Chlorophyll and carotenoid contents of **Pinus caribaea** seedlings and inferences for adaptability[1/*]

C. R. VENATOR**, C. D. HOWES***, LEHEL TELEK****

COMPENDIO

Un análisis estadístico demostró que no hubo correlación lineal entre el contenido de los pigmentos fotosintéticos de Pinus caribaea, *la altitud, y la cantidad de lluvia. Las procedencias insulares tenían mayores concentraciones de pigmentos que las procedencias continentales, sin embargo el crecimiento de las procedencias insulares fue peor que el de las procedencias continentales. La razón molar entre los pigmentos fotosintéticos fue correlacionado en forma negativa con el crecimiento y debido a esta relación se espera poder usar este parámetro para estimar el potencial adaptativo cuando se estudien procedencias.*

Introduction

VARIATION in pigment content within a species is probably related to the climatic origin of the material. For example, plants with the C_4 dicarboxylic acid pathway belong to taxa that originated in areas having intense solar radiation, hot daytime temperatures, and seasonal dry periods (7). They utilize higher light intensities than plants with the Calvin bio-synthetic pathway. This difference apparently results from natural selection for adaptation to particular environments.

Chlorophyll and carotenoid concentrations have also been shown to vary with altitude. In Scots pine *(Pinus silvestris)*, pigment content has been reported to increase as seed origin altitude decreased (1, 9) and conversely to increase as altitude increased (5).

Investigations of carotenoids during the past two decades have revealed that this pigment group is closely associated with chlorophyll in the chloroplast. Quantitative variation in leaf carotenoids occur when plants are moved from one habitat to another (12), and the chlorophyll carotenoid molar ratio could possibly be indicative of a provenance's adaptability. Since carotenoids protect chlorophyll against photo-oxidation (8), plants with a large proportion of carotenoids should be able to withstand the intense solar radiation at high altitudes and to grow in a wider range of altitudes than those with less carotenoids. Wolken (13) has estimated that the chlorophyll/carotenoid molar ratio ranges from 4:1 to 6:1. Thus, within certain limits the chlorophyll/carotenoid molar ratio should be at its optimum in favorable environmental and deviations from this weight ratio may be a physiological reflection of the capacity of plants to adapt to environmental stresses.

The purpose of the present study was to determine if pigment contents differ among 16 provenances of *Pinus caribaea* Morelet and, if possible, to relate any such differences to conditions at the provenance origin. The relationship of pigment content to growth rate and adaptability of the provenance was also examined.

Material and Methods

Nursery Phase. Sixteen seed sources of the Commonwealth Forestry Institute's *Pinus caribaea* international provenance trial (Table 1) were sown in vermiculite germination beds. Within 6 days after emergence, the seedlings were transplanted into clear, polythylene bags (10 × 23 cm) containing a sandy loam soil (pH 5.4). No shade or fertilizer was used in the nursery beds. The Institute of Tropical Forestry nursery is 28 m above sea level at latitude 18°24' N and longitude 66°05' W. Mean annual temperature is 26°C, and mean annual rainfall is 1,800 mm.

Seedling height growth was determined at the time of the first pigment extraction.

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1/ In cooperation with the University of Puerto Rico

** Institute of Tropical Forestry, P. O. Box AQ, Rio Piedras, P. R. 00928

*** Technical Services Department, Loma Lina Foods, Mount Vernon, Ohio 13050

**** Agriculture Research Service, Federal Experimental Station, Mayaguez, P. R. 00709

Table 1.—Comparative data on altitude, rainfall, and geographic origin of *Pinus caribaea* provenances. Data has been abstracted from information supplied by Oxford University except when otherwise noted. Dashed lines indicate that information is not available.

Oxon Number and Variety	Country	Latitude	Longitude	Altitude	Annual rainfall
				Meters asl	*Mm*
var. *bahamensis*					
69(7296)	Bahama Islands[1/]	24°30' N	78°20' W	10	1650
var. *caribaea*					
19/71	Cuba[2/]	22°00' N	83°20' W	300	1750
24/71	Cuba[2/]	22°80 N	83°75' W	50	1750
var. *hondurensis*					
21/70	Nicaragua	12°58' N	83°31' W	10	3500
22/70	Nicaragua	13°31' N	84°17 W	25	2900
24/70	Nicaragua	14°25 N	83°55 W	75	2800
26/70	Guatemala	16°20' N	89°25' W	500	1700
27/70	Honduras	15°45' N	84°40' W	10	2800
28/70	Honduras[3/]	16°27 N	85°54 W	75	2300
34/71	Honduras	14°34' N	86°44 W	600	1000
37/71	Honduras	15°06' N	85°37' W	500	1500
40/71	Honduras	15°20 N	88°25 W	650	1200
44/71	Belize	17°00 N	88°55' W	400	1600
45/71	Nicaragua	13°48' N	86°12' W	700	1500
46/71	Belize[4/]	—	—	—	1500
47/71	Belize	17°00 N	88°20' W	10	2000

1/ Andros Island.

2/ No data from Cuba accompanied the seed lots 24/71 and 19/71.
Information in the Table has been abastracted from FAO Study Tour (4) and Barrett and Golfari (2).

3/ Guanaja Island.

4/ This seed source was provided by Queensland, Australia, from a clonal improved stand of Belize origin.

Chlorophyll Determination. Seven months after germination equal numbers of secondary needles were taken from the midsection of 20 randomly selected seedlings of each provenance. To get an estimate of the provenance (or population) pigment concentration, the needles were pooled, weighed, and immediately homogenized in acetone (100 per cent) with 0.01 g of magnesium carbonate. The acetone extract was brought to volume (250 ml) and thoroughly mixed. Ten ml of this extract was centrifuged at 1470 xG for 7 minutes. This fraction was measured for absorption at 645 and 663 nm (11). A second extraction and determination of pigment content was done 8 months after germination, and the results were pooled with the earlier measurements.

Carotenoid Determination. The chlorophyll-acetone extract was saponified for 25 minutes with a potassium hydroxide-methanol solution, prepared by dissolving 25 g of KOH in 100 ml of methanol. The carotenoids were extracted with petroleum ether followed by a water rinse. This process was repeated until all of the carotenoids were extracted. The carotenoid extract was brought to volume and read at 450 mm. The concentration of carotenoids per gram of needle tissue was calculated with an extinction coefficient E 1% 1 cm 1% value of 2500 at 450 nm (3).

Molar Chlorophyll/Carotenoid Ratio. The molar chlorophyll/carotenoid ratio was determined by the following equation (assuming an average molecular weight of 1000 for chlorophyll a + b and 572 for the carotenoids).

$$\text{Molar Ratio} = \frac{\text{Chlorophyll concentration } (a+b)/1000}{\text{Carotenoid concentration}/572}$$

Field Phase On August 1, 1973, 9 month-old seedlings were planted at Las Marias, Puerto Rico Altitude at this site varies from 180 to 200 m asl, mean annual rainfall is 2,500 mm, and mean annual temperature is 25°C The soil is a deep, red, acid, mountain clay of the Humatas series The area was cleared by machete, and the seedlings were planted on a slope with a south east aspect

On November 1, secondary needles were removed from the mid-section of 20 randomly selected seedlings of each provenance The needles of each provenance were pooled, enclosed in aluminum foil, and brought to the laboratory where the chlorophyll and carotenoids were immediately extracted following the procedures outlined above and the chlorophyll/carotenoid molar ratios were determined. Additional collections and extractions were made on November 28 and December 27, 1973

Results

Chlorophyll Content of Nursery Seedlings Seedling chlorophyll content of the individual provenances ranged from 390 4 to 1570 μg/g The mean for all 16 provenances was 751 3 μg/g (± 63 51) Chlorophyll contents of the individual varieties averaged 1570 μg/g for *P caribaea* var *bahamensis*, 880 9 μg/g for *P. caribaea* var *caribaea*, and 688.4 μg/g for *P. caribaea* var, *hondurensis* (Table 2) Thus, the chlorophyll content of the insular provenances was greater than of the continental provenances

The provenances were divided into a low-altitude group ranging from 10 to 300 m above sea level and a high-altitude group ranging from 400 to 700 m Mean chlorophyll content of the low-altitude group was 779 6 μg/g (± 112 46) However, if the insular provenances, *P caribaea* var. *bahamensis* and *P. caribaea* var *caribaea* are excluded, the mean chlorophyll content of the low-altitude provenances of *P. caribaea* var *hondurensis* was 614 1 μg/g Mean chlorophyll content of the high-altitude group (*P caribaea* var *hondurensis* provenances only) was 715 0 μg/g (Table 2)

Chlorophyll Content of Field Seedlings After outplanting, chlorophyll content of the individual provenances ranged from 764 3 to 2,133 4 μg/g, and the mean for all provenances was 1327 6 μg/g (± 98 26) Chlorophyll contents of the individual varieties were *P caribaea* var *bahamensis*, 1567 μg/g; *P caribaea* var *caribaea*, 1954 4 μg/g; and *P caribaea* var *hondurensis*, 1212 7 μg/g (Table 2)

Chlorophyll content of *P caribaea* var. *bahamensis* did not increase after outplanting Chlorophyll content of the *P caribaea* var *caribaea* provenances increased

Table 2 —Mean chlorophyll and carotenoid concentrations (± standard errors) and chlorophyll/carotenoid molar ratios for nursery and field seedlings randomly selected from each of 16 *Pinus caribaea* provenances plus the percent of increase in pigment content after outplanting

	var *bahamensis* (10 meters asl)	var *caribaea* (50 and 300)	var *hondurensis* High altitude (400 to 700 meters asl)	var *hondurensis* Low altitude (10 to 75) meters asl)	var *hondurensis* High and low
Nursery phase[1]					
chlorophyll, μg/g	1570 0	880 9 ± 76 95	715 0 ± 54 50	614 1 ± 54 50	688 1 ± 32 33
carotenoid, μg/g	156 9	119 3 ± 4 85	99 0 ± 6.62	101 4 ± 7 96	100 1 ± 4 91
chl: carot molar ratio	5 72	4 22	4 13	3 47	3 85
Field phase[2]					
chlorophyll, μg/g	1567 0	1954 5 ± 179 00	1147 5 ± 119 75	1288 8 ± 138 01	1212 7 ± 89 09
carotenoid, μg/g	157 2	171 3 ± 0 80	139 1 ± 11 61	155 0 ± 8 52	146 5 ± 7 45
chl: carot molar ratio	5 71	6 53	4 72	4 75	4 74
Percent increase from nursery to field					
chlorophyll	—0 19	121 9	60 5	109 8	77 7
carotenoids	0 12	43 6	40 5	52 9	46 5

1/ Pigment content of nursery seedlings was determined on needles from 20 random seedlings of each provenance at 7 months and at 8 months; values from the two measurements were pooled

2/ Pigment content of 20 field seedlings of each provenance was determined 3, 4, and 5 months after outplanting and pooled

121.9 per cent. Chlorophyll content of the low-altitude *P. caribaea* var. *hondurensis* provenances increased 109.8 per cent, but the increase was only 60.5 per cent in the high-altitude *P. caribaea* var. *hondurensis* provenances.

Carotenoid Content in Nursery Seedlings. After planting in the field, carotenoid content of the 16 provenances ranged from 106.8 to 189.7 μg/g, and the mean was 150.2 μg/g (± 6.8). Carotenoid content of the individual varieties was *P. caribaea* var. *bahamensis*, 157.2 μg/g; *P. caribaea* var. *caribaea*, 171.3 μg/g; and *P. caribaea* var. *hondurensis*, 146.5 μg/g (Table 2),

The increase in carotenoid content of *P. caribaea* var. *bahamensis* was insignificant; however, the total carotenoid content of *P. caribaea* var. *caribaea* increased 43.6 per cent. Carotenoid content of the *P. caribaea* var. *hondurensis* low-altitude provenances increased 52.9 per cent, the increase in carotenoid content of the high-altitude provenances was 40.5 per cent.

Cholorophyll/Carotenoid Molar Ratios. In both field and nursery measurements, *P. caribaea* var. *hondurensis* had the lowest chlorophyll/carotenoid molar ratio (Table 2). *Pinus caribaea* var. *bahamensis* had the highest ratio in the nursery, and *P. caribaea* var. *caribaea*, because of its rapid increase in chlorophyll after outplanting, had the highest ratio in the field.

Table 3.—Mean height (± standard error) for the four geographical populations of *P. caribaea*. The nursery seedlings were about 7 months old. Heights for field seedlings are means of eight 1-acre plots measured about 5 months after outplanting.

Geographical population	Altitude	Height	
		After 7 months in nursery	After 5 months in field
	Meters asl	cm	
var. *bahamensis*			
Andros Island Las Bahamas	10	7.6 ± 0.34	11.2 ± 0.31
var. *caribaea*			
Pinar del Rio Cuba	50-300	9.4 ± 0.42	12.9 ± 0.34
var. *hondurensis*			
Central America	10-75	15.6 ± 0.44	22.7 ± 0.71
var. *hondurensis*			
Central America	400-700	16.8 ± 0.53	24.1 ± 0.87

Height Growth. Mean height growth of the nursery seedlings after 7 months are given in Table 3. *Pinus caribaea* var. *hondurensis* seedlings were taller ($p<0.05$) than the insular seedlings. This growth difference was maintained after outplanting.

Discussion

Although the low-altitude *P. caribaea* var. *hondurensis* and the *P. caribaea var. caribaea* provenances had the greatest increase in chlorophyll content after outplanting, however, statistical analysis indicated that the chlorophyll concentrations was not strongly correlated with the provenance altitude ($r = 0.21$) or provenance rainfall ($r = 0.19$). The lack of a strong clinal trend between pigment content and either provenance altitude or rainfall is possibly explained by the sharp geographical isolation of the provenances both within Central American and between Central America and the Caribbean Islands (maps 2 and 3 in Lückhoff (10). Moreover, these differences suggest that little gene flow, in respect to pigment concentration, occurs among the Central American provenances or between the Central American and insular provenances.

Chlorophyll content of *P. caribaea* var. *bahamensis* seedlings in the nursery phase was substantially higher than that of seedlings of the other two varieties, but these seedlings were significantly smaller ($p<0.05$) than the *P. caribaea* var. *hondurensis* provenances, both in the nursery and in the field. Thus, high chlorophyll content *per se* is not positively correlated with superior growth. Furthermore, the failure of this variety to increase its chlorophyll content shortly after outplanting emphasizes a lack of growth oriented physiological activity utilizing the pigment system.

Natural forests of *P. caribaea* var. *bahamensis* occur on shallow soils overlying the low, calcareous Bahama Islands. To adapt to these soils, the founder population presumably passed through a bottleneck selection process. Because of this selection process, its successors appear to be genetically less adaptable to stresses of different habitats and in particular to soils which are acidic. Thus, the relatively poor performance of *P. caribaea* var. *bahamensis* in Puerto Rico when compared to *P. caribaea* var. *hondurensis* may be partially explained by the narrow adaptation of this provenance to the environment of Andros Islands.

Pinus caribaea var. *caribaea* seedlings appear to be better adapted, physiologically, to Puerto Rico than *P. caribaea* var. *bahamensis* seedlings since chlorophyll and carotenoid content in *P. caribaea* var. *caribaea* increased substantially after field establishment. Height growth of *P. caribaea* var. *caribaea* seedlings in the field was less than that of de *P. caribaea* var. *hondurensis* provenances ($p<0.05$). Nevertheless, the increase in pigment content indicates that *P. caribaea* var. *caribaea* seedlings were physiologically active after outplanting, and it appears that this activity was directed towards rapid root growth. Shoot/root dry weight measurements of these provenances indicated that after 60 weeks' growth, *P. caribaea* var. *caribaea* seedlings had larger root systems than the other varieties (unpublished data). Barrett and Golfari (2) have also reported that *P. caribaea* var. *caribaea* shows greater root development during the first year than either *P. caribaea* var. *bahamensis* or *P. caribaea* var. *hondurensis*.

In provenance and species trials throughout the lowland subtropics, *P. caribaea* var. *hondurensis* has proven more adaptable outside its natural range than either of the other two varieties. In this study, too, *P. caribaea* var. *hondurensis* adapted best to the Puerto Rican environment, as evidenced by its superior growth (Table 3). This variety had the lowest chlorophyll content and the lowest chlorophyll/carotenoid molar ratio.

The mean pigment content of *P. caribaea* var. *hondurensis* nursery seedlings was about equal for the high- and low-altitude provenance groups. However, the greater increase in pigment contents of the low-altitude group after outplanting suggests that the nursery environment was not favorable for optimum pigment development of the low-altitude provenances. Chlorosis was apparent in most of the Central American provenances except the isolated high-altitude provenances 37/71 and 34/71 of Honduras and 21/70 of the Nicaraguan coastal plain. Since preliminary growth data do not indicate that chlorotic seedlings grew less than the provenances with dark green foliage, the differences in color intensity between the chlorotic and non-chlorotic provenances may be genetic.

Because of the importance of the pigment system to growth, it could perhaps serve as a parameter to indicate a plant's ability to grow under stress, or in other words, its ability to adapt to different habitats. Chlorophyll concentration *per se* is apparently a poor biological indicator of plant adaptability since it is not correlated with growth. A better indicator is perhaps the chlorophyll/carotenoid molar ratio. For statistical comparison, the provenances in this study were grouped into four geographical populations as follows: 1) *P. caribaea* var. *bahamensis* from the Bahamas, 2) *P. caribaea* var. *caribaea* from Cuba, 3) *P. caribaea* var. *hondurensis* (10 to 75 asl) and 4) *P. caribaea* var. *hondurensis* (400 to 700 asl). Statistical correlation between the chlorophyll/carotenoid molar ratios (Table 2) and mean height growth (Table 3) of the nursery seedlings indicated a high negative correlation ($r = -0.77$).

Unfortunately, growth data are not available for the field seedlings since the plantation was destroyed shortly after the final pigment measurement was done. However, the correlation between height growth of seedlings from eight, one-acre plantations of these provenances established throughout Puerto Rico from 1972 to 1974 (Table 3) and the chlorophyll/carotenoid molar ratio of the study seedlings is $r = 0.87$.

A high chlorophyll/carotenoid molar ratio would suggest a high lightgathering ability but limited protection for the chlorophyll against photo-oxidation at high light intensities. A low molar ratio suggests greater protection against photo-oxidation. *Pinus caribaea* var. *bahamensis* and *P. caribaea* var. *caribaea* varieties have higher chlorophyll/carotenoid molar ratios than *P. caribaea* var. *hondurensis* (Table 2). Thus, *P. caribaea* var. *hondurensis* can withstand high light intensities and grow over a wide altitude range (10 to 1000 m asl). *Pinus caribaea* var. *bahamensis* and *P. caribaea* var. *caribaea* are restricted to lower altitudes. After field establishment, the provenances of *P. caribaea* var. *hondurensis* maintain a lower chlorophyll/carotenoid molar ratio than the species as a whole. Therefore, the photosynthetic complex of these provenances appears to be under less stress in Puerto Rico.

Literature Cited

1. BALDWIN, H. O. Winter foliage color in scotch pine from different geographical sources. Fox Forest Notes, Nº 61, 1955. 2 p.
2. BARRET, W. and GOLFARI, L. Descripción de dos nuevas variedades del Pino del Caribe. (*Pinus caribaea* Morelet). Caribbean Forester 23:59-71. 1962.
3. DAVIES, B. H. Carotenoids. *In* Chemistry and biochemistry of plant pigments, T. W. Goodwin, editor. New York. Academic Press. 1965. Chap. 18.
4. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Study tour of Latin-American conifers. Instituto Nacional de Investigaciones Forestales, México, Nº 1. 1962. 161 p.
5. GARRET, P. W. Height growth and foliage color in Scotch pine provenance study in Northern Michigan. USDA Forest Service, Research Note NE-96, 1969. 7 p.
6. GOODWIN, T. W. Comparative biochemistry of carotenoids. London. Chapman and Hall, 1952. 459 p.
7. HESKETH, J. D. and MOSS, D. N. Variation in the response of photosynthesis to light. Crop Science 3: 107-110. 1963.
8. KRINSKY, N. I. Protective function of carotenoid pigment. *In* A. C. Giese, ed. Photophysiology. Volume III, London, Academic Press. 1968. pp. 123 - 195.
9. LINDER, SUNE. Seasonal variation of pigments in needles: a study of Scots pine and Norway spruce seedlings grown under different nursery conditions. Studia Forestalia Suecica. Nr. 100. 1972. 37 p.
10. LUCKHOFF, H. A. The natural distribution, growth, and botanical variation of *Pinus caribaea* and its cultivation in South Africa. Annale University Stellenbosch Number 39, Series A. 1964. 160 p.
11. SMITH, J. H. C., and BENITEZ, A. Chlorophylls: analysis in plant materials. *In* K. Peach and M. V. Tracey, ed. Modern methods of plants analysis. Volume IV. Berlin Springer-Verlag, 1955. pp. 142-192.
12. STRAIN, H. H. Chloroplast pigments and chromatographic analysis. 32nd Annual Priestley Lectures. University Park, Pennsylvania. Pennsylvania State University, 1958. 180 p.
13. WOLKEN, J. J. Photodynamics: The chloroplast in Photosynthesis. *In* Lawrence P. Miller, ed. Phytochemistry, Volume I, New York. Van Nostrand Reinhold. 1973. pp. 15 - 37.

Notas y Comentarios

La próxima revolución agrícola en la India

Justamente cuando una década de notable crecimiento agrícola está alcanzando su fin en la India, sus científicos han creado nuevas maneras de impulsar la producción que no sólo son más baratas que las estrategias de los novecientos sesenta sino que también son más igualitarias La esencia del nuevo enfoque es elevar la producción aumentando no el rendimiento de cada cultivo sino el número de cosechas a dos o más por año (*The Economist* May 28th, 1977 p 68)

Sólo 25 millones de los 142 millones de hectáreas cultivadas de la India producen más de una cosecha en la actualidad Se estima que el doble cultivo podría ser extendido en muy corto tiempo a 20 millones de los 36 millones de hectáreas cultivadas con arroz y a unos 22 millones de hectáreas de tierra bajo riego La difusión de la irrigación podría eventualmente ampliar este total a 109 millones de hectáreas Pero aun un programa a corto plazo limitado a unos 40,5 millones de hectáreas extras de doble cultivo debería rendir por lo menos 30 a 35 millones de toneladas adicionales de granos alimenticios por año en 1985 lo suficiente para elevar la disponibilidad de granos en la India, de 150 kilogramos por cabeza en 1975 a alrededor de 180 kg una década más tarde

Con luz solar durante todo el año, no debería haber una barrera climática para tres y hasta cuatro cosechas por año Pero hay un obstáculo clave de un tipo diferente, al que los científicos han estado empeñados en dominar. Este es el largo y la época de las campañas agrícolas tradicionales

Por ejemplo, en el noroeste no ha sido posible sembrar trigo después del arroz, porque éste demora cinco y medio meses en madurar y la cosecha rara vez se completa a mediados de diciembre lo que es tarde para el sembrío del trigo Los científicos del Instituto de Investigación Agrícola de la India han encontrado que si los campesinos juntan sus almácigos y comparten unos pocos pozos para regarlos, se puede sembrar bastante antes del monzón y trasplantar con las primeras lluvias de julio El plantío más temprano incrementa el sol y calor disponibles para el cultivo, eleva el rendimiento y acorta el período total de crecimiento Con el arroz listo para ser cosechado en noviembre, el camino está libre para sembrar trigo u otro cultivo de invierno

La cosecha del arroz puede ser también adelantada usando algunas de las nuevas variedades enanas de alto rendimiento, que demoran sólo cuatro meses en madurar Las variedades enanas rinden 500 kg de grano por tonelada de materia seca comparando con 300 kg para las variedades tradicionales de tallo largo

En los últimos tres años, los científicos hindúes han estado probando miles de variedades híbridas de arroz de altos rendimientos para seleccionar linajes apropiados para cada región arrocera Esta vez están buscando no los rendimientos más altos con dosis óptimas de insumos, como hicieron hasta los comienzos de los novecientos setenta, sino variedades que se comporten moderadamente bien, aun en condiciones de lluvia, con poco o nada de fertilizante

El cultivo doble tiene un inconveniente: empobrece el suelo Un tercer elemento en la nueva estrategia es el uso de fertilizantes orgánicos, o mezclas de orgánicos con minerales para vigorizar el suelo Hace veinte años, los científicos de la India desarrollaron un método simple para usar el caldo sobrante de una fábrica de biogas (que fermenta estiércol de vaca para obtener por un lado metano para combustible y por otro, un caldo rico en nitrógeno para fertilizante) como iniciador en los pozos de "compost"; mezclando el abono resultante con pequeñas cantidades de urea y superfosfatos se tenía un fertilizante eficiente Pero en los novecientos sesenta, la magia de los fertilizantes químicos causó que todo el mundo se olvidase de estos métodos simples y baratos de enriquecimiento del suelo Pero fueron recordados otra vez cuando las alzas de precio en 1974 pusieron a los fertilizantes químicos fuera del alcance de la mayoría de los agricultores de la India

Los efectos sociales de esta combinación de cultivo doble con nuevas semillas rústicas y fertilizantes orgánicos baratos son casi más importantes que sus ganancias físicas brutas El cultivo doble duplicará virtualmente la demanda por mano de obra y elevará los ingresos de las familias más pobres en cada aldea Lo que es igualmente importante es que, ya que no requiere una inversión inicial, será accesible a la más pequeña agricultura La viabilidad aumentada de las pequeñas propiedades frenará la migración a las ciudades Esta sola característica podría justificar un esfuerzo importante gubernamental para hacer verdadera esta nueva revolución agrícola

Creación artificial de una raza de hongos

Las royas de los cereales siguen siendo una de las enfermedades más temidas por los agricultores debido a que en condiciones naturales se forman nuevas razas del hongo que las provoca Ahora, Mary MacDonald, del Plant Breeding Institute en Maris Lane Cambridge, Inglaterra, ha hecho un interesante trabajo en el que ha duplicado las condiciones en que se originan las nuevas razas Además, ha producido por lo menos una nueva raza fungosa

En un artículo publicado en *Transactions of the British Mycological Society* (vol 67, p 395), la autora explica cómo tomó esporas de dos razas de roya amarilla del trigo (*Puccinia striiformis*), las que se diferenciaban por su capacidad de atacar diferentes variedades de trigo; inoculó entonces mezclas de ambas razas a trigos susceptibles a ambas y, al aparecer los esporangios, se recogieron y cultivaron 50 esporas separadas Cuando las esporas germinadas crecieron lo suficiente, la autora recogió las esporas resultantes y las usó para infectar todas las variedades de trigo usadas para diferenciar las razas fungosas

Los resultados mostraron que de las 50 esporas recogidas de la infección mezclada, 39 eran idénticas a los progenitores (12 a uno y 27 al otro) De los 11 restantes, ocho eran mezclas de razas, pero otras tres mostraron la virulencia combinada de ambos progenitores y constituían una raza nueva previamente no registrada MacDonald efectuó todo el trabajo en invernaderos a prueba de esporas, y tuvo especial cuidado de que no se escapase ninguna de las esporas de las nuevas razas

Este experimento simple pero excitante muestra la facilidad con que pueden originarse nuevas razas de hongos, e ilumina el problema del genetista, cuyos años empleados en desarrollar variedades resistentes a las enfermedades pueden ser borrados en una quincena por la mezcla de hongos

El mecanismo por el cual el hongo recombina estos caracteres sigue siendo algo misterioso El *Puccinia striiformis* no tiene una fase sexual y la frecuencia de las alteraciones parece ser demasiada alta para ser debida a mutación La explicación más razonable sugiere un reordenamiento de núcleos que llevan los diferentes caracteres después de la fusión de células hifales dicarióticas cuando las diferentes razas infectan juntas una planta

Sexta Reunión Latinoamericana de Ganadería

La Asociación Latinoamericana de Producción Animal (ALPA) realizará su sexta reunión en La Habana, Cuba, del 4 al 9 de diciembre de 1977 Los temas principales son: a) Producción de leche en condiciones tropicales con énfasis en el pastoreo; b) Producción de carne en pastoreo en condiciones tropicales; c) Producción avícola con subproductos agroindustriales en el trópico; y d) Producción porcina con subproductos agro-industriales y otras fuentes no tradicionales

La organización corre a cargo del comité organizador de ALPA y de la Asociación Cubana de Producción Animal Las sesiones se llevarán a cabo en el Hotel Habana Libre, de la capital cubana

Toda comunicación se hace por intermedio del Presidente de ALPA, Dr Héctor Muñoz, CATIE, Turrialba, Costa Rica