# Chapter 7. General Discussion

## 7.1 Introduction

This series of experiments were conducted to investigate the overlying hypothesis that rainfall amount is positively correlated with free-living development of *H. contortus*, but that its effects are modulated by rainfall timing and distribution, along with ambient evaporation. Along with contributing valuable information for integrated parasite management programs, this work uncovered some fundamental relationships between *H. contortus* free-living stages and moisture that were previously unverified.

## 7.2 Fundamental relationships between moisture availability and *H. contortus* free-living development

The first major finding from this work was the importance of availability of moisture early in the pre-infective development phase for determining the success of egg hatch. Waller and Donald (1970) highlighted the conflicting early reports on the survival of *H. contortus* eggs following desiccation, but concluded from their own studies that few eggs will survive the effects of desiccation to develop to infective larvae. In the field experiments presented here, 17% of eggs in faeces were able hatch and to develop to pre-infective larvae within two weeks of deposition without receiving any additional water, however success of development to this stage was considerably higher when simulated rainfall treatments were applied within 4 days of deposition. Similarly, development success to pre-infective larvae in unwatered controls in the final laboratory experiment provided convincing evidence that there is adequate moisture in the faeces at deposition for embryonation and hatching, however there were penalties on development success to pre-infective larvae relative to the watered treatments. Faecal moisture content was not measured in the plot studies, but averaged 53% in the first laboratory experiment and 53% in the final set of laboratory experiments.

The rainfall timing treatments also suggested that there was a negligible effect of rainfall on development to the pre-infective larval stage when it occurred more than 7 days after egg deposition. Thus there was no difference in hatching success at d 14 between plots which received a rainfall event on day 8 and those that were yet to receive any by d 14 (Chapter 4). However when rainfall events were applied during the first 7 days post-deposition and then again in the second week after deposition (Chapter 5), there was a detectable effect on L3 recovery. In this case the regression of L3 recovery with cumulative P/E pointed to a small additive effect of the repeated simulated rainfall events, relative to the treatments in which rainfall occurred only in the first week. This contrast in the effects of later rainfall events on pre-infective and infective recovery can be explained by experimental observations of the *H. contortus* lifecycle. In each set of experiments, the largest cohort of pre-infective larvae had hatched within 7 days of egg deposition so there was little influence on development success of events occurring after this point. L3 recovery, however, was still increasing between d 7 and 14, and given that there was a significant effect of amount of rainfall on success of development from pre-infective to infective larvae in the final incubator experiment (Chapter 6), it is reasonable to expect an effect of extra rainfall received during this period on recovery of L3.

We found no evidence to refute the reports of many workers (eg. Barger *et al.*, 1972; Waller & Donald, 1970) that development to L3 is negligible in the absence of rainfall or additional moisture. As reported in Chapter 6, a small number of L3 were recovered from faeces in unwatered controls however none were observed to have migrated from the faecal environment and recovery appeared to be declining by d 14, suggesting mortality and low viability of these intra-pellet L3. The absence of a film of moisture on faeces and soil, widely accepted as favourable or even required for *H. contortus* migration to herbage (Rose, 1964; Silangwa & Todd, 1964; Skinner & Todd, 1980), is likely to have hindered to the emergence of infective larvae from faeces.

The plot experiments (Chapter 4), although disappointing from the perspective of L3 recovery, highlighted the importance of mimicking the rate and intensity of natural rainfall. In subsequent laboratory experiments, where the rate of simulated rainfall was reduced to 4 mm/h, there was a close correlation between amount of simulated rainfall and recovery of infective larvae, with consistently more L3 recovered at greater increments of rainfall. Although not a startling finding, a dearth of studies in which the consequences of a given rainfall event on *H. contortus* development have been measured meant that there has been little published evidence of this effect in the field.

Of the few attempts to correlate free-living development of GIN nematodes with amount of rainfall and evaporation the modelling studies of Barger *et al.* (1972) (*H. contortus*), Barnes *et al.* (1988) (*T. colubriformis*) and subsequently Barnes and Dobson (1990) (*T. colubriformis;* including prediction of evolution of anthelmintic resistance) are the most significant, although each is based mostly on historical meteorological data rather than simulated rainfall treatments. In comparison, models developed in New Zealand for predicting nematodiasis in lambs (Leathwick *et al.*, 1992; Leathwick *et al.*, 1995) relied on observed seasonal patterns of development to derive parameters values. The models of Leathwick *et al.* and Barnes *et al.* are currently the most relevant for predicting the outcomes of grazing management strategies, vaccine development, anthelmintic use and development of resistance (L Le Jambre 2007, pers. comm.). The results of the present studies validate many of the assumptions made by both sets of models, and are likely to considerably enhance the value of the models for prediction of *H. contortus* epidemiology.

Although the effects of evaporation rate were only tested in the final experiment, the findings of and the comparison between both incubator experiments go some way towards explaining the lack of L3 in the plot studies. Evaporation rate was found to be a strong regulatory influence on development of L3, and the recovery rates suggest that under conditions prevailing in the summer plot experiments translation of eggs to L3 would have been low enough to be barely detectable when combined with predation on free-living stages, breakdown of faeces by insects and the low sensitivity of the herbage sampling technique.

As discussed in Chapter 6, evaporation rate regulated the effects of amount of simulated rainfall on *H. contortus* development such that significantly fewer L3 developed under the same amount when evaporation rate was high. In effect, success of development to L3 will be determined not only by how much rain has fallen in the days subsequent to faecal deposition but also the concomitant rate of evaporation, so that identical patterns of rainfall over two different time periods could lead to substantially different levels paddock contamination. The implications of these findings will be discussed further in section 7.3

The effects of rainfall distribution on *H. contortus* appear to be more difficult to quantify than those of evaporation rate and simulated rainfall amount, and although tested in each set of experiments, we are still unable to fully quantify the influence of this variable on *H. contortus* development. Significant distribution effects were detected on pre-infective larval development in the final plot experiment (Chapter 4), when rainfall was applied in either a single event or 3 events over 32 h, and on development to L3 in the 1st incubator experiment (Chapter 5), when rainfall was applied in either a single event or multiple rainfall events spread over a period of 6 days. However in the final incubator experiment (Chapter 6), the negligible differences in development to either pre-infective or infective larvae when the same amount of rainfall fell in a single event or in 2, 3 or 4 events over as many days, was attributed to the overriding influence of evaporation on moisture availability. As was suggested in Chapter 6, it is likely that effects of rainfall distribution on *H. contortus* development in the field will be mediated largely through concurrent cloudy weather and low evaporation rates, hence developmental potential will be affected only indirectly by rainfall distribution. Prediction formulas such as the cumulative ratio of precipitation and evaporation will allow patterns in rainfall distribution to be integrated with other rainfall variables for determination of moisture availability.

## 7.3 Implications of the work for worm control

The fundamental relationships established in this set of studies between *H. contortus* free-living development and moisture provides valuable data for modelling free-living development based on prevailing weather conditions. The relevance of the data was demonstrated by the results of the final incubator study, which indicated a strong relationship between the cumulative ratio of precipitation and evaporation, and transition to L3. These results suggested that P/E in the first few days following deposition of eggs is a key determinant of development potential, and that conditions under which P/E declines to less than 1 within 4 days of egg deposition are unlikely to lead to infective pastures. According to the same regression, the longer P/E takes to decline to less than 1 following egg deposition, the greater the level of infectivity 3-4 weeks later when larvae mature to the infective stage. However, findings from the final incubator study are yet to be verified under field conditions. It is likely that paddock characteristics including pasture and soil conditions, slope and aspect will influence or modulate the effects of moisture in the natural environment, as discussed in Chapter 6. Until the P/E-*H. contortus* development relationship is tested under field conditions we cannot be sure what modification, if any, is required to account for paddock-scale environmental factors. Ultimately, the relationship will need to be tested via field trials in which the developmental outcome on recently deposited eggs of a given set of rainfall and evaporation conditions are measured, either directly through pasture sampling or indirectly through tracer sheep infection levels.

As the design of incubator-based experiments did not permit migration of L3 from faeces to herbage, parameters used to predict L3 availability in the simulation did not include environmental effects on this final step in L3 translation. Field validation of incubator-derived results may necessitate further adjustment of the relationships developed to account for the potentially limiting effect of environmental factors on this process. In addition, modification may be required to the P/E relationship due to the widely-recognised ability of *H. contortus* to adapt to environmental conditions (reviewed by Besier (1992)). The ability of different strains of *H. contortus* to develop under a range of different temperature and moisture regimes may necessitate the validation of the P/E relationship within particular environments to account for regional adaptations of the species. Finally, the findings from this series of studies regarding moisture parameters and prediction of *H. contortus* development are based on a given set of temperature conditions. The general conclusions are made on the presumption that relationships will hold when temperature varies from the simulated conditions.

Despite the lack of validation in the field, it is clear that a relationship such as that established between *H. contortus* development and P/E would largely explain the sporadic nature of haemonchosis outbreaks in the Northern Tablelands regions. During summer much of the rain falls during thunderstorms but temperatures are typically warm to hot and evaporation rates in the range of 4-5 mm/day, promoting rapid drying of the faecal environment. The combination of rainfall events and evaporation rates that will lead to a period of favourable P/E conditions for L3 development are therefore likely to occur on only a small number of days during the summer period. The high fecundity of the female *H. contortus* adult counteracts this ecological constraint to development, hence when favourable conditions do occur outbreaks of haemonchosis in flocks can be both rapid and deadly.

When used in combination with widely accepted temperature thresholds for *H. contortus* development, the P/E relationship developed in Chapter 6 can be used to determine on which days during a grazing event faecal deposition is likely to lead to development of infective larvae. As an example of this, the daily meteorological data recorded in Armidale during 2003 has been collated in Appendix 3, including minimum and maximum ambient temperatures, evaporation and rainfall. Calculation of a cumulative 4-day P/E for each day (ie. P/E at d 4 following faecal deposition, when faecal deposition occur on d 1) indicates that there were 83 days during the year when rainfall and evaporation conditions are such that P/E remained above 1 at d 4. However, favourable moisture conditions may occur in the colder months, when temperature prohibits development regardless of moisture. To account for this limitation, the following assumptions were applied to determine on which days temperature was limiting:

- In winter months (April-October, inclusive) development to L3 will only have occurred when minimum daily temperature exceeded 10°C, and maximum daily temperature exceeded 20°C;
- In summer months (November-March, inclusive) development to L3 will only have occurred when minimum daily temperature exceeded 10°C and maximum daily temperature exceeded 18°C OR when minimum daily temperature was less than 10°C but maximum daily temperature exceeded 20°C.

This largely eliminated the period of May-October, leaving 35 days on which temperature and subsequent moisture conditions were adequate for *H. contortus* eggs deposited in faeces on those days to develop to L3. If the same set of rules are applied to the 2004 and 2005 meteorological data for Armidale (data not shown), there were 48 and 39 days, respectively, when development to L3 would have been a likely result of deposition of infected faeces.

Although not investigated in this series of experiments, it is possible that P/E and FMC will have similarly significant relationships with the free-living development of other nematode genera. Further studies will be necessary to determine the relevance of the P/E model to different species, although it is likely that significantly different thresholds will apply to the dominant genera, *Trichostrongylus* and *Teladorsagia*, given both are recognised as being less desiccation-susceptible than *H. contortus* (see Chapter 2).

The relationship between *H. contortus* development and P/E has significant implications for worm control in rotational grazing systems, where summer grazing periods are typically short (2-5 days) and intensive. As demonstrated above, favourable rainfall and evaporation conditions for development occur only intermittently in Armidale even in the summer months, and under a rotationally grazed system there is the added constraint that these conditions must coincide with the short period during which faeces are deposited – or at least within a few days of deposition, given the short lifespan of pre-infective stages. With stock moved from paddock to paddock on a regular basis, only a small number of paddocks in the grazing system are likely to become infective as a result of the brief grazing event. To demonstrate this, a simple rotational grazing system was applied to the Armidale 2003 meteorological data (Table 7-1), in which sheep were grazed across 15 paddocks with a rotation period (days) of 45 (January, February and December), 60 (March, April, October and November), 75 (May and September) or 90 (June, July and August). As shown in Table 7-1 and Appendix 3, varying numbers of paddocks became infective during each rotation. The practical implications of this are that producers may be able to predict which paddocks are infected based on a given set of rainfall and evaporation conditions, and therefore avoid re-grazing until adequate time has elapsed to allow natural die-off of larvae.

Calculation of the cumulative ratio of precipitation and evaporation, if it is shown to be robust under field conditions, may provide a practical approach to quantifying the moisture conditions facing newly deposited *H. contortus* eggs in a paddock environment. Producers can easily access records of amount of precipitation, either through meteorological services (for example, the Bureau of Meteorology) or on-farm rain gauges. Evaporation rate is also measured and reported by meteorological services, and again, producers can measure evaporation on-farm through a standard 'Class A' evaporation pan. The temperature range within which *H. contortus* eggs will develop to L3 are widely published, although not necessarily well-known at producer level. Extension of these temperature and moisture thresholds in a practical and accessible format to producers would facilitate the integration of such information into grazing and stock management.

**Table 7-1: Graphical representation of a simple rotational grazing system operating in the Armidale region during 2003. Each rotation ranges from 45 days to 90 days in length, with 15 paddocks grazed during this period. Paddocks 1-15 are shown within each rotation period, along with the dates on which they were grazed. The red highlighting over paddocks indicates that they were likely to become infective as a result of the grazing event, based on meteorological data for the region (see Appendix 3), the assumptions listed above for temperature constraints for *H. contortus* development, and the relationship between cumulative P/E discussed in Chapter 6 and above.**

| Rotation & date | Paddock | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rotation 1**<br>**1 Jan – 14 Feb** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Rotation 2**<br>**15 Feb – 10 Apr** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Rotation 3**<br>**11 Apr – 22 Jun** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Rotation 4**<br>**23 Jun – 17 Sep** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Rotation 5**<br>**18 Sep – 19 Nov** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Rotation 6**<br>**20 Nov – 31 Dec** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |

## 7.4 Conclusions

The experiments reported in this thesis were designed to investigate the effects of rainfall and moisture on *H. contortus* free-living development and to determine the relevance of these findings to improvement of *H. contortus* control in sheep production systems. Fundamental relationships between the free-living stages of *H. contortus* and environmental moisture variables were established, allowing the development of a 'formula' that described the relationship between prevailing precipitation and evaporation conditions and potential for infectivity. This information is yet to be integrated into current management programs, however there is considerable scope for its use in combination with other control strategies if validation in the field demonstrates the robustness of these findings at the paddock level.

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# Chapter 8. Appendices

## Appendix 1: Refining and validating the pasture larval recovery process

The major adaptation made to the pasture larval recovery process described by Martin *et al.* (1990) was the inclusion of mesh bags in the initial herbage washing stage. A comparison was made between the original procedure, in which herbage was placed directly in 20 L buckets and soaked in water and non-ionic detergent, and the alternative method, in which herbage was contained in mesh bags during soaking, as described in section 3.7. Six 200 g samples of herbage, clean of GIN free-living nematodes, were contaminated with 4250 *H. contortus* L3 in 2.5 ml. Samples were left at room temperature for several hours and then stored at 4°C overnight.

Three samples were placed in mesh bags and soaked, and the remaining three soaked without mesh bags. All other conditions were the same. Samples were agitated by hand twice during the 6 h soaking period. Following soaking, herbage in the buckets was collected by hand and rinsed manually in two 10 L buckets, before the washings were added to the original 20 L bucket and left overnight to sediment. Herbage in mesh bags was rinsed and drained over the 20 L bucket, and washing left to sediment overnight. All samples were then processed according to the remainder of the procedure described in section 3.7. Recovery of larvae was considerably higher from samples soaked in mesh bags (Table 8-1).

**Table 8-1: Comparison of *H. contortus* larval recovery from herbage soaking in buckets and mesh bags.**

| Soak method | L3 recovery (%) |
|---|---|
| Bucket | 27 |
| Bucket | 0 |
| Bucket | 1 |
| Mesh bag | 33 |
| Mesh bag | 56 |
| Mesh bag | 31 |

To improve the recovery of larvae from laboratory stage of the pasture larval recovery process (ie. flotation and sedimentation) several volumes of KI (rd 1.4) were tested in order to optimise the concentration of KI for both the initial flotation and subsequent sedimentation. Sediment aliquots of either 2 ml or 3 ml were also compared. Initially, volumes of 6, 7, 8 and 10 ml were tested with 2 ml of sediment spiked with a known quantity of L3. Each volume of KI was added to the sediment aliquot, and larvae extracted according to the flotation-sedimentation process described in section 3.7. In the second validation test, an identical process was followed, except that two replicates of each volume were tested (average recovery shown). A third test was conducted using a 3 ml aliquot of sediment with either 6, 7, 8 or 10 ml of KI. The total number of larvae was unknown in this sediment sample (all 3 ml aliquots were taken from the same sediment sample, hence uniform total larval number has been assumed), so larval numbers have been tabulated rather than percent recovery. The results of the KI volume tests are shown in Table 8-2.

**Table 8-2: *H. contortus* L3 recovery at variable KI volumes (validation tests 1-3)**

| | Test 1 | Test 2 | Test 3 |
|---|---|---|---|
| **KI volume** | **L3 recovery (%)** | **L3 recovery (%)** | **Total L3** |
| 6 | 77 | 82 | 33 |
| 7 | 59 | 95 | 36 |
| 8 | 63 | 66 | 37 |
| 10 | 44 | 76 | 13 |

All three tests indicated that 10 ml of KI was sub-optimal for recovery of L3 from sediment. With very little evidence of a significant difference between the three smaller volumes, it was decided that 7 ml of KI would used for subsequent samples. Additionally, a 3 ml aliquot of sediment was used to reduce the dilution factor of the sedimentation/flotation process.

## Appendix 2: Validation of soil larval recovery

To validate the soil larval recovery process prior to the start of experimentation, sterilised soil was placed in a 250 ml jar up to a height of 40 mm and 2 x 0.5 ml aliquots of *H. contortus* L3, each containing 1715 L3, added to the surface followed by the pipette washings. Approximately 50 ml of ethanol (70%) was added to saturate the soil, and then the jar left to sediment for 2 days before removing the excess supernatant. Four replicate 3 ml aliquots of the sediment were processed as per the sediment collected from the polyethylene bags in section 3.7. Recovery across aliquots averaged 90% (Table 8-3).

**Table 8-3: *H. contortus* larval recovery from validation tests of the soil larval recovery process.**

| Replicate | L3 recovery (%) |
|---|---|
| 1 | 81 |
| 2 | 106 |
| 3 | 76 |
| 4 | 96 |

## Appendix 3: Meteorological data for Armidale, 2003.

**Table 8-4: Meteorological data for Armidale, 2003. Minimum and maximum temperatures are ambient. Cumulative precipitation (∑P) and evaporation (∑E) for each day and the subsequent 3 days were calculated to determine the cumulative P/E at d 4 (∑P/E at d 4). Where ∑P/E at d 4 was greater than 1, moisture conditions were favourable for *H. contortus* development (as indicated by yellow highlight). Temperature was unfavourable for development when the assumptions listed in Chapter 7 (section 7.3) were not met (as indicated by grey highlight). Faecal deposition was likely to lead to development of infective larvae on the days highlighted in red. The paddock grazed column refers to a simple rotational grazing system of 15 paddocks (numbered 1-15), as described in section 7.3. Paddocks highlighted in red are likely to become infective as a result of faecal deposition on that day and subsequent moisture and temperature conditions.**

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 1/01/2003 | 27.0 | 10.1 | 0.0 | 6.4 | 6.0 | 23.2 | 0.26 | 1 |
| 2/01/2003 | 23.8 | 11.9 | 6.0 | 4.8 | 6.0 | 23.0 | 0.26 | 1 |
| 3/01/2003 | 25.4 | 8.1 | 0.0 | 6.0 | 0.0 | 25.0 | 0.00 | 1 |
| 4/01/2003 | 26.0 | 9.4 | 0.0 | 6.0 | 0.0 | 25.4 | 0.00 | 2 |
| 5/01/2003 | 25.5 | 12.6 | 0.0 | 6.2 | 24.0 | 27.0 | 0.89 | 2 |
| 6/01/2003 | 27.1 | 7.7 | 0.0 | 6.8 | 24.0 | 28.4 | 0.85 | 2 |
| 7/01/2003 | 29.0 | 10.6 | 0.0 | 6.4 | 24.0 | 28.6 | 0.84 | 3 |
| 8/01/2003 | 30.6 | 11.0 | 24.0 | 7.6 | 24.0 | 28.0 | 0.86 | 3 |
| 9/01/2003 | 25.4 | 11.5 | 0.0 | 7.6 | 0.0 | 27.0 | 0.00 | 3 |
| 10/01/2003 | 22.4 | 4.7 | 0.0 | 7.0 | 0.0 | 25.4 | 0.00 | 4 |
| 11/01/2003 | 22.7 | 6.1 | 0.0 | 5.8 | 0.0 | 24.2 | 0.00 | 4 |
| 12/01/2003 | 22.0 | 10.7 | 0.0 | 6.6 | 0.0 | 25.2 | 0.00 | 4 |
| 13/01/2003 | 22.2 | 8.6 | 0.0 | 6.0 | 0.0 | 24.6 | 0.00 | 5 |
| 14/01/2003 | 24.5 | 8.4 | 0.0 | 5.8 | 0.0 | 25.4 | 0.00 | 5 |
| 15/01/2003 | 25.1 | 9.2 | 0.0 | 6.8 | 0.0 | 27.6 | 0.00 | 5 |
| 16/01/2003 | 27.9 | 9.4 | 0.0 | 6.0 | 0.0 | 29.2 | 0.00 | 6 |
| 17/01/2003 | 31.4 | 10.0 | 0.0 | 6.8 | 0.0 | 33.2 | 0.00 | 6 |
| 18/01/2003 | 33.7 | 11.8 | 0.0 | 8.0 | 0.0 | 34.0 | 0.00 | 6 |
| 19/01/2003 | 35.4 | 20.6 | 0.0 | 8.4 | 0.0 | 34.2 | 0.00 | 7 |
| 20/01/2003 | 33.7 | 14.4 | 0.0 | 10.0 | 3.2 | 31.2 | 0.10 | 7 |
| 21/01/2003 | 35.5 | 14.4 | 0.0 | 7.6 | 3.2 | 26.0 | 0.12 | 7 |
| 22/01/2003 | 32.9 | 14.0 | 0.0 | 8.2 | 3.2 | 24.2 | 0.13 | 8 |
| 23/01/2003 | 24.3 | 16.7 | 3.2 | 5.4 | 3.2 | 23.4 | 0.14 | 8 |
| 24/01/2003 | 25.4 | 11.0 | 0.0 | 4.8 | 0.0 | 26.2 | 0.00 | 8 |
| 25/01/2003 | 30.5 | 7.2 | 0.0 | 5.8 | 0.0 | 30.4 | 0.00 | 9 |
| 26/01/2003 | 34.0 | 5.1 | 0.0 | 7.4 | 8.4 | 30.2 | 0.28 | 9 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 27/01/2003 | 34.7 | 12.0 | 0.0 | 8.2 | 8.6 | 28.8 | 0.30 | 9 |
| 28/01/2003 | 30.9 | 17.1 | 0.0 | 9.0 | 8.6 | 29.0 | 0.30 | 10 |
| 29/01/2003 | 31.3 | 17.0 | 8.4 | 5.6 | 8.6 | 29.0 | 0.30 | 10 |
| 30/01/2003 | 33.9 | 14.9 | 0.2 | 6.0 | 0.4 | 26.6 | 0.02 | 10 |
| 31/01/2003 | 36.3 | 17.5 | 0.0 | 8.4 | 0.2 | 23.2 | 0.01 | 11 |
| 1/02/2003 | 19.7 | 15.5 | 0.0 | 9.0 | 0.2 | 20.4 | 0.01 | 11 |
| 2/02/2003 | 19.4 | 13.3 | 0.2 | 3.2 | 0.2 | 16.2 | 0.01 | 11 |
| 3/02/2003 | 24.0 | 13.0 | 0.0 | 2.6 | 0.0 | 15.4 | 0.00 | 12 |
| 4/02/2003 | 21.2 | 13.6 | 0.0 | 5.6 | 0.0 | 18.4 | 0.00 | 12 |
| 5/02/2003 | 23.1 | 14.1 | 0.0 | 4.8 | 0.0 | 16.6 | 0.00 | 12 |
| 6/02/2003 | 25.4 | 12.7 | 0.0 | 2.4 | 0.0 | 17.8 | 0.00 | 13 |
| 7/02/2003 | 25.2 | 13.1 | 0.0 | 5.6 | 6.4 | 16.8 | 0.38 | 13 |
| 8/02/2003 | 28.9 | 13.5 | 0.0 | 3.8 | 8.8 | 15.6 | 0.56 | 13 |
| 9/02/2003 | 20.5 | 14.9 | 0.0 | 6.0 | 8.8 | 17.2 | 0.51 | 14 |
| 10/02/2003 | 25.3 | 13.3 | 6.4 | 1.4 | 8.8 | 18.0 | 0.49 | 14 |
| 11/02/2003 | 27.3 | 12.5 | 2.4 | 4.4 | 2.4 | 23.0 | 0.10 | 14 |
| 12/02/2003 | 30.4 | 14.0 | 0.0 | 5.4 | 0.0 | 24.2 | 0.00 | 15 |
| 13/02/2003 | 30.4 | 10.8 | 0.0 | 6.8 | 12.4 | 25.0 | 0.50 | 15 |
| 14/02/2003 | 28.6 | 12.5 | 0.0 | 6.4 | 21.2 | 23.6 | 0.90 | 15 |
| 15/02/2003 | 31.0 | 11.9 | 0.0 | 5.6 | 23.4 | 22.0 | 1.06 | 1 |
| 16/02/2003 | 30.0 | 13.0 | 12.4 | 6.2 | 50.4 | 19.0 | 2.65 | 1 |
| 17/02/2003 | 26.9 | 15.4 | 8.8 | 5.4 | 40.4 | 14.6 | 2.77 | 1 |
| 18/02/2003 | 25.0 | 16.5 | 2.2 | 4.8 | 33.2 | 11.8 | 2.81 | 2 |
| 19/02/2003 | 22.7 | 15.8 | 27.0 | 2.6 | 98.4 | 8.6 | 11.44 | 2 |
| 20/02/2003 | 23.1 | 15.7 | 2.4 | 1.8 | 76.8 | 7.4 | 10.38 | 2 |
| 21/02/2003 | 18.5 | 15.9 | 1.6 | 2.6 | 98.0 | 9.8 | 10.00 | 3 |
| 22/02/2003 | 23.6 | 16.0 | 67.4 | 1.6 | 97.6 | 10.6 | 9.21 | 3 |
| 23/02/2003 | 24.7 | 16.6 | 5.4 | 1.4 | 30.4 | 12.0 | 2.53 | 3 |
| 24/02/2003 | 20.2 | 14.6 | 23.6 | 4.2 | 25.0 | 15.2 | 1.64 | 4 |
| 25/02/2003 | 22.5 | 15.0 | 1.2 | 3.4 | 1.4 | 15.8 | 0.09 | 4 |
| 26/02/2003 | 22.4 | 14.3 | 0.2 | 3.0 | 15.4 | 18.2 | 0.85 | 4 |
| 27/02/2003 | 25.6 | 11.7 | 0.0 | 4.6 | 19.2 | 19.8 | 0.97 | 5 |
| 28/02/2003 | 28.9 | 12.1 | 0.0 | 4.8 | 19.2 | 20.2 | 0.95 | 5 |
| 1/03/2003 | 24.0 | 17.7 | 15.2 | 5.8 | 19.2 | 20.4 | 0.94 | 5 |
| 2/03/2003 | 20.1 | 3.9 | 4.0 | 4.6 | 4.0 | 18.2 | 0.22 | 6 |
| 3/03/2003 | 22.6 | 2.9 | 0.0 | 5.0 | 0.4 | 15.8 | 0.03 | 6 |
| 4/03/2003 | 23.9 | 9.0 | 0.0 | 5.0 | 1.0 | 13.0 | 0.08 | 6 |
| 5/03/2003 | 22.1 | 11.9 | 0.0 | 3.6 | 1.6 | 12.0 | 0.13 | 6 |
| 6/03/2003 | 20.5 | 11.8 | 0.4 | 2.2 | 1.6 | 12.2 | 0.13 | 7 |
| 7/03/2003 | 21.4 | 12.9 | 0.6 | 2.2 | 2.4 | 13.2 | 0.18 | 7 |
| 8/03/2003 | 22.8 | 11.7 | 0.6 | 4.0 | 1.8 | 16.0 | 0.11 | 7 |
| 9/03/2003 | 24.0 | 10.8 | 0.0 | 3.8 | 8.0 | 16.6 | 0.48 | 7 |
| 10/03/2003 | 24.5 | 9.6 | 1.2 | 3.2 | 10.4 | 14.4 | 0.72 | 8 |
| 11/03/2003 | 24.2 | 13.7 | 0.0 | 5.0 | 9.4 | 12.8 | 0.73 | 8 |
| 12/03/2003 | 17.1 | 13.4 | 6.8 | 4.6 | 9.4 | 11.2 | 0.84 | 8 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 13/03/2003 | 18.8 | 12.4 | 2.4 | 1.6 | 2.6 | 10.4 | 0.25 | 8 |
| 14/03/2003 | 21.2 | 8.1 | 0.2 | 1.6 | 23.4 | 13.0 | 1.80 | 9 |
| 15/03/2003 | 23.8 | 7.1 | 0.0 | 3.4 | 23.4 | 14.2 | 1.65 | 9 |
| 16/03/2003 | 22.6 | 9.5 | 0.0 | 3.8 | 23.4 | 14.6 | 1.60 | 9 |
| 17/03/2003 | 20.2 | 12.0 | 23.2 | 4.2 | 23.4 | 14.2 | 1.65 | 9 |
| 18/03/2003 | 21.0 | 8.0 | 0.2 | 2.8 | 5.0 | 13.2 | 0.38 | 10 |
| 19/03/2003 | 23.6 | 7.6 | 0.0 | 3.8 | 4.8 | 13.8 | 0.35 | 10 |
| 20/03/2003 | 23.8 | 9.6 | 0.0 | 3.4 | 4.8 | 13.6 | 0.35 | 10 |
| 21/03/2003 | 22.1 | 10.0 | 4.8 | 3.2 | 4.8 | 14.2 | 0.34 | 10 |
| 22/03/2003 | 22.6 | 9.2 | 0.0 | 3.4 | 0.0 | 14.4 | 0.00 | 11 |
| 23/03/2003 | 22.2 | 6.0 | 0.0 | 3.6 | 3.4 | 14.0 | 0.24 | 11 |
| 24/03/2003 | 22.0 | 9.4 | 0.0 | 4.0 | 3.4 | 13.8 | 0.25 | 11 |
| 25/03/2003 | 23.0 | 10.3 | 0.0 | 3.4 | 3.4 | 12.8 | 0.27 | 11 |
| 26/03/2003 | 23.4 | 12.1 | 3.4 | 3.0 | 3.6 | 10.4 | 0.35 | 12 |
| 27/03/2003 | 22.4 | 10.8 | 0.0 | 3.4 | 0.2 | 10.6 | 0.02 | 12 |
| 28/03/2003 | 19.1 | 12.3 | 0.0 | 3.0 | 6.6 | 9.8 | 0.67 | 12 |
| 29/03/2003 | 21.8 | 7.1 | 0.2 | 1.0 | 6.6 | 10.2 | 0.65 | 12 |
| 30/03/2003 | 22.3 | 6.6 | 0.0 | 3.2 | 6.4 | 12.8 | 0.50 | 13 |
| 31/03/2003 | 21.4 | 5.9 | 6.4 | 2.6 | 17.8 | 11.0 | 1.62 | 13 |
| 1/04/2003 | 20.8 | 11.7 | 0.0 | 3.4 | 13.6 | 10.4 | 1.31 | 13 |
| 2/04/2003 | 20.5 | 10.5 | 0.0 | 3.6 | 23.8 | 9.8 | 2.43 | 13 |
| 3/04/2003 | 18.1 | 10.1 | 11.4 | 1.4 | 23.8 | 8.8 | 2.70 | 14 |
| 4/04/2003 | 17.2 | 8.2 | 2.2 | 2.0 | 12.4 | 10.2 | 1.22 | 14 |
| 5/04/2003 | 15.5 | 7.4 | 10.2 | 2.8 | 10.2 | 11.4 | 0.89 | 14 |
| 6/04/2003 | 18.5 | 3.6 | 0.0 | 2.6 | 0.0 | 12.2 | 0.00 | 14 |
| 7/04/2003 | 18.9 | 7.3 | 0.0 | 2.8 | 0.0 | 12.6 | 0.00 | 15 |
| 8/04/2003 | 19.6 | 4.0 | 0.0 | 3.2 | 0.2 | 11.2 | 0.02 | 15 |
| 9/04/2003 | 21.6 | 3.3 | 0.0 | 3.6 | 13.2 | 9.0 | 1.47 | 15 |
| 10/04/2003 | 18.9 | 7.5 | 0.0 | 3.0 | 13.2 | 8.2 | 1.61 | 15 |
| 11/04/2003 | 17.8 | 9.1 | 0.2 | 1.4 | 13.8 | 6.6 | 2.09 | 1 |
| 12/04/2003 | 22.5 | 10.4 | 13.0 | 1.0 | 31.4 | 7.0 | 4.49 | 1 |
| 13/04/2003 | 22.9 | 10.3 | 0.0 | 2.8 | 18.4 | 9.4 | 1.96 | 1 |
| 14/04/2003 | 20.4 | 14.4 | 0.6 | 1.4 | 18.4 | 9.2 | 2.00 | 1 |
| 15/04/2003 | 18.4 | 9.9 | 17.8 | 1.8 | 17.8 | 10.0 | 1.78 | 2 |
| 16/04/2003 | 17.7 | 3.3 | 0.0 | 3.4 | 0.6 | 9.4 | 0.06 | 2 |
| 17/04/2003 | 16.2 | 8.7 | 0.0 | 2.6 | 0.6 | 8.0 | 0.08 | 2 |
| 18/04/2003 | 15.0 | 1.1 | 0.0 | 2.2 | 0.6 | 7.6 | 0.08 | 2 |
| 19/04/2003 | 17.1 | 9.1 | 0.6 | 1.2 | 1.8 | 7.8 | 0.23 | 3 |
| 20/04/2003 | 16.7 | 8.0 | 0.0 | 2.0 | 1.2 | 9.2 | 0.13 | 3 |
| 21/04/2003 | 17.2 | 2.1 | 0.0 | 2.2 | 1.2 | 9.2 | 0.13 | 3 |
| 22/04/2003 | 16.9 | 5.3 | 1.2 | 2.4 | 1.2 | 9.6 | 0.13 | 3 |
| 23/04/2003 | 16.8 | 3.3 | 0.0 | 2.6 | 0.2 | 9.0 | 0.02 | 4 |
| 24/04/2003 | 16.6 | 3.5 | 0.0 | 2.0 | 0.4 | 8.4 | 0.05 | 4 |
| 25/04/2003 | 16.5 | 4.6 | 0.0 | 2.6 | 16.0 | 8.0 | 2.00 | 4 |
| 26/04/2003 | 17.1 | 10.9 | 0.2 | 1.8 | 57.4 | 7.0 | 8.20 | 4 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 27/04/2003 | 18.4 | 9.9 | 0.2 | 2.0 | 57.2 | 7.4 | 7.73 | 5 |
| 28/04/2003 | 20.4 | 12.1 | 15.6 | 1.6 | 57.0 | 7.8 | 7.31 | 5 |
| 29/04/2003 | 17.7 | 11.8 | 41.4 | 1.6 | 41.4 | 7.8 | 5.31 | 5 |
| 30/04/2003 | 19.2 | 3.4 | 0.0 | 2.2 | 0.0 | 7.6 | 0.00 | 5 |
| 1/05/2003 | 19.2 | 0.8 | 0.0 | 2.4 | 0.0 | 7.4 | 0.00 | 6 |
| 2/05/2003 | 17.5 | 5.4 | 0.0 | 1.6 | 0.6 | 7.4 | 0.08 | 6 |
| 3/05/2003 | 17.6 | 4.4 | 0.0 | 1.4 | 1.0 | 7.2 | 0.14 | 6 |
| 4/05/2003 | 14.6 | 1.2 | 0.0 | 2.0 | 1.4 | 7.4 | 0.19 | 6 |
| 5/05/2003 | 13.5 | 6.3 | 0.6 | 2.4 | 1.6 | 8.2 | 0.20 | 6 |
| 6/05/2003 | 15.6 | 7.9 | 0.4 | 1.4 | 1.0 | 7.8 | 0.13 | 7 |
| 7/05/2003 | 17.1 | 10.2 | 0.4 | 1.6 | 0.6 | 8.0 | 0.08 | 7 |
| 8/05/2003 | 18.0 | 3.0 | 0.2 | 2.8 | 0.2 | 7.8 | 0.03 | 7 |
| 9/05/2003 | 16.4 | 0.0 | 0.0 | 2.0 | 0.0 | 7.2 | 0.00 | 7 |
| 10/05/2003 | 16.3 | 1.4 | 0.0 | 1.6 | 0.0 | 5.8 | 0.00 | 7 |
| 11/05/2003 | 16.9 | -0.9 | 0.0 | 1.4 | 0.0 | 5.8 | 0.00 | 8 |
| 12/05/2003 | 12.7 | 0.6 | 0.0 | 2.2 | 4.0 | 6.0 | 0.67 | 8 |
| 13/05/2003 | 17.5 | 6.5 | 0.0 | 0.6 | 10.2 | 4.6 | 2.22 | 8 |
| 14/05/2003 | 19.2 | 6.9 | 0.0 | 1.6 | 10.2 | 5.6 | 1.82 | 8 |
| 15/05/2003 | 15.5 | 11.6 | 4.0 | 1.6 | 10.2 | 5.8 | 1.76 | 8 |
| 16/05/2003 | 17.1 | 10.0 | 6.2 | 0.8 | 6.2 | 6.4 | 0.97 | 9 |
| 17/05/2003 | 15.3 | 8.9 | 0.0 | 1.6 | 2.8 | 9.4 | 0.30 | 9 |
| 18/05/2003 | 19.7 | 3.3 | 0.0 | 1.8 | 2.8 | 11.8 | 0.24 | 9 |
| 19/05/2003 | 23.5 | 6.2 | 0.0 | 2.2 | 2.8 | 12.6 | 0.22 | 9 |
| 20/05/2003 | 17.6 | 10.4 | 2.8 | 3.8 | 2.8 | 12.4 | 0.23 | 9 |
| 21/05/2003 | 15.0 | 9.4 | 0.0 | 4.0 | 0.0 | 10.0 | 0.00 | 10 |
| 22/05/2003 | 12.4 | 3.2 | 0.0 | 2.6 | 0.0 | 7.6 | 0.00 | 10 |
| 23/05/2003 | 16.2 | -5.0 | 0.0 | 2.0 | 0.0 | 6.6 | 0.00 | 10 |
| 24/05/2003 | 13.7 | -3.1 | 0.0 | 1.4 | 0.6 | 5.2 | 0.12 | 10 |
| 25/05/2003 | 14.4 | -2.5 | 0.0 | 1.6 | 6.4 | 5.2 | 1.23 | 10 |
| 26/05/2003 | 12.8 | -1.2 | 0.0 | 1.6 | 8.4 | 5.0 | 1.68 | 11 |
| 27/05/2003 | 14.3 | 6.9 | 0.6 | 0.6 | 8.4 | 4.4 | 1.91 | 11 |
| 28/05/2003 | 13.3 | 7.9 | 5.8 | 1.4 | 7.8 | 5.4 | 1.44 | 11 |
| 29/05/2003 | 12.8 | 7.5 | 2.0 | 1.4 | 2.0 | 4.8 | 0.42 | 11 |
| 30/05/2003 | 15.5 | 0.4 | 0.0 | 1.0 | 0.0 | 4.8 | 0.00 | 11 |
| 31/05/2003 | 16.0 | -0.4 | 0.0 | 1.6 | 5.0 | 4.4 | 1.14 | 12 |
| 1/06/2003 | 17.3 | 5.0 | 0.0 | 0.8 | 6.0 | 4.0 | 1.50 | 12 |
| 2/06/2003 | 14.9 | 5.3 | 0.0 | 1.4 | 6.0 | 4.8 | 1.25 | 12 |
| 3/06/2003 | 17.4 | 7.4 | 5.0 | 0.6 | 6.0 | 6.2 | 0.97 | 12 |
| 4/06/2003 | 17.8 | 4.3 | 1.0 | 1.2 | 1.0 | 8.0 | 0.13 | 12 |
| 5/06/2003 | 15.6 | 3.8 | 0.0 | 1.6 | 0.0 | 9.2 | 0.00 | 13 |
| 6/06/2003 | 14.1 | -2.7 | 0.0 | 2.8 | 0.0 | 8.8 | 0.00 | 13 |
| 7/06/2003 | 12.5 | -2.7 | 0.0 | 2.4 | 0.0 | 6.2 | 0.00 | 13 |
| 8/06/2003 | 13.3 | -3.8 | 0.0 | 2.4 | 0.0 | 4.8 | 0.00 | 13 |
| 9/06/2003 | 11.7 | -4.3 | 0.0 | 1.2 | 0.0 | 3.6 | 0.00 | 13 |
| 10/06/2003 | 13.7 | 1.9 | 0.0 | 0.2 | 0.0 | 3.6 | 0.00 | 13 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 11/06/2003 | 16.0 | 0.8 | 0.0 | 1.0 | 0.0 | 4.6 | 0.00 | 14 |
| 12/06/2003 | 17.4 | -0.2 | 0.0 | 1.2 | 0.0 | 6.0 | 0.00 | 14 |
| 13/06/2003 | 16.2 | 1.9 | 0.0 | 1.2 | 0.0 | 6.4 | 0.00 | 14 |
| 14/06/2003 | 11.0 | 3.0 | 0.0 | 1.2 | 0.0 | 6.2 | 0.00 | 14 |
| 15/06/2003 | 12.5 | -3.6 | 0.0 | 2.4 | 0.0 | 6.4 | 0.00 | 14 |
| 16/06/2003 | 11.1 | -5.5 | 0.0 | 1.6 | 0.0 | 4.8 | 0.00 | 14 |
| 17/06/2003 | 15.4 | -4.6 | 0.0 | 1.0 | 0.0 | 4.0 | 0.00 | 15 |
| 18/06/2003 | 14.0 | -1.0 | 0.0 | 1.4 | 11.8 | 4.2 | 2.81 | 15 |
| 19/06/2003 | 15.8 | 1.3 | 0.0 | 0.8 | 14.6 | 4.4 | 3.32 | 15 |
| 20/06/2003 | 16.7 | -0.3 | 0.0 | 0.8 | 14.6 | 4.8 | 3.04 | 15 |
| 21/06/2003 | 12.6 | 5.9 | 11.8 | 1.2 | 14.6 | 5.6 | 2.61 | 15 |
| 22/06/2003 | 8.9 | 3.9 | 2.8 | 1.6 | 2.8 | 5.0 | 0.56 | 15 |
| 23/06/2003 | 9.6 | -1.1 | 0.0 | 1.2 | 1.8 | 3.6 | 0.50 | 1 |
| 24/06/2003 | 12.9 | -5.2 | 0.0 | 1.6 | 2.2 | 2.8 | 0.79 | 1 |
| 25/06/2003 | 11.5 | -1.7 | 0.0 | 0.6 | 3.4 | 3.0 | 1.13 | 1 |
| 26/06/2003 | 11.3 | 4.7 | 1.8 | 0.2 | 13.0 | 4.0 | 3.25 | 1 |
| 27/06/2003 | 14.4 | 4.0 | 0.4 | 0.4 | 15.2 | 7.2 | 2.11 | 1 |
| 28/06/2003 | 15.5 | 7.4 | 1.2 | 1.8 | 14.8 | 8.2 | 1.80 | 1 |
| 29/06/2003 | 14.6 | 9.7 | 9.6 | 1.6 | 21.0 | 7.0 | 3.00 | 2 |
| 30/06/2003 | 10.9 | 1.5 | 4.0 | 3.4 | 14.0 | 6.4 | 2.19 | 2 |
| 1/07/2003 | 9.6 | 5.7 | 0.0 | 1.4 | 10.0 | 3.8 | 2.63 | 2 |
| 2/07/2003 | 8.9 | 3.5 | 7.4 | 0.6 | 10.0 | 3.4 | 2.94 | 2 |
| 3/07/2003 | 9.4 | 3.0 | 2.6 | 1.0 | 2.6 | 3.6 | 0.72 | 2 |
| 4/07/2003 | 10.0 | -3.6 | 0.0 | 0.8 | 0.0 | 4.0 | 0.00 | 2 |
| 5/07/2003 | 11.2 | -6.5 | 0.0 | 1.0 | 0.0 | 4.0 | 0.00 | 3 |
| 6/07/2003 | 12.2 | -6.1 | 0.0 | 0.8 | 0.0 | 3.8 | 0.00 | 3 |
| 7/07/2003 | 12.3 | -4.5 | 0.0 | 1.4 | 1.0 | 3.6 | 0.28 | 3 |
| 8/07/2003 | 12.2 | 3.7 | 0.0 | 0.8 | 1.0 | 2.8 | 0.36 | 3 |
| 9/07/2003 | 11.6 | 3.1 | 0.0 | 0.8 | 1.0 | 3.0 | 0.33 | 3 |
| 10/07/2003 | 13.7 | -0.4 | 1.0 | 0.6 | 3.0 | 4.0 | 0.75 | 3 |
| 11/07/2003 | 16.4 | 3.2 | 0.0 | 0.6 | 2.0 | 5.4 | 0.37 | 4 |
| 12/07/2003 | 16.5 | 3.9 | 0.0 | 1.0 | 2.0 | 6.2 | 0.32 | 4 |
| 13/07/2003 | 14.8 | 1.8 | 2.0 | 1.8 | 2.0 | 7.0 | 0.29 | 4 |
| 14/07/2003 | 13.2 | -1.4 | 0.0 | 2.0 | 0.0 | 7.0 | 0.00 | 4 |
| 15/07/2003 | 15.7 | -0.6 | 0.0 | 1.4 | 0.0 | 6.4 | 0.00 | 4 |
| 16/07/2003 | 19.4 | -4.1 | 0.0 | 1.8 | 0.0 | 6.6 | 0.00 | 4 |
| 17/07/2003 | 16.6 | -4.4 | 0.0 | 1.8 | 0.0 | 6.8 | 0.00 | 5 |
| 18/07/2003 | 16.0 | 1.6 | 0.0 | 1.4 | 0.0 | 6.4 | 0.00 | 5 |
| 19/07/2003 | 12.5 | 1.5 | 0.0 | 1.6 | 0.0 | 6.2 | 0.00 | 5 |
| 20/07/2003 | 13.0 | 1.3 | 0.0 | 2.0 | 0.0 | 6.4 | 0.00 | 5 |
| 21/07/2003 | 14.4 | 1.1 | 0.0 | 1.4 | 3.4 | 6.4 | 0.53 | 5 |
| 22/07/2003 | 15.7 | 0.9 | 0.0 | 1.2 | 3.4 | 6.4 | 0.53 | 5 |
| 23/07/2003 | 15.9 | -1.7 | 0.0 | 1.8 | 3.8 | 7.2 | 0.53 | 6 |
| 24/07/2003 | 8.2 | 3.4 | 3.4 | 2.0 | 4.6 | 7.0 | 0.66 | 6 |
| 25/07/2003 | 9.4 | 0.6 | 0.0 | 1.4 | 1.2 | 6.6 | 0.18 | 6 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 26/07/2003 | 6.5 | -0.5 | 0.4 | 2.0 | 1.2 | 7.0 | 0.17 | 6 |
| 27/07/2003 | 12.4 | -5.6 | 0.8 | 1.6 | 0.8 | 6.8 | 0.12 | 6 |
| 28/07/2003 | 12.6 | -10.5 | 0.0 | 1.6 | 0.0 | 7.2 | 0.00 | 6 |
| 29/07/2003 | 10.1 | -4.0 | 0.0 | 1.8 | 0.0 | 7.2 | 0.00 | 7 |
| 30/07/2003 | 7.6 | -1.9 | 0.0 | 1.8 | 0.0 | 6.8 | 0.00 | 7 |
| 31/07/2003 | 9.1 | -7.5 | 0.0 | 2.0 | 0.0 | 6.6 | 0.00 | 7 |
| 1/08/2003 | 12.8 | -6.9 | 0.0 | 1.6 | 0.0 | 6.2 | 0.00 | 7 |
| 2/08/2003 | 13.5 | -6.7 | 0.0 | 1.4 | 0.0 | 6.6 | 0.00 | 7 |
| 3/08/2003 | 16.5 | -7.2 | 0.0 | 1.6 | 1.0 | 7.4 | 0.14 | 7 |
| 4/08/2003 | 16.9 | -4.8 | 0.0 | 1.6 | 1.0 | 8.8 | 0.11 | 8 |
| 5/08/2003 | 15.6 | -2.5 | 0.0 | 2.0 | 1.0 | 8.8 | 0.11 | 8 |
| 6/08/2003 | 16.1 | 8.2 | 1.0 | 2.2 | 1.0 | 9.2 | 0.11 | 8 |
| 7/08/2003 | 15.1 | -2.2 | 0.0 | 3.0 | 0.0 | 9.4 | 0.00 | 8 |
| 8/08/2003 | 14.6 | -4.5 | 0.0 | 1.6 | 0.0 | 8.2 | 0.00 | 8 |
| 9/08/2003 | 11.6 | -4.9 | 0.0 | 2.4 | 2.4 | 7.2 | 0.33 | 8 |
| 10/08/2003 | 12.2 | -6.6 | 0.0 | 2.4 | 4.6 | 6.4 | 0.72 | 9 |
| 11/08/2003 | 13.9 | -0.7 | 0.0 | 1.8 | 14.2 | 8.2 | 1.73 | 9 |
| 12/08/2003 | 19.1 | 4.8 | 2.4 | 0.6 | 14.2 | 8.2 | 1.73 | 9 |
| 13/08/2003 | 22.3 | 10.1 | 2.2 | 1.6 | 11.8 | 9.2 | 1.28 | 9 |
| 14/08/2003 | 12.0 | 10.3 | 9.6 | 4.2 | 9.6 | 9.0 | 1.07 | 9 |
| 15/08/2003 | 12.2 | -2.2 | 0.0 | 1.8 | 0.0 | 6.4 | 0.00 | 9 |
| 16/08/2003 | 14.0 | ^ 5.1 | 0.0 | 1.6 | 0.4 | 6.2 | 0.06 | 10 |
| 17/08/2003 | 15.2 | -0.1 | 0.0 | 1.4 | 0.4 | 6.0 | 0.07 | 10 |
| 18/08/2003 | 13.4 | 4.5 | 0.0 | 1.6 | 0.4 | 6.6 | 0.06 | 10 |
| 19/08/2003 | 11.4 | -2.9 | 0.4 | 1.6 | 0.4 | 6.0 | 0.07 | 10 |
| 20/08/2003 | 12.1 | -2.0 | 0.0 | 1.4 | 0.0 | 5.8 | 0.00 | 10 |
| 21/08/2003 | 12.2 | -4.1 | 0.0 | 2.0 | 17.6 | 6.0 | 2.93 | 10 |
| 22/08/2003 | 17.5 | -3.2 | 0.0 | 1.0 | 17.6 | 6.8 | 2.59 | 11 |
| 23/08/2003 | 15.7 | 2.5 | 0.0 | 1.4 | 17.6 | 8.0 | 2.20 | 11 |
| 24/08/2003 | 12.9 | 7.3 | 17.6 | 1.6 | 18.8 | 9.2 | 2.04 | 11 |
| 25/08/2003 | 13.8 | 5.4 | 0.0 | 2.8 | 1.2 | 10.6 | 0.11 | 11 |
| 26/08/2003 | 13.5 | 2.7 | 0.0 | 2.2 | 1.2 | 10.2 | 0.12 | 11 |
| 27/08/2003 | 11.3 | 2.0 | 1.2 | 2.6 | 1.2 | 10.2 | 0.12 | 11 |
| 28/08/2003 | 14.6 | -5.3 | 0.0 | 3.0 | 0.0 | 10.0 | 0.00 | 12 |
| 29/08/2003 | 16.0 | -4.0 | 0.0 | 2.4 | 0.0 | 11.4 | 0.00 | 12 |
| 30/08/2003 | 16.3 | -0.9 | 0.0 | 2.2 | 0.0 | 11.4 | 0.00 | 12 |
| 31/08/2003 | 17.5 | 9.0 | 0.0 | 2.4 | 0.0 | 11.0 | 0.00 | 12 |
| 1/09/2003 | 11.6 | -1.5 | 0.0 | 4.4 | 0.0 | 11.8 | 0.00 | 12 |
| 2/09/2003 | 13.4 | -5.6 | 0.0 | 2.4 | 0.0 | 9.8 | 0.00 | 12 |
| 3/09/2003 | 16.2 | -2.3 | 0.0 | 1.8 | 0.0 | 11.0 | 0.00 | 13 |
| 4/09/2003 | 15.9 | -4.6 | 0.0 | 3.2 | 0.0 | 12.6 | 0.00 | 13 |
| 5/09/2003 | 17.4 | -3.7 | 0.0 | 2.4 | 0.0 | 13.4 | 0.00 | 13 |
| 6/09/2003 | 18.9 | -2.7 | 0.0 | 3.6 | 0.0 | 13.8 | 0.00 | 13 |
| 7/09/2003 | 19.0 | -2.0 | 0.0 | 3.4 | 0.0 | 13.2 | 0.00 | 13 |
| 8/09/2003 | 15.6 | 2.6 | 0.0 | 4.0 | 0.0 | 15.2 | 0.00 | 14 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 9/09/2003 | 16.7 | -2.6 | 0.0 | 2.8 | 0.0 | 15.6 | 0.00 | 14 |
| 10/09/2003 | 21.4 | 1.6 | 0.0 | 3.0 | 6.0 | 14.4 | 0.42 | 14 |
| 11/09/2003 | 19.8 | 0.6 | 0.0 | 5.4 | 6.0 | 16.0 | 0.38 | 14 |
| 12/09/2003 | 19.8 | 2.1 | 0.0 | 4.4 | 6.0 | 16.8 | 0.36 | 14 |
| 13/09/2003 | 17.5 | 6.8 | 6.0 | 1.6 | 6.0 | 8.2 | 0.73 | 15 |
| 14/09/2003 | 18.3 | 2.1 | 0.0 | 4.6 | 0.0 | 10.6 | 0.00 | 15 |
| 15/09/2003 | 12.5 | 3.9 | 0.0 | 6.2 | 0.0 | 10.2 | 0.00 | 15 |
| 16/09/2003 | 12.3 | 1.4 | 0.0 | -4.2 | 0.0 | 8.8 | 0.00 | 15 |
| 17/09/2003 | 18.2 | 5.5 | 0.0 | 4.0 | 0.0 | 18.2 | 0.00 | 15 |
| 18/09/2003 | 19.5 | 5.4 | 0.0 | 4.2 | 0.0 | 18.6 | 0.00 | 1 |
| 19/09/2003 | 20.2 | -1.0 | 0.0 | 4.8 | 0.0 | 19.0 | 0.00 | 1 |
| 20/09/2003 | 21.9 | 2.9 | 0.0 | 5.2 | 0.0 | 20.4 | 0.00 | 1 |
| 21/09/2003 | 23.7 | -2.0 | 0.0 | 4.4 | 0.0 | 21.4 | 0.00 | 1 |
| 22/09/2003 | 26.6 | 6.2 | 0.0 | 4.6 | 0.0 | 24.0 | 0.00 | 1 |
| 23/09/2003 | 27.9 | 16.5 | 0.0 | 6.2 | 0.0 | 26.4 | 0.00 | 2 |
| 24/09/2003 | 26.2 | 9.3 | 0.0 | 6.2 | 0.0 | 27.0 | 0.00 | 2 |
| 25/09/2003 | 25.5 | 7.4 | 0.0 | 7.0 | 0.0 | 27.4 | 0.00 | 2 |
| 26/09/2003 | 25.7 | 2.5 | 0.0 | 7.0 | 0.0 | 24.0 | 0.00 | 2 |
| 27/09/2003 | 20.0 | 3.2 | 0.0 | 6.8 | 0.0 | 22.2 | 0.00 | 2 |
| 28/09/2003 | 17.2 | -5.2 | 0.0 | 6.6 | 0.6 | 18.6 | 0.03 | 3 |
| 29/09/2003 | 18.5 | -4.0 | 0.0 | 3.6 | 23.8 | 13.2 | 1.80 | 3 |
| 30/09/2003 | 18.4 | -1.5 | 0.0 | 5.2 | 35.2 | 12.6 | 2.79 | 3 |
| 1/10/2003 | 15.6 | 4.3 | 0.6 | 3.2 | 47.6 | 8.2 | 5.80 | 3 |
| 2/10/2003 | 19.0 | 11.2 | 23.2 | 1.2 | 53.8 | 6.8 | 7.91 | 3 |
| 3/10/2003 | 11.9 | 7.2 | 11.4 | 3.0 | 32.2 | 7.0 | 4.60 | 4 |
| 4/10/2003 | 14.3 | 4.7 | 12.4 | 0.8 | 31.4 | 5.0 | 6.28 | 4 |
| 5/10/2003 | 14.9 | 7.5 | 6.8 | 1.8 | 19.0 | 7.8 | 2.44 | 4 |
| 6/10/2003 | 15.2 | 6.1 | 1.6 | 1.4 | 12.2 | 10.2 | 1.20 | 4 |
| 7/10/2003 | 16.7 | 8.2 | 10.6 | 1.0 | 10.6 | 12.2 | 0.87 | 5 |
| 8/10/2003 | 17.9 | 0.3 | 0.0 | 3.6 | 0.0 | 16.2 | 0.00 | 5 |
| 9/10/2003 | 17.6 | 1.1 | 0.0 | 4.2 | 0.0 | 16.4 | 0.00 | 5 |
| 10/10/2003 | 15.8 | 1.6 | 0.0 | 3.4 | 0.0 | 15.4 | 0.00 | 5 |
| 11/10/2003 | 13.2 | -2.6 | 0.0 | 5.0 | 0.0 | 15.4 | 0.00 | 6 |
| 12/10/2003 | 15.2 | -3.5 | 0.0 | 3.8 | 0.0 | 14.6 | 0.00 | 6 |
| 13/10/2003 | 16.9 | -1.1 | 0.0 | 3.2 | 0.0 | 15.0 | 0.00 | 6 |
| 14/10/2003 | 18.6 | 7.0 | 0.0 | 3.4 | 1.2 | 13.4 | 0.09 | 6 |
| 15/10/2003 | 19.3 | 2.9 | 0.0 | 4.2 | 1.4 | 13.0 | 0.11 | 7 |
| 16/10/2003 | 17.4 | 5.8 | 0.0 | 4.2 | 1.6 | 11.6 | 0.14 | 7 |
| 17/10/2003 | 19.1 | 8.5 | 1.2 | 1.6 | 11.0 | 13.0 | 0.85 | 7 |
| 18/10/2003 | 19.5 | 4.0 | 0.2 | 3.0 | 9.8 | 15.4 | 0.64 | 7 |
| 19/10/2003 | 23.0 | 5.1 | 0.2 | 2.8 | 9.6 | 16.8 | 0.57 | 8 |
| 20/10/2003 | 18.5 | 10.2 | 9.4 | 5.6 | 9.4 | 19.2 | 0.49 | 8 |
| 21/10/2003 | 20.9 | 1.1 | 0.0 | 4.0 | 0.0 | 18.4 | 0.00 | 8 |
| 22/10/2003 | 22.7 | 3.6 | 0.0 | 4.4 | 0.0 | 19.6 | 0.00 | 8 |
| 23/10/2003 | 24.0 | 3.0 | 0.0 | 5.2 | 2.6 | 19.8 | 0.13 | 9 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 24/10/2003 | 25.5 | 3.4 | 0.0 | 4.8 | 5.8 | 17.8 | 0.33 | 9 |
| 25/10/2003 | 24.4 | 7.0 | 0.0 | 5.2 | 5.8 | 18.2 | 0.32 | 9 |
| 26/10/2003 | 20.7 | 6.6 | 2.6 | 4.6 | 7.8 | 17.4 | 0.45 | 9 |
| 27/10/2003 | 19.4 | 0.9 | 3.2 | 3.2 | 5.2 | 20.2 | 0.26 | 10 |
| 28/10/2003 | 25.7 | 0.9 | 0.0 | 5.2 | 2.0 | 22.0 | 0.09 | 10 |
| 29/10/2003 | 20.0 | 13.3 | 2.0 | 4.4 | 5.8 | 17.6 | 0.33 | 10 |
| 30/10/2003 | 18.6 | 1.5 | 0.0 | 7.4 | 3.8 | 19.2 | 0.20 | 10 |
| 31/10/2003 | 18.7 | 0.3 | 0.0 | 5.0 | 3.8 | 16.4 | 0.23 | 11 |
| 1/11/2003 | 17.0 | 5.0 | 3.8 | 0.8 | 3.8 | 15.8 | 0.24 | 11 |
| 2/11/2003 | 15.5 | -1.6 | 0.0 | 6.0 | 0.0 | 19.8 | 0.00 | 11 |
| 3/11/2003 | 18.3 | -3.0 | 0.0 | 4.6 | 0.0 | 19.4 | 0.00 | 11 |
| 4/11/2003 | 21.6 | 0.6 | 0.0 | 4.4 | 0.0 | 19.2 | 0.00 | 12 |
| 5/11/2003 | 24.1 | 2.0 | 0.0 | 4.8 | 4.8 | 16.2 | 0.30 | 12 |
| 6/11/2003 | 24.4 | 4.5 | 0.0 | 5.6 | 49.4 | 16.6 | 2.98 | 12 |
| 7/11/2003 | 19.1 | 6.9 | 0.0 | 4.4 | 49.6 | 14.4 | 3.44 | 12 |
| 8/11/2003 | 19.4 | 11.0 | 4.8 | 1.4 | 49.6 | 14.0 | 3.54 | 13 |
| 9/11/2003 | 21.4 | 8.4 | 44.6 | 5.2 | 44.8 | 17.6 | 2.55 | 13 |
| 10/11/2003 | 22.9 | 7.7 | 0.2 | 3.4 | 0.2 | 19.0 | 0.01 | 13 |
| 11/11/2003 | 24.7 | 5.0 | 0.0 | 4.0 | 0.0 | 19.6 | 0.00 | 13 |
| 12/11/2003 | 26.8 | 9.0 | 0.0 | 5.0 | 0.0 | 20.4 | 0.00 | 14 |
| 13/11/2003 | 19.8 | 11.7 | 0.0 | 6.6 | 0.0 | 21.4 | 0.00 | 14 |
| 14/11/2003 | 25.0 | 10.1 | 0.0 | 4.0 | 0.0 | 22.0 | 0.00 | 14 |
| 15/11/2003 | 28.5 | 6.5 | 0.0 | 4.8 | 0.0 | 21.2 | 0.00 | 14 |
| 16/11/2003 | 28.7 | 10.3 | 0.0 | 6.0 | 0.0 | 19.8 | 0.00 | 15 |
| 17/11/2003 | 17.8 | 13.3 | 0.0 | 7.2 | 0.0 | 19.2 | 0.00 | 15 |
| 18/11/2003 | 24.9 | 9.9 | 0.0 | 3.2 | 0.0 | 17.6 | 0.00 | 15 |
| 19/11/2003 | 28.5 | 9.2 | 0.0 | 3.4 | 32.4 | 22.0 | 1.47 | 15 |
| 20/11/2003 | 30.0 | 11.5 | 0.0 | 5.4 | 38.4 | 20.4 | 1.88 | 1 |
| 21/11/2003 | 28.5 | 18.0 | 0.0 | 5.6 | 39.4 | 20.0 | 1.97 | 1 |
| 22/11/2003 | 19.2 | 17.3 | 32.4 | 7.6 | 50.6 | 17.6 | 2.88 | 1 |
| 23/11/2003 | 22.6 | 8.0 | 6.0 | 1.8 | 18.2 | 13.8 | 1.32 | 1 |
| 24/11/2003 | 17.0 | 7.5 | 1.0 | 5.0 | 12.2 | 15.8 | 0.77 | 2 |
| 25/11/2003 | 18.1 | 3.1 | 11.2 | 3.2 | 11.2 | 15.6 | 0.72 | 2 |
| 26/11/2003 | 17.1 | 3.2 | 0.0 | 3.8 | 0.0 | 18.0 | 0.00 | 2 |
| 27/11/2003 | 18.4 | 1.2 | 0.0 | 3.8 | 0.0 | 20.4 | 0.00 | 2 |
| 28/11/2003 | 21.5 | 2.6 | 0.0 | 4.8 | 0.0 | 22.0 | 0.00 | 3 |
| 29/11/2003 | 24.1 | 5.4 | 0.0 | 5.6 | 0.0 | 22.4 | 0.00 | 3 |
| 30/11/2003 | 24.6 | 7.5 | 0.0 | 6.2 | 11.2 | 24.6 | 0.46 | 3 |
| 1/12/2003 | 26.5 | 8.4 | 0.0 | 5.4 | 11.2 | 22.0 | 0.51 | 3 |
| 2/12/2003 | 25.9 | 10.1 | 0.0 | 5.2 | 58.4 | 21.8 | 2.68 | 4 |
| 3/12/2003 | 25.2 | 9.5 | 11.2 | 7.8 | 76.6 | 20.2 | 3.79 | 4 |
| 4/12/2003 | 26.4 | 12.2 | 0.0 | 3.6 | 66.6 | 12.4 | 5.37 | 4 |
| 5/12/2003 | 22.6 | 15.0 | 47.2 | 5.2 | 66.6 | 14.2 | 4.69 | 5 |
| 6/12/2003 | 13.5 | 11.5 | 18.2 | 3.6 | 19.6 | 11.6 | 1.69 | 5 |
| 7/12/2003 | 16.6 | 9.5 | 1.2 | 0.0 | 1.4 | 14.8 | 0.09 | 5 |

| Date | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Evap (mm) | ∑P d1-d4 | ∑E d1-d4 | ∑P/E at d 4 | Paddock grazed |
|---|---|---|---|---|---|---|---|---|
| 8/12/2003 | 23.7 | 4.5 | 0.0 | 5.4 | 0.2 | 21.0 | 0.01 | 6 |
| 9/12/2003 | 26.8 | 9.5 | 0.2 | 2.6 | 0.2 | 20.6 | 0.01 | 6 |
| 10/12/2003 | 27.9 | 14.3 | 0.0 | 6.8 | 0.0 | 23.0 | 0.00 | 6 |
| 11/12/2003 | 27.7 | 11.4 | 0.0 | 6.2 | 0.2 | 21.8 | 0.01 | 7 |
| 12/12/2003 | 26.7 | 13.5 | 0.0 | 5.0 | 0.2 | 19.8 | 0.01 | 7 |
| 13/12/2003 | 29.0 | 12.6 | 0.0 | 5.0 | 16.4 | 21.0 | 0.78 | 7 |
| 14/12/2003 | 24.1 | 13.0 | 0.2 | 5.6 | 16.4 | 20.4 | 0.80 | 8 |
| 15/12/2003 | 25.7 | 16.7 | 0.0 | 4.2 | 16.2 | 20.4 | 0.79 | 8 |
| 16/12/2003 | 21.1 | 14.9 | 16.2 | 6.2 | 16.2 | 22.2 | 0.73 | 8 |
| 17/12/2003 | 22.6 | 7.5 | 0.0 | 4.4 | 0.0 | 21.4 | 0.00 | 9 |
| 18/12/2003 | 25.6 | 8.2 | 0.0 | 5.6 | 0.0 | 22.4 | 0.00 | 9 |
| 19/12/2003 | 27.3 | 9.0 | 0.0 | 6.0 | 0.0 | 24.0 | 0.00 | 9 |
| 20/12/2003 | 27.6 | 12.2 | 0.0 | 5.4 | 0.2 | 23.6 | 0.01 | 10 |
| 21/12/2003 | 30.2 | 13.4 | 0.0 | 5.4 | 0.2 | 25.6 | 0.01 | 10 |
| 22/12/2003 | 31.5 | 19.0 | 0.0 | 7.2 | 0.2 | 25.8 | 0.01 | 10 |
| 23/12/2003 | 30.4 | 11.7 | 0.2 | 5.6 | 0.2 | 25.4 | 0.01 | 11 |
| 24/12/2003 | 30.3 | 17.1 | 0.0 | 7.4 | 0.4 | 26.0 | 0.02 | 11 |
| 25/12/2003 | 31.0 | 14.1 | 0.0 | 5.6 | 0.4 | 24.2 | 0.02 | 11 |
| 26/12/2003 | 32.4 | 10.7 | 0.0 | 6.8 | 0.4 | 23.0 | 0.02 | 12 |
| 27/12/2003 | 28.5 | 19.5 | 0.4 | 6.2 | 0.4 | 22.0 | 0.02 | 12 |
| 28/12/2003 | 23.0 | 15.2 | 0.0 | 5.6 | 0.0 | 22.6 | 0.00 | 12 |
| 29/12/2003 | 23.1 | 11.4 | 0.0 | 4.4 | 0.0 | 24.0 | 0.00 | 13 |
| 30/12/2003 | 28.0 | 11.0 | 0.0 | 5.8 | 0.0 | 25.4 | 0.00 | 13 |
| 31/12/2003 | 31.1 | 9.0 | 0.0 | 6.8 | 0.0 | 26.6 | 0.00 | 13 |