Ben Gooden

Research Scientist, Health and Biosecurity, CSIRO

Fellow, Faculty of Science, Medicine and Health; University of Wollongong

Overview

It was with great pleasure that I accepted the 2018 CAWS Early Career Weed Scientist Travel Award to visit fellow researchers, land managers and community members in New Zealand to workshop biological control protocols for the groundcover herbaceous weed wandering trad (*Tradescantia fluminensis*, Fig. 1a) infected with the yellow leaf spot fungus *Kordyana brasiliensis* (Fig. 1b). Wandering trad is a significant invader of forest ecosystems in New Zealand and Australia, with well-documented negative impacts of native vegetation biodiversity (McAlpine et al. 2015). For the past several years, Brazilian (Robert Barreto from the University of Viçosa, Brazil), New Zealand (Landcare Research) and Australian (CSIRO) researchers have been at the forefront of developing fungal biocontrol solutions for wandering trad across the globe (see details here). The candidate fungal agent *K. brasiliensis* was isolated in southern Brazil at the same time that three insect agents were being sought for New Zealand. A fungal agent was expected to complement the three beetle agents in damp, flood-prone contexts where fluctuations in water levels may reduce beetle activity (see information on beetle biocontrol here).

In 2017, New Zealand researchers implemented a release programme for the fungal agent *K. brasiliensis* at a variety of managed forest sites throughout the North Island of New Zealand between Auckland and Wellington, with the support of a network of regional councils (see details of the release programme here). Between 21st and 25th of May 2018, I travelled from Canberra to New Zealand to meet with land managers and researchers at a selection of these release sites in order to evaluate the early establishment success of the fungal agent *K. brasiliensis*. I sought to learn lessons from the New Zealand experience to optimise a future release programme for Australia. I was overwhelmed by the generosity with which the researchers (represented by Chantal Probst from Landcare Research) and local weed managers from various regional councils (see details below) shared their experiences, stories and valuable time with me in the field. I thank the Council of Australasian Weed Societies for generously supporting my travel, which has facilitated stronger connections between the weeds research team at CSIRO and counterparts across the 'ditch' in New Zealand.

I toured a variety of spectacular locations (Fig. 2), from dense, dark, ancient forests clad with mosses and epiphytic ferns, to highly disturbed roadside verges lined with woody weeds and oily drainage ditches – all of which were layered with voluminous, luscious swathes of wandering trad; indeed, some of the densest, deepest monocultures I have had ever seen in a field setting. Below is a chronological account of my journey and meetings, with several boxes showcasing some of the main lessons that I learnt through discussions with weed workers at the coalface of invasion, as well as my own observations from the field. Relevant references are highlighted in hyperlinks throughout the document and not listed in a bibliography at the end of this document.

Figure 1 – Example of (a) wandering trad (*Tradescantia fluminensis*) invasion of a native closed forest community and (b) infection of wandering trad with the yellow leaf spot fungus *Kordyana brasiliensis* at Waingaro, New Zealand (May 2018).

Figure 2 – Distribution of *Kordyana brasiliensis* release sites inspected by Ben Gooden throughout the North Island of New Zealand in May 2018.

A warm greeting in dark, wet, windy Hamilton

I arrived in Auckland and was instantly greeted with a wet, windy drizzle that progressed to a squall by nightfall. Despite this, the next morning, Chantal Probst from Landcare Research greeted me warmly over a coffee in Hamilton to chat about the lab-based methods by which the fungal agent was developed, and the important role that the consortium of regional councils (i.e. the National Biocontrol Collective) in NZ played in sponsoring the agent's development and subsequent release in the field (Box 1).

Next, we hitched up our socks, donned the Wellingtons and raincoats (I forgot mine!), and drove through voluptuously lush valleys and rounded hills to the first release site, located west of Hamilton in the Waingaro Valley (Fig. 2). I was greeted with a green so shockingly vibrant as to be almost alien to my Australian eyes. It had been raining incessantly and the weeds and kikuyu were thus growing with abandon. I was struck with the convergence in alien flora between this corner of NZ and south-eastern Australian: stream banks lined with dense thickets of small-leaf privet (*Ligustrum sinense*), soggy bogs carpeted with wandering trad and creeping buttercup (*Ranunculus repens*) amidst the roaming dairy cattle, and tangled masses of Japanese honeysuckle (*Lonicera japonica*) cloaking the tops of iconic New Zealand cabbage palms.

The ecosystems here, as in Australia, are being squeezed; it was evident from inspecting my satellite map and field observations that much of the relictual native vegetation in this region was confined to creek lines or a few thin reserves bordered on almost all sides by either a dairy farm or a pine plantation. Although the pine plantations seemed to be relatively uninvaded by weeds – do the dense carpet of needles and low light conditions resist the establishment of weed propagules? – and thus may buffer the native vegetation from weed incursions, I could not help but be struck by the battle going on in front of me for what limited space there was for plants to grow. It was a sad irony that the sites most amenable to native plant growth (i.e. those uninhibited by grazing, slashing or tree felling) were likewise best able to support a complex suite of woody weeds and vines that were pushing out the native flora.

Box 1 – Collectives of researchers and management stakeholders drive biocontrol development

A key point that struck me about the biocontrol research framework in NZ is that it is founded upon a partnership between researchers, government regulators and a network of regional councils (termed the National Biocontrol Collective, see details here). Under this model, end-users play a pivotal in prioritising weeds and commissioning biocontrol research from the outset and at all stages of agent development, including post-release monitoring. This enhances the relevance of research for industry, and is catered towards those weeds that have the greatest impacts on the environment and livelihoods for a variety of stakeholders represented by the regional councils. The situation in Australia is necessarily more complex with regards to biocontrol research, given that multiple land management agencies across several tiers of government overlap in their legislative responsibilities for biocontrol regulation and environmental management of weeds – and that end-users tend to be biosecurity officers or restoration practitioners in local councils who supervise on-ground weed control by volunteers and local citizens, who are all somewhat divorced from the legislative framework that governs weed management and biocontrol research in the first place.

We arrived at a nature reserve in the Waingaro Valley managed by Waikato District Council, which was cloaked a deep, dense forest dripping with ferns, strap-leaved epiphytes, bearded lichens and mosses, and the raucous peels of tuis in the high canopy (Fig. 3). Ben Wolf, a local ecologist and weed manager with interests in biocontrol solutions for environmental weeds (Fig. 4), took Chantal and I on a tour of the native forest, which receives a complex management regime of mammalian pest control, weed control and flood mitigation. This site was deemed a perfect location for an initial release of *K. brasiliensis* to complement the effects of the beetle agents released some three years ago on wandering trad, since the beetles seem to be effective on slopes and ridgelines but not low-lying areas prone to inundation during flood events. The fungal agent was released on the 7th March – approximately 12 weeks prior to my visit – in a large infestation of wandering trad, characterised by almost 100% foliage cover and a deep thatch of some 50 cm (Fig. 3), with an almost absent understorey of ferns, native herbs and tree seedlings (Box 2). The fungus was released by planting 10 to 12 infected (with evident discoloured spots and lesions) lab-grown wandering trad plants into the field. The infected stems of the lab-grown plants were entwined with the non-infected, healthy stems of the field plants to enhance contact amongst leaves and likelihood of spores germinating in a moist environment.

Pleasingly, we detected many wandering trad leaves with characteristic signs of infection, indicative of successful agent establishment. Given that the agent was released three months ago, and that the yellow and white lesions (i.e. spots) form about two weeks post infection, it is likely that the leaves that were detected during my trip belonged to recently-infected leaves of resident wandering trad plants and not the original lab-grown plants. We did not find any signs, however, that the agent had spread very far from the initial release points – perhaps only up to a maximum of 1 m. Indeed, agent establishment appeared to be patchy, such that we found only two patches of *K. brasiliensis*, probably corresponding to two of the 10 original lab-grown plants introduced to the site.

Wandering trad – a growing threat to Rotorua's redwood forests

Next, I visited Shane Hona, a Biosecurity Officer based at the Bay of Plenty Regional Council Toi Moana, and inspected redwood forests near Rotorua that were extensively invaded by wandering trad (Fig. 5). Twelve wandering trad plants infected with the *K. brasiliensis* fungus were introduced to the centre of the infestation at a site in the Ngongotaha Valley west of Rotorua on 6th March, yet three months later at the time of my visit we only detected one patch of trad in which the fungus had established (Fig. 5a).

The forest was exceptionally dark and gloomy, and the lime-green, flecked leaves of wandering trad made it difficult to discern the small yellowish spots of *K. brasiliensis* (Fig. 5a). I concluded, therefore, that there were two possible reasons for the apparently low rates of establishment of the fungus in the field at the Rotorua site (i.e. 8%; 1 of 12 plants):

(1) The fungal agent establishes poorly in the field, either by chance alone (in which case more replicate plants may need to be introduced in order to increase establishment success), or

because planting infected lab-grown plants in the field was an unsuitable method by which to release the fungus – perhaps the fungus was 'shocked' by transfer from benign lab conditions to a harsh, stressful field environment? Despite high levels of rainfall in the preceding three months in New Zealand, temperatures in the field may have been sub-optimal for spread of the fungus. Indeed, in lab conditions, the optimal performance of the fungus is when night temperatures are around 13-18 °C and day temperatures are between 20-25 °C (C. Probst personal communication) – temperatures which are more likely to be experienced for many more days of the year in Australia then New Zealand. In Australia, the likely limiting factor to establishment will be local humidity at the leaf interface and rainfall rather than minimum temperatures.

(2) The fungus had in fact successfully established in the field at much higher levels than were evident during my trip simply because I was unable to locate them in the field due to poor light conditions, and concealment by healthy leaves, resulting in false-negative detection. Indeed, it is clear from images in Figures 6 and 7 that a 20 m x 20 m patch of trad may contain many hundreds of thousands of leaves, and yet I was only able to discern a couple of infected leaves in the infestation (Fig. 7b)… it is not unreasonable to expect that there may have been more infected leaves present and thus higher rates of establishment but I was inadequate in finding them.

A key lesson that I learnt by visiting the Rotorua release site was the importance of tagging individual lab-grown plants when releasing the fungus in the field so as to enhance detectability upon subsequent site inspections; and to return to each site within a month of initial release to observe whether infected plants had produced spores, and the likely dispersal of those spores to the leaves of healthy plants.

Compared with New Zealand, trad infestations in Australia grow in relatively stochastic habitats with large diurnal and seasonal variations in temperature, humidity and precipitation, which may result in low rates of fungal establishment in the field. For example, average rainfall for the Melbourne region (representing the core distribution of wandering trad in Victoria where we intend on first releasing *K. brasiliensis*) is about 40 mm per month in January to May, yet actual rainfall for each month in 2018 was 70 mm in January (with 43 mm – a month's worth of rain – falling on one day, 30th January), only 2 mm in February, 30 mm in March (almost all of which fell on one day – 25th March), only 7 mm in April and 56 mm in May. Whilst these monthly values sum to the overall average for the four months (i.e. ~ 160 mm), the large variation in timing and quantity of rainfall caused widespread drying over summer and autumn, leading to considerable die-off of ferns and other shade and moisture-loving plants within the gullies infested with wandering trad (personal observations). Such variability in rainfall was compounded by similarly large variations in temperature. In January 2018, for example, temperatures ranged from 16 °C to 37 °C within a few days at a time when almost no rain fell for almost three weeks – certainly not an environment conducive to fungal growth and spread across the landscape. Therefore, it will be sensible to monitor establishment of the agent more frequently (fortnightly?) and to apply several treatments (e.g. bagging and spraying stems to retain

humidity around infected leaves for a few days) to facilitate establishment in Australia, especially when low rainfall and high temperatures are forecast.

Figure 3 – Wet evergreen forest at Waingaro, with a complex structure of tree ferns, vines, broadleaved mesophyllous shrubs, epiphytes and hardwood trees cloaked in lichens.

Meander through Upper Hutt

For my last two days in New Zealand I headed to Upper Hutt, near Wellington, to meet with Megan Banks, a Biosecurity Officer with Greater Wellington Regional Council. Up to 20 infected plants were released at two sites, one located along a roadside embankment, cut in two by a water-logged drainage culvert (Fig. 6), and the second located next to an native evergreen forest at Battle Hill Farm (Fig. 7). Both sites were heaving with wandering trad and a suite of other woody weeds and vines, including privet and Cape ivy (aka German ivy) *Delairea odorata*. The site next to the drainage line was inundated with stormwater (Fig. 6a) and we were unable to detect any fungal establishment – might the localised flood event have washed away the spores before they were able to spread and germinate on non-infested leaves of wandering trad? Pleasingly, we detected two patches of infected wandering trad at Battle Hill Farm (Fig. 7b) – again, only very low rates of establishment, but establishment nonetheless!

Thank you

My trip was of great value to my research in Australia, principally because I was able to exchange knowledge and expertise with a variety of research and management stakeholders who are working in a similar system. I wish to thank my hosts in New Zealand and The Council of Australasian Weed Societies for generously supporting my travel. I wish to thank Dr Louise Morin, my supervisor at CSIRO, for facilitating my professional development. This trip provided me with sufficient food for thought in terms of developing a release protocol for *K. brasiliensis* for wandering trad in Australia, and highlighted the importance of engaging closely with end-users in the community when implementing biocontrol strategies for environmental weeds.

Box 2 – Is wandering trad an active or passive invader?

Academics have been focused on the 'driver' versus 'passenger' model of weed impacts on native vegetation for some time – that is, do weeds actively cause (i.e. 'drive') the decline in native vegetation diversity by their own volition (e.g. by transforming the ecosystem for their own benefit whilst displacing natives through competitive mechanisms), or do weeds passively replace (i.e. 'passenger') native vegetation removed by some other underlying force of environmental degradation (e.g. grazing or nutrient enrichment)? These are important questions to grapple with, because there are many proponents for *not* controlling weeds in the context of other disturbances that they argue are at the root of invasion itself. An excellent contemplation of this topic can be found here.

My motivation for raising this contention now is that several weeks before my NZ trip a friend of mine slapped down the following challenge to me when he found out that I was currently working on wandering trad: "*well, I'm sure looking forward to hearing of your evidence that trad even actively invades the forest – because, really, all I've seen it do is proliferate along cleared edges, like walkways and roadsides, or in gaps in the forest where a tree has fallen, or flooded areas where the vegetation was probably scoured away before trad's stolons were dumped there from people's gardens… I don't reckon there's much evidence that trad is even having an impact on native vegetation… it just occupies the gaps in the forest that the natives cannot grow in any more*", he said. OK, it's true that I have seen wandering trad proliferate in those disturbed contexts, but during my visit to New Zealand I observed that the densest, deepest, most spatially extensive infestations were evidently located in the interiors of forests (e.g. Fig 4a), surrounded by mature vegetation and old tree ferns that must predate some other form of broadcast deforestation. Importantly, I witnessed two phenomena that convinced me that invasion was an active rather than passive process: (**1**) the proliferation of aerial roots (see below) from stolons overtopping shrubs, ferns and even the trunks of large trees (e.g. see trad stems trailing up the trees in Fig. 1a, as well the trunk below), and (**2**) the spread of stolons away from the core infestations into adjacent non-invaded vegetation without any evident disturbance, which has resulted, according to managers, in a proliferation through time into previously uninvaded vegetation.

Figure 4 – A wandering trad infestation at Waingaro Valley being inspected by (a) Ben Wolf – looking somewhat pensive at the ocean of trad sweeping across the hilltop – and (b) Chantal Probst – overjoyed at spotting an established patch of the fungal agent *K. brasiliensis* approximately three months post release (May 2018).

Figure 5 – A wandering trad (a) stem infected with the fungal agent *K. brasiliensis* infestation in a (b) redwood forest plantation in Ngongotaha Valley (Paradise Valley Road), near Rotorua (May 2018).

Figure 6 – Wandering trad (a) lining a drainage ditch and (b) invading forest (with Megan Banks in the frame for scale) at Moonshine Hill, Upper Hutt (May 2018).

Figure 7 – Wandering trad (a) infestation and (b) infection by *K. brasiliensis* on a river embankment alongside Battle Hill Farm Reserve near the town of Porirua (May 2018)

Appendix – temperature and rainfall data

Daily maximum temperature

Ferny Creek

About this page | 1 year of data | All years of data | PDF

The Daily maximum air temperature is nominally recorded at 9 am local clock time. It is the highest temperature for the 24 hours leading up to the observation, and is recorded as the maximum temperature for the previous day. About temperature data

Station: Ferny Creek | Number: 86266 | Opened: 2011 | Now: Open
Lat: 37.87° S | Lon: 145.35° E | Elevation: 513 m | Details

Show in table... | Key: Units = °C. *12.3* = Not quality controlled or uncertain, or precise date unknown

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Graph												
1st	22.4	20.2	17.1	*23.5*	*19.4*	*10.8*						
2nd	19.8	22.4	22.4	*17.6*	*18.7*	*11.3*						
3rd	18.6	24.9	29.9	*17.5*	*21.2*	*11.2*						
4th	22.9	25.9	19.1	*20.9*	*11.7*	*11.7*						
5th	27.9	26.1	17.7	*17.1*	*13.4*	*12.8*						
6th	36.7	30.1	24.2	*17.8*	*16.6*	*15.0*						
7th	19.5	33.2	26.8	*21.1*	*15.3*	*13.3*						
8th	21.4	28.9	28.2	*26.3*	*14.4*	*9.3*						
9th	19.4	26.8	28.7	*24.9*	*12.6*	*11.7*						
10th	24.9	28.6	31.4	*25.4*	*7.6*	*13.7*						
11th	30.0	18.7	23.5	*27.3*	*9.9*	*12.6*						
12th	24.6	19.1	18.6	*21.6*	*11.6*	*10.1*						
13th	16.5	24.8	19.4	*22.9*	*13.2*							
14th	17.0	19.9	20.6	*11.1*	*12.6*							
15th	18.0	19.7	18.9	*12.8*	*10.0*							
16th	22.2	20.0	24.2	*15.8*	*10.1*							
17th	28.4	25.1	27.8	*13.0*	*10.5*							
18th	33.4	25.9	19.3	*19.0*	*11.9*							
19th	37.1	21.8	23.6	*20.1*	*9.4*							
20th	29.1	26.0	14.2	*18.9*	*10.7*							
21st	28.9	26.4	20.4	*21.2*	*10.7*							
22nd	26.8	28.4	24.1	*20.2*	*11.4*							
23rd	24.1	29.4	25.1	*23.7*	*10.5*							
24th	23.9	27.3	20.3	*22.4*	*11.4*							
25th	31.9	17.6	21.8	*18.2*	*12.8*							
26th	29.4	24.5	12.8	*13.9*	*15.8*							
27th	31.0	27.7	18.6	*13.8*	*16.9*							
28th	34.1	29.6	26.4	*16.5*	*15.8*							
29th	30.8		20.3	*15.2*	*12.8*							
30th	16.2		19.4	*16.9*	*10.4*							
31st	16.3		20.4		*9.9*							
Highest daily	37.1	33.2	31.4	*27.3*	*21.2*	*15.0*						
Lowest daily	16.2	17.6	12.8	*11.1*	*7.6*	*9.3*						
Monthly mean	25.3	25.0	22.1	19.2	12.9							

Daily rainfall

Melbourne Airport

About this page

1 year of data | All years of data | PDF

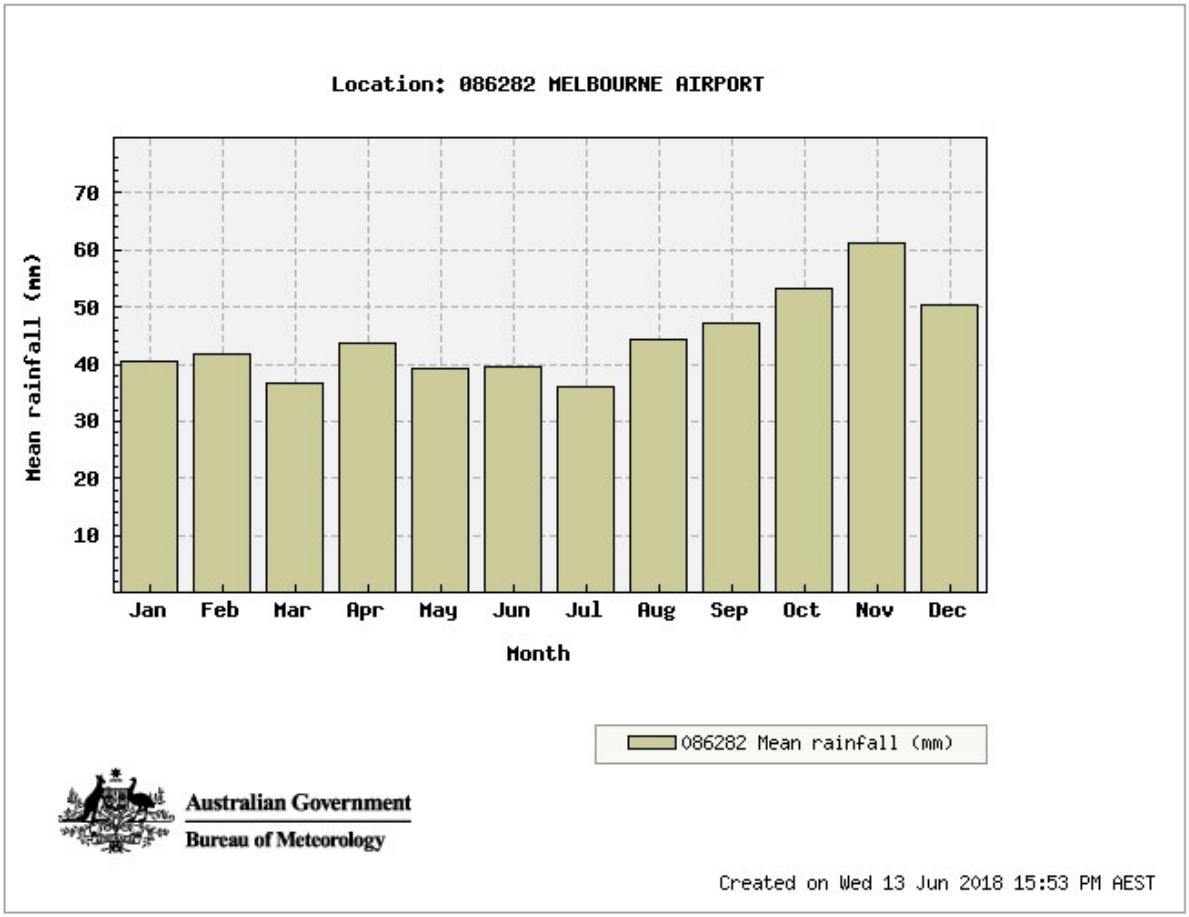
Observations of Daily rainfall are nominally made at 9 am local clock time and record the total for the previous 24 hours. Rainfall includes all forms of precipitation that reach the ground, such as rain, drizzle, hail and snow. About rainfall data

Station: Melbourne Airport **Number:** 86282 **Opened:** 1970 **Now:** Open
Lat: 37.67° S **Lon:** 144.83° E **Elevation:** 113 m Details

Show in table...

Key: Units = mm *12.3* = Not quality controlled. ↓ = Part of accumulated total
28.0↓ Move mouse over rainfall total to view the period of accumulation.

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Graph												
1st	0	0	0.4	0	0	0						
2nd	0	0	0.2	0	0	0						
3rd	0	0	0	0	0	0.2						
4th	0	0	0	0	3.4	0						
5th	0	0	0	0	0.2	1.8						
6th	0	0	0	0	0	0.2						
7th	0	0	0	0	0.2	0						
8th	0	0	0	0	0.2	0						
9th	0	0	0	0	0	1.8						
10th	0	0	0	0	8.8	0.2						
11th	0	0.8	0	0.2	14.6	0.2						
12th	0	0	0	0	15.0	2.0						
13th	3.8	0	0.4	0	4.6	0						
14th	15.2	0	0	0	0.2							
15th	0	0	0	5.8	0.2							
16th	0	0	0	0.4	1.2							
17th	0	0	0	0	0.2							
18th	0	0	0	0	0.4							
19th	0	0.4	0	0	0							
20th	0	0	0	0	0							
21st	0.4	0	0	0	1.0							
22nd	0	0	0	0	0.8							
23rd	0	0.6	0	0	0.2							
24th	0	0.4	0	0	0							
25th	0	0	25.6	0.6	0							
26th	3.4	0	3.4	0	0							
27th	3.8	0	0	0	0							
28th	0	0	0	0	0							
29th	0		0	0	2.4							
30th	43.6		0	0	0							
31st	0		0		2.8							
Highest Daily	43.6	0.8	25.6	5.8	15.0	2.0						
Monthly Total	70.2	2.2	30.0	7.0	56.4							


Location: 086282 MELBOURNE AIRPORT
Mean rainfall (mm)
70
60
50
40
30
20
10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
086282 Mean rainfall (mm)
Australian Government
Bureau of Meteorology
Created on Wed 13 Jun 2018 15:53 PM AEST