hours per site.

- The range in harvest dry mass of 1270 - 1500 g/m^2 was statistically significant. As in the Typing Trials, there was a tendency for the more recent varieties to have greater dry mass compared to their predecessors and for rapid developing varieties to have greater dry mass compared to slower developing varieties. The feasibility of measuring above-ground harvest dry mass in RL trials was demonstrated. The labour required was *c.* 25 person-hours per site.

- Within the overall range 149 - 171 kg/ha ($P < 0.001$), there was a tendency for greater N offtakes for i) more recently introduced varieties compared to older varieties and ii) varieties with a shorter compared to a longer life cycle. This trait could be indicative of a greater overall requirement for fertilizer N. The labour requirement for assessing harvest N offtake is essentially the same as that for harvest dry mass.

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