THE CROSSETT EXPERIMENTAL FOREST'S CONTRIBUTIONS TO SOUTHERN PINE IMPROVEMENT PROGRAMS

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Abstract--Long renowned for its contributions to silvicultural practices in naturally regenerated loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pine, the Crossett Experimental Forest (CEF) has also played an important, if much less well known, role in southern pine tree improvement. A decades-long program centered at Crossett started in 1951. Roland E. Schoenike was hired in 1952 to run the CEF's tree improvement program, then largely "exploratory" in nature. A combined soils and genetics laboratory was constructed on the CEF in 1954, and following Schoenike's departure in 1956, plant geneticist Hoy C. Grigsby was hired from the Mississippi Forestry Commission as the scientist in charge of the program. In the late 1960s, Grigsby installed part of a full- and half-sibling plus tree loblolly pine progeny test on the CEF compared to "woods-run" materials collected from the experimental forest. However, Grigsby would not see this study to completion; after the CEF was shut in 1974 he was transferred to Pineville, Louisiana. Although long closed, portions of the CEF program still offer current and future research opportunities. For example, some plus tree progeny tests remain, and at 46-49 years post-establishment, these tests have unique opportunities to reevaluate growth, bole quality, and other performance measures for known families, as well as the promise of new studies related to genetics, tree defense strategies, carbon allocation, and bole/crown dynamics.

INTRODUCTION

The Crossett Experimental Forest (CEF) was established in 1934 to help refine silvicultural practices in the naturally regenerated loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pine-dominated forests of the Upper West Gulf Coastal Plain (Reynolds 1980). Founding project leader Russell R. Reynolds had a knack for uneven-aged silviculture and quickly developed a successful research and demonstration program over most of the original 680 ha of the CEF (Reynolds 1959). Over the years, other researchers have continued this uneven-aged work while studying many other aspects of these pine forests, including even-aged silvicultural practices, regeneration ecology, competition control, growth and yield, and unmanaged stand dynamics. The CEF's research program has yielded hundreds of publications and many thousands of foresters, students, landowners, and policy makers have toured the facility. Much less well-known is the once very active forest genetics/tree improvement (FG/TI, which also included a significant nursery component) program on the CEF that operated for over 20

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years. When established, the CEF's FG/TI effort was a part of the USDA Forest Service's (USFS's) multi-pronged effort in this discipline, and its waning mirrored trends seen elsewhere in federal FG/TI (Wheeler et al. in press). Today, vestiges of the CEF program remain and offer the promise of new opportunities to learn from work established nearly 50 years ago. This paper provides a brief summary of the CEF FG/TI program, including some current and future plans for research based on the surviving plus tree progeny tests.

THE CEF FG/TI PROGRAM

Reynolds and Wakeley Set the Stage

As successful as the uneven-aged silviculture work on the CEF proved to be, Reynolds was criticized for not including even-aged management as one of his comparisons. Tree improvement pioneer and fellow USFS scientist Philip Wakeley was one of the most vocal critics, pulling no punches in his evaluation (Wakeley and Barnett 2011, p. 57):

> The [CEF] was organized in heyday of "selective cutting"…The Forest was deliberately and avowedly set up to "demonstrate" the virtues of such selective cutting…this unabashed move to "demonstrate" the worth of a current fad and particularly the failure to match many-aged management with the most obvious check, namely, even-aged management, seemed to me a regression…Despite what I consider its long run with only half its cylinders firing—and the poorer half at that!—there is no denying the immense impetus that the Crossett Experimental Forest, under Russ Reynolds' direction, has given both to the Station and to technical forestry throughout the South. The data it has yielded on many-aged management, even without the obvious check, are uniquely valuable.

In correspondence not reprinted in Wakeley and Barnett (2011), Reynolds strenuously objected to Wakeley's characterization of the CEF not having even-aged checks, citing a methods-of-cutting study on 43 ha installed between 1937 and 1942—a move promptly dismissed by Wakeley as inadequate.

Wakeley's criticism notwithstanding, Reynolds did not avoid even-aged research and demonstration—in addition to the aforementioned methods-of-cutting study, one of the first demonstrations on the CEF included an arboretum, and woods-run seeds were provided in 1935 for outplanting studies across the world (e.g., Wakeley 1951). By the early 1940s, new studies that incorporated even-aged, naturally regenerated pine forests began on the CEF. To do this, in March of 1942 the CEF was expanded (to 1,408 ha) with the addition of adjoining land leased from the Crossett Lumber Company (Harris 1945, Reynolds 1980).
The momentum for FG/TI in southern pines was irresistible. Wakeley and other like-minded individuals recognized the potential to improve upon southern pine growth and yield, insect and disease resistance, and wood quality. The greater degree of control under FG/TI was notably more promising than that from the preferential selection of trees during the harvest

process or the reliance on poorly provenanced woods-run seedlings to establish plantations (e.g., Wakeley 1951, Haig 1951, Dorman 1955). In the early 1950s, the Southern Forest Experiment Station (SOFES) of the USFS greatly expanded its FG/TI program by establishing a number of formal research projects at experimental forests and in 1954 the SOFES opened the Southern Institute of Forest Genetics to coordinate these efforts.

Figure 1. One of the better performing longleaf (*Pinus palustris*) x slash (*Pinus elliottii*) pine hybrids produced at the CEF. These seedlings started height growth the first year (no apparent grass stage) and reached 2.74 m tall in four years. USFS photograph, circa early 1960s.

The Schoenike Years

According to Grigsby (1969), the CEF FG/TI program began in 1951—however, this early start was probably limited to the contribution of shortleaf pine seed and provenance plantings for the Southwide Seed Source Study (see Wells and Wakeley 1970). A more proper beginning of the CEF FG/TI program was in 1952, when Roland E. Schoenike was hired to lead this effort (USFS SOFES 1953, Anonymous 1963). Much of the CEF FG/TI work was done in collaboration with the Crossett Company (and eventually Georgia-Pacific), who provided research funding, plant materials, and field logistical support over the years (USFS SOFES 1953, Anonymous 1963). During these early years, CEF's program was exploratory in nature, including local pine seed collection, southern pine hybridization, nursery and propagation techniques, exotic species tests, and the beginnings of loblolly and shortleaf pine plus tree selection, testing, and improvement (USFS SOFES 1955, Wakeley 1955). This period also witnessed considerable investment in infrastructure on the CEF, including the construction of a combined soils and genetics laboratory building (completed in 1954 for $3,338.63; a greenhouse addition was built in 1958 for an additional $6,145.04), planting beds and associated equipment, and the hiring of support staff.

FG/TI work on the CEF was as prominently featured in most of the SOFES annual reports from this period as the better-known uneven-aged silvicultural research (e.g., USFS SOFES 1955, 1956, 1957, 1958). However, although useful for program establishment and other logistical purposes, the early CEF FG/TI studies were rarely published outside of station study plans and annual reports. To date, only two formal publications relating to Schoenike's work on the CEF have been found: both were brief (1 page) notes; one on weather factors leading to the demise of loblolly and shortleaf pine seed crops in 1955 (Schoenike 1955) and the other on using plastic tubes for the controlled pollination of pines (Schoenike 1956). The epic droughts and other

weather-related challenges of the early- and mid-1950s also sorely tested many FG/TI projects across the region, and those on the CEF were no exception—for example, widespread drought-related mortality of progeny test seedlings at the CEF occurred in 1954 (USFS SOFES 1955). A later unpublished closing report (Nance 1978, p. 2) criticized many of the earliest CEF studies, calling them "…generally poorly designed, [of] limited objectives, and in general contribut[ing] little toward the long-term goals of the project." However, not all of these early studies were destined for obscurity—for instance, a comparison of woods-run loblolly pine seedlings from the Crossett area were planted across much of the region to compare with local-origin stock produced multiple publications (Sihvonen 1955, Grigsby 1955, 1975, USFS SOFES 1958). Pine hybridization was also an active part of the CEF program—Schoenike was credited by Wakeley as being one of the first (in 1954) persons to successfully produce Sonderegger pine (*Pinus* x *sondereggeri*) using controlled pollination (Wakeley and Barnett 2011). Hybrid crosses (Figure 1) between different species were sought to improve southern pine resistance to ice damage, insect and disease resistance, high growth rates, and good wood quality (Grigsby 1959).

The Grigsby Era

Schoenike left the CEF in 1956 to start a doctoral program in FG/TI at the University of Minnesota. Later that year, plant geneticist Hoy C. Grigsby was hired to replace Schoenike as the scientist in charge of the program. Grigsby was familiar with the CEF, having aided Schoenike in the establishment of the Arkansas loblolly pine seed source study across Mississippi when he was employed by the Mississippi Forestry Commission (Grigsby 1955). Grigsby was involved in many different aspects of FG/TI research, including some projects associated with nursery practices. An unpublished 1959 summary of the CEF's research program listed 29 active, numbered studies under the "Forest Genetics" category, all assigned to Grigsby (Table 1). While many of these used loblolly and shortleaf pine from local (Crossett area) sources, southern pines from other regions were often tested, as were exotic conifer species. Some of these studies originated with Schoenike, but Grigsby also established quite a number of projects himself. During his tenure, the CEF-based tree improvement and genetics research ranged from nursery practices and seed quality to experimentation with mutagens (both chemical- and radiation-based) and tests of "unique" parents (e.g., "bull" pines, figured wood).

The most prominent CEF FG/TI project related to plus tree selection, breeding, and progeny testing (Figure 2), most of which were summarized in an establishment and progress report written in the late 1960s (Grigsby 1969). These studies ranged considerably in their objectives, but one of the largest was installed between 1966 and 1969 and involved planting the progeny of controlled plus tree crosses in Compartment 3 of the CEF, as well as other blocks placed elsewhere (we will cover this project more in later).

One of the more unusual projects CEF scientists contributed to involved the irradiation of pine seed to see how different levels of exposure affected pine germination, seedling survival, and growth performance. Initiated by Schoenike and Wakeley in 1954, loblolly pine seed was exposed to different dosages of x-rays and then planted at both Crossett and the Harrison Experimental Forest in southern Mississippi. Grigsby contributed to the analysis and eventual

publication of the results, which found decreasing survival of pine seed with increasing levels of radiation but few other significant influences (Snyder et al. 1961). In addition to its uniqueness, this work also highlighted some of the challenges the FG/TI had at the CEF. Because of space and site condition limitations, it was not unusual for some of the FG/TI research directed by CEF staff to be installed elsewhere.

Table 1. Genetics studies listed in unpublished 1959 summary of the CEF's research program, all of which were assigned to Hoy Grigsby.[1]

USFS study number	Study title	Notes
CR-11.01	Geographic seed source	Shortleaf pine seed sources for Southwide Seed Source Study
CR-11.02	Forest nursery	
CR-11.03	Plus tree selection	For "outstanding" loblolly pine in the Crossett area
CR-11.04	Branch habit selection	Loblolly pine
CR-11.05	Seed grading selection	Loblolly pine
CR-11.06	Nursery stock selection	
CR-11.07	Hybridization and controlled breeding	From pine hybrids produced at CEF, Gulfport, and Alexandria
CR-11.08	Exotics and other non-natives	Multiple conifer species
CR-11.09	Local test of Crossett loblolly pine seed	
CR-11.12	X-ray irradiation for cytogenetic effects	Loblolly pine
CR-11.13	Morphological seedling types	Loblolly pine
CR-11.14	Nursery stock test	From outside nurseries in southern Arkansas and northern Louisiana
CR-11.15	Shortleaf pine seed grading	Tested seed size
CR-11.16	Loblolly pine seed grading	Tested seed size
CR-11.17	Controlled breeding—1953	Seedlings produced from 1953 breeding program
CR-11.18	Controlled breeding—1954 breeding program	Seedlings produced from 1954
CR-11.19	Controlled breeding—1955 breeding program	Seedlings produced from 1955
CR-11.20	Controlled breeding—1956	Seedlings produced from 1956 breeding program
CR-11.21	Seed source study	Used loblolly pine seed from Ozan Lumber Company
CR-11.22	Missouri seed source study	Loblolly pine for southern Missouri
CR-11.23	Ultrasonic treatment for cytogenetic tests	Loblolly pine
CR-11.24	Gamma irradiation treatments for cytogenetic effects	Loblolly pine
CR-11.25	Phenotypic variation in open pollinated	Loblolly pine
CR-11.26	Colchicine experiments for cytogenetic effects	Loblolly pine
CR-11.27	"Bull" pine progeny tests	

CR-11.28	Exotic trials in southwest Arkansas	Various exotic conifers
CR-11.29	Loblolly pine seed source	At Prescott, AR (36 seed sources)
CR-11.30	Performance and progeny test for seed lots from Arkansas, Louisiana, and Mississippi	Loblolly pine
CR-11.32	Chemical effects on rooting	Loblolly pine cuttings

[1] Document on file with the senior author.

Schoenike and Grigsby established a number of their progeny tests and other studies on nearby industry lands, as well as on other experimental areas in Arkansas, Louisiana, Mississippi, and other locations across the southeastern US. For example, Grigsby installed some of the replicates of a study on the impacts of tip moth (*Rhyacionia* spp.) on loblolly, shortleaf, and hybrid pines at a site near Many, Louisiana, to complement the treatments installed on the CEF (USFS SOFES 1960).

The End of an Era

It is worthy of noting that Wakeley, even after his sharp critique of the selective cutting focus of the early years of the CEF, later saw fit to praise its FG/TI program: "The Crossett Project's contributions to forest tree improvement are not to be lightly brushed aside and will grow in value as the trees in its hybrid-, progeny-, and provenance-test plantations grow tall." (Wakeley and Barnett 2011, p. 57). Wakeley had penned this statement in 1964 during what probably could have been considered the zenith of the CEF tree improvement program. Obviously, at this time he could not have anticipated the closing of the CEF in a decade, followed by the termination of its FG/TI work.

Figure 2. Hoy Grigsby scaling one of the plus tree loblolly pines on the CEF. Trees with superior form, growth, and disease resistance formed the basis for many of the progeny tests conducted by the CEF staff during the 1950s and 1960s. USFS photograph, circa early 1960s.

The studies established in the mid- to late-1950s were closed by early 1969 (Grigsby 1969). The CEF was shuttered by the SOFES in 1974, with all remaining staff moved to other duty stations; Grigsby was reassigned to Pineville, Louisiana. Some of the FG/TI studies were continued for years afterwards by other US Forest Service scientists, Georgia-Pacific, the University of Arkansas-Monticello (UAM), and other collaborators. Plant geneticist Warren L. Nance assumed the responsibilities for any remaining CEF tree improvement studies in 1974 (Nance

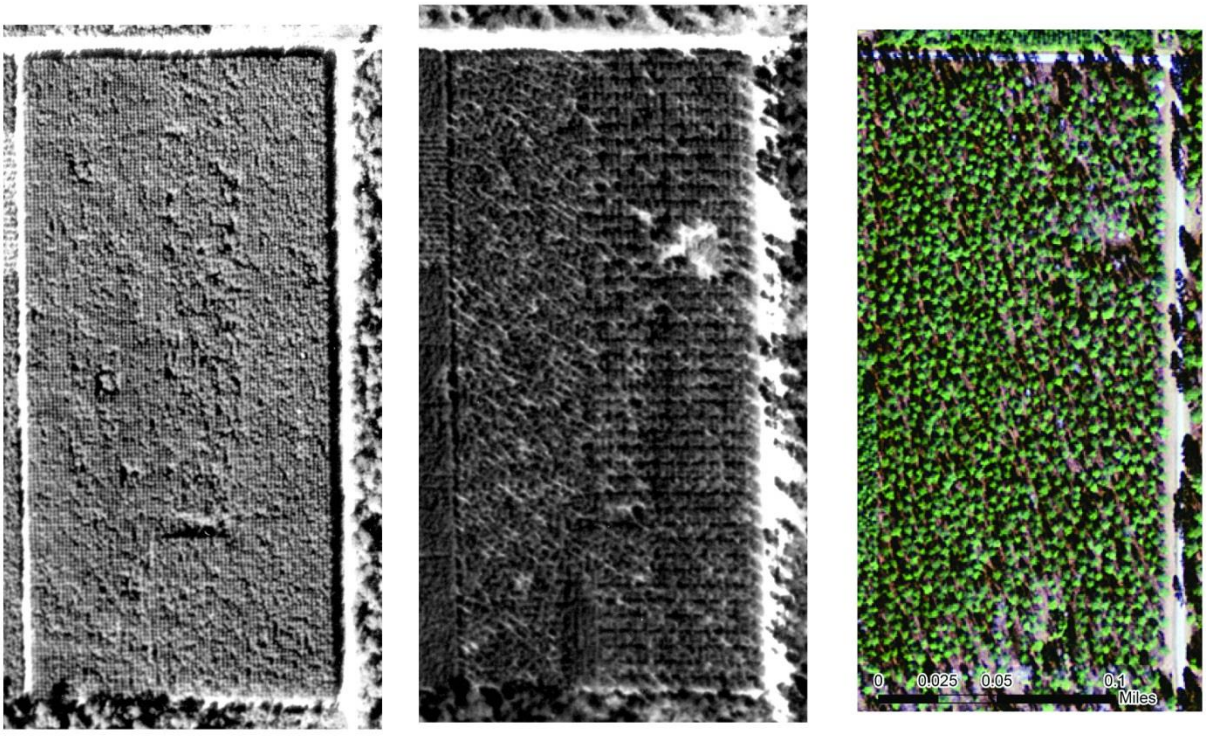

Figure 3. Aerial photographs of Compartment 3 on the CEF from 1980, 1985, and 2006, showing the unthinned (1980) and thinned (1985 and 2006) plus tree progeny tests. USFS photographs.

1978). After 1974, some of the outlying CEF-related plantings were measured by others—for instance, Professor Elwood Shade measured a number of the progeny tests established on the UAM POW Camp, and staff of Georgia-Pacific and other cooperators followed other outplantings during this period.

When the CEF reopened in 1979, its mission then focused on the development of low-cost silvicultural techniques for small forest landowners. Thinnings had been designed into the original study plans and were to have occurred after 10 growing seasons (Grigsby 1969). However, this would have meant thinnings were to have been done between 1976 and 1979, when the CEF was closed. An aerial photograph of the CEF from 1980 shows that Compartment 3 had not received any thinnings, however, the aerial photograph taken a few years later was obviously thinned (Figure 3). In late 1985, the plus tree progeny was thinned, followed by operational thins in 1996 and 2002.

CURRENT AND FUTURE DIRECTIONS

Although the formal CEF FG/TI program has long been closed, vestiges remain that present current and future research opportunities. For example, the plus tree progeny tests of 1966-1969 are largely intact, and at 46-49 years post-establishment offer unique opportunities to reevaluate growth, bole quality, and other performance measures for known families. However, we have found the records on this work fragmentary and hard to reconstruct,

especially since the fate of the plus tree progeny tests on Compartment 3 became murkier following Nance's (1978) internal closing report. The temporary CEF closing and then years of shuffling files around the agency further disrupted the documentation of this plus tree study. Regrettably, very few of the principles in these studies remain to consult, as all have since retired or died—Reynolds passed away in 1986, Schoenike in 1988, and Grigsby in 2009. Furthermore, some of the original installments have been cut, burned, blown over, or even bulldozed—parts of the plus tree pine progeny tests were lost as recently as 2014.

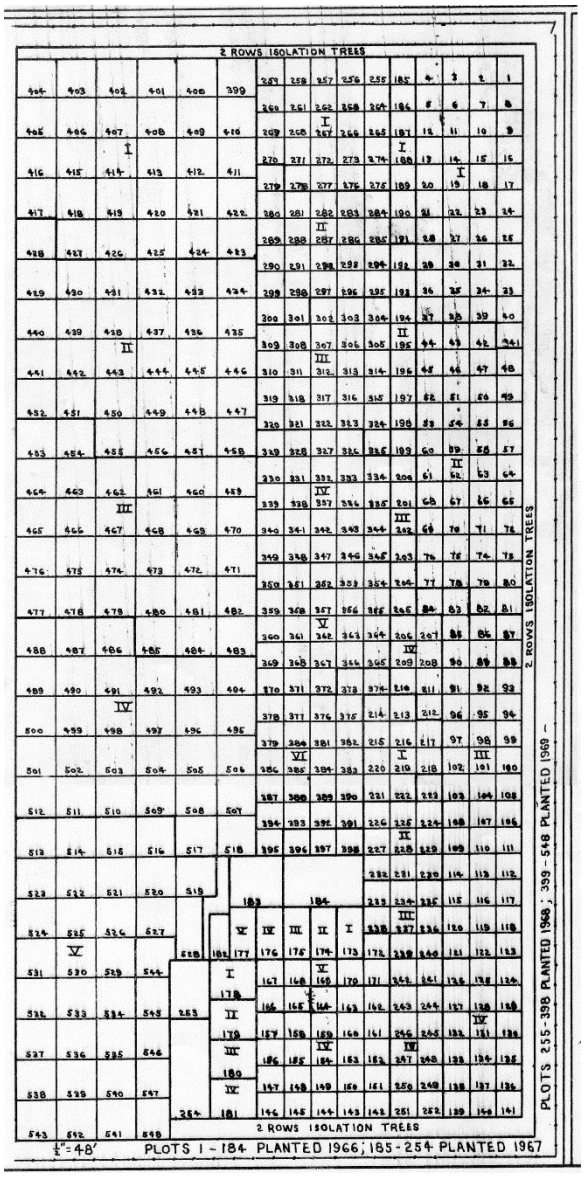

Figure 4. Plus tree deployment map for CEF Compartment 3 progeny tests, circa 1970. This map will help researchers reconstruct the family structure of this planted loblolly pine stand, allowing for new and expanded analysis of this now nearly 50-year-old progeny test.

These challenges notwithstanding, we are optimistic that interesting insights can be gained from the pieces that remain. For example, we recently started reestablishing the original layout of the plus tree pine progeny tests in Compartment 3. From our preliminary assessment, most of the treatment replicates from Grigsby's study survive. Our first step was to gather the remaining study documentation, in which the deployment maps were found (Figure 4). We then used GPS and a laser distance measuring device to produce a stem map that we could overlay a digitized representation of the deployment map to identify the family of each remaining pine. The process will need to be improved, as the horizontal accuracy of the stem map (currently about ± 2 m) is insufficient to definitely assign the correct family for specific trees. To date, we have found a number of the plot corners in Compartment 3 using a metal detector that are probably still in place (tags on wooden posts were used, and the posts have long since decayed away). If this approach works in Compartment 3, a number of other progeny tests remain at least partially intact in CEF Compartments 36 and 46, and some may survive at UAM's POW Camp.

Once the plus tree progeny tests are accurately mapped, we plan to recover the original data collected when these trees were young. This

information was not published when completed in the 1970s, and when combined with diameters and other measurements collected in 2014, we think some interesting lessons could still be learned. For instance, would the best performers indicated by early height growth trends measured in the 1970s still be the best performers decades later? What progeny have shown the best growth performance? Survival? Vulnerability to insects or disease?
We also believe that the plus tree pine progeny tests in Compartment 3 (and elsewhere) offer promise for future studies related to genetics, tree defense strategies, wood properties, reproductive potential, carbon allocation patterns, and bole/crown dynamics, amongst others. As an example, which progeny will do best under future climate scenarios? Having a large number of full- and half-sib families in a concentrated area under relatively similar environmental conditions and consistent management histories can provide a degree of experimental control rarely available.

CONCLUSIONS

With the prominence of the CEF's research programs in naturally regenerated pine forests, few are aware of the substantial, decades-long FG/TI program once centered at Crossett. Undoubtedly, part of this is because the lead investigators of this program did not publish much of their research, especially in the peer-reviewed literature. Using several online search engines (e.g., Google Scholar, Digitop Navigator, ProQuest Natural Science Collection, EBSCOHost Environment Complete) and some forestry publications and reports (e.g., Dorman 1976), only 20 papers were found that had been published by Schoenike, Grigsby, Grano, and their other collaborators on CEF-related tree improvement work (including nursery practices, genetics, etc.) between 1955 and 1978. Many of these papers were in the "gray" literature (e.g., conference proceedings, Forest Service publications) and are hard to access. However, we should have enough information to add considerably to our knowledge of southern pine silviculture using the surviving examples and the past data of the CEF's FG/TI program.

ACKNOWLEDGMENTS

We would like to recognize the efforts of many people over the years to establish and maintain the CEF FG/TI program, including Russ Reynolds, Phil Wakeley, Roland Schoenike, Charles Grano, Hoy Grigsby, and all the other support staff who shepherded the projects over time. Regrettably, most of these people are now deceased, so we can't thank them in person.

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