I- E. Field Notes on the Detection of Soybean Rust, Initial Surveys and the Current Status of the Disease in Hawaii

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Soybean (*Glycine max* (L,) Merrill) is grown in Hawaii primarily as a vegetable crop. The green pods are harvested when nearly mature but before the drying stage begins. The pods are boiled in salted water and the beans are eaten as a snack which provides an excellent source of nutrition and is considered a local delicacy. Soybean is considered a minor crop in Hawaii, grown on approximately 10.8 hectares statewide with an annual production of 86,000 kilograms. This figure excludes seed production which is considerably less. Soybean vegetable farmers, the majority being recent immigrants from Southeast Asia, are typically small truck farmers who continuously crop soybeans on farms 0.2 to 2 hectares in size. On 4 May 1994, soybean rust (SBR) was detected on a farm in Mililani located in the central part of the island of Oahu. This was the first report for the State. The causal organism was tentatively identified as *Phakopsora pachyrhizi* Syd. & P. Syd, (6).

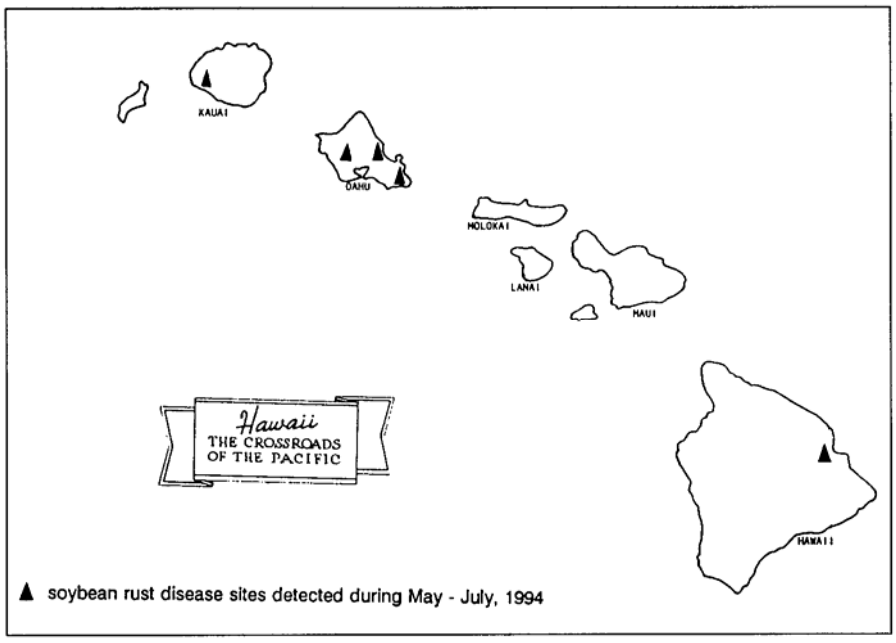

Figure 1. Incidence of soybean rust in Hawaii as of July 1994.

The Hawaii Department of Agriculture (HDOA) immediately set the stage for emergency action by initiating legal procedures for mandatory eradication of diseased soybean fields. The Department then apprised the USDA APHIS PPQ officials in Honolulu of the detection of SBR and they in turn alerted their appropriate offices. Federal Plant Quarantine officials did not express much concern on a quarantine level for the presence of SBR in Hawaii for three reasons: (i) federal quarantine measures were already in place that prohibit the movement of fresh soybean pods from Hawaii to the continental U.S., due to the presence of two insect pests - the bean pod borer (*Maruca testulalis* (Geyer)) and the bean butterfly (*Lampides boeticus* L.), (ii) soybean plant parts other than pods were not likely to be transported to the continental U.S. and (iii) since SBR is not seed transmitted, there was no risk in the export of seed material to the continental U.S.

As a precaution, a recommendation— was made to all soybean seed producers in Hawaii by the HDOA that seed for export be thoroughly cleaned of any chaff or plant contaminants before shipping.

Soon after the first determination was made, the HDOA initiated surveys of soybean fields on all islands in order to determine the extent of the disease in Hawaii. Soybean rust was found on three islands: on one farm in the Hilo area on the Big Island of Hawaii; in a commercial seed production field at Kekaha, Kauai; and on several other farms on the island of Oahu (Figure 1). Due to the widespread occurrence of the disease, the emergency status for SBR eradication was cancelled.

SYMPTOMATOLOGY AND DISEASE DEVELOPMENT IN SBR-INFECTED FIELDS SURVEYED DURING THE PERIOD MAY TO JUNE 1994

Field 1 - Mililani, Oahu, 5 May 1994. This 0.2 hectare soybean field in which the disease was first detected was being kept for seed (replant), rather than for table or vegetable use. The pods numbered 5 to 8 per plant and were beginning to turn brown. The plants were only 25 to 35 cm high with few leaves remaining on the stem (Figure 1). Some were still green, but most were yellowed and necrotic. Numerous light to reddish brown spots were visible on the upper surface of the leaves. On the underside of the leaves, numerous pustules were observed using a 40x power lens. Also present were larvae of the fungus feeding midge (*Mycodiplosis fungi- cola* (Felt)). The planting date and the variety was not determined.

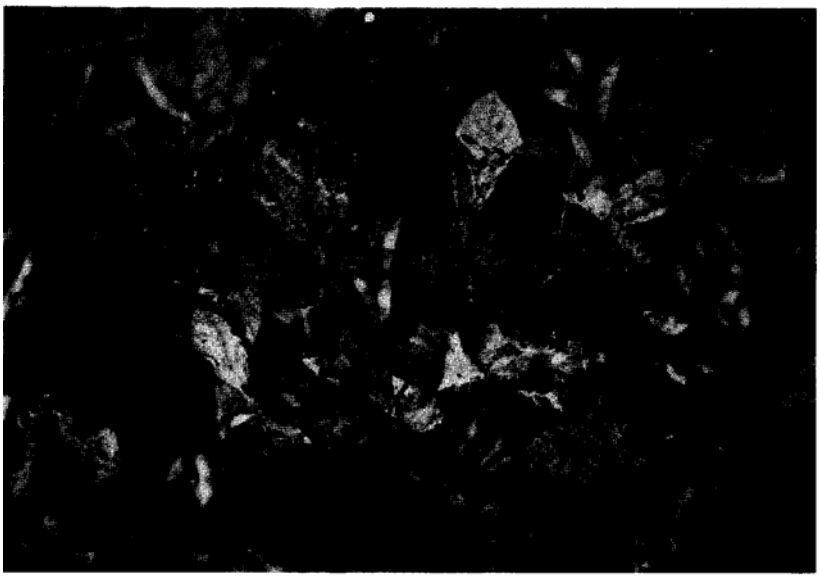

Figure 2. Soybean plants with advanced soybean rust disease at Mililani, Oahu, on 4 May 1994.

Figure 3. Typical symptoms of SBR on cotyledons of soybean plants at Miliani, Oahu.

A moderate number of fuzzy rattle pod (*Crotalaria incana* L.) and Japanese tea (*Cassia lescheriaultiana* DC.) plants were growing in the field. Although the soybeans were heavily infected, relatively few rust pustules were present on the leaves of C. *incana* and none on C. *lescheriaultiana.* The only other leguminous weedy plants along the edge of the field were stands of koa haole (*Leucaena leucocephala* (Lam.) de Wit), which were not infected with SBR.

A younger soybean planting which had just begun to flower had numerous reddish- brown rust spots on the unifoliolate leaves and first trifoliolates (Figure 3). The unifoliolate leaves were beginning to yellow. This section of the field was being misted with an overhead irrigation system in the middle of the afternoon. There was another section of the field planted with soybeans at the first trifoliolate leaf stage, but there was no rust.

Field 2 - Mililani, Oahu, 5 May 1994. This 0.2 hectare soybean farm was adjacent to field 1. Part of the field was near harvest and very little rust was observed. Some yellowing was noticeable on the unifoliolated leaves and first trifoliolates. Younger soybean plants (two to three trifoliolate leaf stage) on this farm were free of the rust. The field was equipped with an overhead irrigation system, but the field was not as wet nor misted as field 1. Varietal information was not known. Contact with the grower was never made. Five other soybean farms were surveyed in the Mililani area, all within a 3.2 kilo meters radius of these two farms, but no SBR was

detected. At neighboring farms, green beans (*Phaseolus vulgaris* L.) and yard long beans (*Vigna unguiculata* (L,) *Walp. subsp. sesquipedalis* (L.) Verdc,) were not found infected with SBR.

Field 3 - Waimanalo, Oahu, 9 May 1994. SBR was detected on the windward side of Oahu in the Waimanalo area, soon after the initial detection at Mililani, Total acreage on this farm was 0.8 hectare with soybean plants at varying stages of development. Soybean rust was clearly evident on the most matured field. Yellowing was very pronounced (Figure 4). Harvesting of this section had begun. The grower did not know the cultivar of the soybean but had purchased the original seed material from a local seed importer. From HDOA seed certification records, it was determined that the seed source was Japan and mostly likely one of two cultivars, Kiyohime or Midori. The grower had installed an overhead irrigation system and the field condition was maintained at a very high level of moisture. Larvae of M. *fungicola* were present. This farmer had five successive plantings of soybeans, each about 3 weeks apart so that he could maintain a harvest every 2 weeks. Soybean rust was detected only on those plantings that had reached the flowering stage. The farmer was not aware that he had a disease problem. A recommendation was made to this grower to reduce the watering frequency. Six other soybean farms were surveyed in the Waimanalo area all within a 3.2 kilometers radius, but SBR was not detected (Figure 5). Weedy legumes, *Canavalia cathartica* Thouars (maunaloa vine) and Glycine *wightii* (Wight & Arnott) Verdc., also were examined, but did not have rust.

Figure 4. SBR infected field (foreground) in Waimanalo, Oahu, no sign of rust in younger planting in background.

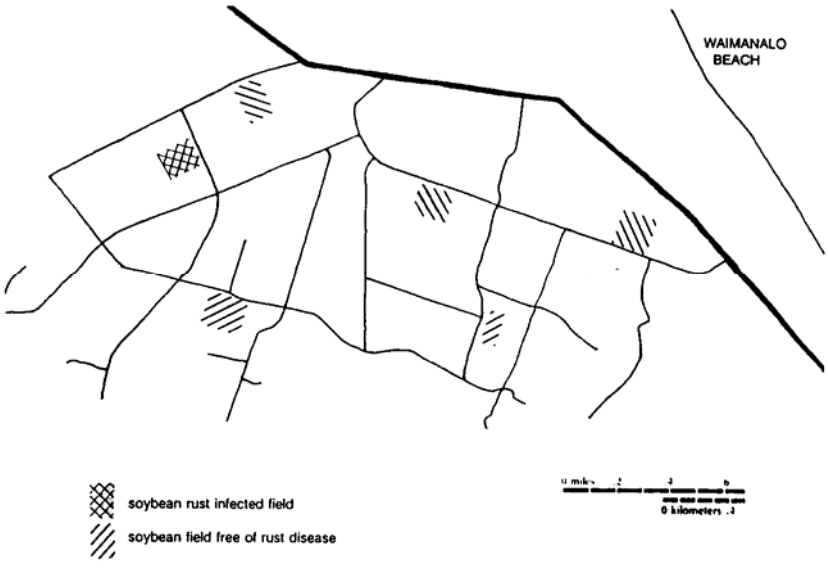

Figure 5. Surveyed soybean fields in Waimanalo, Oahu, June-July 1994.

Field 4 - Kahaluu, Oahu, 25 May 1994. This small, backyard planting of soybeans was nearing harvest. Soybean rust infection was extensive although the leaves were not yellowed. Larvae of M. *fungicola* were present in high numbers. The owner did not know the cultivar of soybean, but mentioned that the "disease" had been observed for several years. Rainfall is normally abundant in this part of the island so that irrigation is not necessary. Across the street from this residence, a homeowner had converted his front yard to a soybean patch, which was twice as large as the aforementioned residential plot. SBR was not detected in this plot even though the soybeans plants were at a more mature stage of development.

Field 5 - Kekaha, Kauai, 14 June 1994. SBR was identified in the remnants of a commercial seed field in Kekaha, Kauai. The field had already been harvested and the soybean rust infected field soybean field free of rust disease

remaining rows were severely defoliated. From what was examined on the few remaining leaves, the disease was not extensive and, for this reason, it probably remained undetected. The defoliation was probably due to causes not related to SBR. The seed company was notified immediately. The Department was then informed that the seeds from this field had been already planted on the U.S. mainland, somewhere. Needless to say, the field was probably under close observation from that point on. The Department was not able to locate any other soybean field on Kauai at that time.

Field 6-Hilo, Hawaii, 20 June 1994. A heavily infected field was found on the island of Hawaii, near the Hilo area. This was a 0.1 hectare field with soybeans at different stages of development. The leaves on the mature plants were yellowed and slightly necrotic. The grower was about to harvest this section of the field. He mentioned that he had observed this disease for several years but was not concerned since the yields were not lower than usual. The grower remembered planting the Japanese cultivar Local Green many years ago and has always kept a part of his field for seed production.

STATUS OF SOYBEAN RUST DURING DECEMBER 1994. A subsequent statewide survey for SBR was conducted in December 1994. The disease was not detected in any of the previously infected fields on Oahu. The soybean field identified as field 1 - Mililani, was completely plowed and left barren. There were still soybeans growing in field 2 - Mililani, but the rust was not observed. Other soybean farms were surveyed in the Mililani area but the disease was not present. Field 3 - Waimanalo was in full production, with soybeans at all stages of growth, but the rust was not observed. The grower was not irrigating his fields as frequently. SBR was not detected at field 4 - Kahaluu. Surrounding soybean fields also were surveyed and SBR could not be detected. There were no soybeans planted on Kauai during December 1994 at any of the commercial seed producers' fields. The only site that SBR was detected was in field 6 - Hilo on the island of Hawaii.

Figure 6. Adaxiol surface of soybean leaf with numerous rust lesions.

STATUS OF SOYBEAN RUST DURING JUNE 1995. On Oahu, the incidence of SBR was minimal. Field 1 - Mililani was no longer in soybean production. Low levels of the rust were detected in field 2 - Mililani and field 4 - Kahaluu. Field 3 - Waimanalo was free of SBR. University of Hawaii Extension Plant Pathologist Jeri Ooka, reported seeing no evidence of soybean rust on the island of Kauai in the winter and spring plantings by two commercial seed growers (personal communication).

On the Big Island of Hawaii, there was a very low level of SBR reported in field 6 - Hilo. However, an additional soybean farm was discovered in the Honomu area, north of Hilo. SBR was clearly evident in this 2 hectare field, being most pronounced on the oldest planting. The leaves were yellowed and necrotic, and the plants were beginning to defoliate.

DESCRIPTION AND IDENTIFICATION OF CAUSAL AGENTS. Pustules are more abundant on the abaxial surface of the leaves although they erupt on the adaxial surface as the lesions mature (Figure 6). On inoculated soy bean plants kept in enclosed chambers under controlled greenhouse conditions at temperature ranging from 20° to 24° C, 90% relative

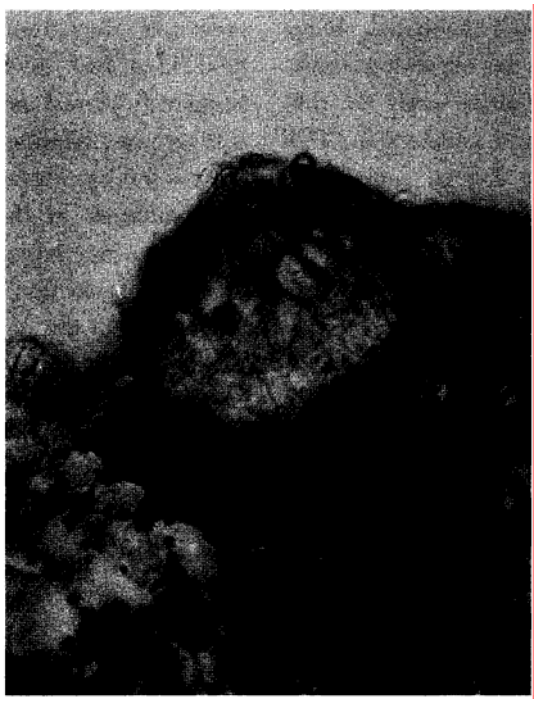

Figure 7. Photomicrograph of a young erupting pustules of *Phakopsora pachyrhizi*, with urediniospores and paraphyses.

Figure 8. Typical rust pustule of SBR on soybean leaves collected from the field.

humidity and 12 hours light, sporulation is visible with columns of spores extruding from the uredinia, These urediniospores are aerosolized easily by the slightest air movement. Under field conditions, these spore columns are not as pronounced. Those spores not aerosolized become a food source for larvae of *M. fungicola*, which are commonly seen wherever the disease occurs (Figure 9). Hollowed cavities of uredia frequently are observed in rust lesions.

The urediniospores are light cinnamon-brown in color, obovoid to ellipsoid. They measure 16 to 24 by 24 to 31µm and are uniformly and finely echinulate. The germ pores are obscure. The numerous, pale yellow paraphyses have a slightly thickened apex (Figure 7). The sori are hypophyllous with spores extruded through a prominent central pore. There may be up to five to eight sori per lesion (Figure 8). Only the uredinial state of the rust organism has been observed in Hawaii.

Since the two soybean rust organisms, *P. pachyrhizi* and *P. meibomiae* (Arthur) Arthur (7), are indistinguishable by their uredinial state (1) and since the telial state has not yet been observed in Hawaii, theoretically, it is not possible to identify this *Phakopsora*. It is, however, more likely that *P. pachyrhizi* is the cause of soybean rust in Hawaii. According to Bromfield *et al.* (2), the SBR organism from Puerto Rico is less virulent on soybean. Soybean rust under ideal conditions in Hawaii can be severe, causing extensive yellowing and leaf drop. Inoculations under controlled laboratory conditions using the University of Hawaii's soybean cultivar Kahala resulted in the formation of the TAN-type of lesions (3), 10 days after inoculation, followed by yellowing, necrosis and defoliation within 30 days.

SOME INSIGHTS ON THE RELATIONSHIP OF WEATHER TO THE INCIDENCE OF SOYBEAN RUST IN HAWAII.

All known soybean farms were intensively surveyed on the island of Oahu during May to June 1994. The majority of the farms are situated in agricultural areas where crops must be irrigated. SBR was found on three

Figure 9. Aboxial soybean leaf surface with pustules and fungus midge larvae (Mycodiplosis fungicold).

of 11 soybean farms in the survey, two of which are located in areas of low rainfall (Figure 10) (4). The soybean field at Mililani, where soybean rust was first detected, and the Waimanalo field were irrigated with overhead watering systems. The majority of farmers use drip irrigation. Both fields were extremely wet even at midday when visits were made. The Mililani farmer was not in soybean production by December 1994. At Waimanalo, SBR was not detected during that December survey. The farmer had significantly reduced the moisture level in his field. The third, a residential plot, is situated in a rainy section of Oahu and SBR was found there in two of three surveys. The commercial soybean seed producers on Kauai are located in an arid part of the island where rainfall is at trace levels for most of the year (Figure 11). Prospects for SBR outbreaks for this area is, in the opinion of the author, minimal.

A different situation exists on the Big Island of Hawaii. Soybean farms are located on the northeast coastal section of the island, where rainfall is quite abundant during most of the year (Figure 12). There is sufficient rainfall to preclude any need for field irrigation. This would explain the occurrence of SBR in the .Hilo area in December 1994, when SBR was not detected on the island of Oahu. For the first half of 1995, however, recorded rainfall for the Hilo area has been significantly lower than normal and probably has resulted in the lower incidence of SBR.

Year round temperatures for the State range from approximately 20° to 30°C, which is definitely within the temperature requirements for SBR urediniospore germination and disease development (4). Therefore, temperature is not a limiting factor for the incidence nor development of SBR in Hawaii.

GENERAL COMMENTS ON SBR IN HAWAII. The discovery of soybean rust disease was a chance discovery. If a grower had decided not to keep his field for seed and if an HDOA entomologist had not surveyed this particular soybean field for Chinese rose beetle damage and

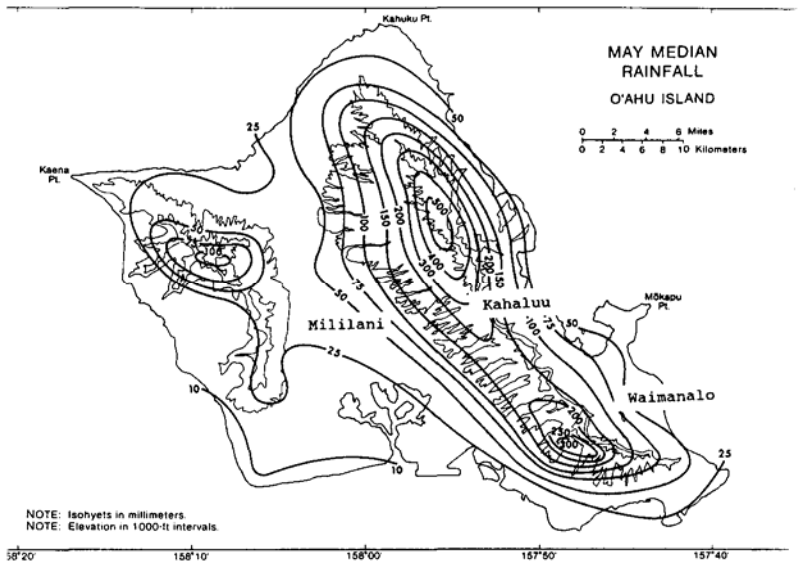

Figure 10. Locations of three SBR infected farms – Miliani, Waiamanalo and Kahaluu, and the May median rainfall levels (isohyets) for the island of Oahu.

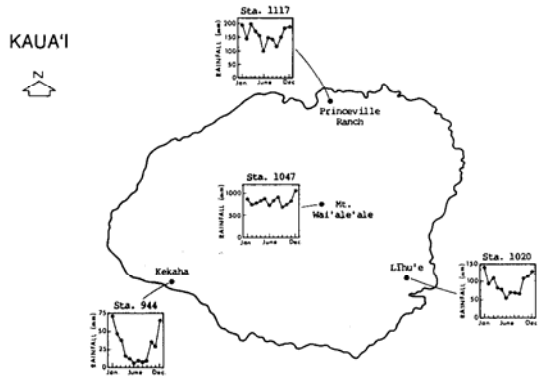

Figure 11. Annual rainfall cycles for the island of Kauai, indicat ing extremely low levels of rainfall for Kekaha (Rainfall Atlas of Hawaii).

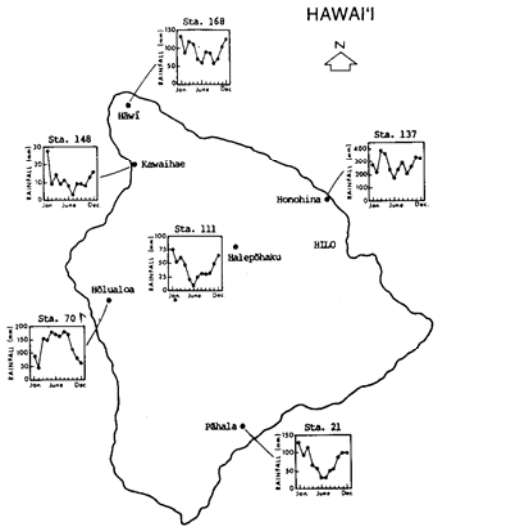

Figure 12. Annual rainfall cycles for the island of Hawaii, indicating high rainfall levels for the northeast coastal area (Honohina) which includes Hilo and Honolulu (Rainfall Atlas of Hawaii).

had not noticed the fungus feeding midge larvae (Figure 9), SBR may still not exist in Hawaii today.

Soybean rust does not appear to be a major problem for the soybean vegetable farmer. The majority of soybean growers do not have SBR in their fields. Although studies on yields have not been done, growers with SBR in their fields have been satisfied with their yields. Perhaps plants harvested for vegetable use before maturity are not significantly affected by SBR disease.

How did SBR become established in Hawaii? There is speculation that SBR was brought into the State from Southeast Asia on soybean plants or planting material by immigrant farmers. This cannot be substantiated since difficulties in communication have been a major roadblock in getting information. This mystery will probably never be solved. Although SBR is not known to be seed transmitted, seed contaminated with infected plant material may be a means for introduction.

Besides C. *incana*, no other leguminous host of SBR has been identified in Hawaii. However, current cultural practices, such as continuous cropping and grower's seed increases, will ensure that SBR remains a threat to all soybean growers.

For the past several years, the State has been experiencing lower than normal rainfall levels and higher than normal temperatures. It would be difficult to predict future weather patterns but in all probability, climatic conditions, particularly rainfall, will be the critical factors in determining the future status of SBR in Hawaii.

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