EFFECTS OF SOIL MULCHES ON SOIL TEMPERATURE, PLANT GROWTH AND POTATO YIELDS IN AN ARIDIC ISOTHERMIC ENVIRONMENT IN PERU[1] /

L. A. MANRIQUE*
R. MEYER*

Resumen

Se evaluó el efecto de plásticos y paja de cebada usada como cobertura, sobre la temperatura del suelo y el crecimiento y rendimiento de variedades de papa comerciales peruanas, durante las estaciones de invierno y verano (1975-1977) en el medio arídico, isotérmico de la Molina

Durante el invierno, la temperatura del suelo cubierto con plástico negro y blanco osciló entre 18 y 26°C. Bajo estas condiciones, los rendimientos de papa aumentaron en la mayoría de las variedades. En el verano, las coberturas plásticas elevaron la temperatura sobre 30°C, desfavoreciendo el crecimiento de las plantas y la formación de tubérculos.

El suelo cubierto con paja mantuvo una temperatura óptima y estable (inferior a 21°C) para la papa durante el invierno. En el verano, la paja redujo considerablemente la temperatura del suelo durante el día, pero en la noche siempre se mantuvo sobre los 20°C. El rendimiento con este tratamiento durante el verano solo alcanzó el 48% del rendimiento de invierno. Los resultados indican que si bien se logra reducir la temperatura del suelo con el uso de paja, el cambio no es suficiente para que la papa crezca bien en el verano

Introduction

Different types of materials (straw, polyethylene plastic, gravel, and asphalt) have been used as soil mulches for different purposes. Some beneficial effects of soil mulches on soil temperature, moisture content, nutrient availability, and disease and weed control have been reported (1, 2, 3, 4, 5, 7, 8). Mulches have been used in extreme climatic conditions, either to increase night soil temperatures or to decrease day soil temperatures. However, very little information exists on the effects of soil mulches on potato performance in tropical and subtropical environments. The purposes of this paper are twofold: (1) to report the effects of soil mulches on soil temperature, and (2) to evaluate the effects of soil mulches on plant growth and tuber yields of non-heat tolerant potato varieties in an arid coastal environment of La Molina, Lima, Peru.

Potato production in the central arid coastal zone of Peru is limited to the winter season (June-September). Maximum and minimum air temperatures during this period are 22 and 12°C, respectively (Figure 1). With good water management, yield production during this season is similar to yields from high productive areas in the Andean region. However, no commercial production is conducted during the summer (December-March)

High temperatures and also high incidence of diseases and insect attack increase greatly the risk of crop failure during this season. Thus, potato production during the summer is entirely conducted in the

1 Received for publication in July 13, 1983.
Journal Series No. 2760 of the Hawaii Agricultural Experiment Station. This work was supported by the International Potato Center, Lima, Peru.

* Research Associate/Agronomist, Benchmark Soils Project, University of Hawaii, Honolulu, Hawaii 96822, and former CIP Agronomist now Edaphologist, Water Management, Dryland Agriculture, S&T/AGR/RNR/AID, Washington, D.C. 20523.

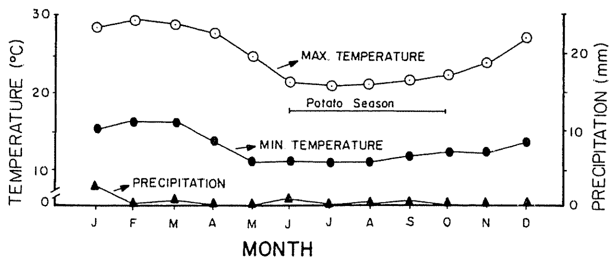

Fig. 1. Climatological data. Period 1968-1974. La Molina, Peru (Latitude 12°S, Longitude 76°57'W. Altitude 238 m.).

fairly favorable environment of the Andean region. No or very little potato is grown in the Andean region during the dry-winter season due to high risk of frost-killing temperatures and also to lack of irrigation. Thus, the potato production cycle in Peru is restricted to the winter in the Coast and to the summer in the Andean region.

Materials and methods

Experiments on soil mulches were conducted during the winter season of 1975 and summer seasons of 1976 and 1977 in a nonacid, coarse loamy, isothermic soil family of Typic Torrifluvents. The experimental site was located at the La Molina Agricultural Experiment Station, Lima, Peru.

Treatments of barley straw, and black and white polyethylene plastics were included in experiments conducted during the winter of 1975 (Experiment 1) and summer of 1976 (Experiment 2) (Table 1). A splitplot design was used with mulch treatments as main plots and varieties as subplots. Peruvian commercial varieties were planted in plots of two rows, spaced 90 cm apart and 3 m in length. The plastic mulches covered approximately 60 cm of the row width, whereas the straw mulches covered the plots completely. Plastic mulches were applied before planting. Holes 5 cm in diameter spaced 30 cm apart provided planting locations. Straw mulches were applied immediately after planting. In the unmulched + weed control treatment (control treatment), weed control was made either by repeated hand weeding (winter of 1975) or by application of the herbicide Sencor (metribuzin) after planting and 20 days after emergence (summer of 1976). The growth periods (planting to harvest) during the winter of 1975 and summer of 1976 were 110 and 93 days, respectively. During the summer of 1977, barley straw mulch rates of 5, 10, 15 and 20 metric tons/ha were applied in plots of four rows, spaced 90 cm apart and 6 m in length (Experiment 3). The control treatment (0 metric tons/ha of straw) received similar application of herbicide as the unmulched + weed control treatment in Experiment 2. Half of the mulch rate was applied after planting and the other half after 30 days. The growth period for this experiment was 105 days.

Table 1. Treatment and varieties included in mulch experiments.

Winter 1975	Summer 1976	Summer 1977
	Mulch treatments	
Black plastic	Black plastic	–
White plastic	White plastic	–
Unmulched + weed control	Unmulched + weed control	Unmulched + weed control
Straw 5 metric t/ha	Straw 5 metric t/ha	Straw 5 metric tons/ha
		Straw 10 metric t/ha
		Straw 15 metric t/ha
		Straw 20 metric t/ha
	Varieties (tbr x adg) +	
Rv, A, Y, C, R, M	Rv, M, Y, C, R	A, Y, C, MP
	Experimental Design	
Split-plot	Split-plot	Split-plot
(Rep. = 3)	(Rep. = 5)	(Rep. = 4)

\+ tbr = tuberosum, adg = andigena, Rv = Revolucion, M = Mariva, A = Antarqui, Y = Yungay, R = Ranrahirca, MP = Mi Peru, C = Cusco.

Each experiment received fertilizer rates of 160, 120 and 120 kg/ha of N, P_2O_5 and K_2O, respectively. Phosphorus and K fertilizers were applied at planting, whereas half of N fertilizer was applied at planting and half at 30 days after planting. Irrigation was scheduled when the soil water tension (measured at 20 cm depth) exceeded 0.50 bars. Daily soil water tension readings were taken using tensiometers installed at 20 cm depth. Soil temperature data were recorded using thermocouples installed at 5, 10 and 15 cm depths. Only soil temperature data for days representing critical stages of the growing season are included in this study. Emergence, plant height, number of harvested plants, tuber yield and tuber size (data not included) were measured during the growing season and at harvest time.

Results and discussion

Soil temperature

Variations in soil temperature (5 cm depth) during the winter of 1975 (June 27-July 5) and summer of 1976 (December 24-February 21) are presented in Table 2. Soil temperatures during the winter of 1975 were recorded approximately 20 days after planting. Soil temperatures in straw mulched plots were below 21°C during the winter of 1975. Stable soil temperatures (small difference between daily maximum and minimum temperature) in straw mulched plots contrasted with those high variable soil temperatures in the unirrigated bare soil. Black plastic mulched plots had soil temperatures between 22 and 26°C whereas white plastic mulched plots had soil temperatures between 18 and 25°C.

Soil temperatures during the summer of 1976 were recorded approximately 20 days after planting (December 1975), during early plant development (January 1976), and during tuber initiation and early tuber development (February 1976). The daily soil temperature variation in straw mulched plots was slightly greater than that found during the winter season and the night soil temperature always was maintained above 20°C, particularly in critical stages such as tuber initiation and tuber enlargement. According to Went (9), optimum tuber formation usually occurs with night soil temperatures of 10 to 16°C and day temperatures of 16 to 20°C.

In the summer of 1976, black and white plastic mulched plots had day soil temperatures above 30°C and night soil temperatures above 20°C in most days (Table 2). The increase in soil temperature in plastic mulched plots was more a consequence of the vapor-barrier formed rather than differences in net radiation. White plastic materials have a higher reflectance than black plastic materials, therefore their net radiation should be less. However, white plastics allow a more effective entry of solar energy, producing a greenhouse effect. The stable night soil temperatures in irrigated inmulched plots during the summer of 1976, which were considerably lower than night soil temperatures in the unirrigated bare soil, show the effectiveness of irrigation in lowering soil temperatures. The accompanying reduction in soil temperature is attributed to the increase in specific heat and thermal conductivityof the soil with wetness and to greater evaporative cooling from the wet soil (6).

Soil temperatures at different straw mulch rates are shown in Figure 2. The effect of mulch rate on night soil temperature was minimal but there was a substantial decrease in diurnal soil temperature. No differences in soil temperature were found between straw mulch rates of 5 and 20 metric tons/ha, suggesting that low rates can be as effective as high rates. Although there was an overall effect of straw mulches on soil temperature, the data in Figure 2 shows again that night soil temperatures always were above 20°C. Effective decrease in day soil temperature was also found in irrigated unmulched plots.

Plant growth and tuber yields

In the winter of 1975, barley straw mulches caused initial low emergence but later increased plant height for all varieties (Table 3) and tuber yields for Revolucion and Yungay (Table 4). This delay in emergence was probably attributed to the physical barrier effect of the straw layer. Black plastic mulches initially caused a delay in plant growth, but the final tuber yields for Mariva, Yungay, Revolucion and Ranrahirca were significantly increased.

Visual observations taken during the summer of 1976 in some varieties showed important changes in plant morphology. Varieties, which in normal habitats, such as the winter season in the Peruvian coastal zone, develop great plant canopy, vigorous stems and large leaves, developed small plants with long and thin stems, small leaves, profused root development but few and small tubers during the summer of 1976. Similar changes in plant morphology were observed in potato mulched experiments conducted in an isohyperthermic Typic Taleudult at Yurimaguas (Meyer and Manrique, unpublished data). These changes are attributed to high soil temperatures, since other limiting factors, such as water and nutrient availability, were maintained at optimum levels. Such high soil temperatures probably altered important physiological processes such as water and nutrient uptake, photosynthesis and respiration rate, which are strongly reflected in the low tuber yields (Table 4).

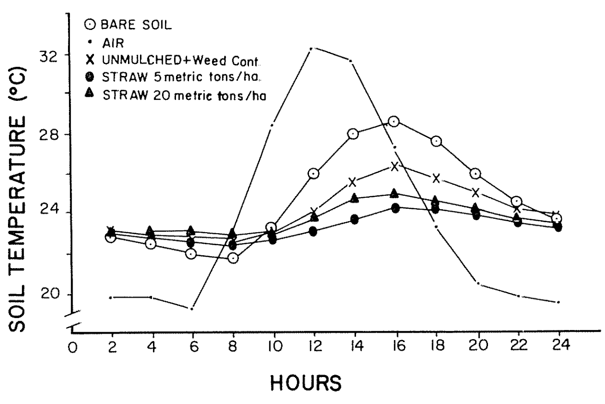

Fig. 2. Soil temperature variation (at 10 cm depth) in straw mulched plots (menas of six daily observations, February 13-18, summer of 1977).

Table 2. Effect of soil mulches on soil temperature (5 cm depth). Winter of 1975 and summer of 1976.

Season	Date		Air Temperature		Mulch Treatments: Bare Soil		Control*		Black Plastic		White Plastic		Straw	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
			°C											
Winter 1975	June	27	10.5	18.0	15.0	25.0	–**	–	23.0	26.0	–	–	18.0	20.5
		28	10.0	18.0	15.0	20.0	–	–	23.0	25.0	–	–	18.0	19.0
		29	10.5	19.5	14.0	25.0	–	–	23.0	25.5	–	–	17.0	20.2
		30	12.0	17.0	15.0	21.0	–	–	23.0	24.0	–	–	18.0	19.5
	July	1	12.0	18.0	15.0	22.5	–	26.0	23.0	24.8	–	25.0	17.5	20.0
		2	9.0	18.0	12.0	22.0	14.0	–	22.5	–	–	–	16.5	–
		3	10.0	15.0	15.0	18.0	–	21.0	–	24.0	–	23.0	–	21.0
		4	10.0	12.0	14.9	15.0	16.0	17.0	23.0	23.5	19.0	21.0	20.5	20.5
		5	10.0	12.5	13.0	15.0	15.0	17.0	23.0	–	18.0	–	20.0	–
Summer 1976	Dec.	24	17.0	26.0	19.0	35.0	19.0	32.5	21.5	34.0	20.5	34.0	20.0	23.5
		25	16.0	25.0	20.0	32.0	20.0	30.0	21.5	32.5	–	32.5	20.0	–
		31	17.0	26.0	20.0	32.0	–	35.0	–	36.0	–	34.5	20.0	24.0
	Jan.	1	16.0	25.0	20.0	34.0	20.0	35.0	20.0	37.0	22.0	34.0	–	24.0
		2	16.0	27.0	20.0	36.0	–	–	–	–	–	–	–	–
		9	17.0	25.0	20.0	30.0	–	27.0	–	30.0	–	30.0	–	22.0
		10	17.0	27.0	19.0	39.0	20.0	27.5	21.5	31.5	23.0	31.0	21.0	23.0
		11	17.5	28.5	20.0	36.0	21.0	–	–	–	–	–	22.0	–
	Feb.	5	–	–	22.0	29.0	–	30.5	–	34.0	–	29.5	–	27.5
		6	–	–	22.0	29.0	21.0	27.5	24.8	33.0	21.0	27.0	22.5	27.0
		7	–	–	22.0	30.0	21.0	31.0	25.0	32.0	21.0	–	–	–
		19	20.0	25.5	23.0	26.0	–	23.0	–	26.5	–	–	–	23.0
		20	20.0	30.0	22.0	29.0	20.5	28.5	25.0	31.0	22.0	28.5	22.0	24.5
		21	20.0	31.0	22.0	31.0	20.8	–	24.0	–	20.0	–	21.5	25.0

* Control = Unmulched + weed control treatment.
** No available data.

Table 3. Effect of soil mulches on plant growth. Winter of 1975.

Varieties	Mulch Treatments: Unmulched + weed control	Black plastic	Straw
	Emergence (%)*		
Revolucion	75.0	90.0	85.0
Cusco	90.0	75.0	70.0
Antarqui	90.0	80.0	70.0
Mean	85.0	82.0	75.0
	Plant height (cm)**		
Revolucion	25.0	30.0	37.0
Cusco	33.0	27.0	38.0
Antarqui	28.0	26.0	33.0
Mean	28.7	27.7	36.0

* Measured at 20 days after planting.
** Measured at 55 days after planting.

Symptoms of N deficiency in some white plastic mulched plots were also observed during the summer of 1976. Similar symptoms were reported in sorghum plants grown in gravel mulched plots (1). The author attributed such deficiency to radiation emitted from the gravel which could alter the metabolic process of N uptake and translocation. Also, symptoms of stem and leaf damage by burning were observed in black plastic mulched plots suring emergence. These effects reduced the final number of harvested plants (Table 5). Similar unfavorable effects were reported by Clarkson (5).

In the summer of 1976, yields of straw mulched plots were significantly superior to yields of other mulch treatments (Table 4). Yields in straw mulched plots, however, were only 48 percent of yields in similar plots during the winter of 1975. These results reflect the inability of Peruvian commercial varieties to perform in hot environments, even though a favorable decrease in soil temperature was obtained by the use of straw mulches.

Figure 3 shows the effects of straw mulch rates on tuber yields during the summer of 1977. Except for the variety Antarqui, which showed an almost linear response to mulch rate, significant yield response was obtained up to 10 metric tons/ha only. This response was consistent with the small variation in soil temperature at mulch rate higher than 5 metric tons/ha.

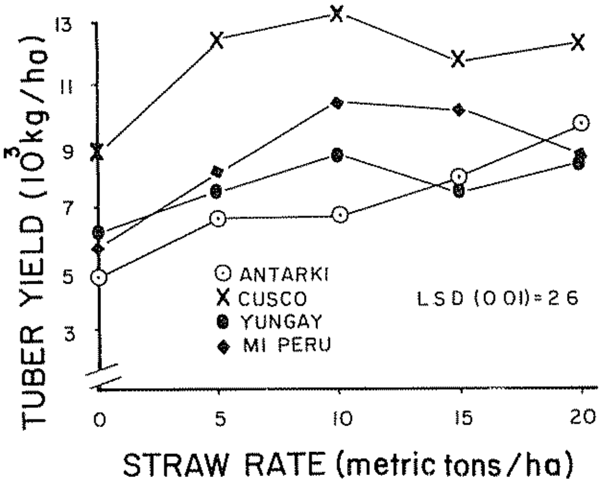

Fig 3. Effect of straw mulch rates on tuber yield. Summer of 1977.

Conclusions

Favorable soil temperatures for potato growth was found under straw mulches during the winter season. The straw mulched environment promoted rapid plant growth for all varieties and high tuber yields for Revolucion and Yungay. During the summer, straw mulches reduced considerably day soil temperature and maintained a low daily variation, but the night soil temperature always remained above 20°C, which was significantly greater than the optimum required to assure adequate tuber initiation and tuber enlargement.

During the summer, black and white plastic mulches maintained high but also stable soil temperatures which were not conducive for tuber formation. Overall, the use of straw mulches holds better promise for increasing potato yields than plastic mulches, especially during hot and dry seasons. However, the favorable effects on soil temperature attributed to the straw mulches are not sufficient to overcome the inability of commercial varieties to produce tubers in hot environments such as coastal Peru in the summer.

Summary

Polyethylene plastic materials and barley straw mulches were used on a potato field to evaluate their effects on soil temperature, plant growth and tuber yields of Peruvian commercial varieties during the winter and summer seasons (1975-1977) in an aridic, isothermic environment at La Molina, Peru.

Table 4. Effect of soil mulches on tuber yields. Winter of 1975 and summer of 1976.

Season	Varieties	Mulch Treatments				
		Unmulched* weed control	Black plastic	White plastic	Straw	Mean for varieties
		10^3 kg/ha				
Winter 1975	Mariva	19.9	22.0	–*	19.3	20.4
	Cusco	27.0	23.3	–	23.1	24.1
	Yungay	15.9	19.7	–	17.1	17.6
	Revolucion	27.9	32.4	–	31.5	30.6
	Ranrahirca	14.0	22.3	–	14.8	17.0
	Antarqui	21.5	21.7	–	17.5	20.2
	Mean for mulches	21.0	23.4	–	20.6	–
	L.S.D. (0.01) Means for varieties				3.3	
	Means for mulches				2.7	
Summer 1976	Mariva	8.4	3.9	3.9	12.8	7.3
	Cusco	5.0	1.0	0.9	9.2	4.0
	Yungay	4.9	1.0	1.2	9.1	4.1
	Revolucion	7.7	0.7	0.6	9.7	4.7
	Ranrahirca	6.2	3.1	1.0	8.1	4.6
	Mean for mulches	6.4	1.9	1.5	9.8	–
	L.S.D. (0.01) Means for varieties					2.5
	Means for mulches					2.9

* No available data.

Table 5. Effect of soil mulches on the percentage of harvested plants. Summer of 1976.

Varieties	Mulch Treatments			
	Unmulched + weed control	Black plastic	White plastic	Straw
	%			
Mariva	67.0	57.0	55.0	72.0
Cusco	40.0	24.0	10.0	48.0
Yungay	58.0	22.0	35.0	72.0
Revolucion	67.0	39.0	34.0	65.0
Ranrahirca	58.0	46.0	27.0	70.0
Mean	58.0	37.6	32.2	65.4

During the winter, soil temperatures in black and white plastic mulched plots ranged from 18 to 26°C. The soil environment under these plastic mulches during the winter promoted relatively high tuber yields in most varieties. In the summer, plastic mulches significantly increased day soil temperatures above 30°C, resulting in a highly unfavorable environment for plant growth and tuber formation.

Straw mulches maintained optimum and stable soil temperatures (< 21°C) for economic potato production during the winter. During the summer, straw mulches reduced considerably day soil temperatures, but the night soil temperatures always remained above 20°C. Yields of straw mulched plots in the summer were 48 percent of yields of similar plots in the winter The results indicate that straw mulches significantly lowered soil temperatures, but may not do so sufficiently to overcome excessively high soil temperatures during the summer months.

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Notas y comentarios

Premio Nobel de Química de 1984

Bruce Merrifield, de la Universidad Rockefeller, en Nueva York, quien efectuó roturas de frente cruciales en la revolución biotecnológica, ganó el premio Nobel de Química de 1984. En los primeros años de la década de los novecientos setenta, Merrifield tuvo una idea que revolucionó la química de los péptidos e inventó el procedimiento que lleva su nombre, "la síntesis péptida de estado sólido".

Para comprender muchos procesos biológicos, el científico debe trazar la secuencia de aminoácidos de una proteína. Debe saber cómo duplicar esa secuencia para manipular sus componentes en su investigación. Antes de Merrifield, los biólogos demoraban meses y aún años para sintetizar una cadena péptida. Las secuencias de aminoácidos no debía ser variada, pues ella era la que determinaba la clase de proteína resultante. La estrategia era poner las moléculas cuidadosamente en etapas. Después de cada paso, el producto deseado era aislado, trasladado a otra etapa, se efectuaba la nueva reacción, el nuevo producto se aislaba, y así sucesivamente. El tiempo empleado era enorme y los rendimientos muy pobres.

Las ideas de Merrifield irrumpieron en la escena en 1963 con una síntesis fácil de la bradikinina, una hormona péptida de nueve aminoácidos (nonapéptida). Lo que asombró a los químicos ese año fue el alto rendimiento y rapidez de la nueva síntesis: 68 por ciento en sólo ocho días. Bradikinina era la gran favorita como causa de la trasmisión del dolor, y para investigarla se necesitaban grandes cantidades de la sustancia. Para 1968, esas investigaciones demostraron que no existía tal papel importante para esta hormona.

Pero Merrifield no se había quedado quieto; tenía otras sorpresas sintéticas. Había fabricado ribonucleasa, con su secuencia de hasta 124 aminoácidos. Había automatizado el procedimiento, y con la ayuda del computador, los reactivos requeridos se podían agregar a intervalos predeterminados, y retirarlos cuando habían cumplido su misión. Y esto se realizaba sin parar, día y noche, en un solo recipiente. La ribonucleasa es importante como medicamento y para investigar estructuras de ácidos nucleicos y de cadenas proteínicas.

La idea concebida en 1961 era simple. En vez de separar la creciente cadena péptida después de cada paso de su síntesis, ¿por qué no adherirla a un soporte insoluble? De esta manera, cualquier subproducto indeseable, y las materias que no reaccionaron en cada paso, podrían ser lavados, dejando al protegido péptido pegado al soporte.

Para su soporte, escogió un plástico que era un copolímero de estireno y de divinilbenceno, en el cual algunos anillos bencénicos habían sido funcionalizados con grupos químicos reactivos. El primer aminoácido se introduce al sistema y reacciona con un grupo funcional de la resina, quedando pegado a ella. El grupo es extraído y se introduce el segundo aminoácido. La cadena péptida se va extendiendo en una serie de pasos, lavando bien después de cada uno de ellos y dejando la creciente cadena pegada en el soporte. Al final, se separa el péptido sintetizado de la bolita soporte. Este prototipo complicado se mejoró hasta llegar a modelos controlados por el computador programado para realizar todas estas operaciones. En ningún momento de la operación se separaba un producto intermedio y se purificaba, algo parecido a un acto de herejía química.

La técnica de Merrifield aceleró drásticamente la síntesis de péptidos, en especial cuando fue enteramente automatizada. Actualmente, Merrifield en la Universidad Rockefeller y Bob Sheppard en el laboratorio de Biología Molecular de Cambridge, han mejorado sustancialmente sus resinas y las condiciones para despegar los péptidos al final. Esto conduce a péptidos y proteínas grandes, de gran pureza, los que deben, por lo menos, ser tan buenos como los obtenidos por injertos de genes de la biotecnología.

Ya se está especulando sobre la aplicación, en el futuro, de esta técnica a otros grandes polímeros del mundo orgánico, los ácidos nucleicos tales como el DNA y el RNA. Esto sería otra revolución en la biotecnología y en la ingeniería genética. Merrifield probablemente sería el último en reclamar crédito por estas proyecciones de largo alcance de su idea. Modesto y de habla suave, su fortaleza de carácter es evidente en la larga batalla personal que él sostiene contra el cáncer de la piel. Adalberto Gorbitz