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MULTI-ADVERSITY RESISTANCE BREEDING PROCEDURE IN COTTON IN THE PHILIPPINES

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ABSTRACT

The rapid accumulation of genes that condition multi-adversity resistance is made possible through sequential selection pressures exerted in several stages of the crop from seed to maturity and retaining only the superior individuals in each stage.

The selection criteria for seeds are size and density while deterioration and velocity are used in the germination stage. For seedlings, the criteria are damping-off and nematode resistance. On the other hand, aphid and leafhopper tolerance are selected for in the vegetative stage and bollworm and flowerweevil tolerance at flowering and bolling stages. Hairiness and nectariless characteristics are also selected for including high number and weight of bolls per plant and high lint recovery.

Introduction

Improved crop varieties are a key to progressive agriculture. Substantial improvements in seedcotton yield, resistance to pests, fiber quality and utilization of the cotton seed for animal feed and human consumption can be attained through skillful manipulation of cotton genotypes.

The Philippines benefits from the experiences of cotton-producing countries especially on insect and disease control researches. The unfortunate consequence of depending almost entirely to chemical pest control prior to the 70's has spurred new research directions in cotton pest control. Host-plant resistance to cotton insects and diseases is now in advanced stages of development in some countries. The following characters are important in pest control and can be incorporated in our varieties:

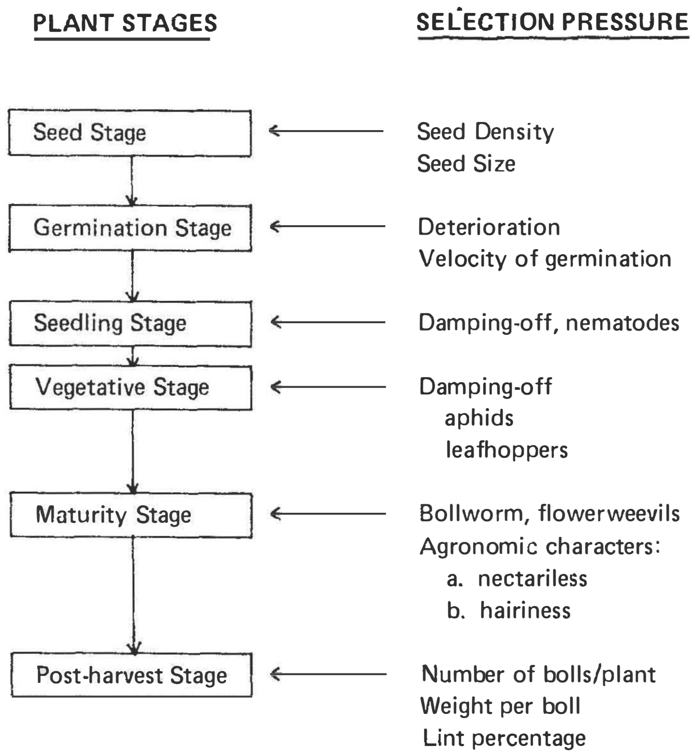
1. Nectariless (absence of nectar-producing glands). In Mississippi, this character was found to account for about 60% reduction of plant bugs and *Heliothis* sp. in cotton.
2. Hairiness – a coat of long hairs on the surface of the leaves prevents damage due to leafhoppers (Hautea, 1980; Toledo, 1980).
3. Deciduous bract (bract falls off after boll formation). This character

appears important in controlling boll rot and more importantly helps in controlling the lung disease (byssinosis) of cotton mill workers.

Procedure in Breeding for Multi-Adversity Resistance (MAR)

The main objective of the technique is to select cotton genotypes that possess multi-adversity resistance by exposing the selection population to a series of selection pressures throughout the growing cycle of the plant. The procedure is effective and efficient in screening large number of genotypes in a short time to be of good value to cotton plant breeding. The procedure involves exerting selection pressures on the different stages of the crop (from seed germination to maturity) and retaining only those superior individuals which give resistance and escape from adversities.

Advanced generation crosses either heterozygous-heterogenous (F_2, F_3, etc.) and heterogenous-heterozygous population as well as established cultivars are subjected to the program. The following diagram briefly illustrates the multi-adversity breeding procedure:



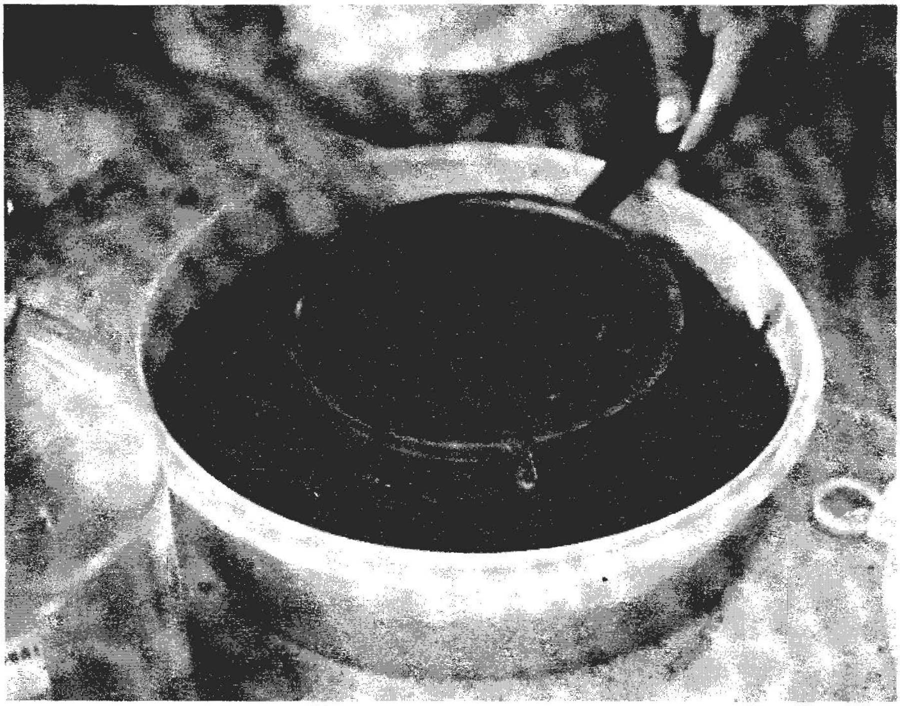


Figure 1. Cotton seeds are delinted in sulfuric acid solution before they are sorted wherein only large, dense and fully-developed seeds are selected.

Each stage of plant growth is subjected to adversities from the seed stage to the post-harvest stage.

Seed Stage

At this stage, seeds are bulked resulting to a mixture of mature, immature and insect-infested seeds. However, a simple selection based on seed density and seed size is made. These are indices of survivability and field performance of plants. Cotton seeds are delinted in sulfuric acid solution, washed thoroughly in running water and then dried. Delinted seeds are sorted, selecting only large, dense and fully developed seeds. Sorting of seeds could either be done manually or by using the flotation method.

Large, dense and fully developed seeds have been shown to be able to tolerate seedrot and damping-off, tend to grow faster and become more vigorous and early maturing (Cabangbang, 1978). Dense or heavy seeds are believed to be of high quality since the cotyledons that constitute the large position of the seed is responsible for their being heavy or light. Seeds that do not reach full development before harvest are immature, hence cotyledons that do not reach full development, when

Table 1. Comparative performance of seeds at different germination velocities (UPLB-PCARR Project 147, 1975-79).

Germination velocity (Days after germination)	*Seed-rot and mold infection (%)*	*Damping-off infection (%)*	*Abnormal plants (%)*	*Discarded plants (%)*	*Plants selected (%)*	*Early maturing plants (%)*	*Plant height (%)*	*Boll diameter (cm)*	*Lint (%)*
2	10.4	4.2	22.1	44.9	35.0	55. 0	79.58	3.27	36.16
3	4.7	3.8	31.9	40.7	60.5	41.10	83.37	3.31	33.95
4	10.5	3.7	41.3	50.3	49.7	45.83	83.32	3.30	35.75
5	8.9	4.5	35.3	47.4	52.5	33.26	79.65	3.30	36.02
6	15.1	3.2	26.1	42.4	57.4	22.03	77.60	3.18	36.41
7	34.1	4.1	20.5	56.1	43.8	22.03	72.89	3.11	34.85
8	54.0	3.5	23.13	79.13	20.3	–	74.58	3.31	25.75
MEAN	19.67	3.8	28.6	51.6	45.6	36.5	78.7	3.25	35.55

Figure 2. Seedlings from rapidly germinating seeds are selected and transplanted in plastic cups.

dried, shrink. The air spaces in the seeds are believed to be responsible for the floating of seeds when put in water separating them from "full" seeds that sink to the bottom. The seeds that float are categorized as light seeds and are discarded.

Germination Stage

Selection at this stage is based on deterioration resistance and fast germinability. At this stage, selected seeds from the different entries are germinated in flat trays moistened with pond water covered with moistened materials, e.g. newspaper, provided with an aerobic condition. Pond water encourages seed rot and mold infection. Seeds that do not deteriorate and those that germinate faster are selected. On the other hand, seeds that deteriorate or those that are slow to germinate prolong the period at which they are attacked by microorganisms thus killing them before they can establish themselves into full seedlings. Consequently, those seeds that germinate earlier can benefit from the moisture available in the field at planting time. Studies at UPLB-CA (Cabangbang *et al.*, 1978; Mateo, 1981), on the correlation of resistance to deterioration and germination velocity of seeds to some agronomic features gave evidence to support the soundness of the selection criteria (Table 1).

Table 2. Summary of performance of cotton strains subjected to MAR procedure (1979).

Set No.	*Weight of seeds selected (g)*	*Number of plants transferred to cups*	*Number of plants transformed to pots/seed flats*
1	260	818	–
2	348	891	129
3	360	1,178	12
4	245	1,076	133
5	193	387	51
Total	1,406	4,350	325

Only those seeds which germinated rapidly within 3-4 days from sowing and without mold infection are selected and consequently transplanted in plastic cups.

Seedling Stage

In many cases, seeds may have a germination percentage of 90% and above. However, actual emergence in the field with normal planting conditions will sometimes be 50% or less. Almost always, the seeds germinate but fail to emerge or develop into healthy seedlings. It is the purpose of selecting genotypes that can tolerate seedling diseases to correct this anomaly.

Aside from the effects of extreme fluctuation of moisture supply at planting time, seedling diseases such as seed rot, pre-and post-emergence damping-off and root rot result in reduced field stand. These diseases are caused by a number of fungal and nematode species. The screening procedure against the two pests could be carried out most conveniently and effectively by combining the two organisms in the same media. Seeds are sown in plastic cups infected with *Sclerotium rolfsii* and *Potylenohulus reniformis.* The interaction between nematode and damping-off organisms is a significant phenomenon in this procedure. The presence of nematodes increases the susceptibility of cotton plants to fungal infections by providing infection points for the fungi.

After a period of approximately one month on this selection pressure, five individuals with vigorous and disease-free seedlings or genotypes that are resistant to or can tolerate infection are selected for the next stage of selection pressure.

Vegetative Stage

The selection pressure applied at this stage is confined to sucking insects that greatly affect plant performance. Among the common insects found at this stage are aphids, leafhoppers, thrips and defoliators. The screening consists of rearing

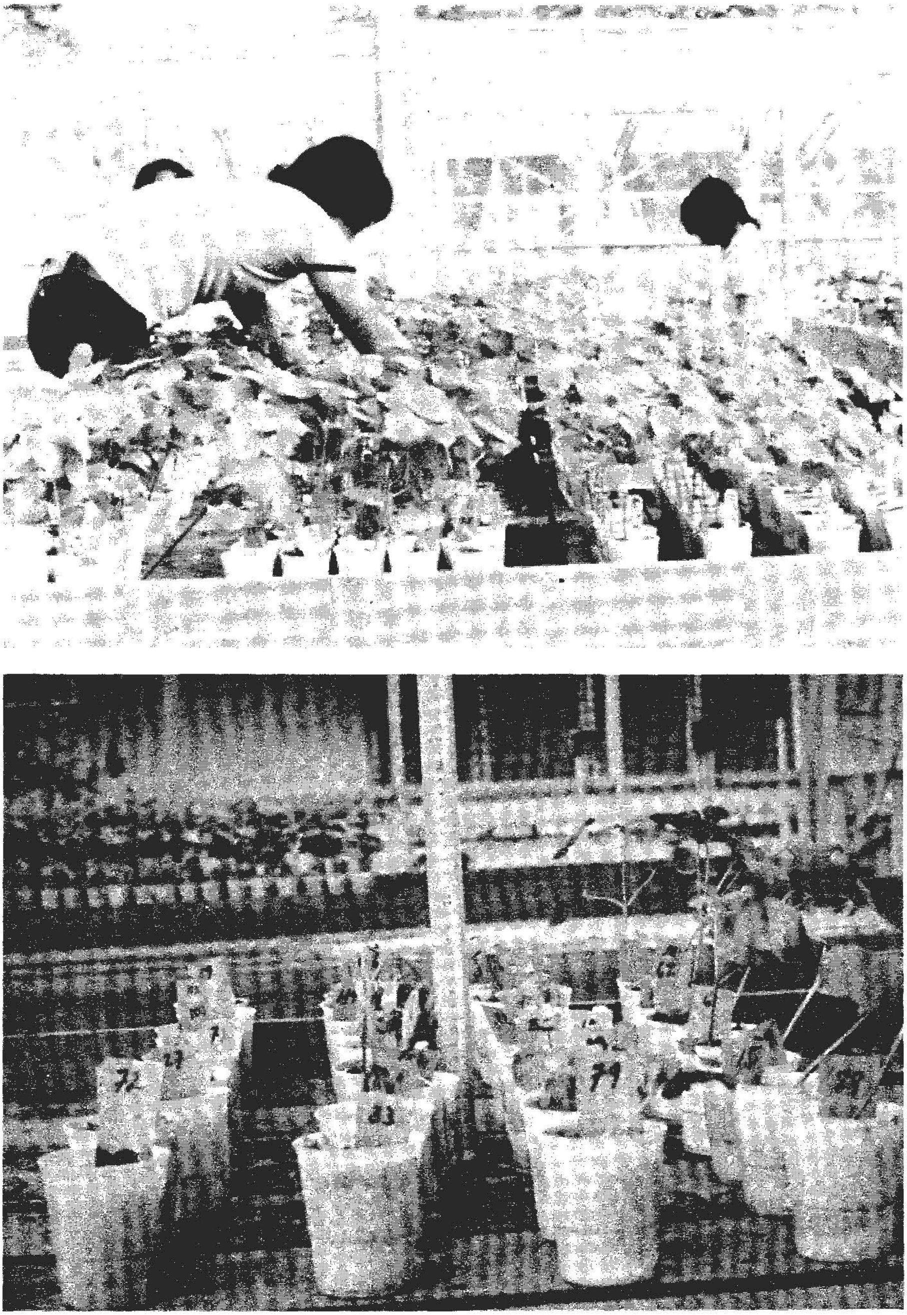


Figure 3. Genotypes that can tolerate seedling diseases like seed-rot, damping-off and root-rot, are selected for at the seedling stage.

Table 3. Performance of MAR selections tested in 2 locations (1979).

Entry	*College, Laguna*				*San Juan, Ilocos Sur*			
	Plant height (cm)	*Weight per boll (cm)*	*Seedcotton yield (kg/ha)*	*Lint recovery (%)*	*Plant height (cm)*	*Weight per boll (cm)*	*Seedcotton yield (kg/ha)*	*Lint recovery (%)*
MAR-67	103.5^{ab}	5.07^{a}	2124.24^{a}	33.97^{a}	64.9^{b}	4.64^{b}	1372.75^{a}	36.53^{a}
MAR-68	133.7^{a}	5.37^{ab}	1740.65^{a}	35.99^{a}	73.0^{ab}	5.43^{a}	1290.96^{a}	38.92^{ab}
MAR-72	98.5^{b}	5.39^{ab}	2368.11^{ab}	34.62^{a}	66.9^{b}	4.79^{a}	1490.74^{a}	35.72^{b}
MAR-82	104.0^{ab}	5.65^{a}	2229.26^{a}	36.02^{a}	79.0^{a}	5.02^{a}	1468.35^{a}	40.55^{a}

Means followed by the same letter(s) are not significantly different from each other.

Figure 4. Disease-free seedlings are selected and transferred to pots for the next stage of selection pressure.

a large number of the three insect species and infesting the seedlings one after the other. When natural infestation of any one of the three insect species is heavy, artificial infestation is discontinued.

Maturity Stage

Selection for morphological features as well as resistance to insects attacking the flower, squares, bolls and other parts is accomplished at this stage. These agronomic characters include nectariless, and hairiness.

The nectariless character of the plant refers to the absence of gland which produces the nectar that serves as an attractant. Nectaries are also major sources of food, primarily sucrose, for several types of moths.

This character has been reported to provide beneficial levels of resistance to plant bugs (*Lygus lineolaris*), cotton leafhopper (*Predatomoscelis sireatus*) and pink bollworm (*Pectinophora gossypiella*). Boll rot organism has been reported to enter through extrafloral flower and boll nectaries; thus, nectariless cotton has reduced boll rotting (Shepherd, 1982).

The screening procedure for bollworm and flowerweevil resistance is quite flexible since a number of techniques could be employed. These include mass rearing and artificially infesting the insect pests and/or subjecting the plants to

Table 4. Mean performance of different cotton varieties in Manaoag, Pangasinan and College, Laguna (Advanced Trial, 1982-81).

Entry	*Plant height (cm)*	*Weight per boll (g)*	*Seedcotton yield (kg/ha.)*	*Lint percentage*
Deltapine 16 (L)	76.9	4.41	994.2	37.5
Acc. 005	72.0	4.43	877.6	37.7
085	78.0	4.07	961.0	36.6
111	75.4	4.38	1020.0	37.2
142	82.2	3.64	907.1	33.1
161	73.4	4.56	994.3	39.1
162	79.2	4.43	948.9	38.2
164	79.3	4.42	958.9	35.4
385	76.7	4.61	956.7	35.8
MAR-67	92.0	4.69	898.3	35.3
MAR-72	93.0	4.43	916.8	33.9
MAR-82	91.2	4.74	780.9	37.7

Table 5. Mean performance of cotton varieties in College, Laguna: Victoria, Tarlac and Polomolok, South Cotabato (Advanced Trial, 1981-82).

Entry	*Plant height (cm)*	*Average weight per boll (g)*	*Seedcotton yield (kg/ha.)*	*Lint percentage*
Batac 1	80.8	4.3	1580.2	37.9
Deltapine 16(L)	83.6	4.4	1379.5	39.0
Acc. 001	80.2	4.5	1404.1	36.7
MAR-67	92.2	4.5	1170.9	33.8
MAR-72	103.2	4.6	1395.9	35.5
Acc. 157	90.8	4.3	1412.0	38.6
394	87.9	5.1	1619.2	36.6
396	71.1	4.2	1659.7	38.8

natural infestation. Growing alternate hosts including susceptible cotton varieties earlier to increase insect population level in time for the selection population is also a convenient method. The problem with this procedure, however, is the complication brought about by the infestation of other insect pests which could not be controlled without killing bollworm or flowerweevil.

Figure 5. The selection pressure applied at the vegetative stage is confined to sucking insects that greatly affect plant performance.

Table 6. Performance of cotton accessions in the 1982-83 preliminary trial at College, Laguna.

Entry	*Plant height (cm)*	*Number of bolls per plant*	*Seedcotton yield (kg&ha.)*	*Lint recovery (!)*
UPL-C1	124.09	5.29	1490.8	39.20
UPL-C2	107.00	5.42	1693.4	38.54
Deltapine 16(A)	120.33	6.36	1862.5	39.28
Acc. 431	140.67	9.25	1882.2	39.66
432	131.33	7.81	1829.7	41.97
436	118.67	7.79	1807.8	40.16
437	100.50	7.19	2135.7	40.63
438	110.00	6.65	1984.1	39.90
439	135.80	5.11	1514.6	39.57
454	154.00	8.97	1641.0	34.03
459	131.00	6.95	1876.4	36.71
MAR-5	117.00	5.09	1234.6	36.72
6	111.67	6.66	1472.1	39.22
7	100.33	6.33	1517.9	38.28
8	105.33	7.73	1505.1	33.74
9	112.00	7.30	1715.3	37.86
10	120.33	6.75	1679.0	34.24
11	122.33	9.40	2380.5	39.51
12	132.33	5.82	1585.9	35.60

Table 7. Fiber properties of cotton accessions in College, Laguna (Preliminary Trial, 1982-83).

Entry	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
UPL-C1	29.0	4.3	77,528	85.0
UPL-C2	29.0	4.4	81,871	88.0
Deltapine 16(A)	29.5	4.1	73,657	86.5
Acc. 431	27.5	3.9	70,577	79.0
432	26.6	4.4	74,941	88.0
436	29.1	4.1	73,277	84.0
437	29.2	4.2	72,669	86.0
438	29.2	3.4	73,123	77.0
439	29.3	4.1	83,342	87.0
454	28.3	4.3	78,848	88.5
459	29.0	4.2	82,364	86.5

Table 7 continued

Entry	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
MAR-5	27.3	4.3	84,620	92.5
6	28.7	4.1	74,789	80.0
7	28.8	4.3	74,864	85.0
8	26.3	4.7	72,467	81.5
9	28.6	4.3	74,701	82.5
10	26.7	4.5	70,597	85.0
11	25.3	4.8	76,785	87.0
12	27.5	4.2	74,277	87.5

Table 8. Performance of cotton varieties entered into the Advanced Trial in three locations (1982-83).

Location	*Entry*	*Plant height (cm)*	*Number of bolls per plant*	*Seedcotton yield (kg/ha.)*	*Lint recovery (%)*
College, Laguna	UPL-C1	93.46	7.29	2021.8	41.30
	UPL-C2	89.60	6.05	1902.7	38.45
	Deltapine 16(A)	106.53	7.22	2016.4	38.62
	Acc. 043	96.13	6.04	2133.0	36.35
	184	94.67	5.09	1754.6	36.90
	MAR-1	109.14	4.36	1669.9	36.63
	MAR-3	125.78	4.21	1529.3	34.39
San Juan, Ilocos Sur	UPL-C1	88.20	6.70	2481.0	40.90
	UPL-C2	88.40	7.80	3014.0	37.20
	Deltapine 16(A)	102.20	6.70	2926.0	33.30
	Acc. 043	94.50	6.80	3061.0	35.50
	184	78.10	5.90	2220.0	36.40
	MAR-1	118.80	4.90	2252.0	40.50
	MAR-3	127.00	4.40	1911.0	36.30
Polomolok, South Cotobato	UPL-C1	102.00	9.50	1900.0	41.10
	UPL-C2	79.90	8.60	2020.0	41.50
	Deltapine 16(A)	107.00	8.60	2320.0	41.60
	Acc. 043	101.20	8.90	2110.0	39.60
	184	93.80	7.40	2060.0	37.80
	MAR-1	109.10	6.40	2220.0	41.00
	MAR-3	120.10	7.70	1750.0	39.20

Table 9. Fiber properties of cotton accessions tested in 3 locations (Advanced Trial, 1982-83).

Location	*Entry*	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
College, Laguna	UPL-C1	28.6	4.10	75,378	85
	UPL-C2	28.7	4.60	84,713	91
	Deltapine 16(A)	28.9	4.00	74,154	83
	Acc. 043	28.1	4.00	81,603	84
	184	26.5	4.20	65,883	79
	MAR-1	26.3	4.00	78,258	85
	MAR-3	28.2	3.90	78,999	85
San Juan, Ilocos Sur	UPL-C1	25.6	5.05	80,305	89
	UPL-C2	28.4	4.36	88,069	87
	Deltapine 16(A)	25.1	5.07	76.939	94
	Acc. 043	25.4	4.56	84,639	88
	184	24.3	4.29	69,249	78
	MAR-1	25.3	4.28	81,361	86
	MAR-3	25.5	4.47	86.014	89
Polomolok, South Cotobato	UPL-C1	26.6	3.16	74,498	67
	UPL-C2	27.8	3.94	81,041	78
	Deltapine 16(A)	27.5	4.40	69,421	78
	Acc. 043	26.0	3.21	74,324	67
	184	26.1	2.90	68,661	54
	MAR-1	27.3	4.12	84.452	80
	MAR-3	26.4	3.68	76,177	77

Post-Harvest Stage

Seeds of plants possessing desirable characters are collected for the preliminary trial. Yield components such as number of bolls per plant, weight of bolls per plant, lint percentage and other necessary components are determined and serve as bases for selection.

a. Number of bolls per plant. Inasmuch as the plant had been subjected to similar stress condition, it is assumed that individual plants with more bolls have higher yield potentials than those with lesser number of bolls.

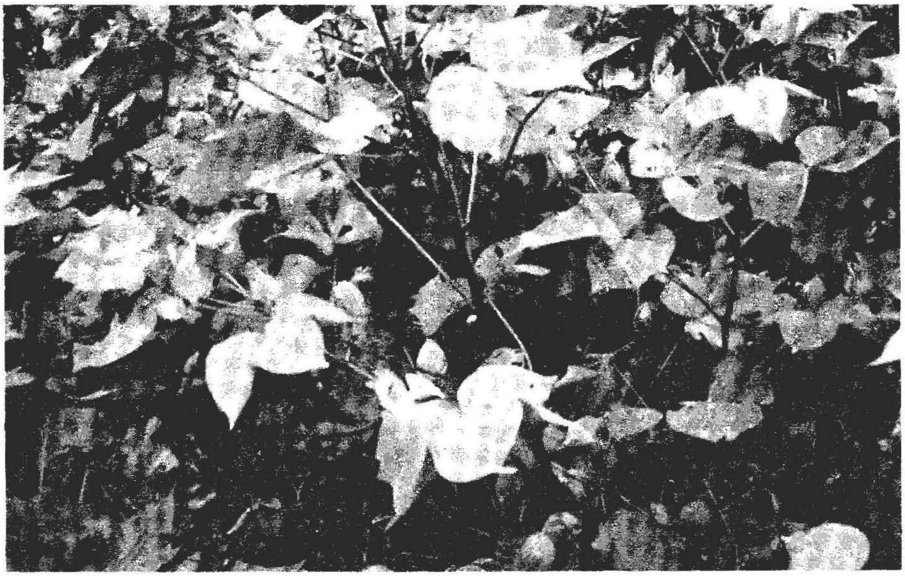


Figure 6. At the maturity stage, selection for morphological features as well as resistance to insects attacking the flower, squares, bolls and other parts is done.

Figure 7. Selected strains are entered into variety trials in different locations to obtain additional information on their resistance and agronomic characteristics.

b. Average weight per boll. Assuming the same number of bolls, plants with heavier boll will have higher yield potential than those with lighter bolls.

c. Lint percentage. Cultivars with high lint percentage is highly desired since quality and quantity of lint harvested determine varietal potential. Usually, lint recovery from the farm is about one-third of seedcotton harvested.

Varietal Trials

The performance of four (4) cotton strains subjected to the MAR procedure in 1979 is indicated in Table 2. In the same year four (4) selections from a previous MAR test were entered into the preliminary test in College, Laguna and San Juan, Ilocos Sur. Table 3 indicates the results of the test. Three of these varieties were carried on to the Advanced Trial at Manaoag, Pangasinan and College, Laguna in 1980 (Table 4). The Advanced Trial of 1981-82 again included two MAR selections (Table 5). This was conducted in three (3) locations: College, Laguna; Victoria, Tarlac and Polomolok, South Cotobato. During the 1982-83 cropping season, other MAR selections were entered into the preliminary (Tables 6 and 7) and advanced (Table 8 and 9) tests. These include the fiber properties of the cotton strains tested.

Conclusion

The MAR procedure should be a standard breeding technique for multi-adversity resistance. Subjecting the plants to a succession of pressure from seed stage to harvest stage should yield an improved population. The replicated yield trials are expected to give additional information for a more reliable index of resistance and agronomic characteristics.

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M.M. Lantin, Discussant

A crop breeding program is usually aimed at improving not only one but several traits that determine the total worth of a cultivar. In addition to yield and quality, traits being improved include production stabilizing attributes such as resistance to insect pests, diseases and environmental conditions that adversely affect crop productivity. Cotton is a host to a variety of pathogens and insect pests. It is one of the world's important crops that is grown under the protection of large amounts of pesticides. Genetic resistance to pests is obviously desirable and it is always a major objective of the total breeding effort for this crop.

Multi-adversity resistance (MAR) is a common goal of most crop breeding programs. Differences, however, exist in the basic strategies used in accomplishing this objective. The cotton breeding program at the Institute of Plant Breeding adopts a scheme wherein sequential selection pressures are imposed at various stages of the crop (during which the different adversities occur) from seed to maturity. It is an integrated and fairly comprehensive procedure that systematically combines screening for resistance to insect pests and diseases with selection for good seedling vigor and high yield. However, this same feature basically characterizes all multiple-trait selection schemes. So how does the MAR breeding procedure as described in the paper differ from the other schemes? What are the limitations of such a selection system? Under what conditions could we expect it to be successful?

The MAR breeding procedure is what one may call an "all-or-nothing" kind of selection system. If a particular genotype fails to pass the seed or seedling stage screenings then it is discarded and not exposed anymore to other adversities in later stages of growth. The high selection pressure imposed in the early stages usually results in the elimination of large fraction of the population being screened. The number is further reduced in subsequent stages and oftentimes, the breeder is left with very few genotypes even before the maturity stage. It may then turn out that the surviving few would not be acceptable because of low yield rating as indicated by the different yield components. This tandem method of improvement differs from the more common independent culling scheme where each genotype being evaluated has complete data on the traits which are being improved simultaneously. The breeder discards or retains a genotype on the basis of minimum scores set for the different traits. Such breeding procedure recognizes the possible inverse relationships that may exist among traits. In such cases, the breeder may choose to give higher weights to more important traits. For example, the breeder would probably save a genotype that yields 4 tons per hectare even if it has a relatively lower level of resistance to a disease. Combining the traits in an index which becomes the sole selection criterion could even lead to faster progress.

Progress in plant breeding, however, is not solely dependent on the selection procedures or the means through which the desired genotype is isolated from the source population. The nature of the breeding population itself plays an equally important, if not a more dominant, role. No amount of selection effort would result to the desired type if, to start with, the genes are not present in the source population. The key to the successful development of the target genotype through MAR breeding procedure or any multiple-trait selection scheme is the creation of a broad-based gene pool which has all the genes controlling the desired traits. This is developed out of germplasms previously screened or evaluated for the different traits. Such assemblage of genes should be allowed to undergo as many generations of recombination as possible in order to generate new genic combinations involving as many resistance genes and yield genes as required. Selection can then proceed with higher probability of isolating the desired high-yielding and multi-adversity resistant cultivar.

Gregorio B. Begonia, Discussant

By exposing the selection population to a battery of selection pressures throughout the growing cycle of the plant, we can select cotton genotypes possessing multi-adversity resistance in a relatively short time. The above features of the MAR breeding technique as excellently described by Dr. Cabangbang make the method a very efficient and effective tool in plant breeding – especially in cotton where it was first tested way back in the early 60's.

However, despite the merits and simplicity of the breeding procedure, there are some points that need further clarification.

a. *Definition of the parental generation:*
The characteristics/attributes of the parents involved in the crosses must be clearly defined. It is very unlikely that we can find all the necessary attributes in a few parents. In other words, we need a substantial number of parents to create a wide germplasm pool that contain all the attributes mentioned in the MAR procedure. If we have already created a wide germplasm pool, I think that is the appropriate time to tinker with MAR.

b. *Population Size:*
If we commence the MAR procedure using F_2, F_3, etc. materials, how big is the population to start with? The basic question here is: How many genes control each of the characters involved in the MAR procedure? We must note that as the number of genes determining a certain character is increased, a corresponding increase in the population is needed in order to obtain the desirable recombinations. Also, the question of population size is further complicated if there is *linkage*. The closer the genes are, the lesser the chance to break that linkage. In order to observe the desirable recombination, you need a large

population. Furthermore, we still need to know the linkage relationship between characters.

c. *What is the most effective generation for selection?*
Is it the F_2, the F_3, or what?
We must remember that not all characters can be effectively evaluated at an early generation of the segregating population (F_2, F_3). For example, if we use F_2, this may be effective for qualitative characters (e.g. petal colors, etc.) but not for quantitative characters (e.g. yield).