Water consumption by rusa deer (Cervus timorensis) stags as influenced by different types of food

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Abstract
During winter in southern Queensland, eight rusa deer stags aged 4 years were given ad libitum lucerne (Medicago sativa) hay and confined in individual metabolism pens for 26 days. Stags ate 2·04 kg dry matter (DM) per day and drank 6·4 kg water per day, while the drinking water : food DM ratio was 3·3 l/kg. In experiment 2, seven rusa stags were given ad libitum lucerne hay or oat (Avena spp.) hay with or without barley grain supplementation (200 g/day) for 56 days (four periods). This experiment was conducted from 26 July to 19 September 2001, when the stags were exhibiting the behaviour characteristic of the rut. Rusa stags ate 1·19 and 1·17 kg DM per day of lucerne and oat hay respectively. Rusa stags given oat hay drank slightly more water than those that received lucerne hay (5·34 and 4·47 kg/day, respectively). The drinking water : food DM ratios were 3·81 and 4·67 kg/kg for lucerne and oat hay, respectively. Barley grain supplementation (200 g/day) had no influence on total food or water intakes of the rusa stags.

Keywords: Cervus timorensis, drinking water, food intake, water intake.

Introduction
Rusa deer (Cervus timorensis) are widely farmed in northeastern Australia, Southeast Asia, the Pacific Islands and Mauritius (Sookhareea, 2001). To obtain optimum production from farmed animals it is axiomatic that they must be given an adequate supply of good-quality water (Squires, 1993). Knowledge of water requirements is also needed to design watering facilities on the deer farm, particularly in areas of limited water supply, such as arid and semi-arid localities.

Water requirements of ruminants are met from drinking water, water contained in food, and metabolic water. The volume of drinking water consumed is influenced by many factors such as the animal species including its capacity to conserve water, the age of the animal and its activity (Pond et al., 1995). Sheep and goats, for example, conserve water better than cattle; while young animals are likely to need more water than older animals. The effects of age and sex of deer on their water requirements, or the ability of deer to conserve water are not known. External factors that may influence the drinking water requirements of animals include the water content, chemical composition and quantity of food, the amount and nature of dissolved ions in water, water temperature, and environmental factors such as the ambient temperature and humidity (Agricultural Research Council, 1980; National Research Council, 1981; Squires, 1993). It is generally accepted that water consumption is related to dry matter (DM) intake (Church, 1976).

There are few reports on the drinking water requirements of those deer species which are farmed in northern Australia and other subtropical and tropical regions. Some limited data has been published for the Timor rusa deer (Cervus timorensis timorensis; Bale-Therik et al., 1996) and some for red deer (Cervus elaphus; Barrell and Topp, 1989; Alexander and Segiura, 1990; Domingue et al., 1991). At this time there is no information on the drinking water requirements of the Javan rusa, which is the rusa subspecies most commonly farmed in northern Australia, New Caledonia and Mauritius (Sookhareea, 2001). This lack of information presents a potentially important constraint to efficient deer farm management in northern Australia, where rainfall is highly seasonal and droughts occur frequently (Daly, 1994).

Rusa stags grow slowly during winter (Sookhareea et al., 2001) because they are in the rut (breeding season) and because many tropical grass-based pastures have low digestibilities and protein contents in winter (Norton, 1982). The effects of low pasture quality are exacerbated by the relatively high protein requirements of growing deer (e.g. Puttoo et al. (1998) have shown that weaned rusa stags need about 16% protein for adequate growth) and the preference of venison processors for an animal weighing 75 kg at slaughter (Sinclair 1997a). Animal growth targets are thus difficult to meet from conventional pasture resources. Hmeidan and Dryden (1998) have shown that cereal grain supplements will give a substantial boost to growth in stags given a basal diet of low-quality hay. Many Queensland deer farmers routinely use lucerne hay (43% of farmers) and cereal grain...
supplements (70%) (Sinclair, 1997b). The use of protein-rich lucerne hay might increase urea excretion and so increase drinking water requirements (Holter and Urban, 1992), while feeding energy-rich concentrates might lead to higher metabolic water production (National Research Council, 2000) and possibly reduce drinking water requirements.

In light of the limited data on the drinking water requirements of any deer, and the lack of any data for the Javan rusa deer in particular, the objectives of this study were to determine the typical levels of drinking water consumption, and to measure the influence of different types of food on the total and drinking water consumptions of Javan rusa deer stags when they were given foods representative of those used in deer farming in subtropical Australia.

Material and methods
Two experiments were conducted at the Deer Research Unit, University of Queensland, Gatton. The unit is located at 27°36'S at an elevation of 90 m above sea level, and the climate is subtropical. Experiment 1 was conducted between 8 June and 3 July 2001 (i.e. the southern hemisphere winter), and experiment 2 was conducted from 26 July to 19 September 2001 (southern hemisphere winter to early spring).

Animals and housing
Javan rusa deer stags (Cervus timorensis rusa), 4 to 4-5 years old, were used in these experiments. They were introduced to metabolism pens in early June 2001 to become accustomed to the pens and handlers. Eight stags, weighing 128 (s.d. = 12·8) kg, were used in experiment 1. In experiment 2, seven of these animals, then weighing 125 (s.d. = 13·1) kg, were used. All displayed the behaviour characteristic of the rut (breeding season), in both experiments.

Experimental design
Experiment 1. The stags were given ad libitum lucerne (Medicago sativa) hay (Table 1) and water. Food and water intakes were measured for two, 4-day periods, after 18 days adaptation. Food and water were offered at 08:00 and 16:00 h and residues (food and water) were either measured at 2-h intervals between 08:00 and 20:00 h, or at 12-h intervals, in order to compare the effects of sampling frequency on the accuracy of water intake measurements and animal behaviour. These two types of measurement were made in a randomized complete blocks design.

<table>
<thead>
<tr>
<th>Table 1 Chemical composition of rusa deer foods</th>
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<tbody>
<tr>
<td>Experiment</td>
</tr>
<tr>
<td>Dry matter (DM) (g/kg)</td>
</tr>
<tr>
<td>Constituents in DM (g/kg)</td>
</tr>
<tr>
<td>Crude protein</td>
</tr>
<tr>
<td>Ether extract</td>
</tr>
<tr>
<td>Organic matter</td>
</tr>
<tr>
<td>Neutral-detergent fibre</td>
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<tr>
<td>Acid-detergent fibre</td>
</tr>
</tbody>
</table>

Experiment 2. Two forages, a high-quality lucerne and an oaten (Avena spp.) hay, were offered with or without a supplement of 200 g/day of kibbled barley (Table 1) in a 2 × 2 factorial treatment design. The four treatments were imposed in a complete randomized blocks design in which the deer constituted the blocks. The experiment was conducted over 56 days, in four periods (14 days each period, including 7 days adjustment and 7 days data and sample collection). The forages were offered ad libitum at 08:00 h. Total food refusals were measured individually at 08:00, 14:00, and 20:00 h daily.

Measurements
Water consumption. In both experiments, deer had continuous access to water. They were offered 15 l water (570 mg/l total dissolved salts) placed in a 20-l bucket. Water refusals were discarded and the buckets refilled after cleaning, daily at 08:00 h. A separate container with 15 l of water was placed in an adjoining area to measure the amount lost by evaporation.

Drinking water intake was measured daily by subtracting the amount of water remaining from the amount of water provided. Food water was determined each day during the data collection periods by drying in a forced-draught oven overnight at 103°C. Total water intake was determined by summing the amounts of drinking water and water contained in food consumed.

Food intake
Food intakes in experiment 1 and 2 were measured by total collections of amounts offered and refused. In experiment 1, the uneaten food was weighed at every sampling time. A sample of approximately 60 g was collected from each animal, and the remainder was returned to the food bin. In both experiments, about 200 g samples of the food offered and refused were collected each day. At the end of the collection periods, these food and refusals samples were bulked individually for each animal over the 4 day (experiment 1) or 7 day (experiment 2) collection periods, thoroughly mixed, and subsamples were taken for chemical analysis.

Analytical methods
The daily samples of food and refusals were dried overnight at 103°C to determine DM contents. A semi-micro Kjeldahl digestion using Cu catalyst was used to determine the nitrogen content of the food and refusals. Organic matter (OM) was determined by ashing overnight at 550°C. Samples were also analysed to determine acid-detergent fibre (ADF) and neutral-detergent fibre (NDF) contents (Goering and Van Soest, 1970).

Ambient temperature and humidity
The ambient temperature and humidity were recorded continuously at a weather station located approximately 10 km from the Deer Research Unit.

Data analysis
The trends for drinking water intake were examined by multiple regressions using stepwise elimination to identify which independent variables contributed most to variability in drinking water intake. Variables tested were NDF and protein.
intakes. Variables remained in the model provided that they were significant at P<0.15. Treatment effects were compared by t test (experiment 1) and analysis of variance (experiment 2), using the general linear model (Glm) procedure of SAS (Statistical Analysis Systems Institute, 1989).

**Results**

**Experiment 1**
The mean maximum and minimum temperatures during experiment 1 were 22.5 and 7.7°C and the mean relative humidity was 0.84. Overall mean drinking water (DW) intake was 6.4 (s.e. = 0.26) l/day, with a mean DW : DM ratio of 3.13 (s.e. = 0.062) l/kg. When the stags were monitored every 2 h they ate 0.15 kg more DM daily (P = 0.001). The shorter sampling interval increased the total water (TW) intake (P = 0.001) but had no effect on the TW DM ratio (P = 0.637; Table 2). Within animals, between-day variation in water intake was low, with CV = 0.13. Although between-animal variation in DM intake was large (CV = 0.25), variation in the DW DM ratio was much less (CV = 0.1). The relationship between DW (y, l/day) and DM intakes (x, kg/day) was linear (y = 0.74438 + 3.5069 * x, R^2 = 0.7808, P < 0.001).

**Experiment 2**
The mean maximum and minimum temperatures during experiment 2 were 23.4 and 7.7°C and the mean relative humidity was 0.63. All but one of the stags lost live weight during the course of experiment 2. Mean live-weight loss was 12.9 (s.e. = 2.1) kg over the 56 days; one stag gained 3.5 kg.

Mean daily intakes of DM and OM were not significantly different between deer offered lucerne and oaten hay, 1.19 v. 1.17 and 1.04 v. 1.06 kg/day, respectively (Table 3). The rusa deer stags ate all the barley grain given (200 g/day), but their total food intake only increased by 0.04 kg DM per day when barley grain was added to the basal food (P = 0.719).

Protein (N × 6.25) and NDF intakes were significantly different between deer given lucerne and oaten hays (P = 0.006 and P = 0.001, respectively). Deer that received lucerne consumed 54 (s.e.d. = 16.6) g more protein daily than those given oaten hay. However, deer given lucerne hay consumed 157 (s.e.d. = 33.9) g less NDF daily than those given oaten hay. Barley grain supplementation did not affect the intake of total DM or of any food constituent. There were no significant interactions between hay type and concentrate supplement for any of the responses measured.

Mean daily DW and TW intakes were significantly different when the stags were offered different types of hay (Table 3). Overall, deer offered oaten hay consumed 0.88 (s.e.d. = 0.38) kg more DW daily than those eating lucerne hay (P = 0.038). Daily TW intake was also higher in rusa stags offered oaten hay (P = 0.051). However, the addition of barley grain did not change the stags' DW consumption or TW intake (P = 0.878 and P = 0.881, respectively).

Multiple regression analysis was used to identify those food composition variables which apparently had the greatest effect on DW intake (kg/day). The final multiple regression models contained only NDF intake (kg/day) as the regressor variable, and were (estimate±s.e.):

For lucerne hay:

\[
\text{DW intake} = (0.77 ± 0.424) + [(11.3 ± 1.258) \times (\text{NDF intake})] \\
R^2 = 0.87, P = 0.001.
\]

For oaten hay:

\[
\text{DW intake} = (1.37 ± 0.764) + [(8.21 ± 1.488) \times (\text{NDF intake})] \\
R^2 = 0.72, P = 0.001.
\]

The regression coefficients were significantly different (P < 0.05).
**Discussion**

**Comparisons with other deer species**

When they were given lucerne hay *ad libitum*, the mean water consumption of our Javan rusa stags ranged from 4.5 to 6.7 kg daily. Data for other deer species are given in Table 4. There is only one other published data set for tropical deer. Bale-Therik et al. (1996) reported that Timor rusa (*C. timorensis timorensis*) drank 1 to 2.5 l/day when eating dry pasture. The water intakes reported for temperate deer vary between 2.0 l/day (mule deer, *Odocoileus hemionus*, fed lucerne hay plus a grain mixture; Knox et al. (1969)) and 4.4 l/day (red deer given a dry pelleted diet; Barrell and Topp (1989)). These intakes are influenced by different body weights (in particular, the Timor rusa deer is a much smaller animal than the Javan rusa), ambient temperatures and humidities, the different chemical compositions and water contents of the foods consumed, and possibly measurement errors.

**Seasonal effects**

The DW consumption of rusa stags in experiment 2 (mean 4.47 (on lucerne hay) to 5.34 (on oaten hay)/l/day, July to September) was less than that recorded in experiment 1 (June to July). In experiment 1, where rusa stags were given *ad libitum* a lucerne hay of similar quality, mean water consumption ranged from 5.8 to 6.7 l/day. These differences could result from seasonal changes in temperature and humidity, or seasonal changes in food intake (discussed below).

There were no differences in the ambient temperatures recorded during these two experiments, but the average humidity in July to September was less than that recorded in June to July. Low humidities might cause deer to drink more (humidity and water intake by lactating Frisian cows were negatively correlated, Cowan *et al.* (1978)) but we did not observe this. We suggest that the effects of food intake and composition on DW intake are likely to be quantitatively more important than those resulting from the small climatic differences recorded in our experiments.

Our experiments were done in the southern hemisphere winter/spring, and there are several lines of evidence that suggest that DW intakes in summer will be higher than those which we recorded. Domingue *et al.* (1991) demonstrated that the size of the rumen liquid pool of red deer was higher, and the fractional outflow rate of water from the rumen was faster, in summer than in winter. The maximum temperatures which we recorded in winter/spring were 23°C, but summer temperatures in northern Australia may reach 40°C. We would expect that, following observations reported for cattle and goats kept under high (38°C) environmental temperatures (Richards, 1985; Olsson *et al.*, 1995), and relationships between ambient temperature and water intake reported generally (National Research Council, 1981), DW intakes in summer would be higher than those recorded in winter. Furthermore, rusa deer are a tropical species, and if cattle water use (*Vercoe et al.*, 1972) is an appropriate guide then tropical deer subjected to high summer temperatures may increase their water consumption (even more than in temperate deer) to allow more sweating.

**Effects of food intake**

Alexander and Segiura (1990) investigated the relationship between DM and TW (i.e. drinking water + food water) intakes in red deer stags grazing at pasture and showed that a decline in TW intake was followed by a reduction in DM intake. Our experiment has also demonstrated that there is a clear relationship between food and water intakes in Javan rusa deer. This is to be expected from data reported for other species of domestic animals, e.g. cattle (Winchester and Morris, 1965), sheep (Silanikove, 1992), and goats (Misrah and Singh, 2002).

Temperate deer have pronounced seasonal cycles of food intake (Milne *et al.*, 1978; Kay, 1979; Fennessy *et al.*, 1980). Males of species such as red (*Cervus elaphus*), fallow (*Dama dama*), sika (*Cervus nippon*), and Chinese water deer (*Hydropotes inermis*) have a higher food intake a few weeks before the rutting season and their food intake falls during the rut. There is still discussion about the nature of seasonal cycles of food intake in tropical deer farmed in subtropical areas. Sookhareea and Dryden (2004) found the food intake of 2-year-old rusa deer stags given lucerne and Rhodes grass (*Chloris gayana*) hays declined slightly, from 1.4 kg DM per day during winter to 1.3 kg DM per day during spring and summer. In the present experiment, we also found

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**Table 4 Characteristics of water consumption by tropical and temperate deer**

<table>
<thead>
<tr>
<th>Deer species</th>
<th>Diet</th>
<th>Drinking water intake</th>
<th>Total (food water + drinking water) intake</th>
<th>Total water; dry matter (kg/kg)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(kg/day)</td>
<td>(g/kg M⁰.⁷₅ per day)</td>
<td>(kg/day)</td>
<td></td>
</tr>
<tr>
<td>Javan rusa</td>
<td>Lucerne hay</td>
<td>6.4</td>
<td>168.1</td>
<td>6.8</td>
<td>180.4</td>
</tr>
<tr>
<td></td>
<td>Lucerne hay</td>
<td>4.5</td>
<td>124.3</td>
<td>4.7</td>
<td>128.6</td>
</tr>
<tr>
<td></td>
<td>Oaten hay</td>
<td>5.3</td>
<td>147.6</td>
<td>5.5</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>Dry pasture</td>
<td>1-2.5</td>
<td>115.9</td>
<td>2.6</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Lucerne</td>
<td>2.0</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Deer pellet</td>
<td>4.4</td>
<td>4.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass silage</td>
<td>2.3</td>
<td>10.6</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pasture</td>
<td>2.6</td>
<td>110</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pasture</td>
<td>3.6</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lucerne hay (summer)</td>
<td>5-6.⁵</td>
<td>313</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lucerne hay (winter)</td>
<td>5-6.⁵</td>
<td>386</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Wilted forage</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fresh forage</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Calculated from water intakes g/kg live weight.
that the food intake of our mature stags decreased from 2·0 (s.e. = 0·03) kg DM per day when given lucerne hay during winter, to 1·2 (s.e. = 0·06) kg DM per day when given lucerne or oaten hays during spring. The decline in food intake was accompanied by reduced water consumption. These stags consumed about 6 kg water per day in June, but only 5 kg/day during spring when they showed more pronounced rutting behaviour.

We found that in experiment 1 the deer had a lower TW : DM ratio (3·34 kg/kg) than in experiment 2 (3·98 kg/kg when given lucerne hay and 4·83 kg/kg when given oaten hay). A decline in food intake during the rut may cause body fat and protein to be used to meet the energy and protein requirements for maintenance. M. C. Hmeidan (personal communication) has found a proportionately 0·07 higher maintenance energy requirement for Javan rusa stags in the rut. We assume that over this period, these animals needed to consume more water per kg DM intake to excrete metabolic wastes formed as a consequence of the degradation of body tissue. Some metabolic water is formed when body tissue components are oxidized. However, these stags tend to become leaner as the rut progresses (Sookhareea, 2001) and the metabolic water produced per gram of amino acids oxidized is lower than for fatty acids, 0·40 v. 1·07 g/g (Pond et al., 1995). The metabolism of these organic substances also results in increased respiration and heat dissipation, and for amino acids, an increased urinary excretion of urea. Therefore, animals need to consume extra water via drinking water, leading to an increased TW : DM ratio.

**Effects of food type**

The food intakes of rusa deer stags were not affected by the addition of kibbled barley grain at the rate used in this study (about 0·17 proportion of the unsupplemented hay intake), showing that grain was substituted for hay. This was unexpected, as Hmeidan and Dryden (1998) and Puttoo and Dryden (1998) have reported that adding barley grain (at proportionately 0·3 or 0·2 of the unsupplemented hay intakes, respectively) to lucerne and Rhodes grass hays, but not to soya-bean hay, may increase the total DM intake. The addition of this amount of cereal grain did not reduce DW intake. The amount of metabolic water (0·56 g/g starch; Pond et al., 1995) expected to be produced from the starch in the kibbled barley grain was clearly insufficient to affect the overall DW requirement, especially since grain was substituted for roughage in this experiment.

Ruminants may drink more water when they are offered foods of higher protein content (National Research Council, 1981) and it was expected that rusa deer would drink more water when given lucerne hay. However, we found that they drank less water, even though they had a significantly higher protein intake than when given oaten hay. It is assumed that increased water intakes are associated with higher dietary protein contents when the animal has to excrete urea produced from the deamination of excess amino acids (Agricultural Research Council, 1980). The relationship between dietary protein content and water intake depends on the animal’s protein requirements as much as the diet protein content. For example, positive relationships between protein content and water intake have been reported by Holter and Urban (1992) for dry but not lactating dairy cattle, and Abdelatif and Ahmed (1992) for the DW : DM intake ratio of desert goats but not their total DW intake. Consistently with this, Higginbotham et al. (1989) reported that the water intakes of dairy cattle increased when excess ruminally degradable protein was given. Both the total DW intake and the DW : DM intake ratio were higher when our rusa deer were given oaten hay than when given lucerne hay, indicating strongly that protein intake did not increase DW intake in our experiment. Although the lucerne hay had more protein than is required by Javan rusa deer (Tomkins and McMeniman, 1996; Puttoo et al., 1998), this excess was not large and apparently did not generate sufficient additional urea to significantly increase the water requirement.

Based on the multiple regression results, the greater water intakes by the deer that received oaten hay were related to the higher NDF content of this food (deer consumed 157 g extra NDF daily when given oaten hay). There is limited evidence that the water intakes of herbivores increase when they are given fibre-rich diets. Holtzer et al. (1976) reported a proportionately 0·11 larger DW intake in steers given diets with 450 v. 250 g/kg low-quality forage but this difference could not be tested statistically. Warren et al. (1999) reported that horses drank more water when given a fibre-rich diet. On the other hand, Al-Homidan and Ahmed (2000) found no effect of dietary fibre content on water intake by rabbits. These published data offer only limited support for the hypothesis that water intake by these deer was influenced by their dietary NDF intake. It is possible that some other food characteristic, correlated with NDF, was responsible for the regression analysis results. This remains an area requiring more investigation.

**Conclusions**

Different types of food and reproductive status influence the water consumption of Javan rusa deer stags. The main influences on water consumption appear to be DM intake and the NDF content of the food. In addition, stags appear to drink less water per day, but more water per kg DM intake, during the rut than in the pre-rut. Northern Australian deer farmers should be able to give protein- or energy-rich concentrate supplements in winter without markedly increasing the water requirements of their rusa stags, but care should be taken in predicting the water requirements of rutting stags from their expected DM intakes.

**Acknowledgements**

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