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A tribute to Dr. Anthony C. Bellotti and his contributions to cassava entomology

Stephen L. Lapointe

Abstract

Anthony (Tony) Bellotti's career as a humanitarian and entomologist followed a trajectory that took him to El Salvador with the Peace Corps (PC) in 1962, New Mexico State for a Masters, Paraguay (again with the Peace Corps), Cornell University for a Ph.D., and Colombia where he worked for the Centro Internacional de Agricultura Tropical (CIAT) from 1974 until his passing in March 2013 in Naples, Florida. Tony became a passionate advocate of cassava, and one of the world's pre-eminent authorities on the entomology of that orphan crop that sustains millions of the world's poorest populations. Tony played a crucial role in one of the most often cited and successful examples of classical biological control, the introduction of a parasitoid wasp from Paraguay to control the cassava mealybug throughout a broad area of Africa known as the Cassava Belt. His career spanned a period of time that might be referred to as a golden age of commodity programs at the international "CG Centers" organized under the Consultative Group on International Agricultural Research (CGIAR), which followed in the footsteps of Norman Borlaug and Robert McNamara, the unlikely alliance that led to the Green Revolution. Among Tony's lesser accomplishments was his recruitment of the author to CIAT in 1986, where I worked on pests of tropical forages and then on cassava integrated pest management in northeastern Brazil and West Africa. Tony was a mentor and a friend whose career offers a chance to look at a unique life and his contributions to international agriculture.

Key Words: classical biological control; cassava mealybug; cassava green mite; Peace Corps; CGIAR

Resumen

La carrera de Anthony (Tony) Bellotti como humanitario y entomólogo siguió una trayectoria que lo llevó a El Salvador con el Cuerpo de Paz en 1962, la Universidad Estatal de Nuevo México, Paraguay (de nuevo con el Cuerpo de Paz), la Universidad de Cornell para su doctorado y Colombia, donde trabajó para el Centro Internacional de Agricultura Tropical (CIAT) desde 1974 hasta su fallecimiento en marzo de 2013 en Naples, Florida, USA. Tony se convirtió en un apasionado defensor del cultivo de la yuca y una de las autoridades más prominentes del mundo en la entomología de ese cultivo huérfano que sustenta a millones de las poblaciones más pobres del mundo. Tony jugó un papel crucial en uno de los ejemplos más citados y exitosos de control biológico clásico, la introducción de una avispa parasitoide de Paraguay para controlar el piojo harinoso largo de una amplia zona de África conocida como el cinturón de yuca (*cassava belt*). Su carrera abarcó un período de tiempo que podría denominarse como una edad de oro de los programas de cultivos en los "centros GC" organizados por el Grupo Consultivo para la Investigación Agrícola Internacional (CGIAR) que siguió los pasos de Norman Borlaug y Robert McNamara, la extraña alianza que llevó a la Revolución Verde. Entre los logros menores de Tony era su reclutamiento de este autor al CIAT en 1986 donde trabajé sobre plagas de forrajes tropicales y luego sobre el manejo integrado del cultive de la yuca en el nordeste de Brasil y África Occidental. Tony era un mentor y un amigo cuya carrera ofrece una oportunidad de ver la vida única de sus contribuciones a la agricultura internacional.

Palabras Clave: control biológico clásico; piojo harinoso; yuca ácaro verde; Cuerpo de Paz; CGIAR

It was a particular honor to be asked to present the 2014 Pioneer Lecture and I thank Dr. Norm Leppla for the suggestion. Dr. Anthony Charles Bellotti (Fig. 1), known as Tony to his friends and colleagues, was born in Graniteville on Staten Island, New York City, Nov 19, 1937. Tony had 2 brothers, John and Frank, and although he did not have children of his own, he was an important influence on his nephews including Robert, who was able to attend the FES meeting in Jupiter. The trajectory of Tony's career, as it happens, had several parallels with my own including service in the Peace Corps, graduate studies at Cornell, employment at the International Center for Tropical Agriculture in Colombia, and international work on cassava. Tony was responsible for recruiting me to CIAT in 1985 and became a close personal friend during my tenure at CIAT in Colombia and later in Brazil. This tribute is both a professional testament and a very personal remembrance of a singular entomologist.

Tony's journey led to him to become the world's preeminent cassava entomologist and a passionate promoter of the cassava crop (Fig. 2). For our purposes, his story begins in 1962—the year the Beatles auditioned for Decca Records, Pope John XXIII excommunicated Fidel Castro, the satellite Ranger 3 was launched to study the moon (it missed by 22,000 miles), the U.S. announced an embargo against Cuba, Wilt Chamberlain scored 100 points, West Side Story won Best Picture award, Dodger Stadium saw its first game, Ranger 4 crashed into the moon, Andy Warhol showed his soup cans in Los Angeles, The Rolling Stones made their first appearance in London, the last atmospheric test detonation of a nuclear bomb occurred in Nevada, the Mariner 1 spacecraft was destroyed shortly after launch, Telstar transmitted the first live trans-Atlantic television signal, Marilyn Monroe died, Spider-Man appeared in Marvel Com-

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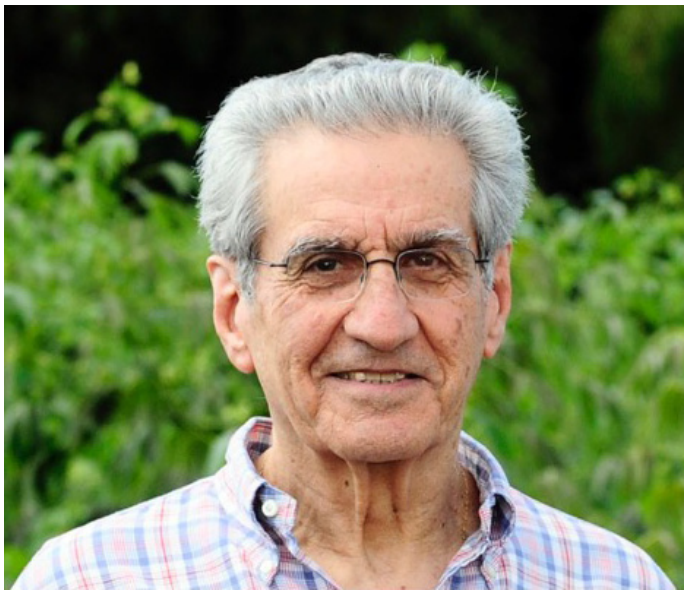

Fig. 1. Dr. Anthony C. "Tony" Bellotti, 1937–2013. Photo courtesy of CIAT, Cali, Colombia.

ics, the Soviet Union sent arms to Cuba, President John F. Kennedy (JFK) promised a man on the moon by 1970, Bob Dylan released 'A Hard Rain's a-Gonna Fall," Silent Spring was published, James Meredith registered at the University of Mississippi, Johnny Carson became host of the Tonight Show, the Cuban Missile Crisis freaked out everybody, the term "personal computer" was first used, and Watson, Crick, and Wilkins were awarded the Nobel Peace for the discovery of the structure of DNA. Quite the year! It was in this tumultuous context that the 24-yr-old Tony Bellotti answered the call to service of the nation's young President Kennedy and joined the Peace Corps. Tony traveled with the first group of volunteers to go to El Salvador in 1962. While there, he worked on vegetable, fruit, and small animal projects. And he learned to speak Spanish without ever surrendering his distinctive Staten Island accent. The idea for an "army" of American youth to provide technical advice and assistance to developing countries originated during the 1950s. Democratic senator Hubert Humphrey introduced the first legislation in 1957 at the request of President Eisenhower. It failed. But Kennedy used the idea during his campaign, gave the organization its name and then promised to create the program in his inaugural address when he famously challenged, "ask not what your country can do for you—ask what you can do for your country." Some politicians were critical of the program; Richard Nixon predicted it would become a cult and haven for draft evaders. Others suggested it was naïve and doubted the ability and maturity of young and unskilled Americans. In his autobiography, Humphrey wrote,

"It is fashionable now to suggest that Peace Corps Volunteers gained as much or more, from their experience as the countries they worked. That may be true, but it ought not demean their work. They touched many lives and made them better." (Humphrey 1976).

Fig. 2. Dr. Tony Belllotti examining a cassava plant. Photo courtesy of CIAT, Cali, Colombia.

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The first group of volunteers was already in training stateside before passage of the legislation authorizing the Peace Corps was enacted in Sep, 1961. The group of 51 young men trained at Rutgers University were sent to Colombia. It is interesting to consider the confluence of motivations, justifications, and campaign rhetoric surrounding the founding of the Peace Corps in the context of JFK's experience as president. He had just been humiliated by the Bay of Pigs ill-fated and ill-conceived invasion of Cuba. And he had a notable lack of confidence in the U.S. foreign policy establishment. During his campaign, he had criticized the "ill-chosen, ill-equipped, and ill-briefed ambassadors" (Cobbs Hoffman 2009) and wanted more Americans with grassroots experience and language ability (Schwarz 2010). And there was the image of America sending its finest youth to do good for the poorest countries of the world. Perhaps the predominant view from the volunteers was one of patriotism and eagerness to learn—and undoubtedly also for adventure. I do not think it is different today even if new volunteers are perhaps a bit more savvy or better informed about international politics and our role in it. Perhaps not.

At the time Tony went to El Salvador in 1962, there were 2,816 volunters in the field in 28 host countries. Norman Rockwell traveled to Ethiopia on assignment for Look Magazine, and his iconic portrait of JFK and volunteers appeared in Jun, 1966 (http://peacecorpsworldwide.org/babbles/2009/10/09/peace-corps-ethiopia/). In 2010, there were 8,655 volunteers in 77 countries. To date, > 215,000 volunteers have served in > 139 countries. My own experience, some 16 years after Tony's tour in El Salvador, was as a Peace Corps volunteer in Honduras, where I worked in a remote area near the north coast on projects dealing with production of vegetables, tropical fruits, and small livestock. And, to contribute further to the confluence of coincidence, my elder daughter, Lauren, is just now going through in-country training for the Peace Corps in Ethiopia after graduating in May 2014 from Cornell, my alma mater. Tony was Lauren's godfather. She was very nearly born on his doorstep in Cali, Colombia, in 1992 on our way to a clinic. He was proud of her continuing the Cornell tradition and would have been pleased, I think, to know of her adventures in Africa. Over the years, the demographic makeup of the Peace Corps has evolved such that, beginning in 1985, women volunteers outnumber men. In 2014, women comprise 63% of the 7,200 volunteers, 7% are married, and 8% are > 50 yr old (New York Times 26 Jul 2014, Peter D. Hart Research Associates Survey of > 11,000 returned volunteers).

After leaving the Peace Corps, Tony attended New Mexico State University, completing his Masters, and then accepted a position of training officer for the Peace Corps in Paraguay and then California. In 1970, he began work on his Ph.D. at Cornell and completed his degree in 1974. I was an undergraduate at Cornell at that time. Tony might have been a teaching assistant in my undergrad Biology of Insects class taught by George Eickwort. But we were unlikely to have encountered each other at Cornell as I was busy not inhaling and protesting a war in Southeast Asia, and Tony was writing his Ph.D. dissertation, "Impact of diversified selective pressures on the housefly," under the tutelage of David Pimentel. As Tony was finishing his degree, Cornell announced a faculty position in potato integrated pest management (IPM) in the entomology department. There were 3 finalists for the position and 2 were recent Cornell grads: Tony and George Kennedy, who went on to become the William Neal Reynolds Distinguished Professor of Agriculture at North Carolina State University. After a period of hiring Cornell grads for Cornell positions, the faculty instead decided to offer the position to a recent graduate of the University of Arizona, Dr. Ward Max Tingey. We will get back to Ward, but this left Tony at odds and he quickly landed on his feet by accepting a post-doctoral fellow position funded by the Rockefeller Foundation at the International Center for Tropical Agriculture (CIAT) located near Cali, Colombia. He would work at CIAT (the Spanish acronym for Centro Internacional de Agricultura Tropical) from 1974 until his passing in March, 2013 in Naples, Florida. Tony became a passionate advocate of cassava, and one of the world's pre-eminent authorities on the entomology of that orphan crop that sustains millions of the world's poorest populations. Tony played a crucial role in one of the most often cited and successful examples of classical biological control, the introduction of a parasitoid wasp from Paraguay to control the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae), throughout a broad area of Africa known as the Cassava Belt. His career spanned a period of time that might be referred to as a golden age of commodity programs at the international "CG centers" organized under the Consultative Group on International Agricultural Research (CGIAR), which followed in the footsteps of Norman Borlaug and Robert McNamara, the unlikely alliance that led to the Green Revolution.

Among Tony's lesser accomplishments was his recruitment of the author to CIAT in 1986, where I worked on pests of tropical forages. In 1980, I had been accepted into a graduate program at Cornell under the supervision of Ward Tingey to work on the role of glandular trichomes in wild relatives of the potato in deterring aphid feeding and virus transmission. This work, funded by the International Potato Center, another CGIAR center headquartered in Lima, Peru, allowed me to travel through Bolivia to collect wild potato species and return botanical seed of glandular species to the USDA potato germplasm facility at Sturgeon Bay, Wisconsin. As I was finishing my degree, I met Tony at an Entomological Society of America meeting where he encouraged me to apply for a position at CIAT. Eventually, I would join Tony in the 1990s to work on cassava IPM in northeastern Brazil and West Africa.

Tony was a great student of U.S. history. The library at his home in Cali (where he lived for > 30 yr) overflowed with books of history, the civil war, the cold war, presidential biographies, etc. So he would approve, I think, if we take a look at the history of the CGIAR, the organization to which he devoted his career. The story of the Consultative Group on International Agricultural Research begins with Norman Borlaug, son of a Wisconsin farmer, who received his Ph.D. in plant pathology and genetics from the University of Minnesota in 1942. Borlaug took a position in Mexico with the Cooperative Wheat Research Production Program funded by the Rockefeller Foundation and the Mexican Ministry of Agriculture, where he and the other members of the wheat research team were spectacularly successful at breeding high-yielding dwarf varieties resistant to lodging and drought (critical for the U.S. after the dust bowl catastrophe of the 1930s) but also incorporating resistance to rust disease (*Puccinia* spp.; Puccinales: Chaconiaceae) in multilines (backcrossing a recurrent parent possessing multiple resistance genes in multiple backcrossing lines) and crossing Japanese semi-dwarfs with U.S. wheat varieties. This approach, drawing on the knowledge emerging from genetics and an understanding of the basis for plant disease compatibility, resulted in more stable resistance (Borlaug 1983). This was the beginning of the so-called Green Revolution that would bring modern plant breeding methods to the major world crops, especially cereals and grains. The success of the wheat project was extended to India with the result that India was transformed from food-deficient status with dire predictions of imminent Malthusian disaster, to a net exporter of wheat (India's 2014 target for wheat export was 2 million metric tons). Robert McNamara, president of the World Bank (1968–1981) after serving as U.S. Secretary of Defense 1961–1968 and briefly as president of Ford Motor Company, played a key role by arranging for wheat sales to India only if India invested the sales in new agricultural research and production methods. Indian wheat productivity (yield) tripled. The model was extended to another major staple, rice, through collaboration between the Ford and Rock-

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efeller Foundations and the government of the Philippines through the founding of the International Rice Research Institute (IRRI). Incidentally, the current Director General of IRRI, Dr. Bob Zeigler, Cornell Ph.D. graduate of 1982, was a colleague at CIAT for several years. Results with rice were equally spectacular. Norman Borlaug in 1970 received the Nobel Peace Prize, the first time the award was received by an agriculturalist. He created the World Food Prize (WFP) in 1986. He died in 2009 at the age of 95. Recipients of the WFP include Edward F. Knipling in 1992 (the New York Times, referring to the sterile insect technique, noted, "Knipling…has been credited by some scientists as having come up with 'the single most original thought in the 20th century'" leading to eradication of the screwworm), the Swiss entomologist Hans Herren in 1995, and Ray Smith and Perry Adkisson, fathers of IPM, in 1997.

One of the early international centers, the Centro Internacional de Agricultura Tropical (CIAT) was founded in 1967 at Cali, Colombia, and joined the CGIAR in 1971 as one of the original 4 international centers: CIAT, IRRI, the International Institute for Tropical Agriculture (IITA) in Nigeria, and the Center for Improvement of Maize and Wheat (CIMMYT) in Mexico. These Centers were funded by the Ford and Rockefeller Foundations with support from the World Bank, U.S. Agency for International Development, and others. At their inception, the International Centers were charged with addressing critical needs related to improving agricultural productivity in the poorest countries of the world, and each center was given specific geographical and crop mandates. CIAT was responsible for 4 areas: rice and tropical forages for Latin America, and global mandates for beans and cassava. Although the organization of the CG centers has, in recent years, evolved and diverged from the model that prevailed at their founding until the end of the 20th century, they still maintain an invaluable resource, namely germplasm collections. For cassava, this function is particularly critical and relevant to many millions of the world's most disadvantaged poor.

So what is cassava, where did it come from, and why is it important? Cassava (*Manihot esculenta* Crantz; Malpighiales: Euphorbiaceae) is a woody shrub most likely to have evolved in the Amazon basin, where it has been traditionally utilized by indigenous peoples in a variety of ways. Not to be confused with yucca (you can blame Linnaeus for the original mistake—see the Wikipedia entry for yucca), cassava is known as yuca in Spanish, mandioca in Portuguese, tapioca when dried, powdered, and pearled, farinha as a course dry flour, and many other denominations. There are so-called sweet varieties (*aipim* in Portuguese) and bitter varieties so named for the cyanogenic potential of both roots and leaves, the result of hydrolysis of constitutive cyanogenic glucosides present in widely varying concentrations depending on the variety (Bellotti & van Schoonhoven 1978).

Cassava is sometimes referred to as a noble crop and as an orphan crop. Noble because it can withstand extreme and repeated biological and abiotic insults and still produce an edible root. The presence of the large starchy root makes the plant resistant to drought and defoliation by pests such as mealybugs and leafcutter ants. Also, the root can be left in the ground for extended periods and harvested when needed—a very valuable trait during famines and in areas without access to refrigeration. Cassava is sometimes referred to as an orphan crop because it has not received the interest and research investment from the international community and multinational corporations that other crops have received.

Tony was involved in a historic success for classical biological control with impact over several African countries. A mealybug pest of cassava of the genus *Phenacoccus* was known from northern South America and caused yield loss in northeastern Brazil (Bellotti et al. 1983). An unknown mealybug appeared in central Africa (Congo and the Democratic Republic of the Congo) in 1973. By 1986, it had spread across 70% of the African cassava-growing region with losses of up to 84% (Bellotti et al. 1999). Explorations for natural enemies focused on northern South America and Central America, but in 1980 it was found that *Phenacoccus herreni* Cox & Williams populations included males, whereas the African species did not. The South American mealybug was then described as *P. herreni.* The species introduced into Africa was located in Paraguay by Bellotti in 1980 (Herren & Neuenschwander 1991). An encyrtid parasitoid, *Apoanagyrus* (= *Epidinocarsis) lopezi* De Santis (Hymenoptera: Encyrtidae), was collected in Paraguay and became established in Africa across all zones infested by *P. manihoti* resulting in effective control and dramatic recoveries in cassava yield (Bellotti et al. 1999). The contributions of CIAT and IITA to the successful classical biological control of cassava mealybug in Sub-Saharan Africa were recognized in 1990 by the Belgian government's King Baudouin Award for International Agricultural Research. By 1990, mealybug parasitoids and predators had been released in > 20 African countries and established in 25 countries covering an estimated 2.7 million square kilometers of the African cassava belt (CGIAR 2015).

Bellotti et al. (1983) suggested that *P. herreni* was introduced recently into northeastern Brazil. High populations of *P. herreni* in the northeast suggested that biocontrol was insufficient, and we (Bento et al. 1999) imported 3 parasitoid species from northern South America (Venezuela and Colombia). Two of these, *Apoanagyrus diversicornis* (Howard) and *A. coccois* (Hymenoptera: Encyrtidae), dispersed fairly quickly in the state of Bahia from our release points (up to 130 km in 6 mo). This may be associated with flight and prevailing wind or with the transport of planting material, cassava being propagated vegetatively by stakes. The irregular distribution of *P. herreni* in Brazil could reflect movement of infested planting material. We speculated that the destruction of the Atlantic forest of northeastern Brazil may result in periodic local extinctions of parasitoids thereby requiring periodic reintroductions.

Tony's work in classical biological control also focused on phytoseiid predatory mites for control of the cassava green mite, first reported from northeastern Brazil in 1938 and from Uganda in 1971, after which it spread rapidly across the cassava belt (Bellotti et al. 1999). Several species were evaluated, introduced, and established in Africa (Yaninek et al. 1998), the most successful of which appears to be *Typhlodromalus aripo* De Leon (Mesostigmata: Phytoseiidae).

The cassava hornworm, *Erinnyis ello* L. (Lepidoptera: Sphingidae) is widespread in the Neotropics and can cause serious defoliation. In the early 1970s, a granulosis virus was observed on the grounds of CIAT attacking hornworm larvae (Arias & Bellotti 1987). Tony's group developed a simple, easily transferred method that involved collecting infected larvae, maceration in a blender, and reapplication to control hornworm infestations even after refrigeration (Bellotti et al. 1992). Tony was particularly proud of this method because of its simplicity and relevance to conditions in developing countries.

The successful area-wide classical biological control of cassava mealybug and cassava green mite in Africa—carried out by the IITA in collaboration with many other institutions—has not been replicated in Latin America, where pest management must rely on farmer participation due to the more localized nature of constraints to productivity. During the late 1990s, Tony and I were involved in a project sponsored by the United Nations Development Programme to promote participatory research and implementation in northeastern Brazil through establishment of local farmer research cooperatives. This was a highly rewarding experience whose story must be related elsewhere.

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Tony authored > 250 publications in refereed and non-refereed journals, book chapters, and proceedings of symposia and workshops. He received numerous awards for research conducted and presented by the technicians and students in his laboratory at annual meetings of the Colombian Entomological Society (SOCOLEN). New Mexico State University awarded him one of its Outstanding Alumni Awards in 1988. Other distinctions included CIAT's Distinguished Service Award (1990), special recognition conferred by SOCOLEN for "a continued and fructiferous contribution to Colombian Entomology" in 2001, SOCOLEN's award for outstanding entomological research (2003 and 2004), and CIAT's Outstanding Research Publication Award (2005).

Tony continued to be productive and engaged through his later years. When the cassava mealybug appeared in southeast Asia, Tony was called upon to consult on the importation of parasitoids, and he was present for the first releases of *A. lopezi* in Thailand in 2010 as noted in the New York Times (Mydans 2010) and National Geographic News (Than 2010). He was consulting in Viet Nam in 2012 when illness overtook him. Tony helped provide sustenance for a hungry world by working on a neglected crop that supplies the caloric needs of millions of the world's poorest. He was fortunate to find a lifelong professional niche at CIAT and the cassava program that allowed him to contribute his unique blend of interest, ability, dedication, and personality. The world is measurably better for his passing, and those of us who shared time with him were fortunate to have known him.

Acknowledgments

I thank Dr. Norm Leppla (University of Florida) for encouraging me to undertake this project. Many of the sources I called upon to buttress my memory are available online through organizations such as the Peace Corps, the Consultative Group on International Agricultural Research, the International Center for Tropical Agriculture and other resources. Some of these are not explicitly cited in the text but are easily found. I thank the Florida Entomological Society for this forum to express my appreciation of a friend and mentor, an entomologist, a Cornellian, and a Yankees fan to the end.

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