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Small grain variety development and adaptation in Idaho

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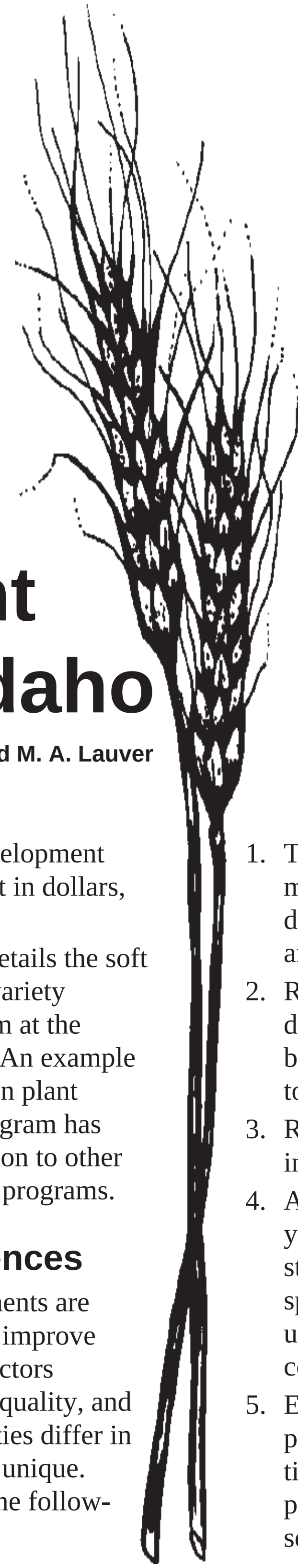

Plant breeding for genetic improvement provides new crop varieties with unique characteristics that are beneficial and profitable. Plant breeding and Cooperative Extension support programs have given us improved small grain varieties adapted to many growing environments.

Growers are curious about the procedures and programs that make varieties unique and where new traits originate. Also, growers may wonder why it takes so long for new varieties to be released and why the perfect varieties have not yet been developed.

The procedures for breeding new varieties vary from crop to crop, and depending on the desired result, within a crop. A common characteristic among crop development programs is high cost in dollars, personnel, and time.

This publication details the soft white winter wheat variety development program at the University of Idaho. An example of the effort needed in plant breeding, this UI program has many features common to other variety development programs.

Variety differences

Genetic improvements are made by breeding to improve plant performance factors affecting crop yield, quality, and harvestability. Varieties differ in these factors and are unique. Breeding improves the following plant attributes:

1. Tolerance to adverse environmental conditions, such as drought, flooding, heat, cold, and freezing.
2. Resistance or tolerance to diseases caused by fungi, bacteria, viruses, and nematodes.
3. Resistance or tolerance to insects and other pests.
4. Agronomic traits affecting yield, test weight, straw strength, shattering, preharvest sprouting, seed bleaching, uniformity of maturity, and competitiveness against weeds.
5. End-use grain quality for protein level, milling properties, baking properties, malting properties, digestibility, and seed color.

University of Idaho College of Agriculture

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Where new traits are found

The expression of desirable traits is controlled genetically. Some genes always will be expressed while the presence of others will be detected only under certain environmental or management situations.

Traits easy to breed for are controlled by a few genes. Other traits, such as yield, may be affected by many genes, and these genes interact by varying degrees. Therefore, improvement of multigene characters is complex and time consuming. New varieties are created by combining genes, and modern technology, such as biotechnology, provides us wit new sources and new ways of mixing genes.

Plant breeders often look to the wild relatives of field crops for desirable traits. These wild types are found in the region of the world where the crop originated before cultivation by man. Within the United States, plant introduction centers preserve and increase seed stocks of wild crop ancestors and of selected or improved crop cultivars. These centers provide a genetic reservoir for plant breeders to utilize.

Genetic mutations may provide new genotypes for variety improvement. Mutations occur naturally, but chemical or X-ray treatment can increase mutation frequency.

Biotechnology offers nontraditional approaches for adding desirable characteristics through interspecific hybridization, gene transfers, and man-made genes. Biotechnology has the potential to enable specific and relatively rapid tailoring of the genetic makeup of plants, but such genetically-engineered plants are not yet available for public use. The actual utility and application of biotechnology is being developed, and could be a valuable tool complementing traditional breeding methods in the future.

Pursuit of the 'perfect' variety

Plant breeding

Plant breeding efforts of crops, including small grains, has been going on for thousands of years. Before the recording of history, crop improvements were made by the selection process: saving seed from plants with desirable characteristics to plant the following season. Today's plant breeders still use this process, but it is focused and coupled with the creation of genetic diversity and sophisticated character evaluation methods.

There are three general stages in a breeding program developing new winter wheat varieties. First is recombination, producing progeny from mating (crossing) of two or more plants with different genes. Second is segregation, the assortment of genes into new combinations. Finally, selection picks the best new combination of genes.

The relationship of these three stages to the timing of a breeding program for soft white winter wheat at the University of Idaho is shown in Table 1. Each breeding generation has an $F_{(n)}$ designation that starts with F_1, the progeny of a cross, and progresses through the entire breeding process. A plant breeding line is a genetically similar group of plants treated as a unique population. Each generation of the breeding program uses lines from the previous year for advancement

Table 1. University of Idaho's soft white winter wheat breeding program stages, generations, and locations.

Stage	Generation	No. of lines	Designation	Location
Recombination	Crossing ↓	500	2, 3, or 4 parents	Moscow, Idaho
	F_1[a] ↓	450	Bulk population	Moscow, Idaho
Segregation	F_2 ↓	400	Bulk population	Moscow, Idaho
	F_3 ↓	400	Bulk population	Moscow, Idaho
	F_4 ↓	20,000	Head rows	Moscow, Idaho
	F_5 ↓	500	Preliminary yield test	Moscow, Idaho
	F_6	80	Preliminary yield test	Grangeville
and	↓			
Selection	F_7 ↓	10	Advanced yield test	} Moscow, Idaho; Eight Idaho locations (six northern, two southern)
	F_8 ↓	5	Advanced yield test	
	F_9 ↓	3	Regional testing	}
	F_{10} ↓	3	Regional testing	Many western USA locations
	F_{11} ↓	3	Regional testing	
	Variety			

[a] Each generation in winter wheat equals 1 year.

through successive generations.

How adapted a line will be to the various Northwest environments depends on selecting advanced lines with desirable genetic makeup in generation F_7 and later.

To make beneficial selections, a breeder must decide what traits to improve and which methods define the best gene combinations of these traits. Before deciding what traits to improve, the plant breeder must define the desirable wheat plant type. Some visible selection traits defining plant type include plant height, lodging, disease resistance, insect resistance, yield, and test weight. Some nonvisible selection traits include grain protein content, protein quality, milling yield, and end use quality.

Trait selection occurs at different generations (Table 2). Selection for some traits may be difficult at certain generations because of environmental influence on trait expression and lack of adequate seed. Nonvisible selection traits require laboratory determination. Time and cost limits nonvisible trait evaluation to later selection generations.

Some traits, such as stripe rust, can be selected only in years when adequate levels of disease potential will cause genetic expression of the trait. There may be environments with too little or too much stripe rust to allow good selection.

Other traits, such as yield, can be assessed every year, but are subject to environmental variability. Environmental variability dictates that selection occurs over several generations and evaluation continues after variety release. The growing environment changes over time and having the right genetic makeup for both current and future environments mandates ongoing breeding, selection, and evaluation. Selection for both visible and nonvisible traits across many environments ensures varieties have the genetic makeup to meet production and market needs.

Evaluation of genetically unique soft white winter wheat is a dynamic, ongoing process. Evaluation starts during the breeding process and continues through variety release by environmental adaptation testing and grower acceptance.

Continuing evaluation

Cooperative Extension System personnel and university researchers evaluate varieties for crop adaptability and management studies, adding to the knowledge about a variety's performance and potential worth. This information is valuable to growers who use it to determine when, where, and how to grow a variety to the best advantage.

Extension agents and researchers begin testing variety performance in late generations of selection. Through advanced yield and regional testing, plant breeders will narrow the number of lines being evaluated. After 2 years in regional testing, a few promising lines

Table 2. Selection traits, plant generation, and when evaluation begins in the University of Idaho's soft white winter wheat breeding program.

Selection trait	Beginning generation
Disease resistance	
Stripe rust	F_3
Foot rot	F_7
Cephalosporium stripe	F_6
Dwarf bunt	F_6
Septoria	F_6
Insect resistance	
Russian wheat aphid	F_6
Hessian fly	F_7
Plant height	F_3
Lodging resistance	F_4
Stand establishment	F_5
Heading date	F_5
Winter-hardiness	F_7
Yield	F_5
Yield stability	F_6
Test weight	F_5
Protein content	F_4
Kernel hardness	F_4
Dough viscosity	F_5
Milling quality	F_5
Baking quality	F_5

Table 3. The University of Idaho Cooperative Extension System variety testing and commercial seed production sequences for soft white winter wheat.

F_{11} breeding generation[a]	
↓	↓
Extension variety testing (3 to 5 regional locations, 10 to 15 statewide locations)	Breeder's seed
	↓[b]
↓	
Continued Extension testing	Foundation seed
↓	↓
Continued Extension testing	Registered seed
↓	↓
Continued Extension testing + county Extension strip demonstrations	Certified seed
↓	
Continued Extension testing + county Extension strip demonstrations	
↓↓↓+	↓
Extensive use by growers, continued testing, and development of variety management practices	Limited use by growers, limited testing

[a] See Table 1 for the relation of this sequence to the breeding program.

[b] Each downward pointing arrow represents 1 testing year or seed production year.

(usually at the F_{11} generation) will be entered into replicated Extension variety performance trials. Table 3 outlines the Extension testing timeline for soft white winter wheat in Idaho.

Extension trials give performance information in a wide range of environments under grower field conditions. This information is useful to breeders when deciding to release a variety. In addition to the multienvironment performance information, these trials provide important exposure of potential varieties to growers and preliminary information about specific management practices influencing variety performance.

The performance data from multiyear testing in the replicated Extension trials gives an extensive database for a variety's use and management. When commercial seed is available for widespread planting of a variety, (usually 2 years after release) the potential benefits of the variety are established, environmental adaptation limitations are identified, and some variety specific management is available.

The adoption of a new variety by growers marks its successful development. The process of evaluation and research, however, should not stop until a variety is outdated by better varieties. Ultimately, the growers determine a variety's useful life and ultimate value.

Seed production

To take advantage of a variety's uniqueness, growers must use seed that is identical to the breeding line selected for by the breeder. This may sound simplistic, but it takes many steps and quality checks to achieve.

When a new variety release becomes likely, the plant breeder begins increasing the line's seed by producing breeder's seed. A seed increase plot is usually less than an acre because of seed limitations and the need to remove any off-type plants.

Foundation seed organizations use the breeder's seed to grow foundation seed (Table 3). Seed companies, in turn, increase foundation seed first to registered seed and then to certified seed.

During each seed increase, the crops are monitored for purity and the seed must pass rigid quality standards. This seed production process assures growers of high quality certified seed free of noxious weeds, of good germination, and with the genetic makeup of the labeled variety.

Summary

The development and adoption of a new variety is a complex process. Large amounts of human and capital resources are needed for the breeding, Extension testing, and seed production necessary to bring a new variety to growers.

Despite this effort, most new varieties give a relatively modest improvement in crop performance or quality.

From the initial cross of parent plants to adoption of a variety by growers takes at least 12 years or as long as 15 years. New genetic technology may shorten some of the breeding time when specific genes are desired, but the trait evaluation processes should not be cut.

Is this exacting effort worth while? "Yes" is the answer most persons in agriculture give because the potential returns for successful breeding are so great.

To stay competitive in domestic and international markets, it is necessary for a production area to use improved varieties for higher production capacity and crop quality.

Although growers support variety development in many ways, adoption of a new variety has little or no direct cost to the grower. If a new variety provides even a small increase in yield, decreased input requirement, or improvement in grain quality, it can change a grower's profitability. Multiply this increased profitability by many growers, and you will justify plus "pay back" the investment of creating a new variety.

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