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Competition for Herbage by *Phaulacridium vittatum* (Sjöstedt) (Orthoptera: Acrididae) and Sheep During Summer Drought

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ABSTRACT Wingless grasshopper (*Phaulacridium vittatum*) populations inhabiting grass-dominant sheep rangeland in the south-east of South Australia reached peak biomass in summer and possibly competed with sheep for available herbage when pastures were drying off. Laboratory studies indicated adult wingless grasshopper (WG) ate clover species at faster rates than other herbage species on the rangeland, while most dicotyledonous species were eaten at faster rates than grasses. The point of competition between WG and sheep is in respect to green clover. Calculated daily consumption rates of clover by WG indicate that for densities of 10 per m², they have maximum daily potential consumption 0.85 dry sheep equivalents (DSEs) per ha and proportional consumption at higher densities. Field densities of 10-20 WG per m² are common in some seasons on rangelands in southern Australia and may exceed 30 per m² in patches. Competition for perennial clovers may occur during summer with a maximum potential value of 2.6 DSEs per ha in years when WG are generally dense (30 per m²).

Introduction

Wingless grasshoppers (WG), *Phaulacridium vittatum* (Sjöstedt), are grazers who share their habitat with merino sheep over much of their range in southern Australia, including a grass-dominant rangeland at Wattle Range, near Penola, South Australia. In this area, the WG population reaches peak biomass during summer when the total quantity of green pasture is declining. Quantification of any competition would allow landholders to make rational decisions in controlling WG.

The sheep grazing rate at Wattle Range is about 10 DSEs per ha throughout the year. If WG is numerous in late summer, landholders report competition with sheep for the remaining herbage. WG densities over 20-30/m² are regarded by landholders as damaging. The landholder must make a decision whether to control WG or to buy fodder for the sheep until Autumn rains come. Without quantification of the extent of competition of WG and sheep, the landholder is not able to make a good economic judgement on (a) whether to use insecticide ($6-8/ha plus application costs of approximately $5/ha), (b) buy fodder or (c) do nothing. In practice, landholders prefer buying fodder to spraying in years of high WG numbers.

This study was undertaken to quantify WG consumption and equate damage with reduced carrying capacity during summer.

Methods

Study site. The study site was at Wattle Range, near Penola, South Australia where the pastures are dominated by grasses, with clovers growing during winter and spring, while perennial clover may remain green until late summer. WG hatch during spring and develop into adults in January-February. During this time, the pasture starts to dry, but some green growth may persist if showers fall during the summer. The area has an average annual rainfall of 660 mm, of which 80 mm falls from January-March, the driest quarter of the year. Rainfall from November 1990 to March 1991, the time which grasshopper populations in these experiments developed, was 148 mm, near to the average of 156 mm.

Estimation of grasshopper numbers and pasture composition. WG numbers in the field were estimated using 0.1 m² circular wire hoops; 20 hoops were placed in a line on the ground at approximately 3 m intervals (Onsager and Henry 1977). The WG were allowed 3-5 min to redistribute after placement of the hoops. The vegetation within each hoop was then disturbed with the handle of a sweep net (1.5 m long), and the number of WG counted as they jumped from the vegetation within the hoop. The incidence of green herbage and the species composition of the pasture were estimated at the same time by noting the presence or absence of green herbage in each 0.1 m² quadrat, and the species of green plant with the greatest ground cover within the quadrat.

Laboratory trials on feeding rate on herbage species, temperature and feeding rate and daily food consumption. Consumption of various species of herbage found to be common in the pasture at Wattle Range was measured by confining a mature male and female WG in a clear plastic 250 cc container covered with gauze at one end, then presenting the hoppers with part of a leaf whose area had previously been measured. The WG were starved for 18 h prior to testing. The pair of WG was allowed to eat the leaf for 1 h after which the uneaten part was measured. If all the material offered was eaten within an

hour, further leaf tissue was presented. After 1 h, the WG were presented with a second species of leaf and so on until a sequence of five species of leaves were presented to each pair of WG. This test was repeated with five separate pairs of WG with which the sequence of presentation was rotated, so that each plant species was presented in each ordinal position.

Leaf consumption of strawberry clover was measured at different temperatures by confining five male and five female WG in separate containers, and measuring leaf consumption in 1 h. The WG had previously been acclimatised to the test temperature for 1 h prior to feeding.

Daily food consumption was measured by confining single mature WG in gauze topped plastic containers and presenting new leaves of strawberry clover every hour during an 8 h "day" and once during a 16 h "night" in an incubator 25 °C. In the days prior to these observations, WG were allowed free access to strawberry clover leaves, so that the test situation simulated field conditions with free availability of food.

Measurement of competition in the field. A representative site was chosen in the Wattle Range district and four treatments were applied to each of two replicates: 1. − WG − sheep; 2. − WG + sheep; 3. + WG + sheep; 4. + WG − sheep. Treatments were randomly allocated to four contiguous plots each 0.5 ha (71 m × 71 m). The sheep were controlled by fences and were stocked at the rate of 5 sheep per plot with a water trough provided in each plot. Prior to fencing the plots in January 1991, the area was part of a paddock which was grazed at normal stocking rates. WGs were allowed to move freely in the " + " plots, and were misted with insecticide (alphamethrin 16 g

active constituent per ha) in the " − " treatments at intervals of approximately 2-3 weeks.

To account for the time-density relations between plots, density was integrated over the season as WG-days; (number at time 1 + number at time 2)/2 ÷ number days between measurements, summed for all periods. The amount of herbage in each plot was estimated by cutting to ground level in a rectangular quadrat, 0.25m², and storing in a large plastic bag. A total of 8 quadrats (= 2 m²) was cut.

Results

Feeding rate on herbage species. The major species of green herbage present in the pasture in early March 1991 are listed in Table 1; grasses were the main green herbage, strawberry clover (a perennial) was dominant in some quadrats, while the remaining herbage consisted of other dicotyledons. The dry herbage consisted of grasses: Mediterranean barley grass (*Hordeum hystrix* Roth), silver grass (*Vulpia myuros* L.), soft brome (*Bromus hordeaceus* L.) rough dog's tail grass (*Cynosurus echinatus* L.) and winter grass (*Poa annua* L.).

Six species of these green plants were presented to pairs of WG in laboratory feeding studies; red gum leaves were also included, since WG were observed feeding on eucalypt trees growing on the rangeland. Also included were subterranean clover and ryegrass which, although not found in the pasture surveys, occur in the district. Leaves of each species were presented to each pair of WG in rotating sequence; inspection of the data indicated the species ranking was quite consistent regardless of the sequence in which the species was presented, indicating that the consumption rate

Table 1. Mean consumption rates of leaves presented to pairs (1 male and 1 female) of wingless grasshoppers (25 °C) and species composition of pasture (% quadrants in which species was dominant).

Species	Consumption rate (mg dry wt/pair/hour ± SE)	% Frequency of green plants
subterranean clover, *Trifolium subterraneum* L.	4.6 ± 0.54	0
strawberry clover, *Trifolium fragiferum* L.	3.7 ± 1.58	12
curled dock, *Rumex crispus* L.	3.5 ± 0.65	11
red gum, *Eucalyptus camaldulensis* Dehnh.	1.6 ± 0.67	0
perennial ryegrass, *Lolium perenne* L.	0.9 ± 0.30	0
strawberry clover (dicot stage)	0.7 ± 0.29	
sorrel, *Rumex acetosella* L.	0.7 ± 0.17	13
Yorkshire fog grass, *Holcus lanatus* L.—young shoots	0.5 ± 0.05	22
Yorkshire fog grass—old leaves	0.5 ± 0.20	
paspalum, *Paspalum* sp.	0.2 ± 0.17	2
phalaris, *Phalaris aquatica* L.	0.05 ± 0.05	25
knotweed, *Polygonum salicifolium* Brouss.	—	6
couchgrass, *Cynodon dactylon* L.	—	6
flatweed, *Hypochaeris radicata* L.	—	3

Table 2. Influence of temperature on feeding rates: mg dry weight of strawberry clover consumed by male and female wingless grasshopper (WG).

mgdwt/WG/hr	Temperature °C									
	5	10	15	18	20	23	25	27	30	35
female	0.3	0.6	1.3	0.7	2.1	2.3	5.0	3.7	3.1	2.9
male	0.1	0.2	0.3	0.5	1.8	2.0	2.2	1.7	1.6	1.4

was characteristic of the plant species being consumed, and independent of the species of plant previously eaten. As a summary of these data, the mean consumption rate for each species is shown in Table 1.

The consumption rates for all dicotyledonous plants were mostly greater than grasses (Table 1). The stage of plant growth was important for clover; the mature trifoliate leaf was ranked above the hairy-leaved dicotyledonous stage. In contrast, the age of the leaf did not appear to be important with grass, since the consumption rates of young and old fog grass were similar.

Temperature and feeding rate. The influence of temperature on feeding rates of WG is shown in Table 2. Female WG (uncorrected for bodyweight) had a higher consumption rate than males at all temperatures. Feeding was slow at 10°C and below, and was highest in the range 25°-27°, above which it declined. These observations suggested that food consumption would be maximum at about 25°C.

Daily food consumption. Consumption of strawberry clover leaves during a 24 h-period was measured for 25 female and 26 male WG; females consumed a mean of 11.1 mg dwt/day (SE ± 1.16) and males consumed a mean of 4.3 mg dwt/day (SE ± 0.49); this difference was significant (P < 0.001).

Hourly observations indicated that WG do not feed continuously during the day, but feed over periods of no longer than 3 h and, usually less than 1 h per day, at constant 25°C. Further, feeding of individuals may occur at any time during the day; there did not appear to be any pattern of feeding during the day in the test population of WG.

The measurements of daily food consumption were compared with that of sheep (Table 3). The weight of a "standard" DSE is 45 kg and the recommended pasture allowance for maintenance of body weight is 0.87 kg green dry mass/day (Beattie and Thompson 1989). The calculated weight of green food eaten per/ha by densities of 10 WG per m² approaches that of 1 DSE per/ha, assuming both WG and sheep both select clover.

Measurement of competition in the field. WG density in the eight experimental plots was measured at intervals of 3-5 weeks during the experiment. Sampling precision ranged between 7% and 31% (mean: 21%, 67 observations— expressed as the ratio of standard error/mean × 100) for densities of 5/m² or greater.

The grasshopper plots were sprayed four times during the experiment: 5 and 29 January, 14 February and 5 March 1991. After about 5 d post-spraying, there was substantial reinvasion which, at densities greater than 10/m² reached 80% of the unsprayed density at the site, while low density (< 10 m²) reinvasions stabilised at about 40% of the unsprayed plots.

The effectiveness of spraying as a method of manipulating WG can be seen by the range of WG-days produced in each treatment (Fig. 1). Spraying reduced the mean number of WG days in each replicate to between 11% and 34% of those in unsprayed plots of the same replicate. The peak density of WG measured during the experiment was 36/m².
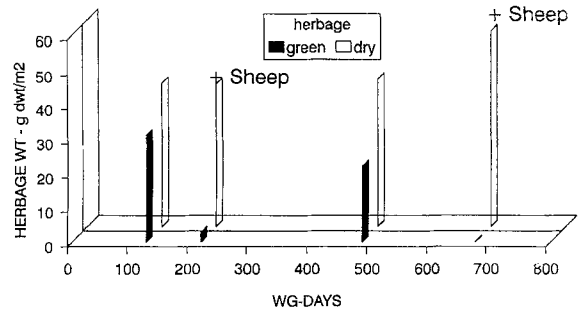

Fig. 1. Herbage weights from plots with varying intensity of wingless grasshopper (WG) feeding (those at 125 and 215 WG-days were sprayed to control WG numbers) in the presence and absence of sheep.

Pasture in the plots was sampled on 27 March 1991. The 8 × 0.25 m² pasture cuts from each S.E./mean plot were sorted into green and dry herbage. For green cuts in which the mean weight exceeded 2 g (23/28 cuts), the S.E./mean % ranged from 6% to 28% (mean 19%). These data were analysed as a two level factorial (+ and −) and demonstrated a significant effect of sheep grazing (P < 0.05) on green herbage, but no effect of WG numbers could be demonstrated. No effect of either sheep or WG on dry herbage could be demonstrated. The pooled replicate data are shown in Fig. 1.

Table 3. Biomass of wingless grasshoppers (WG) at different densities and estimate of food consumption assuming most favourable conditions.

WG density		Biomass of WG kg/ha[a]	Daily consumption of green clover kgdwt/ha/day[b]	DSE[c]
Per m²	per ha			
10	100,000	12.7	0.77	0.9
20	200,000	25.4	1.54	1.8
40	400,000	50.8	3.08	3.5

[a] Based on mean female body weight 0.176 g (SE ± 0.0079), male 0.0767 g (SE ± 0.0016) and assuming 1:1 sex ratio.
[b] Based on daily consumption rate of strawberry clover of 11.1 mg and 4.3 mg per day respectively for females and males.
[c] 0.87 kg green dry mass/day for maintenance (Beattie and Thompson 1989).

The failure to detect any significant effect of WG grazing posed the question of how much WG grazing would be necessary to detect significant treatment effects using the present experimental technique. This was estimated using the LSD (least significant difference) from the analysis of variance. The difference (Dg) between the means of green herbage in + and − grasshopper plots is significantly different if (Dg) > LSD (= 4.127). The LSD as a proportion of the sheep effect was 4.127 ÷ 6.290 = 66%. Thus, the experiment would have detected differences in greenweight caused by grasshopper feeding equivalent to (66 ÷ 100) × 10 (No. of sheep/ha in this experiment) = 6.6 sheep per/ha.

Discussion

Laboratory studies on consumption rates by WG of plants forming the major components of the pasture at Wattle Range indicate higher consumption rates of dicotyledonous plants, especially clover, compared with grasses. The preference for clover over other species was noted by Clark (1967), Sale (1983) and Chaiyawat (1986). In our study daily consumption rates of strawberry clover were used to estimate maximum potential competition by WG of 2-3 DSEs per/ha during summer. The pasture effects of WG calculated in this study from WG consumption rates are of a similar order as those measured by Sale (1983) at Braidwood N.S.W. using direct pasture measurements of WG enclosure and enclosure cages. Braidwood is similar to Penola in having a predominantly winter rainfall, but the average annual rainfall (724 mm) is slightly higher and the summer slightly wetter (Jan-Mar, 209 mm) and has an average capacity of 12 DSE. During the summer of 1979/80 at Braidwood, peak WG numbers of ca 50/m² resulted in pasture loss equivalent to 2.5 DSE/ha and in 1980/81, a density of ca 75/m² resulted in equivalent to 3.3 DSE/ha.

The magnitude of the competition is likely to be modified by (a) density variations in WG between years, (b) the ability of WG to select strawberry clover, a relatively uncommon plant in the pasture, (c) the availability of alternative food species (such as dock) which are not desirable sheep food, and (d) the growth of green pasture herbage during summer, usually the result of rain showers. In calculating DSEs it has been assumed that WG in the field is able to select favoured herbage species from those less favoured. Preliminary field observations suggest this does not occur; during the plant census, evidence of WG feeding was found on most green plants. Roberts (1972) similarly found WG eating grasses while more favoured food was available in the pasture. Thus, the little evidence available suggests that WG does not selectively graze pasture species. The consumption rates calculated for strawberry clover in Table 3 therefore represent the highest potential consumption by WG and the maximum limit of dietary overlap with sheep. Landholders regard strawberry clover as good sheep food because it grows following summer showers, but its availability is likely to decrease during dry periods. The other dicotyledonous plants in the pasture are not highly regarded by graziers as sheep food and some (e.g. dock) are weeds. The preference of WG for eucalypt leaves over grasses may explain the defoliation of eucalypt trees on grass-dominant rangelands.

The sheep-WG grazing experiment reported in this paper was intended to measure whether WG and sheep do compete for green herbage during late summer. The results from this experiment allow only limited conclusions. Sheep grazing reduced green herbage by 95% compared with ungrazed plots, but within the range of WG densities measured, no effect of grasshopper grazing could be demonstrated. The importance of this negative result is limited by the relatively poor sensitivity of the experiment: it would have detected wingless WG feeding only if it exceeded 6.6 DSEs, whereas the laboratory feeding studies indicate an experiment capable of detecting at least 2 DSEs is necessary. Sensitivity may have been improved by increased replication and by separating the species weights of green herbage, particularly clover.

The potential for competition between WG and sheep at Wattle Range is probably typical of that of much of the sheep grazing range in South Australia, western Victoria, southern Western Australia and the southwestern slopes of New South Wales which experience dry summers. But competition is considerably less than that found in summer rainfall areas of the Northern Tablelands of N.S.W. where damage has been estimated as high as 10 DSE/ha/12 week period (Sale 1983).

The peak density of 36 adult WG/m² reported in this study was of similar order to that recorded in the Wattle Range area in a previous, 1989 survey, (38 and 50/m² were the two highest densities), the peak of 22/m² recorded by Emery and McFadden (1988) in southwestern W.A., a uniformly high density of 20/m² recorded by Baker (1988) on the central tablelands of N.S.W., and a density of ca 30/m² on the Northern tablelands of N.S.W. (a summer rainfall area) reported by Sale (1983). This indicates that there is likely to be significant economic competition over much of the range of WG in winter rainfall areas of southern Australia.

A number of options for managing WG populations on pastures in eastern Australia have been suggested by Farrow and Baker (1993); these include reduced grazing pressure in drought years to avoid bare areas which are favourable habitat for WG, and the maintenance of a grass-dominant

pasture. These methods need to be tested before they can be recommended for areas in southern Australia such as that described in this paper. At Wattle Range, the rangeland is flat, and bare areas rarely develop in spring and further, there is no clear evidence that reduction of legume species in the pasture would result in increased carrying capacity for sheep. The experiments reported by Chaiyawat (1986) indicate the potential for developing pasture legumes with levels of resistance to WG feeding. The development of even moderate levels of WG resistance in clover and lucerne is likely to be of considerable benefit in pastures of southern Australia.

Acknowledgments

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