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The short and medium term impact of insect herbivory on Short Rotation Coppiced Willow and Eucalyptus crops grown for biomass in Ireland

Key external stakeholders:
Growers, Farmers, Agronomists, Crop Protection Specialists, Policy Makers, Governmental Organisations

Practical implications for stakeholders:

- Populations of economically important herbivorous beetles of biomass crops will increase in significance, with some attaining additional generations under current climate change scenarios, in the medium term
- As such, the development and planting of resistance and semi- resistant clones should be considered as a part of an Integrated Pest Management strategy for these pests
- Some commercial and native Willow clones display resistance and partial resistance to herbivory from both Brown and Blue Willow beetles

Main results:

- The negative impact of beetle herbivory on short rotation coppiced willow is likely to increase, with climate prediction models estimating that 50% of emerging adults will attain a second generation by 2050
- Populations of the Brown Willow Beetle were more prominent in observed commercial plantations, with higher numbers of eggs and larvae being present. Infiltration of Brown Willow Beetles from the margins, into the main body of crop occurred earlier than with the Blue Willow Beetle.
- Plant with high levels of insect defoliation suffered premature leaf drop, but compensated for this by the proliferation of 3 to 4 new leaves emerging at the nearest node.
- Climate modelling suggests that the non-native beetle, *Paropsisterna selmani* could attain 2 generations in Ireland and up to 4 generations in the southern UK. Larval feeding was observed into November, with significant damage being caused to plantations.

Opportunity / Benefit:

This project research has highlighted and demonstrated the potential negative impact defoliating beetles may have on bio-massing crops, both now and in the medium term. While some consideration has been given to alleviating fungal diseases through the use of mixed plantations, it is now evident that resilience to herbivory should also be considered as an appropriate attribute to be considered in provenience (clone) selection and should be considered. Eucalyptus has significant potential as a biomass crop; however the non-native beetle, *Paropsisterna selmani*, is a significant defoliator of this crop. This project has gone a significant way to increase the understanding of the biology of this non-native pest species.

Collaborating Institutions:

University College Dublin (UCD)
Maynooth University

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1. Project background:

The effect of defoliating beetles in Irish biomass crops is little understood with these beetles being a major threat to attaining economically viable yields for these crops, but now and also as the climate changes. Therefore it is critical to gain a greater understanding of the reproductive potential, reproductive rates, herbivory rates and impact and stability of resistant plant varieties in the face of increasing pest densities and in the face of changing climate scenarios. Energy crops have the potential to produce energy but also offer environmental co-benefits through reducing greenhouse gases, being carbon dioxide neutral and a source of income and employment in rural areas. While there are different crop options available, such as poplar, miscanthus, a large amount of attention has been focused on the short rotation coppicing (SRC) of willow and Eucalyptus. Willow selection for coppice has been based on past/current climate statistics, however with herbivore abundance decreasing with latitude and expected to allocate fewer resources to anti-herbivore resistance in conjunction with Irish temperatures projected to increase by >0.2^{o}C per decade, this may result in Irish willow plantations becoming more susceptible to beetle herbivory. The blue (*Phratora vulgatissima*) and brown (*Galerucella lineola*) willow beetles (Coleoptera: Chrysomelidae) are identified as the two most damaging insect pests of SRCW in Ireland. Policies which mandate levels of renewable energy use, to mitigate future climate change, fail to consider adaptation in the energy sector under increased levels of pestilence due to projected changes in the climate system. Given the optimal life spans of >15-20y, many coppice willows may not adapt to projected future temperature and herbivore scenarios, reducing yield and ultimately reducing their financial competitiveness with other crop commodities. Eucalyptus has been suggested as an alternative biomass crop to SRC willow, with potential yields of 10-12 ODT ha^{-1} year^{-1} compared with expected yields for willow of 7-12 ODT ha^{-1} year^{-1}. However this crop, and particularly the species identified as most suitable for biomass (*E. nitens*) is very susceptible to defoliating by a leaf beetle, *Paropsisterna selmani*. The adult and larvae both feed on the foliage, disbudded stems and cause a typical broom-top damage to trees. The biology and rates of herbivory of *P. selmani* under Irish conditions is little understood and would need to be elucidated in order to develop control strategies for this defoliating pest. Given the productive time span of plantations the effect of changes in climate also need to be considered if Eucalyptus is to be a viable biomass crop in Ireland.

2. Questions addressed by the project:

- What is the impact of host plant variety on insect development?
- What are the impacts of temperature and photoperiod on the development of herbivorous beetles, particularly in a changing climate scenario?
- How resilient is willow to high levels of defoliation and how does the plant compensate for loss of leaf biomass?
- Will the future development of Eucalyptus for biomass be impacted by the presence of the invasive beetle, *Paropsisterna selmani*?

3. The experimental studies:

Experiments were conducted to assess the impact of temperature on insect life-cycle stages. This was conducted at a range of temperatures, from 10^{o}C to 31^{o}C, to ascertain the effect of thermal energy on insect development/performance. A critical day length for reproduction for *P. vulgatissima* was defined by altering day: night light ratios. Host preference and herbivory studies were conducted, in the main in small containers as close-contact bioassays, in order to ascertain feeding and oviposition preferences of the

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beetles. Observed daily mean temperature data-sets were acquired for eleven Irish synoptic stations, from the meteorological service, Met Éireann, using the 1961-1990 data sets as a baseline period. To determine future estimations for budburst occurrence and insect emergence, future temperature projections were required. In this regard, statistically downscaled climate scenarios derived from global climate models by identifying and establishing mathematical transfer functions or empirical relationships between observed large scale atmospheric variables and the surface environmental variable of interest were employed. Future daily mean temperature projections relating to the eleven stations was derived from previous work by the author (R. Fealy) for a range of emissions scenarios and global climate models. Model means of the phenology/ voltinism model outputs for the baseline period were calculated to represent control period foliage and insect emergence for each location; confidence in the simulations for the model control period was assessed against the model output employing the observed temperature data-sets for the same period (i.e. 1961-1990). Means of the model outputs during the 2020s, 2050s and 2080s were calculated to represent future time period foliage and insect emergence for each location, using the downscaled temperature data-sets for all climate models. Ranges, derived from different models/emissions scenarios, are also reported.

4. Main results:

(1) Previous studies had indicated that the Blue Willow Beetle (*P. vulgatissima*) was the dominant leaf beetle in Irish willow plantations, however within this study the Brown Willow Beetle (*G. lineola*) was found to be the most prevalent leaf beetle in sites monitored (n=6), with the species having higher average densities of egg and larva on stems, than *P. vulgatissima*. This is an important observation as it identifies the contribution of the Brown Willow beetle to herbivory damage in Irish willow plantations.

(2) Studies of the phenology of both willow beetle species indicate that *G. lineola* laid eggs for a longer period than that observed for *P. vulgatissima*, and the subsequent eggs and larva of *G. lineola* where present in the plantation later and in greater densities than *P. vulgatissima.* Spatial and temporal studies showed that the Brown Willow beetle penetrated into the crop faster with a greater numbers of eggs and larvae being found within the plantation. In contrast the Blue willow beetle remained along the edge of the plantation longer with a slower migration into the plantation.

(3) Data generated from this study indicates that willow beetle herbivory preference and egg laying are related, showing that by provenances less susceptible to herbivory also had reduced egg laying. This finding was consistent in both choice and no-choice experiments. This suggests that provenances found to be less palatable could be used in plantation to reduce damage by larval populations.

(4) *P. vulgatissima* was found to have a reproductive diapause induced by declining day length, which suggests that it could produce a second generation in Ireland if development of the first generation was completed before mid-August.

(5) Temperature had a profound influence on aspects of Blue willow beetle reproduction, with mean oviposition period decreasing as temperature increased towards 27^{o}C, with it levelling off at temperatures at 25^{o}C. Total fecundity was found to be greatest at mid-range temperatures between 15^{o}C and 20^{o}C.

(6) Statistical models indicate that the Blue willow beetle develops at lower temperatures compared to the Brown willow beetle and that the brown willow beetle develops at higher temperatures compared to the Blue willow beetle.

(7) Estimation of future life-cycle stage emergence and occurrence of further generations were made by employing the phenology/voltinism model with observed temperature data-sets and climate projection data-sets as input. Second generations were estimated to occur for 5% of all emerging adults for all stations, with this estimated to increase to 50% of emerging adults by the 2080s.

(8) Plants treated with beetle defoliation at high levels, suffered premature leaf drop, a response not

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observed in manually defoliated crops. Beetle defoliated crops resulted in the plant producing 3 to 4 leaves at each node, a response not observed in manually defoliated crops. This is an important observation for future defoliation experiments.

(9) The biology of *Pt. selmani* was unknown in Ireland or in its native range in Tasmania. In Ireland the beetle phenology was found to be generally bivoltine with the second generation not being observed to lay eggs but to continue to feed extensively to November. However larvae were also found to be present in November with adults emerging in December, the fate of these adults is unknown. This late season reproduction and postponing of diapause can be lethal in insects, but is common in insects undergoing latitudinal expansion. Experiments highlighted the severe damage this species can do to Eucalyptus in Ireland and also confirmed fecundity rates in excess of those required for it to attain 'pest status', even at temperatures close to prevailing temperatures in Ireland (15^{o}C; Mean fecundity 1076.5 eggs).

(10) Climate modelling suggests that this beetle could attain 2 generations in Ireland and up to 4 generations in the southern UK and that only 1.64 generations per year are required for a population to be stable in an area

5. Opportunity/Benefit:

This project has identified several factors which will benefit the bio-massing industry, plant breeders, growers, policymakers and the scientific community. This project research has highlighted and demonstrated the potential negative impact defoliating beetles may have on bio-massing crops, both now and in the medium term. While some consideration has been given to alleviating fungal diseases through the use of mixed plantations, it is now evident that resilience to herbivory should also be considered as an appropriate attribute to be considered in provenience (clone) selection and should be considered.

Eucalyptus has significant potential as a biomass crop in Ireland and is included in the '*Afforestation Grant and Premium Scheme 2014-2020*' as an eligible species under the '*Forestry for Fibre*' section. The greater understanding of the lifecycle of *Pt. selmani*, which is a significant defoliator of this crop, will facilitate the creation of crop protection strategies. Currently the severe levels of defoliation caused by this beetle, the lack of an appropriate control strategy and the fact that under the terms of the aforementioned grant scheme that the plantation should remain for a minimum of 10 years, has seen limited uptake of this crop in Ireland. This project has gone a significant way to increase the understanding of the biology of this non-native pest species.

This project has highlighted the increasing effect that the changing climate will have on insects in general, and herbivorous beetles in particular. Greater cognisance will need to be given to future control and management of insect pest species.

6. Dissemination:

Recommendations from this project will be included in the next edition of the Willow Management Guide, published by Teagasc.

Main publications:

Fanning, P.D., Baars, J.R. (2013) Biology of the Eucalyptus leaf beetle Paropsisterna selmani (Chrysomelidae: Paropsini): a new pest of Eucalyptus species (Myrtaceae) in Irealnd. Agricultural and Forest Entomology 16, (1), 45-53.

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