# CLIMATIC INFLUENCES ON POST-RELEASE POPULATIONS OF THE BIOLOGICAL CONTROL AGENT *CECIDOCHARES CONNEXA* IN NORTHERN QUEENSLAND.

K. Pukallus, A. Kronk and M. Butler
Queensland Department of Agriculture & Fisheries, Tropical Weeds Research Centre, Charters Towers, Queensland.

## ABSTRACT

*Cecidochares connexa*, stem-galling fly, is Australia's only mass-reared and released biological control agent for the invasive weed species, *Chromolaena odorata* (Siam weed). Releases of *C. connexa* commenced in late 2019 in northern Queensland and have now covered eight Local Government Areas. In this paper we will assess the gall infection rate of *C. connexa*, at two trial sites within two different climatic zones over several years. One site is within the wet tropics (Nyleta Hill), with a mean annual rainfall of 3,294 mm and the other site is situated in the dry tropics (Black River), with mean annual rainfall of 1,135 mm.

All climatic parameters were analysed, with strong positive correlations existing between an increase in rainfall and gall infection rate (galls versus growing tips). Black River experienced an increase of *C. connexa* galls by 2,428% in early 2023, compared to the previous years. This was due to the site receiving double the amount of rainfall than the previous year (1,844 mm) in the same period. These boom-and-bust rainfall events in the dry tropics compared to a constant supply of moisture in the wet tropics creates different plant and agent responses.

**Keywords**: stem-galling fly, Chromolaena, rainfall, climatic influence, biocontrol, tropics.

## INTRODUCTION

*Chromolaena odorata* (L.) R.M. King & H. Rob (Siam weed) was first detected in Australia, near Bingil Bay, Queensland in 1994 (Waterhouse 1994) and subsequently in July 2019 in the Northern Territory (NT Govt. 2020). *C. odorata* is a fast-growing multi-stemmed perennial shrub of the Asteraceae family. Plants can grow two to three metres tall unsupported, and up to 10 metres when supported by other vegetation. Plants die back in drier periods and rapidly reshoot after rain. *C. odorata* reproduces vegetatively and via seeds which are produced following the peak flowering period of May to August in Australia (QDAF 2020).

*Cecidochares connexa* (Macquart) (Diptera: Tephritidae), stem-galling fly, is native to central America and is Australia's only released biological control agent for *Chromolaena odorata*. Adults are between three and five millimetres long and have a distinct black "M" patterning on their wings. Females use their ovipositor to deposit eggs into the growing tips of *C. odorata* plants. Once these eggs hatch, the larvae feed on plant material inside the stem causing a gall. These galls act as nutrient sinks, limiting the plant's ability to flower and produce seed and therefore reduce its reproductive potential. One to ten adults can emerge from a gall depending on the size of the gall and number of eggs laid. The lifecycle from egg to adult takes approximately 50-80 days depending on climatic conditions. During warmer and wetter conditions, the lifecycle duration decreases (Pukallus *et al.* 2022).

Releases of *C. connexa* commenced in Queensland in late 2019 and have now covered eight Local Government Areas within northern Queensland. A total of 44,504 adult flies and 3,388 galled stems have been released between 2019 and 10 August 2023.

## METHODS

Two 20m x 20m plots were assigned on council/public land in two different climatic bioregions with *C. odorata* infestations - wet tropics (Nyleta Hill) and dry tropics (Black River). These plots were approximately 250 kilometres apart. Assessments were conducted on 20 randomly allocated *C. odorata* plants scattered throughout each plot. The total assessment period was nearly three years and 10 months. At the end of the assessment period, all 20 plants survived at Nyleta Hill, while only 15 plants at Black River survived.

On each plant, active growing tips, number of galls (in any development stage) and reproductive branch structures on cyme compound flower arrangement (represented as buds or flowers) were counted. *Cecidochares connexa* were released at Nyleta Hill on 18 July 2019 (26 female and 76 male adult flies) and on 18 November 2019 (101 galled stems). At Black River, 53 female and 53 male adult flies were released on 10 March 2020. These were from either QDAF's Tropical Weeds Research Centre or EcoSciences Precinct colonies.

While site assessments were done at other times, data collected at four time points are used. May 2020 (following the last *C. connexa* release between each site) and in March of 2021 to 2023. Assessments were taken to determine if there was any relationship between plant growth, gall production and climate parameters. March data was used, after determining that March was the peak period of gall production and plant growth from years of assessments. Rainfall data for the sites was obtained from the Long Paddock website (State of Queensland 2023).

## RESULTS

Gall detection at both sites occurred within several months after releases and persisted at the sites throughout the years.

At Black River the mean number of growing tips per plant increased from 27.6 in 2020 to 758.6 in 2023. While the mean gall numbers per plant increased from 0.87 galls to 225 per plant in the same period. A strong correlation ($r^2$=0.8719) between number of galls per plant and growing tips per plant was shown at the Black River site (Figure 1) during the four-year study. This indicates that *C. connexa* populations can rapidly increase in response to large increases in growing tips as indicated by the number of galls.

At Nyleta Hill, the mean number of galls per plant increased from 5.55 in 2020 to 12.5 by 2022 and then decreased in 2023 to 5.8. The mean number of growing tips remained relatively constant from 2020 to 2023 ranging from 13.15 to 17.3 per plant. In contrast to the Black River site, Nyleta Hill displayed a weaker correlation ($r^2$=0.3549) between galls per plant and growing tips per plant during the study period (Figure 2).

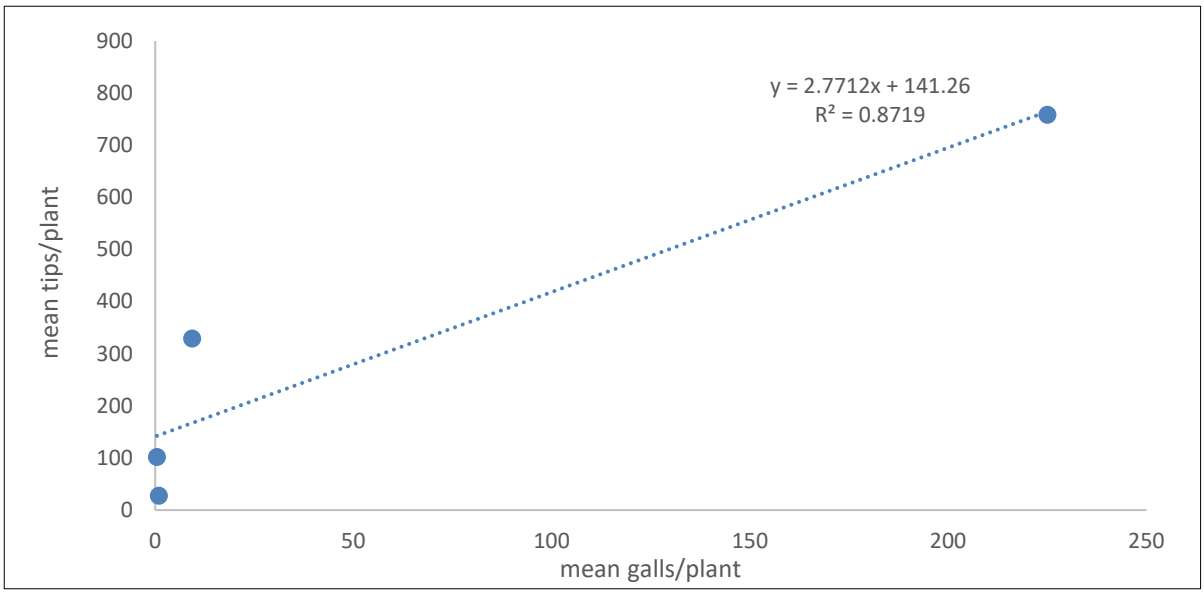


**Figure 1**. The strong correlation between galls/plant and growing tips/plant at Black River (dry tropics site).

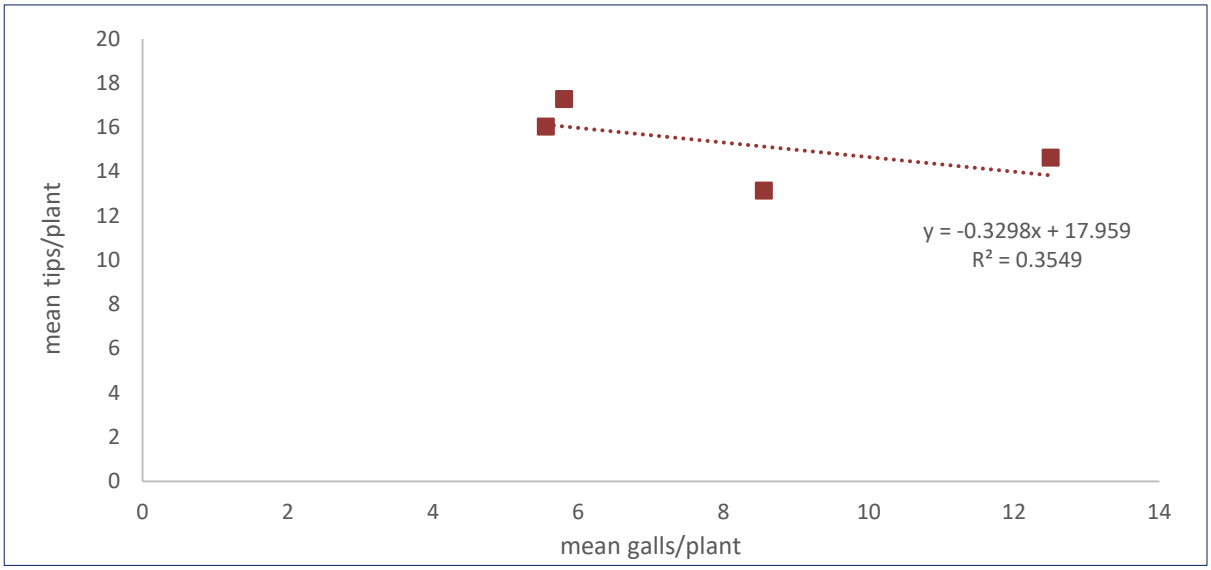


**Figure 2.** The relatively weak correlation between galls/plant and growing tips/plant at Nyleta Hill (wet tropics site).

Gall infection rate (total number of galls/growing tips per site) appears to be highly driven by rainfall at Black River (Figure 3) with a strong positive correlation ($r^2$=0.978). The infection rate in 2023 (0.296) is more than 10 times that of 2022 (0.028). Rainfall was calculated as the mean monthly rainfall (mm) per year between assessment periods. Overall, Black River rainfall is highly variable both seasonally and annually (709 – 1,844 mm), producing a corresponding level of variability in infection rate over the years.

In contrast, at Nyleta Hill there was a very weak positive correlation ($r^2$=0.1506) between infection rate and rainfall (Figure 3). This indicates that rainfall is not a major factor in gall infection rate at Nyleta Hill. The more consistent and higher rainfall (2704 – 3883 mm) recorded supports more consistent plant growth and higher infection rates (0.33 – 0.85).

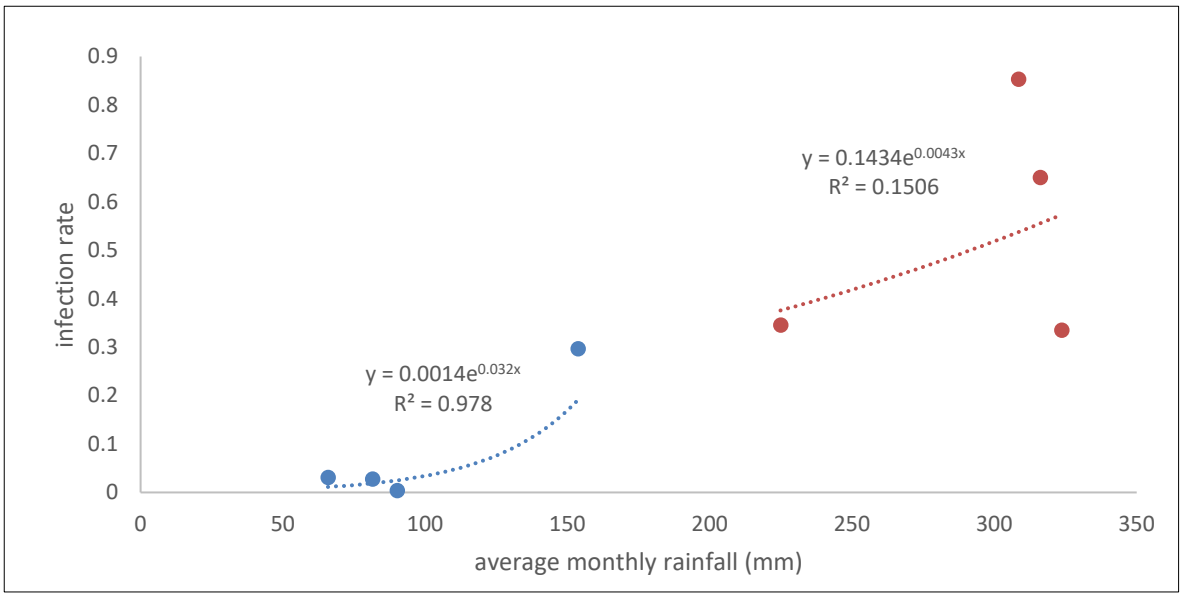


**Figure 3.** The correlation between mean monthly rainfall per year (mm) and infection rate (galls/growing tips) at Black River ( ) and Nyleta Hill ( ).

**Figure 4.** *Chromolaena odorata* flower arrangement (left) and flower arrangement with *Cecidochares connexa* galls at flowering (centre) and at seeding (right).

The number of buds and flower branches were counted for 2020 & 2021 seasons. At Nyleta Hill, production was consistent with 902 and 951 produced in 2020 & 2021 respectively. At Black River however, bud and flower production increased from 161 in 2020 to 3,567 in 2021 resulting in a ratio of 2.33 flower branches for each growing tip. In 2023, 11,379 growing tips were counted at Black River. Using the 2021 ratio of flower branches to growing tips, a predicted likely number of 26,513 flower branches should have been present in 2023. However only 3,066 flower branches were produced, a reduction of 88.4% of the predicted flower set.

The daily maximum and minimum mean temperatures (°C), mean relative humidity at maximum temperature (%) and solar radiation (MJ/m$^2$) formed weak correlations with infection rate at both sites, so the results are not included here.

## DISCUSSION

Climatic influences on *Cecidochares connexa* establishment and impact on *Chromolaena odorata* in other countries is not new. Reports of prolonged dry periods, variable rainfall between seasons and temperature extremes on *C. connexa* gall production have been documented in several countries (Day *et al*. 2013a, Day *et al*. 2103b and Wilson & Widayanto 2002).

The dry tropics are known for boom-and-bust periods of rainfall. Our data shows the number of galls can increase rapidly, in response to increase in rainfall and growing tip production. This is clearly shown at Black River in the March 2022 to 2023 assessment period where the rainfall amount doubled (1,844 mm) from 2021 to 2022 period. This created an increase gall production by 2,428% and an increase in growing tips by 230%. Nyleta Hill has a higher but more constant rainfall and is not the driving factor between gall and tip production. Infection rate reached 0.85, the highest value, in 2022.

Our assessments over several years have shown *C. connexa* can persist through extended dry periods in the dry tropics. Our assessments also indicate that *C. connexa* will continue to persist in wet tropics due to more constant rainfall conditions resulting in more consistent *C. odorata* plant growth. As shown, gall production slowed at Nyleta Hill with a reduction in available growing tips.

If high gall infection rates occur prior to the flowering period, a dramatic decrease in flower production is likely. As shown at Black River, with a reduction of 88.4% of the predicted flower set in 2023. Flower clusters were stunted, less in numbers and had fewer flower heads (Figure 4) than compared with *C. odorata* plants less than 20 kilometres away where the number of galls per plant were low.

An increasing number of growing tips creates more oviposition opportunities for *C. connexa*, this in turn forms more galls and reduces the overall number of flower heads produced. This assists in the management and control of this invasive weed species by limiting the number of seeds released into the environment and the size of the future seed bank.

The ability of *C. connexa* to survive the dry periods and rapidly increase in population following rainfall, should enable it to adapt to predicted weather patterns forecasted. A trend towards a greater chance of high intensity and short duration rainfall events, across northern Australia is predicted (BOM 2023). This will ensure *C. connexa* has a continuing impact on *Chromolaena odorata* populations across bioregions where this invasive weed exists or may occur within Queensland into the future.

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