YIELD AND COMBINING ABILITIES IN ANDIGENA POTATOES AFTER SIX CYCLES OF RECURRENT PHENOTYPIC SELECTION FOR ADAPTATION TO LONG DAY CONDITIONS[1]

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Abstract

Changes in yielding ability were studied in a population of Andigena which had been subjected to six cycles of selection. Significant increases were detected for percent tuberization, mean yield per hill, mean tuber weight, and average rating for tuber appearance. The earliest improvement in yield was largely the result of improving percentage of tuberization. Later gains came from improving mean tuber weight as well as continued improvement in percentage of tuberization. The largest improvement was observed during the last cycle of selection.

Changes in combining ability were studied in twenty test-crosses produced by pollinating four *Tuberosum* females with bulked pollen from plants within each of five of the six *Andigena* cycles. Appreciable gains were observed for total yield, mean tuber weight, and yield of large tubers. The most advanced hybrids outyielded a comparable group of seven *Tuberosum* x *Tuberosum* progenies with regards to total yield, tuber number, and yield of large tubers. Mean tuber weight was similar in both groups.

The overall results suggest the potential of *Andigena* in the production of inter-group hybrids. The results also indicate that the limits of improvement in the *Andigena* population have not yet been reached and that the combining ability with Tuberosum should continue to improve.

Resumen

Se han estudiado los cambios en la capacidad de rendimiento de una población de Andigena sujeta a seis ciclos de selección. Se determinaron incrementos significativos para el porcentaje de tuberización, rendimiento promedio por planta, rendimiento promedio de tubérculo y promedio de calificación para la aparencia del tubérculo. El incremento inicial en rendimiento fue mayormente el resultado de mejorar el porcentaje de tuberización. Los incrementos posteriores fueron el resultado de mejoras en el rendimiento promedio del tubérculo al igual que mejoras contínuas en el

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porcentaje de tuberización. La mejora más significativa se observó durante el último ciclo de selección.

Se estudiaron los cambios en la habilidad combinatoria de veinte cruces de pruebas producidos por la polinización de cuatro hembras *Tuberosum* con una mezcla de polen proveniente de plantas dentro de cada uno de los cruces de los seis ciclos de *Andigena*. Se observaron apreciables ganancias para el rendimiento total, peso promedio de tubérculo y rendimiento de tubérculos grandes. Los híbridos más avanzados superaron a un grupo comparable de progenies de siete híbridos *Tuberosum* x *Tuberosum* con respecto al rendimiento total, número de tubérculos y rendimiento de tubérculos grandes. El rendimiento promedio de tubérculo fue similar en ambos grupos.

Los resultados totales sugieron el potencial de *Andigena* en la producción de híbridos inter-grupos. Estos resultados también indican que los límites de mejoramiento en las población de Andigena, todavía no han sido alcanzados y que la habilidad combinatoria con *Tuberosum* continuará sujeta a mejoramiento.

Introduction

The white potato (*Solanum tuberosum* ssp. *tuberosum* Hawkes) (Tub) varieties of North America and Europe are the result of several generations of hybridization and selection within a limited gene pool. This suggests that intense selection for yield improvement may have reduced genetic variability to the extent that further progress may be difficult to attain.

Several potato breeding programs have developed selection programs which involve ssp. *andigena* (Adg) as the foundation genetic material. Paxman (8) in 1965, working with some of N.W. Simmonds' selections observed that the amount of heterosis existing in some inter-group hybrids surpassed by far the yield of the most productive intra-group progenies. Simmonds (10) reported progress on the performance of an Adg population which had been subjected to 2 cycles of selection over a period of 6 years. His results show a radical improvement with regards to percentage of tuberization, tuber yield, mean tuber weight, tuber number and a slight decrease in top weight.

Since 1969 D.R. Glendinning (2-7) has made several reports on the progress of Adg-Tub hybrid progenies after taking charge of Simmonds' experiment with Neotuberosum. Most of his reports show gradual but consistent improvements in the performance of both inter-group hybrids and intra-adg progenies with regards to tuber yield and other agronomic traits.

T.R. Tarn and G.C.C. Tai (11, 12) have also made several reports on the behavior on inter- and intra-group progenies involving selected Adg and Tub. They have shown improvements in favor of selected Adg x Adg progenies and inter-group hybrids as compared to the performance of intra-Tub progenies. Tarn and Tai and Glendinning have made it clear, however, that

the expression of heterosis in Adg-Tub inter-group hybrids relies heavily on previous selection for adaptation to north temperate conditions within the exotic Adg material.

In 1974, A.G. Cubillos (1) presented information on the yielding ability of intra- and inter-group F_1 Adg-Tub hybrids. The Adg stocks had undergone five cycles of phenotypic recurrent selection for adaptation to long day conditions. At northern latitudes, Cubillos reported a consistent 15 to 19% increase in total yield in favor of the inter-group hybrids.

The potato project at Cornell University has produced 6 cycles of phenotypic recurrent selection of Adg for adaptation to long day conditions. The details have been described by Rasco (9). The purpose of the present work is to evaluate the ability to tuberize, changes in yielding ability as they relate to tuber weight and number, as well as changes in external appearance of these cycles. A second part of this work is designed to evaluate the effects of selection on the combining ability of the same set of Neotuberosum materials. This is approached by testing the performance in yield of representative samples of the same sub-populations in hybrid combination with a set of Tub clones.

Materials and Methods

In 1963, a collection of hybrid Adg progenies was obtained from breeding programs in Peru and Colombia. Seeds originating in the CPC which had one cycle of selection in England were obtained from N.W. Simmonds. Selections were made and crosses attempted between selections within the Simmonds' and within the S. American sources. This represents the completion of the first cycle. These seeds were sown and the seedlings transplanted directly in the field along with an equal number of seedlings from a second introduction from Simmonds which had an additional cycle of selection in England. Reproduction was by means of seeds from open pollinated fruits from plants selected for their tuber yield. Identity of female lineage was preserved. This procedure was repeated for the third cycle. The OP seeds of the fourth cycle were sown and the seedlings transplanted directly to the field. Selections for tuber yield were made and plants of these selections were grown in the greenhouse where they were intercrossed using bulked pollen. This represents the start of the fifth cycle. This same sequence was repeated and the crosses among the fifth cycle selections produced the sixth cycle. The selection intensity at each cycle as measured by the ratio of the number of clones selected to be parents to the number of plants grown in the field was between 3.6% and 4.9% for the first five cycles and 0.8% the sixth cycle.

To alleviate some of the differences in inbreeding among cycles due to use of open pollinated or cross pollinated seeds, remnant OP seeds of the second through fifth cycle generations, harvested in bulk from the plants in

the field, were planted and fifty unselected seedlings from each cycle were intercrossed in bulk within each cycle. The fifth cycle selections were intercrossed to produce the sixth cycle. No remnant seeds of the original population were available, but a second introduction from the Commonwealth Potato Collection and from South America had been made and bulk OP seeds from these introductions were used to produce 50 seedlings for intercrossing to produce seeds to represent the 0 cycle.

The bulk pollen collected from the 50 plants of each of five cycles was used to pollinate four tuberosum clones: Hudson, NY59, NY60, and NY62. These seeds were used in the combining ability experiments. All the research was conducted at Ithaca, NY.

Three yield trials of the performance of the successive cycles of the andigena populations were conducted. The 1977 trial consisted of five replications of 72 transplants per treatment spaced at 91 cm. These were placed in the field on May 26, and the vines were killed on September 5. Tubers saved from the 1977 trial were used to plant a similar trial in 1978. This trial had six replications of 50 hills per cycle at a spacing of 1.02 meters. It was planted May 12, and the vines killed on September 11. The 1979 trial was also planted with tubers, but these had been produced in pots in the greenhouse in 1978. This trial had 10 replicates of 20 hill plots at 30 cm spacing. This was planted on April 30, and the vines killed on September 4.

The yield trials of the combining ability section of the experiment were conducted in 1978 and 1979. The seed for these trials was seedling tubers produced in the greenhouse in pots in 1977 and 1978. In 1978, the growing season was from May 12 to September 12, and in 1979 from April 30 to September 4. There were five replications of 20 hill plots planted at 30 cm spacing between hills. In the 1979 trial, the cultivar Katahdin and seven progenies derived from crosses between the four tuberosum testers and two common tuberosum bulk pollen sources were included.

Results and Discussion

Percentage of tuberization in the Adg population was markerdly improved with selection (Table 1).

TABLE 1. — *Percent tuberization of six cycles of selection. 1977 data.*

Cycle	Percent tuberization
0	21.7±2.3
2	58.9±8.4
3	52.1±7.3
4	59.0±3.4
5	77.0±4.5
6	85.0±8.3

It appears that the improvement in percentage of tuberization was negligible between the second and fourth cycles or that the performance of the second cycle was unusually good. Similar performances of the second cycle occurred in a related experiment by Rasco (9) which used remnant cycle seeds directly rather than the randomly mated offspring used in this trial. The positive response to selection for percentage of tuberization suggests that considerable variability for this trait exists in andigena and that it is relatively responsive to selection (Table 2). Similarly, mean yield per hill

TABLE 2. — *Yield characteristics for six cycles of selection in three years of trial.*

Cycle	Mean yield per hill (kg)			Tuber number per hill			Mean tuber weight (g)		
	1977	1978	1979	1977	1978	1979	1977	1978	1979
0	.18	.54	.24	16.6	15.3	1.9	11	36	59
2	.21	.94	.89	14.4	16.3	7.7	16	59	54
3	.19	.92	.71	14.3	19.6	7.0	13	48	47
4	.30	1.13	.78	19.1	19.8	6.0	16	57	60
5	.31	1.20	.96	15.6	14.8	6.2	20	73	70
6	.63	1.64	1.84	16.3	17.9	9.3	38	93	91
SMRT	.13	.49	.60	5.5	8.8	4.2	16	29	30

responded to selection. Again the second cycle seemed to be an exception to a steady improvement. Without it, the average yield in kg. per hill over three years of tests was as follows: 0.32, 0.61, 0.74, 0.82, and 1.37 for the 0, 3, 4, 5, and 6 cycles, respectively. The second cycle mean was 0.68 kg. The greater gain in the last cycle of selection is reasonable in light of the greater selection pressure applied in producing that cycle. Since the 1978 and 1979 trials were planted with tubers, those clones which could not produce tubers were eliminated. Thus, the early cycles with a higher percentage of such clones received a favorable bias.

The tuber number per hill is also presented in Table 2. The disparity between 1979 and the other two years is due to the difference in spacing, from 30 cm to .90 or 1.0 meters. The numbers fluctuated between 15 and 20 per hill in widely spaced plants with no consistent changes due to cycles of selections. This was not expected in light of the selection for tuber size applied in the later cycles.

Mean tuber weights showed seasonal differences (Table 2), but the effects of selection were evident. The average of the three year's data was 35g, 43g, 36g, 44g, 54g, and 74g, for the 0, 2, 3, 4, 5, and 6 cycles, respectively. Again the second cycle was higher than the third cycle. The greater gains in

the fifth and sixth cycles are not surprising in light of the greater emphasis given to this trait in these cycles.

Although the rating for tuber appearance was assessed in a subjective way, the data presented in Table 3 show a consistent improvement. Similarly, the

TABLE 3. — *Mean ratings for tuber appearance*[a]

Cycle	1977	1979
0	2.3 ± 0.1	2.0 ± 0.1
2	2.4 ± 0.1	2.1 ± 0.1
3	2.6 ± 0.1	2.0 ± 0.1
4	2.7 ± 0.1	2.6 ± 0.1
5	2.8 ± 0.1	2.8 ± 0.1
6	3.5 ± 0.1	3.6 ± 0.2
SMRT[b]	0.21	1.01

[a]Tuber appearance ratings: 1 = poorest, ..., 5 = nicest.
[b]Scheffé's multiple range test at 5% level.

percentage of tubers with white skin and white flesh was also increased (Table 4). Though no direct selection pressure was applied for white flower color, it also increased in frequency.

TABLE 4. — *Percent of clones with white flowers, white-skinned tubers and light colored tuber flesh: 1977 data.*

Cycle	White flowers	White skin	Light-colored flesh
0	3 ± 0.8	57 ± 4	78 ± 8.0
2	44 ± 5.0	74 ± 6	69 ± 4.0
3	48 ± 0.8	77 ± 4	74 ± 4.0
4	37 ± 1.0	87 ± 2	85 ± 4.0
5	55 ± 5.0	68 ± 1	86 ± 2.0
6	66 ± 2.0	96 ± 2	99 ± 0.4
SMRT[a]	15	11	19

[a]Scheffé's multiple range test values at 1% level.

The results of the combining trials in 1978 and 1979 are presented in Table 5. The analysis of variance of these data showed that the variation among the tuberosum testers was not significant for yield and tuber number, but was for tuber weight. The combining ability for yield of the

TABLE 5. — *Mean yield and tuber number per hill and tuber weight of the combining ability trial progenies.*

Parental Stocks	Yield per hill (kg 1978	1979	Tuber number per hill 1978	1979	tuber weight (g) 1978	1979
			Tuberosum clones as females			
Hudson	.74	.61	7.8	7.3	95	87
NY59	.68	.53	7.7	6.8	88	80
NY62	.61	.61	7.6	7.9	80	79
NY60	.63	.70	7.5	7.7	89	92
			Andigena populations as males			
Cycle 0	.56	.47	9.7	7.7	58	62
Cycle 2	.69	.53	8.2	7.3	85	77
Cycle 3	.65	.60	7.1	7.4	93	82
Cycle 4	.59	.64	6.5	7.5	91	87
Cycle 6	.84	.83	6.9	7.3	121	115
Tub x Tub		.66		5.3		129
Katahdin		.77		3.9		201

Adg cycles improved over cycles. Though this trend was erratic in 1978, the combined analysis of variance (2 year's data) produced a highly significant F value of 8.95. The interaction between Tub testers and Adg cycles was also highly significant ($F = 3.99$). The tuber number component of yield in the hybrid progenies was not significant within either set of parents. The effect of selection for larger tuber size was evident in the progenies of Tub x Adg hybrids. The mean tuber weight of the hybrids of the sixth cycle was double that of the hybrids of the unselected cycle and almost as large as Tub x Tub hybrids. The combined ANOVA for tuber weight had an F value of 50.7 for comparisons among the andigena cycles. The variation among Tub clones had an F of 4.8 and the interaction between the two an F of 1.0.

The results are presented on a per plot basis in Figures 1, 2, and 3. Included in these graphs for comparison with the sixth cycle progenies are plots of the performance of Katahdin, and the progenies of the Tub testers, and two bulk sets of Tub clones. The Tub x Adg hybrids from the sixth cycle yielded more than the Tub x Tub hybrids and were equal to Katahdin. In yield of tubers larger than 4.76 cm, Katahdin produced 12.9 kg, the Tub x Tub hybrids 8.1 kg, and the Tub x sixth cycle Adg hybrids 9.3 kg. The larger number of tubers in the Tub x Adg hybrids is illustrated in Figure 2. The steady improvement in tuber size over cycles of selection is illustrated in Figure 3, however, the mean size is still less than Tub x Tub progenies and markedly less than Katahdin.

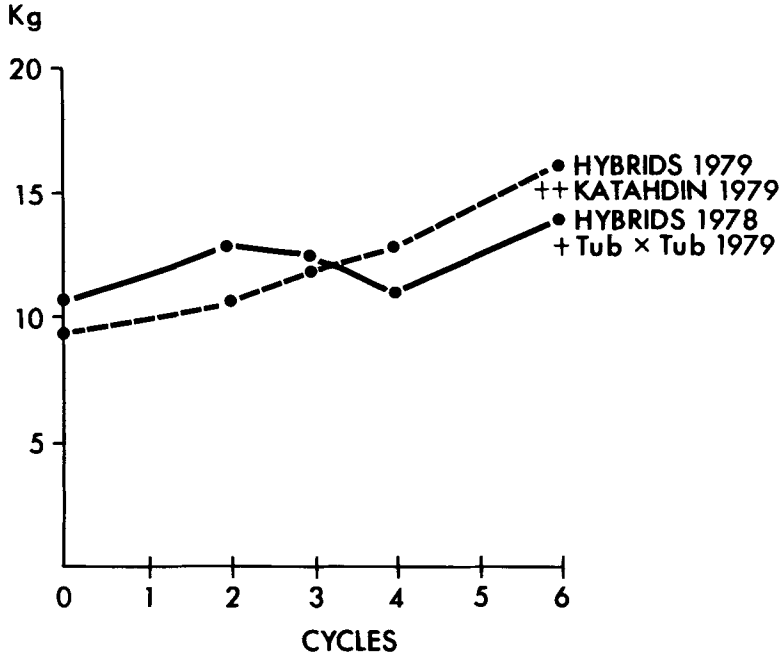

FIG. 1. Mean yield per plot of hybrids between andigena from 6 cycles of selection and a common set of tuberosum clones.

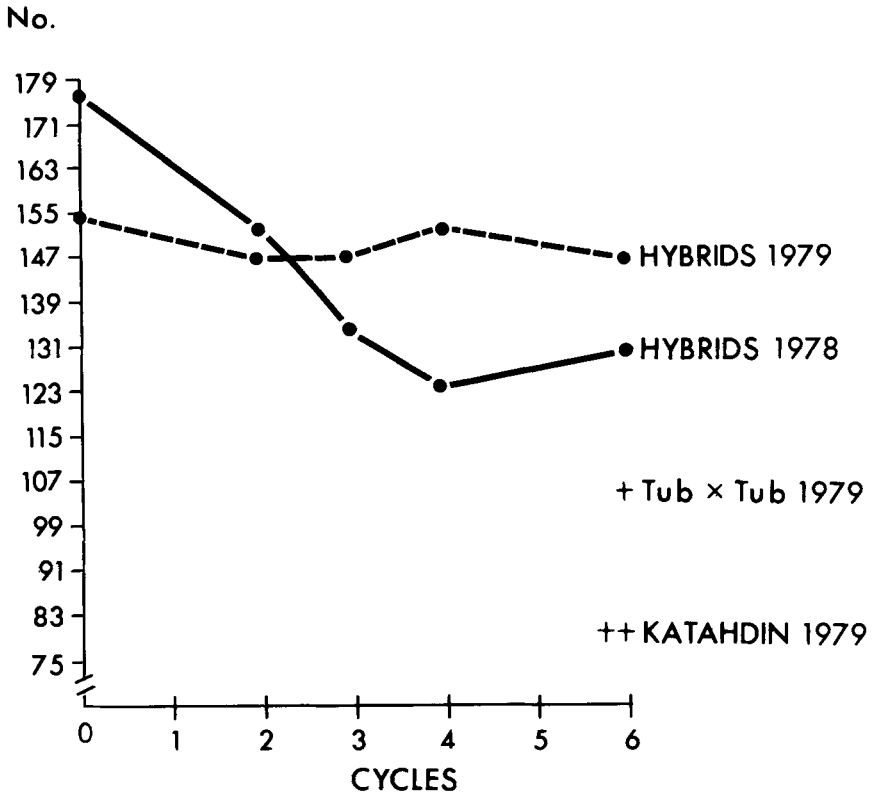

FIG. 2. Mean tuber number per plot of hybrids between andigena from 6 cycles of selection and a common set of tuberosum clones.

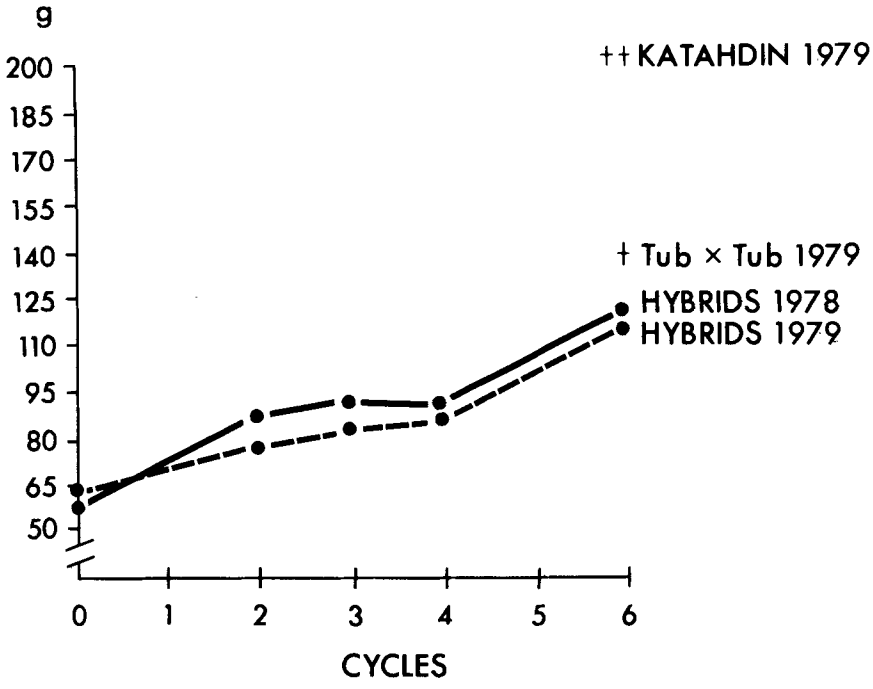

FIG. 3. Mean tuber weight of hybrids between andigena from 6 cycles of selection and a common set of tuberosum clones.

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