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FLAG LEAF AREA IN FIVE SPRING WHEAT CROSSES AND THE RELATIONSHIP TO GRAIN YIELD[1]

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SUMMARY

Five spring wheat crosses were evaluated over a 6-year period using comparisons between F_2 and F_3 data and between near-isogenic F_4 populations selected for flag leaf area. Nonsignificant r values for F_2 vs. F_3 flag leaf measurements may be due to the effect of environment on flag leaf area, but are probably also an indication of low heritability for this plant character. Near-isogenic populations selected on the basis of flag leaf area showed little difference in grain yield, an indication that other plant parts must be more influential in determining grain yield. Flag leaf area, by itself, appears not to be a good index to plant performance.

INTRODUCTION

The flag leaf of wheat, *Triticum aestivum* L., is an easily recognized plant characteristic. Appearance of the flag leaf identifies the 'boot stage' to wheat producers, a stage of plant development immediately preceding head emergence. Emergence of the head represents the end of the plant's vegetative phase and the beginning of its flowering phase.

According to THORNE (1966), very little stored sugar is lost from stems and roots after head emergence, suggesting little or no translocation of sugar to form carbohydrates in developing seed. If this is so, grain yield must be largely determined by post-heading photosynthesis in the flag leaf and in the head, as found by WATSON et al. (1958) in their work with three barley cultivars. Shading experiments by QUINLAN & SAGAR (1965) with two wheat cultivars have also demonstrated the importance of the head and flag leaf and its sheath, and the unimportance of lower plant parts, in providing assimilates for grain formation. THORNE (1959) has observed that photosynthesis in a barley leaf sheath is about 50% of that of the lamina of the same leaf. She has further observed that photosynthesis of any particular leaf and leaf sheath is

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about 70% of that of the one immediately above on the same stem. Watson (1952) concluded that leaf area is the major determinant of crop yield, but suggested that more information is needed on how to control leaf production and leaf size.

If THORNE's and WATSON's et al. (1958) assessment is correct, that grain yield is mainly determined by photosynthesis in the flag leaf and head, after head emergence, then the flag leaf must play an important role in this growth process. In experiments from 1970 to 1975 we have evaluated the relationship between flag leaf area and grain yield.

MATERIALS AND METHODS

Experiment I. In the summer of 1970, we made two crosses for a flag leaf study: PI 225408 (ex Uruguay, small flag leaf) with ND 464 (North Dakota, large flag leaf), and PI 290752 (Yaqui 53, large) with PI 178692 (Erzurum Exptl. Station no. 182–3, small). Crossed seeds were planted in the greenhouse during the winter of 1970–71 to provide F_2 seeds. These F_2 seeds were space-planted in the field at Bozeman in 1971, with parents interspersed, and the flag leaf from the main tiller of each plant was measured using the Hayshi Denko leaf area planimeter.[2] The means and their standard errors were used in interpreting the data from each cross.

Each F_2 plant was harvested separately and its seed was planted in 1.5 m F_3 progeny rows at Bozeman in 1972. Flag leaf area measurements were obtained for each F_3 row by totaling the readings from ten randomly selected flag leaves. Correlation coefficients were calculated between these F_3 flag leaf measurements and the measurements from F_2 plants.

Seed composites were made from F_3 progeny rows with low flag leaf values and from rows with high flag leaf values, for each cross. Ten grams of seed from each of the 25 highest and 25 lowest flag leaf values were composited in PI 255408/ND 464, and 20 g of seed from each of the 15 highest and 15 lowest were composited in PI 290752/PI 178692. These four composites, with the four parents and a 'Norana' check, were then planted in a randomized block design, using six replications of 4-row plots, at Bozeman in 1973; rows were 3 m long and spaced 30 cm apart. These composites were considered as near-isogenic populations, as suggested by MCNEAL et al. (1971).

Data obtained in 1973 included days from January 1 to heading, plant height, flag leaf area from 50 leaves in the border rows of each plot, test weight, and grain yield from 4.9 m of each plot area. Analysis of variance was used in data evaluation.

Experiment II. PI 178692 (small flag leaf) was crossed to large flag leaf cultivars MT 7154 (Montana), 'Iassul' (Brazil), and 'Ariana 66' (Tunisia) at Bozeman in the summer of 1972. Crossed seed was planted in the greenhouse during the winter of 1972–73 to provide F_2 seed for field-planting in 1973.

The F_2 seed was space-planted at Bozeman in the summer of 1973, without including parents, and the flag leaf area from the main tiller of each F_2 plant was

[2] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

measured using the planimeter. Each F_2 plant was harvested separately and the seed was used to plant F_3 progeny rows, with parental rows interspersed, at Bozeman in 1974. Ten randomly chosen flag leaves were measured from each parental and F_3 progeny row, and correlation coefficients were calculated between F_2 and F_3 data.

Fifty grams of seed from each of the 20 highest and 20 lowest F_3 progeny row flag leaf areas were composited for each of the three crosses. These six near-isogenic population composites, with the four parents and a Norana check, were planted in a randomized block design with four replications of multiple-row plots at Bozeman, Kalispell, Moccasin, Havre, and Huntley, Montana in 1975. Data obtained included days from January 1 to heading, plant height, flag leaf area from 50 leaves in the border rows of each plot at Bozeman, test weight, and grain yield from 4.9 m of each plot area. Analysis of variance was used in data evaluation.

RESULTS AND DISCUSSION

Experiment I. F_2 means of both crosses grown in 1971 were intermediate between the two parents, suggesting additive gene action (Table 1). The F_2 of PI 290752/PI 178692 was near the mid-parent, but the F_2 of PI 225408/ND 464 was close to the low parent, indicating dominance for small leaf.

Correlation coefficients between 1971 F_2 flag leaf data and 1972 F_3 progeny row data were at nonsignificant levels of 0.15 for PI 290752/PI 178692 and 0.04 for PI 225408/ND 464. These small r values suggest very low heritability for the flag leaf characteristic.

Both high flag leaf area composites yielded more than the low compositics in a 1973 nursery, but only in the case of PI 290752/PI 178692 (cross 7069) was the difference significant (Table 2). Differences between the high and low composites in heading, plant height and test weight were so small as to be of little consequence in a breeding program. Flag leaf areas were significantly different among populations, suggesting that plant breeders should be able to alter this plant characteristic even though heritability is low.

Table 1. Number of plants examined and average flag leaf area from two crosses grown at Bozeman, Montana, 1971.

Cross and population	Number of plants	Leaf area (cm^2)	
		range	average
PI 225408/ND 464			
♀	100	14.0–33.0	21.86 ± 0.44
F_2	580	5.0–53.0	23.56 ± 0.35
♂	100	19.5–56.0	37.48 ± 0.87
PI 290752/PI 178692			
♀	100	5.0–39.5	18.37 ± 0.84
F_2	268	5.5–31.0	15.53 ± 0.29
♂	100	6.0–30.0	13.72 ± 0.56

Table 2. Average agronomic data from the Flag Leaf Area Nursery grown under irrigation at Bozeman, Montana, 1973.

Cultivar[1]	Jan. 1 to heading (days)	Plant height (cm)	Flag leaf area (cm^2)	Test weight (kg/hl)	Grain yield (kg/ha)
Norana-check	190	78.7	20.58	77.0	3565
Cross 7069, High composite	185	100.0	19.76	77.5	3027
Cross 7069, Low composite	185	101.5	16.38	77.3	2764
Cross 7069, ♀	183	86.3	17.36	77.2	2852
Cross 7069, ♂	192	106.6	16.38	77.2	2731
Cross 7065, High composite	190	114.2	24.40	78.0	3007
Cross 7065, Low composite	187	111.7	21.00	77.5	2973
Cross 7065, ♂	189	111.7	24.94	77.2	3309
Cross 7065, ♀	189	111.7	18.00	78.5	3087
L.S.D. ($P = 0.05$)	0.2	4.6	0.07		202

[1] Cross 7069 is PI 290752/PI 178692; Cross 7065 is PI 225408/ND 464.

Experiment II. Flag leaf areas obtained in 1974 on F_3 plants from PI 178692 crossed to MT 7154, Iassul, and Ariana 66 are included in Table 3. The F_3 values obtained in 1974 were intermediate between the two parents, suggesting additive gene action.

There was no significant relationship between F_2 and F_3 flag leaf measurements, as indicated by r values of 0.10, 0.11, and –0.04 for crosses with MT 7154, Iassul, and Ariana 66, respectively. These r values are similar to those obtained in 1972 from the two crosses of Experiment I. The lack of relationship between F_2 and F_3 measurements may be due to the effect of environment on flag leaf size, and it may also be an indication of low heritability for this plant character.

Flag leaf area measurements taken at Bozeman showed the high composites to have higher flag leaf readings for each cross, as expected (Table 4). This suggests that progress can be made in selecting for flag leaf size, but that the lack of relationship between generations noted above would still be a deterrent in a selection program.

Table 3. Number of parents and F_3 plants examined and average flag leaf area from three crosses grown at Bozeman, Montana, 1974.

Parents and crosses	Number of plants	Leaf area (cm^2)
Parents		
PI 178692	160	11.70 ± 0.38
MT 7154	50	19.46 ± 0.70
Iassul	40	19.20 ± 1.53
Ariana 66	70	23.00 ± 1.14
Crosses		
PI 178692/MT 7154	246	14.85 ± 0.15
PI 178692/Iassul	190	15.69 ± 0.16
PI 178692/Ariana 66	323	18.60 ± 0.16

Table 4. Flag leaf area, test weight, and yield from the Flag Leaf Nursery grown at five Montana locations in 1975.

Crosses and parents	Flag leaf area, Boz. (cm^2)	Test weight (kg/hl)					Grain yield (kg/ha)				
		Boz.	Kal.	Mocc.	Havre	Hunt.	Boz.	Kal.	Mocc.	Havre	Hunt.
Crosses											
178692/MT 7154,											
high	19.30	77.7	72.2	80.8	75.2	73.9	3450	4009	1083	1722	1076
low	17.54	76.6	69.9	80.8	74.4	74.1	3202	3767	1150	1937	1164
178692/Iassul,											
high	20.48	75.2	70.3	78.8	74.3	72.3	3074	3605	861	1883	1110
low	19.61	75.8	70.8	79.5	74.1	73.1	2879	3841	1224	1735	1056
178692/Ariana 66,											
high	22.25	75.7	70.8	73.5	74.0	73.5	3074	3841	1096	1486	1036
low	19.66	76.2	72.6	79.0	74.9	73.5	3309	4009	1143	1755	1083
Parents											
Norana	20.15	78.5	73.9	80.7	71.2	73.6	4594	6174	1096	1856	874
MT 7154	19.22	76.2	73.2	80.8	73.4	73.4	4506	5798	1271	2085	1211
Iassul	20.71	77.1	72.2	77.9	74.8	70.3	3713	4533	807	1641	1143
PI 178692	15.94	74.6	65.3	81.3	75.2	75.8	2576	2300	1184	1897	1345
Ariana 66	37.09	67.6	67.1	55.3	-	73.4	1870	4305	1063	-	404
L.S.D. (P = 0.05)	1.20	1.3	-	3.2	1.7	1.5	545	713	282	350	323

Test weights and grain yields for the high and low composites were each significantly different in only one of 15 comparisons, both at Moccasin (Table 4). When test weights and grain yields were averaged over crosses and locations, no differences could be detected between the high and low composites (Table 5). Significant differences between high and low composites were observed in heading and plant height, but the size of these differences was too small to have any practical meaning.

These data suggest that flag leaf area by itself is not a very good index to plant performance. The head, including awns, the leaf sheaths, and other leaf areas also need to be considerdd as contributors to grain yield.

Table 5. Agronomic data comparing high flag leaf composites with low flag leaf composites, using averages of three crosses grown in the Flag Leaf Nursery, 1975.

Flag leaf composite[1]	Jan. 1 to heading (days)	Plant height (cm)	Test weight (kg/hl)	Grain yield (kg/ha)
High	197.2a	85a	75.4a	2159a
Low	196.1b	82b	75.9a	2220a

[1] Values in vertical columns followed by the same letters are not significantly different at P = 0.05 by Duncan's Multiple Range comparisons.

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