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ABSTRACT

The effect of *Triticum turgidum* cytoplasm on soft red winter wheat (*T. aestivum*) was studied relative to test weight (bushel weight) and agronomic traits such as heading date, resistance to leaf rust, and plant color. The cytoplasmic effects were studied in three genetic backgrounds by crossing the cultivars Jackson, Pioneer 2684, and Wakefield with a plant introduction PI590277 that carried *T. turgidum* cytoplasm. Twelve alloplasmic and euplasmic populations were developed through a backcrossing procedure. The study used a micro test weight procedure to compare F_4 lines within the populations for test weight. The data for other agronomic traits were taken by field ratings. Statistical analysis showed no significant gain in test weight due to *T. turgidum* cytoplasm (P=0.32). However, an important effect on leaf-rust reaction was observed. The lines derived from 'Pioneer 2684' and 'Wakefield' that carried *T. turgidum* cytoplasm were more resistant to leaf rust than were their respective euplasmic lines. Euplasmic and alloplasmic lines derived from 'Jackson' did not show difference in leaf-rust reaction. A yellow color at harvest and late heading date were observed on alloplasmic lines derived from 'Pioneer 2684' and 'Wakefield' cultivars. The third cultivar 'Jackson' showed no yellow coloration at harvest.

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MEET THE STUDENT-AUTHOR

Juan Mayta

I graduated in May 2003 with a major in crop science and a minor in agricultural business. I am originally from Bolivia. I had the opportunity to get an associate degree in agronomy at the Pan American School of Agriculture "Zamorano" in Honduras. I transferred to the University of Arkansas in 2001. I was awarded the Foundation for International Exchange of Student (FIES) Scholarship. I was also recipient of the World Hunger Scholarship from the Methodist Church and the Fontaine Richard Earle Scholarship, which helped me to accomplish my goals. My two years at the University of Arkansas have been an excellent experience not only academically but also in my personal life.

From the beginning I was able to gain hands-on research experience, first through my job with the Wheat Breeding Program getting experience in cultivar development of wheat. I was also able to enroll in the Honors Program of the Department of Crop, Soil and Environmental Sciences, which I think helped me to get the most from the college experience not only by learning research techniques but also by allowing me to grow as an individual. I was also an active member of the Agronomy Club in my department, for which I served as a treasurer. By getting involved with the Agronomy Club I had the opportunity to get acquainted with the faculty and make good friends. I pursued my undergraduate research as a requirement for the Honors Program and also had the opportunity to present my undergraduate research at the American Society of Agronomy Meeting in Indianapolis in 2002. I will continue my graduate studies at the University of Arkansas working with the Soybean Breeding Program. My long-term goals are to go back to Latin America and be able to improve food production in our countries. I would also like to teach at some point and share the great experience I had in the U.S.

INTRODUCTION

Genes from wild relatives of common crops can have desirable effects on agronomic characteristics. It is possible to introduce cytoplasmic variability to broaden the genetic base; this resulting genetic base can be used for breeding desirable characteristics. The wild and cultivated relatives of common wheat (*Triticum aestivum*) that produce fertile alloplasmic lines may provide a large reservoir of cytoplasmic variability for this crop (Kofoid and Maan, 1981).

The weight of a volume of seed (test weight) is an important characteristic of cereals. Test weight is economically important for wheat growers as well as for industrial users of wheat. Wheat is traded on the basis of USDA #2 standard, which among other things has a minimum requirement for test weight of 746 kg/m3 (58 lb/bu). Farmers that produce lower test-weight wheat will receive lower prices. Test weight is used because it is considered to be a predictor of flour yield; thus, millers are also concerned about this trait. Another important consideration is transportation and storage of grain. Costs are lower if millers can transport and store more weight in less space (Schuler, 1992). Therefore, improvements in this characteristic benefit the farmers and the wheat industry in general.

Schuler (1994) indicated that cultivars differ in test weight when grown under similar conditions. This difference indicates a genetic component, and therefore, a potential for improvement of test weight through plant breeding.

The Agricultural Research Service, U.S. Department of Agriculture and the Agricultural Research Center of Washington State University reported that *T. turgidum*

had a positive effect on test weight of 'Stephens', a soft white winter wheat cultivar (Allan, 1997). Although research has shown alien cytoplasm effects when introduced into specific cultivars, each breeding program must test adapted germplasm in its local region to see if gains in traits can be uncovered and exploited locally. The objective of this research was to determine the effect on test weight and other agronomic traits contributed by *T. turgidum* cytoplasm introduced into three soft red winter wheat backgrounds.

MATERIALS AND METHODS

The adapted cultivars Jackson, Pioneer 2684, and Wakefield and the plant introduction with the alien cytoplasm (PI590277) from *T. turgidum* were used in this study. Since the cytoplasm is maternally inherited, reciprocal crosses were made using PI590277 as both the male and female parent. The resulting F_1 plants had 50% of their nuclear genes from each parent. A backcross was made in order to produce plants with 75% of their nuclear genes from the adapted cultivars. As a result two populations were created: one alloplasmic having the alien *T. turgidum* cytoplasm, and one euplasmic having the conventional *T. aestivum* cytoplasm. Additionally, both populations had 75% of the nuclear genes derived from the cultivars. These populations were allowed to self-pollinate until the F_4 generation.

Seeds threshed from single F_4 spikes were planted on 5 Oct. 2001. The seeds were planted 0.4 cm apart in blocks 1.5 m wide with four 1.8 m-long plots. The plots were planted at the University of Arkansas Research and Extension Center, Fayetteville, on a Captina silt loam. For weed control, "Hoelon" was applied at a rate of 1.5 L/ha on 7 Nov. 2001. Additionally, 112 kg/ha nitrogen were applied on 15 Mar. 2002. The total number of plots was 960 with 160 plots for each of the six crosses.

The six populations were divided in two groups of 80 plots in order to have replications for statistical analysis. The design was a randomized complete block with two replications in a 3x2 factorial. The characteristics measured for each individual plot were test weight, days to heading, and leaf rust reaction. A contingency table was constructed to compare differences in leaf rust reaction. Histograms were used to compare days to heading. Color at harvest was observed but was not subjected to formal statistical analysis.

Test weight

Four spikes per plot were harvested. The spikes were threshed and cleaned in a wheat single-spike thresher (Precision Machine Company, Inc. Lincoln, Neb.). The seeds from three spikes were bulked in order to measure their weight in a 4.5 ml cylinder. This micro test weight per volume of 4.5 ml was then expressed in kilograms per cubic meter and also in its equivalent in pounds per bushels. This procedure reported by Schuler (1992) was developed by the wheat breeding program at the University of Arkansas.

Days to heading

Days to heading were considered as the number of days from 1 Jan. until 50% of the spikes emerged from the leaf sheath or boot. The ratings were taken from 24 Apr. through 20 May 2002

Leaf rust assessment

The following scale was used: 0-immune; 1-practically immune; 2-extremely resistant; 3-resistant; 4-moderately resistant; 5-transition of 4 to 6; 6-moderately susceptible; 7-susceptible; 8-transition of 7 to 9; 9-highly susceptible (USDA/ARS Cereal Disease Laboratory at the University of Minnesota, 2003.) The ratings were taken at Feekes stage 10.5, which represents the flowering stage (Large, 1954).

RESULTS AND DISCUSSION

Test weight

Among the three genetic backgrounds the alloplasmic and euplasmic lines were almost identical for the 'Jackson' and 'Wakefield' populations (Table 1). The alloplasmic and euplasmic lines derived from 'Pioneer 2684' showed the biggest difference (10 kg/m^3); however, this difference was not statistically significant. The effect of *T. turgidum* cytoplasm on average test weight was not statistically significant by itself (P=0.32) or in its interaction with cultivar (P=0.46).

Heading date

The effect of cytoplasm was different for heading date for each cultivar. Lines derived from 'Jackson' did not show variation between alloplasmic and euplasmic lines; both populations averaged 121 d to heading. Although there were no differences between the euplasmic and alloplasmic lines derived from 'Jackson,' the earliest heading date in our study (116 d) was among the euplasmic lines using 'Jackson' as a parent (Fig. 1). Lines derived from 'Pioneer 2684' and 'Wakefield' both showed differences among their respective alloplasmic and euplasmic lines; the data distribution for alloplasmic lines derived from 'Pioneer 2684' showed a group of lines with an average days to heading of 121 d, and another group with an average of 137 d. Likewise, the data distribution for lines derived from 'Wakefield' showed a group of lines with an average number of days to heading of 122 d and another group with an average of 138 d (Fig. 1). The alloplasmic lines derived from Wakefield were the latest to reach the heading stage.

Table 1. Test weights of alloplasmic and euplasmic lines derived from three genetic backgrounds of soft red winter wheat.

Cultivar	Cytoplasm	Test-weight
		kg/m³ (lb/bu)
Jackson	Euplasmic	694 (54.0)
	Alloplasmic	692 (53.8
Pioneer 2684	Euplasmic	664 (51.6)
	Alloplasmic	654 (50.8)
Wakefield	Euplasmic	682 (53.0)
	Alloplasmic	680 (52.8)
		NS[1]

[1] NS = non-significant (P<0.05)

Leaf rust assessment

Leaf rust reaction assessment showed differences between and among the different populations; for instance, the alloplasmic lines derived from 'Jackson' showed more susceptible plants than the euplasmic lines derived from 'Jackson' (Fig. 2). On the contrary, 'Pioneer 2684' showed more resistant plants among the alloplasmic lines (99 out of 160). 'Wakefield' lines showed the largest number of resistant lines among its alloplasmic population (122 out of 160).

Color

An interesting characteristic that was observed was the color of the plants at maturity. The alloplasmic lines with a genetic background from 'Pioneer 2684' or 'Wakefield' both showed more yellow color at maturity than the other wheat lines. The effect was more consistent among lines derived from 'Wakefield' (data not shown). There were no coloration differences between euplasmic and alloplasmic lines derived from 'Jackson'. all the lines had the traditional wheat color at maturity.

Effects of alien cytoplasm were not consistent among the genetic backgrounds. The results indicated a nuclear-cytoplasmic interaction. According to Kofoid and Maan (1981) the mode of inheritance and interrelations between maternal parents and cytoplasmic and nuclear genetic controls are not well understood, and more research is needed.

Triticum turgidum cytoplasm did not show a positive effect on test weight of lines derived from the three cultivars of soft red winter wheat. Although the effect on test weight was not significant in our study, it might be possible to select individual lines within the populations that have higher test weights. As Schuler (1992) points out, packing efficiency, kernel size, and shape should be evaluated. Also spike characteristics such as spike density, number of spikelets per spike, and the number of fertile florets per spikelet should also be considered. A study evaluating these variables could lead to a better understanding of the effect of cytoplasm on test weight

The difference in leaf-rust reaction was more significant among the alloplasmic lines of 'Pioneer 2684', and 'Wakefield'. For leaf rust reaction, it is possible that each cultivar had resistance genes for leaf rust; however, since there was variation among the different lines for each cross, the data indicated an effect of the alien cytoplasm. This result was particularly true with the 'Pioneer 2684' and 'Wakefield' populations, which showed the highest number of resistant lines. Additionally, it is important to point out that the lines that had the highest leaf-rust reaction among the alloplasmic lines of 'Pioneer 2684' and 'Wakefield' also had late heading dates. These data indicate the possibility of linkage between leaf-rust resistance and late heading date; however, there were exceptions among these lines, with some lines having an average to early heading date.

The bimodal distribution of days to heading for the alloplasmic lines derived from 'Pioneer 2684' and 'Wakefield' is another example of nuclear-cytoplasmic interactions (Fig. 1). The distribution of the data was divided into two groups; one group with number of days to heading as early as 118 d, and as late as 127 d; the second group of lines had the latest number of days to heading having a range from 137 to 140 d.

Regarding the color of the spikes at harvest, the alloplasmic lines of 'Wakefield' and 'Pioneer 2684' showed a more yellow coloration than typical wheat. Although in our study we did not take measurements on this variable, it can be subject of further research studying cytoplasmic effects.

ACKNOWLEDGMENTS

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LITERATURE CITED

Allan. R.E. 1997. Registration of ten pairs of alloplasmic and euplasmic 'Stephens' wheat germplasm. Crop Sci. 37:1033.

Kofoid K.D., and S.S. Maan. 1981. Agronomic and bread-making performance of fertile alloplasmic wheat. J. Ser. North Dakota Agri. Ext. No.1160.

Large, E.C.1954. Growth stages in cereals: Illustration of

the Feekes scale. Plant Pathology 3:128-129
Schuler, S. F. 1992. Characterization of test weight and its relationship to end use quality of soft red winter wheat. Ph.D. Dissertation. Crop, Soil, and Environmental Sci. Dep., Univ. of Arkansas, Fayetteville.
Schuler, S. F., R. K. Bacon, and E. Gbur.1994. Kernel and spike character influence on test weight of soft red winter wheat. Crop Sci. 34:1309-1313.
USDA/ARS Cereal Disease Laboratory at the University of Minnesota; verified April 2003. <http://www.wsu.edu:8080/~wheaties/rust.html>

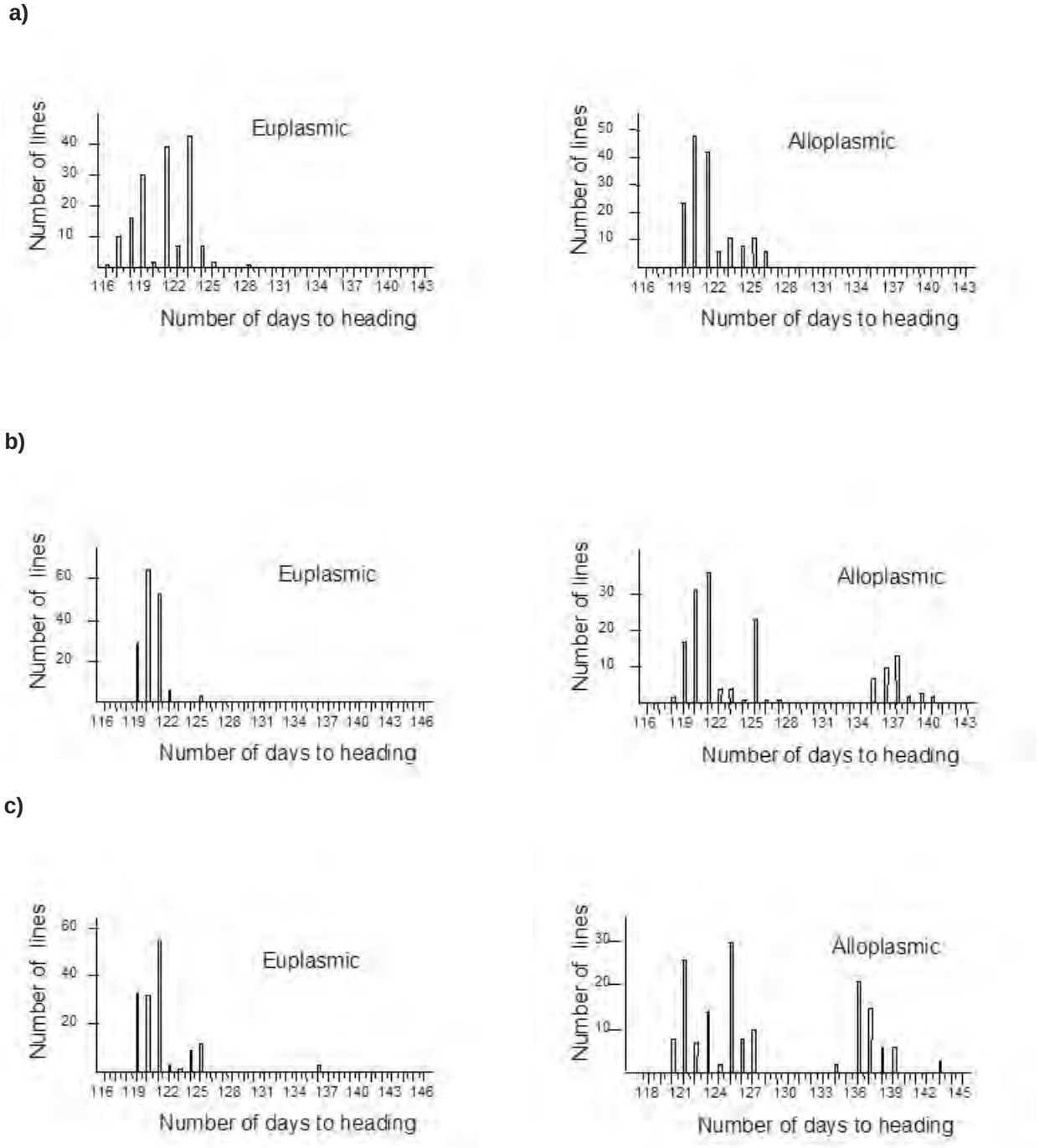

Fig. 1. Distribution of number of days to heading (x-axis): comparing euplasmic and alloplasmic populations. a) 'Jackson', b) 'Pioneer 2684', c) 'Wakefield'.

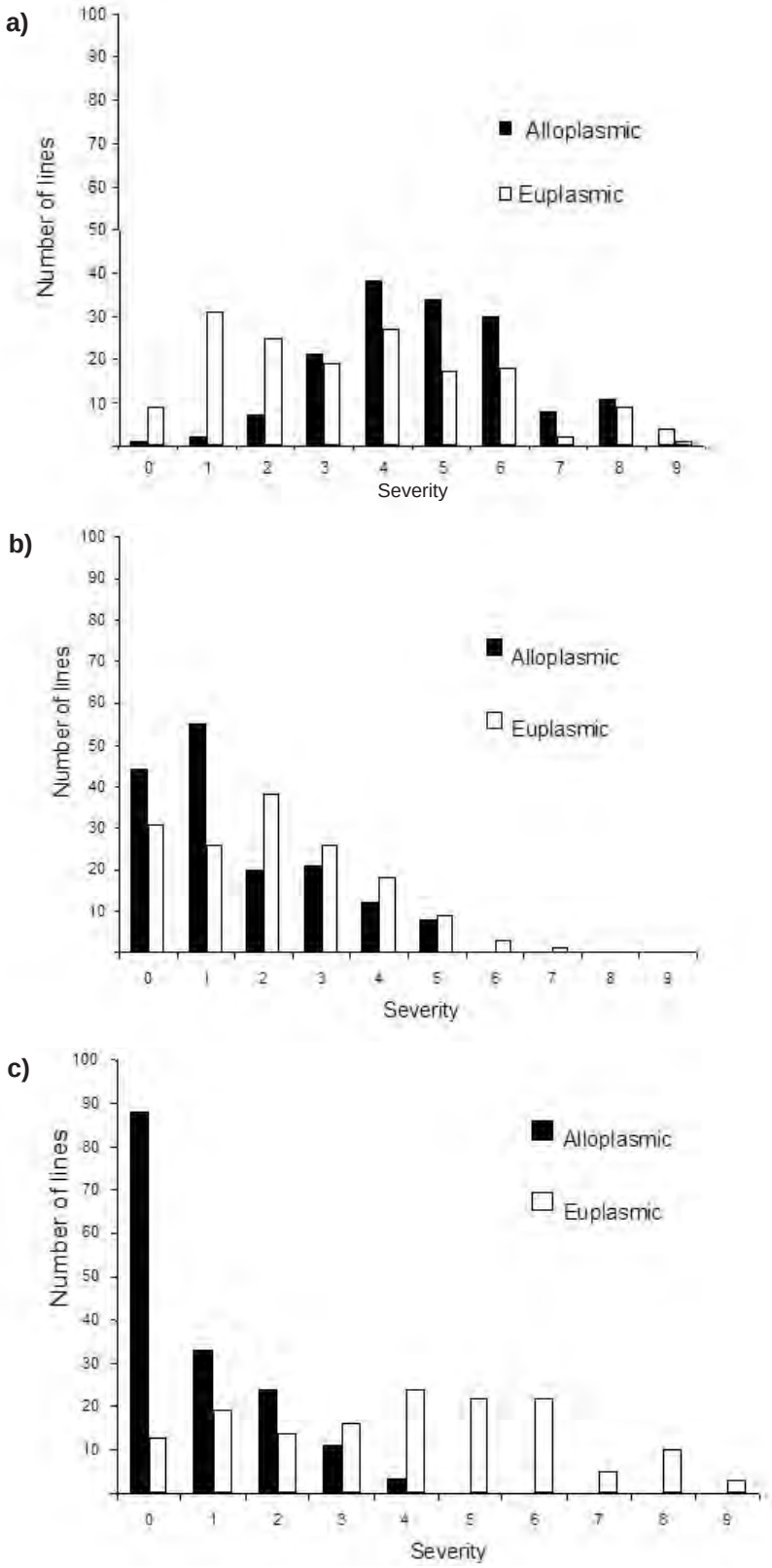

Fig. 2. Leaf rust reaction among alloplasmic and euplasmic lines derived from: a) 'Jackson', b) 'Pioneer 2684', and c) 'Wakefield'.