as a reservoir of germplasm. Thus, bulk populations may be maintained over extended periods with periodic artificial selection.

An issue of considerable importance in this regard is whether natural selection leads to high yielding varieties of high agricultural worth. Natural selection, as well as artificial selection, causes changes in gene frequency from generation to generation. Forces of natural selection or differences of viability and fertility are always present. However, they may or may not be relevant to a practical breeding program. Seasonal variation may be such that first one type is favored and then another. Characters that are either neutral or have selective advantage may not have any agricultural worth. Natural selection may be more discerning than the plant breeder for subtle differences in yielding ability and survival. However, if the plant breeder is more discerning, then changes in gene frequency would be more effective in a pedigree system because selection in early generations could be practiced within families. In bulk populations only between-family selection can take place. Competitive ability may not be correlated with yielding ability so that a breeding line that survives well in a bulk population may be highly competitive but it may not necessarily be a high yielding line. The number of crosses that can be exploited by bulk populations, as compared to pedigrees, in terms of time and space, highly favors bulk populations. After the F_2 generation, approximately 6 bulk populations can be grown in the same space which would be required for a pedigree of only 50 families.

Results from experiments on bulk population breeding are very limited. Tucker and Harding (Heredity 20(3):393-402, 1965) have shown that the genotype which was more acceptable commercially was very rare after 11 generations of natural selection in a bulk population. In another study by the senior author (unpublished), it was found that survival in this population was not correlated with the yielding ability of individual genotypes when they were grown separately. Experiments by Sanchez and Tucker (unpublished) indicate that homozygous lines from two bulk populations which had good agronomic characters in some cases yielded greater than two of the parents which are commercial varieties.

The best current evidence that bulk breeding has an important place in lima bean breeding is the fact that four commercial lima bean varieties have been released from the lima bean project in the Agronomy Department, University of California at Davis, California. These varieties are made up of selections from bulk populations in the F_9-F_{16} generations.

Although the evidence from experimental populations seems to be contradictory, the applied results from bulk population breeding favor this scheme as a sound method for developing improved lima beans in California.

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Lima Bean Breeding in California

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The principle aims of the lima bean breeding project at the University of California are to make improvements in nematode resistance, seed quality, earliness, and yielding ability. In the short range experiments, characters which are simply inherited are being incorporated into the large seeded, dry edible variety Ventura. This variety has a green seed coat which when dry bleaches to shades of greenish white. A more commercially acceptable seed coat is one which is white at a very immature stage and which remains white after drying. This simply inherited character has been transferred into Ventura by backcrossing. The new improved variety White Ventura 63 has been grown commercially since 1965 and is now planted on approximately 75% of the large dry lima acreage in California. Nematode resistance has also been incorporated into a white seed coated Ventura type by backcrossing. Sufficient seed stocks of this improved variety will be available for commercial planting in 1969.

In the northern part of Santa Barbara County, California, bush-type, large dry limas appear to be better adapted than vine types (they tend to be earlier and to yield more). The variety and improved varieties of Ventura mentioned above are vine-types. A by-product of the improved Ventura varieties is a white seed coated bush type that lacks nematode resistance and one that has nematode resistance. Commercial seed stocks of the white-seeded bush Ventura type will be available in 1969. Commercial quantities of the nematode resistant type will be available in three or four years.

Nematode resistant lines of baby processing types and Fordhook types are also being developed by backcrossing. It will be several years before commercial stocks of seeds of these varieties will be available.

Long-range breeding programs aimed at developing new varieties with greater yielding ability are also in progress. Several pedigrees have been attempted but only one has produced any promising breeding lines. Two lines from one of these pedigrees show promise as a commercial variety. Most of the effort in long-range breeding is in bulk populations. (See Bulk Breeding of Lima Beans in California.) As many as 35 bulk populations have been grown in five locations in California. To date, four varieties have developed from bulk populations, and two lines from a single bulk show promise as improved varieties.

Population genetic studies are integral parts of the lima bean breeding project. The purpose of such studies is to lend insight into areas such as selection, mutation, and the effect of the mating system on plant breeding populations and associations between major genes and quantitative traits in isogenic lines. Four publications describing the results of research in these areas are mentioned in the bibliography at the end of the BIC report.

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Some Aspects of Our Breeding Work in Beans

Vreeken's Zaden
Dordrecht, Holland

Bush Beans: Suitable for mechanical harvest resistance: Virus, Halo blight, Anthracnose, Botrytis. Pods: Green - dark green, round and flat, with small seeds and thick podwall. Stringless, firm structure, pithy taste. White seeded.