Garry oak ecosystems recovery team

Annotated Bibliography on the Ecology and Management of Invasive species:

Trifolium subterraneum
Subterranean Clover

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for the Garry Oak Ecosystems Recovery Team

September 2010

Funding provided by the Habitat Stewardship Program for Species at Risk of Environment Canada

Environment Canada Environnement Canada

Peer-reviewed sources

Barbetti, M.J. 2007. The expression of resistance in Subterranean Clover (*Trifolium subterraneum*) to races 1 and 2 of *Kabatiella caulivora* is affected by inoculum pressure but not by combinations of the two races. Australasian Plant Pathology 36 (4): 318-324.

Abstract: The performance of subterranean clover (*Trifolium subterraneum*) varieties in the field in the presence of the clover scorch pathogen, Kabatiella caulivora, can be highly variable in terms of the disease levels that develop. Although the influence of environmental conditions on development of this disease is documented, the influence of inoculum pressure or race combinations has not previously been investigated. Hence, separate controlled environment studies were undertaken to identify the effects of inoculum concentration and the effects of race combinations upon the expression of resistance to clover scorch disease in seedlings of seven subterranean clover varieties. In relation to the percentage of petioles with lesions following inoculation with different conidial concentrations of either race 1 or race 2 of *K. caulivora*, there was a significant effect of races ($P < 0.001$), varieties ($P < 0.001$) and of inoculum concentration ($P < 0.001$) and also a significant interaction between races and varieties ($P < 0.001$), and of inoculum concentration with varieties ($P < 0.05$). Although levels of disease observed on the varieties tested were generally comparable to those observed in the field, the findings in relation to inoculum concentration may explain why the performance of some subterranean clover varieties in the field in the presence of the clover scorch pathogen can be highly variable, as evidenced by certain incidences of severe disease and/or collapses of field swards of Meteora and Karridale varieties in Western Australia. When inoculated with varying proportions of race 1 and race 2, there was a significant effect of race combination treatments ($P < 0.001$), but there was no indication of any additive or interference effects between the two races when present together as a combination on the same plant in relation to host expression of resistance to each individual race. Together, these studies showed, for the first time, that expression of resistance to *K. caulivora* in subterranean clover is dependent on pathogen inoculum level but independent of the races present as mixtures. The implications of these studies are 3-fold. First, that variable expression of resistance in the field is related to inoculum pressure. Second, that seedling resistance to individual races should be able to be identified even where both races occur together in combination, eliminating the current expensive requirement of utilising a separate field screening site for each race. Third, these results indicate that while effective deployment of host resistance is particularly rewarding where cultural and/or chemical strategies are in place to keep the inoculum of the pathogen at manageable levels, it can also be rewarding even under high inoculum pressure.

Jones, R.A.C. 1994. Infection of Subterranean Clover swards with bean yellow mosaic potyvirus: Losses in herbage and seed yields and patterns of virus spread. Australian Journal of Agricultural Research 45 (7): 1427-1444.

Abstract: During 1989-82, Subterranean Clover (*Trifolium subterraneum* L.) was grown in field experiments in which swards of six cultivars were infected with bean yellow mosaic potyvirus (BYMV) by transplanting small BYMV-infected Subterranean Clover plants into them. The swards were then grazed by sheep or mown to simulate grazing. The infected transplants were the primary virus source for subsequent spread by aphids. Spread initially centered on infected transplants resulting in circular expanding infected patches. Later, secondary patches, isolated affected plants and more generalized infection sometimes developed. The extent of spread within swards from the transplants varied with cultivar, BYMV isolate, site and year. Final BYMV incidence ranged from 12% of plants symptom-affected by isolate MI in cv. Junee in 1991 to 100% by isolate SMB in cv. Leura in 1992. BYMV spread mostly occurred in spring and was increased around the edges of areas of bare ground in swards. In two experiments at one site in which 'mini swards' of cv. Green Range, Karridale and Leura were mown repeatedly, BYMV infection decreased herbage yields (dry weights) by 12-16% while seed yields were decreased significantly (by 37-40%) in one experiment. In a grazing experiment at a second site with swards of cv. Esperance and Karridale, BYMV-infection decreased overall yields of herbage by 18-39% and seed by 11-12%; herbage yield losses within symptom-affected patches were 28-49%. In a further grazing experiment at this site with swards of cv. June and Karridale, BYMV-induced losses determined from symptom-affected patches were 21-29% for herbage and 15-25% for seed. In a grazing experiment with swards of cv. Denmark and Leura at a third site, BYMV-induced overall herbage yield decreases of 8-12% were still recorded despite extensive BYMV spread to control swards; yield losses within symptom-affected patches were 18-25% for herbage and 35-47% for seed. Seed yield losses were due to decreased seed size (mean seed weight), fewer seeds being produced, or both. Estimates of the effects of different levels of BYMV infection on herbage yields in partially infected grazed swards were obtained for cv. Denmark, Karridale and Leura by plotting individual quadrat data for herbage dry weights against % symptom-affected plants. Losses increased in proportion of the level of infection, but their magnitude also varied with cultivar and experiment. It is concluded that BYMV infection of Subterranean Clover pastures is cause for concern, not only as regards herbage yield losses but also as regards depletion of the seed bank, which, when compounded year by year, results in pasture deterioration. Early and prolonged aphid activity, reseeding the pasture with susceptible cultivars, heavy grazing and extended growing seasons are all likely to magnify BYMV-induced losses.

Komatsuzaki, M. 2007. New weed management strategy using Subterranean Clover reseeding under different tillage systems: Numerical experiments with the Subterranean Clover-tillage dynamics model. Weed Biology and Management 7: 3-13.

Abstract: Subterranean Clover (*Trifolium subterraneum* L.) appears to be a suitable winter legume cover crop for Japan because the Subterranean Clover stands maintain themselves by reseeding in autumn and the large seeds facilitate establishment and enable early fall production. However, there is little information on the relationship between reseeding and tillage systems for Subterranean Clover under

Japanese climatic conditions. A weed-tillage population dynamics model was developed to investigate the effects of the tillage method and timing on the reseeding of Subterranean Clover. The field experiments were conducted in a silage corn and subterranean clover rotation system. The life cycle of Subterranean Clover was modeled to describe the seed production competing with weed growth, seasonal changes in the buried seeds' viability, and the movement of seeds by tillage treatments. In the numerical simulation, the effect of the tillage method on the seedling population of reseeded Subterranean Clover was investigated and the simulation results showed good agreement with the experimental results. Rotary tilling immediately after Subterranean Clover seed maturation successfully produced a good Subterranean Clover stand the following spring. However, rotary tillage conducted 2 months after seed maturation killed the emerging Subterranean Clover seedlings and the field was dominated by winter weeds. These simulation results suggest that a suitable tillage system can maintain successful Subterranean Clover re-establishment from year to year.

Smetham, M.L. 2003. A Review of Subterranean Clover (*Trifolium subterraneum* L.): Its Ecology, and Use as a Pasture Legume in Australasia. Advances in Agronomy 79:303-350.

Abstract: Australian and New Zealand research investigating the ecology and use of the annual pasture legume Subterranean Clover (*Trifolium subterraneum* L.) is reviewed. The species and its distribution are described, together with the soil conditions and soil reaction to which it is adapted. Vegetative responses to light and temperature are briefly considered. Environmental control of reproduction is described in relation to vernalisation, seed dormancy, hard-seed development and decline, and burr burial. The history and manner of use of Subterranean Clover in Australasia is detailed. The management of this legume is discussed in relation to choice of variety, establishment, and seed production. Problems associated with hard seededness are listed together with possible solutions. The usefulness of hardseed carryover is debated. The level of herbage productivity obtained in various localities is catalogued, and quality for animal performance is discussed. Use of the species as a pure sward or in mixture with grass is debated. Pests and diseases are catalogued, together with an assessment of relative importance. Symptoms associated with the occurrence of oestrogenic substances in this species are detailed.

Vollsnes, A.V., O.M.O. Kruse, A.B. Eriksen, U. Oxaal and C.M. Futsaether. 2010. *In vivo* root growth dynamics of ozone exposed *Trifolium subterraneum*. Environmental and Experimental Botany 69: 183-188.

Abstract: Although leaves are the primary sites of tropospheric ozone exposure, it has been postulated that ozone may cause greater and earlier disruption of below-ground growth with long-term consequences for productivity. As plant roots are hidden in soil, the time-course of ozone-induced below-ground changes remains poorly characterized. In this study, the in vivo root development before, during and after short term ozone exposure of individual subterranean clover seedling shoots (*Trifolium subterraneum* L.) was studied non-destructively using a new experimental growth and exposure system. Plants were grown individually in thin root growth chambers, where the entire root system could be observed non-invasively for weeks. Seedlings were exposed individually in separate exposure cuvettes to either charcoal filtered air (n=3, ∼1–3 ppb ozone) or charcoal filtered air supplemented with ozone giving a concentration of 75±10 ppb ozone (n = 3) for 8 h during daytime for five consecutive days (AOT40 index 1400 ppb h) starting eleven days after sowing. 171 High-resolution digital images of the roots were captured every one–four days and were analyzed to determine root length and root tip formation. Altered root growth occurred within the first week after exposure and persisted for three weeks. Root tip formation and elongation rates were reduced by 35–40%. Doubling of the number of root tips was delayed by one week. Roots of exposed plants were therefore shorter and less branched. Above-ground changes were apparent about one week after below-ground changes. The leaf development rate was reduced by about 25%, but the number of flower stems at harvest was unaffected. Ratios between below and above-ground growth were significantly reduced by ∼60% the first week after exposure and remained lower for up to three weeks suggesting reduced carbon allocation to root growth. Nevertheless, biomass and biomass ratios at harvest five weeks after exposure were not significantly altered, indicating that traditional destructive sampling once, at harvest, would not have revealed any of the early below-ground changes observed in this study. Thus, ozone caused substantial changes to root architecture that may ultimately affect the root's function and thereby the plant's overall health and ability to cope with stress.

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Clarke, R. November, 1999. Subterranean Clover virus diseases. Agricultural Notes AG0724 ISSN 1329-8062. www.dpi.vic.gov.au/DPI/nreninf.nsf/9e58661e880ba9e44a256c640023eb2e/9c6ba16bd3070389ca256f35000a41ab/$FILE/AG0724.pdf. State of Victoria (Australia), Department of Primary Industries.

COSEWIC. 2006. COSEWIC assessment and status report on the Coast Microseris (*Microseris bigel*ovii). Prepared by M. Fairbarns, A. MacDougall, A. Ceska and O. Ceska. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 26 pp.

Summary:
Common name
Coast microseris
Scientific name
Microseris bigelovii
Status
Endangered
Reason for designation
A small annual herb present in a few fragmented sites within a narrow coastal fringe on southeast Vancouver Island in a densely inhabited urbanized region. Development, recreational activities, site management practices and competition from invasive alien plants continue to impact the species.
Occurrence
British Columbia
Status history
Designated Endangered in April 2006. Assessment based on a new status report.

Fontanelli, M., C. Frasconi, L. Lulli, D. Antichi, F. Bigongiali, S. Carlesi, P. Barberi and A. Peruzzi. 2008. Innovative crop and weed management strategies in organic spinach: machine performances and cultivation costs.. 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008. http://orgprints.org/view/projects/conference.html

Abstract: Weed competition is one of the most serious problems in vegetable crops. Physical and cultural methods represent the only adoptable solutions in organic farming systems. A two-year (2006-08) on-farm research is being carried out to test innovative operative machines for physical weed control on a typical vegetable crop sequence in the Arno Valley (Pisa, Italy). In this work we present the first results, obtained on organic fresh market spinach (*Spinacia oleracea*). The new strategy is compared with the standard crop and weed management system, characterised by the use of biodegradable maize starch mulch, and with a system in which the use of improved physical methods is coupled with the use of a subterranean clover (*Trifolium subterraneum*) living mulch. Performances of the operative machines, labour time requirement and cultivation costs of the three crop and weed management systems are reported. The two innovative strategies showed interesting results, determining effective weed control and a significant reduction of costs for working and hand labour (-70%).

Johnston, W.J., G.K. Stahnke and R. Parker. 2007. Lawn weed control for Washington state homeowners. www.puyallup.wsu.edu/turf/pdf/eb0607.pdf. Washington State

Cooperative Extension. College of Agriculture and Home Economics, Pullman, Washington.

Penn, B. February 19, 1998. Macoun's Meadow-foam and Lawn Burweed. Botanical Electronic News No. 184. www.ou.edu/cas/botany-micro/ben/. Adolf Ceska (Ed.) Victoria, BC.

Prologue: Briony Penn's article describes a fight between a rare endemic species, Macoun's Meadow-foam (*Limnanthes macounii*) and an aggressive introduced species, Lawn Burweed (*Soliva sessilis*). Both species met in Ruckle Park on Saltspring Island in southwestern British Columbia. Ruckle Park is the only locality of Macoun's Meadow-foam on Saltspring Island; another locality we knew of disappeared under a sun deck that an owner of the property built over the vernal pool where meadow-foam used to grow. Thanks to Briony Penn and to the *Gulf Island Driftwood* for permission to post the article on BEN.

Online sources

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