Individual mare grazing behaviour and pasture management compared between two Thoroughbred stud farms in New Zealand

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Abstract

This study focused on the grazing behaviour of individual mares and how this behaviour changes in relation to stocking density and pasture dry matter at hand, possibly affecting faecal avoidance behaviour and its effect on parasite (re)infestation. In regard to worldwide anthelmintic resistance, more understanding of reducing parasite infection through farm management is called for. Two different Thoroughbred stud farms were included in this study, situated near Palmerston North, Manawatu-Wanganui region, on the North Island, New Zealand. The measured parameters were pasture dry matter (kg DM/ha), individual grazing behaviour (ethogram), BCS, FECs and faeces load on pasture. The main findings were as follows: only in pastures in which dry matter decreased did horses spend more time grazing the roughs, a decline in horse density potentially leads to an increase in pasture dry matter, and less fecal avoidance behaviour is seen due to less selective grazing with higher horse density at pasture. In conclusion, the used anthelmintic products are still effective but in the light of upcoming resistance a more selective, individual and sustainable antiparasitic approach is needed.

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1. Introduction

1.1. Background of New Zealand's Racing Industry

New Zealand's Thoroughbred racing industry started officially in 1840 when the first race was organised in Wellington (Rogers, Gee & Bolwell, 2017). Subsequently, the racing industry has grown to what it is today, a recognizable industry with a focus on flat racing, consisting of around 22.910 horses in total of which 8084 are broodmares and an annual foal crop of 4500 foals (table 1) (Bolwell, Rogers, Gee & Rosanowski, 2016; Rogers et al., 2017; Rogers & Vallance, 2009). Of this annual foal crop approximately 40% are exported, clearly showing the export driven focus of New Zealand's Thoroughbred racing industry. Being aware of the relatively smaller size of the New Zealand Thoroughbred racing industry compared to other larger industries, such as those in the United States and Australia**,** it is astonishing to know that New Zealand Thoroughbred breeders produce about 4% of the annual global Thoroughbred foal crop, making New Zealand's Thoroughbred breeding industry the most sizeable horse enterprise in the country commercially (Bolwell et al., 2016; Fennessy, 2010; Rogers et al., 2017; Rogers, Gee & Firth, 2007; Waldron, Rogers, Gee & Bolwell, 2011; Williamson, Rogers & Firth, 2007).

Table 1. The number of horses involved within the New Zealand Thoroughbred Industry. Adapted from Livestock Production in New Zealand, Chapter 8 Horse Production (Rogers, Gee and Bolwell, 2017).

Thoroughbred Industry	Number
Broodmares	8.084
Sires (incl. shuttle stallions)	± 94
Annual foal crop	4.500
Young stock not yet registered for racing	4.500
Racehorses	5.576
Total Thoroughbred industry – racing and breeding	22.910

Economically the Thoroughbred industry, breeding and racing branches combined, contributes roughly $1.100 million New Zealand Dollar (NZD) to New Zealand's gross domestic product (GDP) annually, that translates to 1% of total annual GDP (Fennessy, 2010; Rogers et al., 2007; Rogers et al., 2017; Williamson et al., 2007). Each year an estimated $120 million NZD is generated by exporting New Zealand bred racehorses, mostly sold as yearlings (Goold, Baars & Rollo, 1988; Rogers et al., 2007; Stowers, Rogers & Hoskin, 2009). These numbers display the importance of maintaining an outstanding reputation, as a country of origin for first-class

Thoroughbreds, to conserve the continuous international demand resulting in a sustainable breeding industry in New Zealand (Fennessy, 2010). Not only is the New Zealand Thoroughbred breeding industry successful, New Zealand bred Thoroughbreds also perform outstandingly on both domestic and international level. This becomes beyond evident when taking a look at records of, for example, the famous Melbourne Cup. Of the last 57 completed Melbourne Cup races, up to and including 2015, 30 of races have been won by New Zealand bred Thoroughbreds (New Zealand Thoroughbred Breeders [NZTBA], Melbourne Cup record, n.d.).

Both the Thoroughbred racing and breeding industry in New Zealand are regulated by the New Zealand Thoroughbred Racing Inc. (Rogers et al., 2017). At a global level, Thoroughbred breeding industries are under control of the International Stud Book Committee (ISBC). Under ISBC regulation using either Artificial Insemination (AI) or Embryo transfer (ET) is prohibited. In other words, only if Thoroughbred foals are produced by natural service, live mating of a mare and stallion, they are eligible to be recorded in approved Thoroughbred Stud Books (International Federation of Horseracing Authorities [IFHA], 2017; Rogers et al., 2007; Rogers et al., 2017). Prohibiting both AI and ET can be seen as constraining since it limits the number of mares a stallion can cover. In practice, this means mares will be visiting stud farms, standing a stallion, to be served during the breeding season (Figure 1) (Goold et al., 1988; Rogers et al., 2007; Rogers et al., 2017). On top of that, New Zealand has a short effective breeding season, respectively from 1st of September till the 1st of December, resulting in a challenge for Thoroughbred breeders to produce foals born close to the 1st of August; the official birth date for racehorses born in the Southern Hemisphere (Rogers et al., 2007; Rogers et al., 2017).

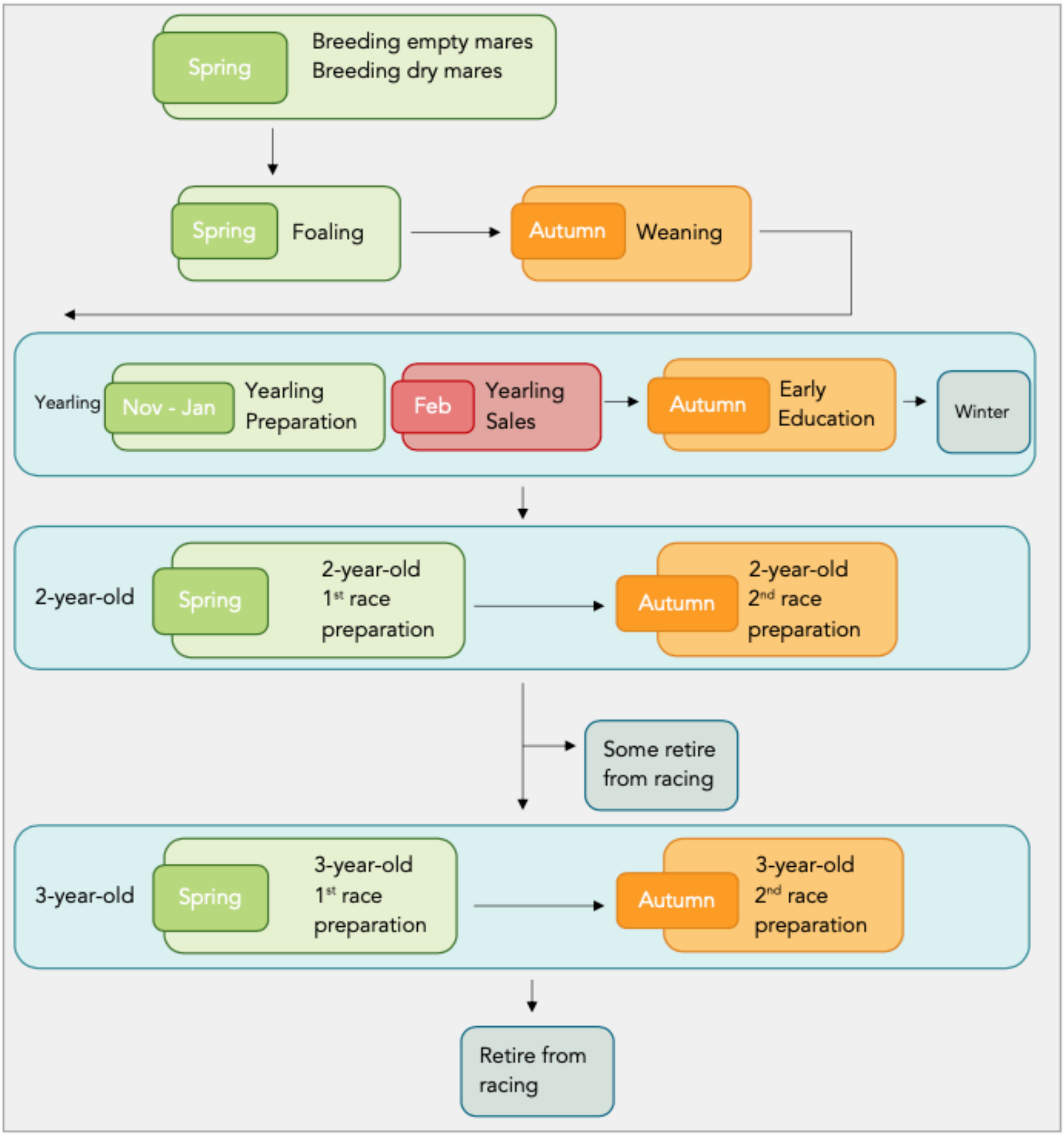


Figure 1. An overview of the production calendar for the Thoroughbred industry in New Zealand. Adapted from Livestock Production in New Zealand, Chapter 8 Horse production (Rogers, Gee and Bolwell, 2017).

Ideally, mares produce a foal every year. In order to do so mares need to be served soon after foaling using either the foal heat or short cycled (e.g. PGF2α administration to shorten the luteal phase) to return the mare in oestrus as soon as possible. This is done to make sure the foaling date will not be too late in the season, in regard to the official birth date of August 1st as well as the following training schedule of young racehorses (Figure 1) (Rogers et al., 2017; Munroe & Weese, 2011). This again shows how bustling the breeding season is in New Zealand. Horse density on stud farms standing a stallion thus increases during the breeding season (Goold et al., 1988, Rogers et al., 2017). During the breeding season shuttle stallions visit New Zealand from the Northern Hemisphere (Fennessy, 2010). The number of stallions at stud has declined from 294 to 94 over the last 25 years. Meanwhile an increase was seen in both the number of foals sired by a stallion and the percentage of stallions covering ≥ 100 mares during the breading season. Displaying, once more that mare density increases greatly in the breeding season on stud farms, standing one or more stallions. (Rogers et al., 2017).

This increased horse density on stud farms during the breeding season indicates the importance of good farm management, and in particular good pasture management, as a higher density of mares on the pasture translates to more pressure on the pasture (Rogers et al., 2007; Rogers et al., 2017). Additionally, good farm and pasture management is important because the international success of New Zealand's Thoroughbreds might be accounted for by the pasture-based production system (Avery, 1997; Rogers et al., 2007).

1.2. Farm management

1.2.1 Pasture-based production system

Whilst on the subject of pasture-based production systems; Thoroughbred stud farms in New Zealand have a tremendous advantage being situated in a country with a temperate climate, as this permits the keeping of horses on pasture year-round. New Zealand's pasture-based production system thus gives stud farms the opportunity to manage horses in a way that reflects how horses would live in their natural habitat (Brown-Douglas, Parkinson, Firth & Fennessy, 2005; Grace, Rogers, Firth, Faram & Shaw, 2003; Hoskin & Gee, 2014; Rogers et al., 2007; Rogers et al., 2017). Consequently, this system provides benefits in regard to equine health, on both psychological and physical level. Stereotypic behaviour, for instance, is seen far less in horses kept at pasture than in stabled horses, because horses can move without restriction, live in social groups and exhibit their normal behaviour such as grazing a daily 16-20 hours (Hampson et al., 2010; Henderson, 2007; Rogers et al., 2017). A possible explanation why the pasture-based production system in New Zealand might play a major part in the industry's great successes is the opportunity for young foals, born and raised at pastures, to stimulate their musculoskeletal system because of the ability to move freely (Rogers et al., 2007).

Another advantage New Zealand's pasture-based production system is reduced production costs because the diet mostly consists of grass (Brown-Douglas et al., 2005; Grace et al., 2003; Hoskin & Gee, 2004; Rogers et al., 2007; Rogers et al., 2017; Stowers et al., 2009). Hence, in rural areas owning horses is neither exclusive nor extremely costly (Rogers et al., 2017).

These two advantages additionally point out the major differences between horses kept in New Zealand and horses kept in some European countries. In the Netherlands, for example, it is not uncommon for horses to be stabled for most of their time and receiving silage and concentrate feeds as their main diet (Henderson, 2007; Mills & Clarke, 2007).

The pasture composition on most stud farms, in New Zealand, is a mix of perennial ryegrass (*Lolium Perenne*) and white clover (*Trifolium Repens*) (Hirst, 2011; Randall, Rogers, Hoskin, Morel & Swaison, 2014; Rogers et al., 2007; Rogers et al., 2017). Per kilogram of dry matter (kg DM) these pastures contain 18.6 megajoules (MJ) of DE in summer (Hirst, 2011). From October to November, pasture growth is the fastest and provides around 60 kg DM per hectare per day. Fortunately, during this time period most mares have their foals (Rogers et al., 2017). Regarding nutritional needs of broodmares, which are estimated to be 76 MJ of digestible energy per day (DE/day), this pasture composition provides sufficient macro-elements during the lactation period, even during late gestation when requirements increase roughly 10%, they are fulfilled by the pasture offered (Grace, Gee, Firth & Shaw, 2002a; Grace, Shaw, Gee & Firth, 2002b; Grace et al., 2003; Rogers et al., 2017). As for some minerals this isn't the case. Calcium, for example, is thought to be present in amounts that might be marginal. Luckily, it seems the marginal amounts of calcium do not cause problems because of high bioavailability (Grace et al., 2003; Hosking & Gee, 2004; National Research Council [NRC], 2007). Copper concentrations, on the other hand, quite often do fall below the minimum concentrations needed (Rogers et al., 2017; NRC, 2007) On most farms these requirements are fulfilled though, by providing supplementary minerals specifically copper, zinc, calcium and phosphorus, during the third trimester in the form of mineral pellets. On commercial stud farms the mean sward height is 10 cm, corresponding to around 3500 kg/DM/ha (Rogers et al., 2007; Rogers et al., 2017).

The pasture-based production system comes with a challenge though. With horses being selective grazers, it is important to maintain pasture quality during several breeding seasons (Rogers et al., 2007). In spring and summer, at the peak of the breeding season, stocking densities can be very high on stud farms, respectively 0.8 horses per ha. High stocking densities on stud farms provides a challenge for stud farm management to maintain the balance in demand for nutrients and their supply, because pastures are more heavily grazed and sward height is decreased. Hence, high stocking density is a negative factor on pasture quality and causes difficulties in maintaining pasture quality in times of high stocking density (Rogers et al., 2007). Therefore, it is not surprising that most stud farms try to maintain pasture quality, often by sowing and renewing their pastures and by cross-grazing pastures with cattle or sheep or both species. Fertilisers are applied to maintain growth of pastures (Rogers et al., 2007, Stowers et al., 2009). Cross-grazing, also referred to as mixed grazing or multi-species grazing, is thought to promote an efficient use of the pasture forages due to the different selection of vegetation on pasture by different herbivores (Lopez et al., 2019; Walker, 1997). The more uniform grazed pasture favours a clean regrowth of pasture, adding to the pasture quality (Lopez et al., 2019; Walker, 1997).

1.2.2 Equine Health

High stocking densities on stud farms are not only a negative factor on pasture quality but can also negatively influence equine health. For instance, when pastures are heavily grazed, sward height declines and horses will be coerced to start grazing near faeces, in the so-called roughs, to foresee in their nutrition need (Leathwick, Pomroy & Heath, 2001; Rogers et al., 2007; Rogers et al., 2017). Thereby, horses are at risk to take up infective larvae of, amongst others, Ascarids and Strongyloides. The number of ingested infective larvae depends on parasite control practices used on the stud farms. Due to high stocking densities and consequentially increased risk at parasitic infections, rather large amounts of anthelmintics are used at high frequencies (Leathwick et al., 2001; Rogers et al., 2007; Rogers et al., 2017). A survey conducted by Rogers, Gee and Firth (2007) on 22 stud farms on New Zealand's North Island showed that anthelmintics were used, on all surveyed stud farms, to treat the mares with a mean average interval of 6 to 26 weeks between doses. Most treatments were in the form of an oral paste. Between doses there were 7 farms that alternated between the anthelmintics used on the stud farm (Rogers et al., 2007). Additionally, a study conducted by Bolwell *et al.,* (2015) illustrated that most Thoroughbred breeders in New Zealand used interval drenching (treatment with anthelmintics at a predetermined interval) for both non-pregnant mares and pregnant mares every 6 to 8 weeks. Per annum the mares received 4 treatments on average (Bolwell, Rosanowski, Scott & Rogers, 2015). A survey conducted by Stowers, Rogers and Hoskin (2009) on 46 stud farms situated on the North Island of New Zealand, showed most stud farms, 64% to be precise, treated their foals with anthelmintics via oral pastes. These drenches were given with a mean interval of 6 weeks (range 3-14 weeks) (Stowers et al., 2009). Pregnant mares are additionally, besides the normal deworming schedule, treated before foaling to ensure protection, as good as possible, against *Strongyloides Westeri* and *Parascaris equorum* (McKenna, 2009; Nielsen, Reinemeyer & Sellon, 2014; Scott, Bishop & Pomroy, 2015). These studies display the high dependence on anthelmintic products in the New Zealand thoroughbred industry. This dependency on anthelmintics is not completely without reason. Due to the high numbers of horses present on the stud farms, frequent introduction of new horses, an annual large foal crop and the frequent shifting from one pasture to another (as either the whole group changes pasture or an individual mare changing groups) stud farms are relying on anthelmintics to ensure equine health.

Relying on anthelmintics is not as self-evident anymore due to the emergence of anthelmintic resistance. Globally, anthelmintic resistance in parasites is causing more and more concern. Especially in regard to the previously mentioned dependency on the efficacy of anthelmintics. Adding to the reliance on current anthelmintic products is the negative outlook on the making or discovering of new anthelmintic products. Thus, the amount of usable anthelmintics is decreasing due to resistance in parasites (Scott et al., 2015). Other factors causing anthelmintic resistance are overdosing, off-label use, underdosing and drenching the entire herd at once, the latter hindering the presence of 'refugia' (Eysker, van Doorn, Lems, Weteling & Ploeger, 2006; Scott et al., 2015).

In New Zealand multiple studies were conducted to shed a light on the upcoming resistance in the country. For example, a study by Bishop et al., (2014) shows that in regard to deworming foals against *Parascaris equorum*, ivermectin does no longer have a 100% efficacy against adult egg-laying stages and foals can continue to shed after receiving treatment. Another study by Rosanowski, Bolwell, Scott, Sells and Rogers (2017) suggested the presence of shortened egg reappearance periods on 3/6 farms studied, which could indicate that ivermectin is becoming less efficient against the luminal stages of strongyles.

Thus, when anthelmintics are used, they should possess a high efficacy and be used in the correct dose to not further promote anthelmintic resistance (Kaplan & Nielsen, 2010; Scott et al., 2015). Also, the importance of reducing parasite infection risk, other than relying on the use of anthelmintics, is underlined and further indicates the importance of non-anthelmintic prevention of parasite infection such as good stud farm and pasture management. In New Zealand's Thoroughbred industry, most farms implemented the use of both rotational grazing and cross-grazing with other species such as sheep and cows, in their grazing management. Besides the positive effect on pasture quality, multi species grazing (either simultaneous or alternating) has shown to be effective to reduce parasites in sheep (when mixed grazing with cows) (Brito et al., 2013; Jordan, Phillips, Morrison, Doyle & McKenzie, 1988). Further prevention of adding to the already known anthelmintic resistance is the use of faecal egg counts (FEC's), selective treatment, prolonging intervals between treatments, quarantine of new horses on property, rotation of used anthelmintics and using a combination of anthelmintics (Kaplan & Nielsen, 2010; Scott et al., 2015).

In regard to pasture management, grazing management and parasite (re)infection it is important to understand individual horse grazing behaviour under different circumstances.

1.3. Aim & Importance of the Study

The aim of the study is to obtain insight into the individual grazing behaviour of horses and thus a better idea of the risk of parasite re-infestation due to grazing behaviour and pasture management. And thus, to compare management differences and their possible effect on two variables, respectively pasture dry matter and the individual mare grazing behaviour, by measuring and comparing these variables between two Throughbred stud farms.

2. Material and Methods

2.1. Experimental design

During a 7-week period a total of 40 Thoroughbred broodmares were observed at two different stud farms. Their individual grazing behavior was monitored weekly as well as their body condition score [BCS] obtained. Each week the pastures the horses resided on were assessed for pasture dry matter of the total pasture, the roughs present in the pasture and the lawns of the pasture. Stud farm management was further investigated by talking with the stud farm owners and/or working staff. The last two weeks of the experiment the fecal load on the pasture was also assessed. FEC's were carried out on incidentally collected manure of the followed mares.

2.2. Sampling locations & Site description

For this study data was collected and sampled from two commercial thoroughbred stud farms. Both located near Palmerston North, in the Manawatu-Wanganui region, which is situated in the lower half of the North Island of New Zealand. Data was collected from these two different stud farms to be able to compare management differences and their possible effect on two variables, respectively pasture dry matter cover and the individual mare grazing behaviour.

2.2.1. Stud farm 1

Stud farm 1 is a commercial thoroughbred stud farm comprising 121 hectares, which stands three stallions (table 2). For this reason, mares from other thoroughbred breeders are transported and managed at this stud farm during the breeding season, as the mare must be covered using natural mating. Visiting mares will stay approximately 30 days on the farm. These visiting mares add to the number of horses on pasture thus creating a higher stocking density, which as previously described, is a negative factor for pasture quality since pastures are more heavily grazed and sward height is decreased. Stud farm 1 also offers the service to mare owners to have their mare foal under their supervision at the farm. Which again leads to a high density of mares on the farm during the breeding season.

Deworming management on stud farm 1 consisted of drenching each mare every 6-8 weeks. New mares or visiting mares are obliged to have had proper vaccinations, their hooves trimmed and to have been dewormed. If the stud farm management is under the impression the mare has not been dewormed the mares were drenched on arrival. During the season the deworming product, Strategy-T® (Virbac) was routinely used. This broad spectrum anthelminthic is a combination of oxfendazole (group of benzimidazoles) and pyrantel (group of tetrahydropyrimidines) (Nielsen et al., 2014).

On this farm, similar to other commercial stud farms in New Zealand, rotational grazing with ruminants (sheep and / or cattle) is used to maximize pasture utilization, increase pasture quality and to hopefully break the life cycle of strongyles and ascarid species, commonly affecting horses. At the time of our experiment the farm was already overcrowded, in comparison to their normal horse stocking density.

2.2.2. Stud farm 2

Stud farm 2 is a commercial thoroughbred stud farm that does not stand a stallion and because of this has a small highly commercial broodmare herd, and is classified as a boutique commercial thoroughbred stud farm (table 2). Therefore, there are few visiting mares during the breeding season and the mares on the farm predominantly consist of the stud's own mares, mares visiting to foal and mares and foals to use the weaning service. Due to the lower mare density, there is less grazing pressure on the pasture. The farm consists of 86 hectares of pasture, divided into different paddocks.

The anthelminthic programme on stud farm 2 was previously similar to that in practice at stud farm 1, but after a study conducted by Massey University a couple of years ago, they changed their drenching intervals and the products used (Bolwell et al., 2015). At present, the farm drenches the broodmares every 10 weeks, foals have their first drench at 8 weeks of age and yearlings are drenched every 8-10 weeks. The same drench product (Equitak Excel® (Bayer)) is used for 2 years and then alternated for 1 year with another anthelminthic product (Ultramax Equine® (Pharmachem)). Equitak Excel® contains a combination of anthelmintics, respectively abamectin (macrocylic lactones), oxfendazole (benzimidazoles) and praziquantel (pyrazinoisoquinoline derivative). Ultramax Equine® contains a combination of ivermectin (macrocyclic lactones) and praziquantel.

Additionally, a dozen FEC's per year are carried out to check whether the deworming management is still effective. When visiting mares are introduced on the farm their vaccination and deworming history is asked for. If there is a suspicion that the mare is not vaccinated or dewormed, she will be treated on arrival. When the farm introduces their own new mares, they will get treated on arrival and will then join the deworming schedule of the farm.

Regarding other management measurements to decrease chances for parasite infection, both pasture rotation and grazing with other species, such as cattle and sheep, are implemented on the farm.

Table 2. Overview of characteristics of stud farm 1 & stud farm 2.

Stud farm 1	Stud farm 2
3 Stallions at stud	No stallion
Commercial stud farm	Boutique commercial stud farm
Visiting mares: higher density	Few visiting mares: lower mare density
Higher grazing pressure on pasture	Lower grazing pressure on pasture
Drenching (every 6-8 weeks)	Drenching (every 8-10 weeks)
Rotational grazing	Rotational grazing
Cross grazing with cows & sheep	Cross grazing with cows & sheep
121 ha	86 ha

2.3. The mares

A total of 40 mares were followed during this observational trial. From these 40 mares, 19 broodmares were followed on stud farm 1 and 21 broodmares were followed on stud farm 2. The mares were randomly selected from different paddocks and followed during the 7 weeks (1 day of data collection each week) of the experiment. The mares were between 4 – 19 years of age. The mares were either "dry" (not covered), "in foal" (pregnant) or "with foal". Depending on the week and the mares' estimated delivery date, mares could change groups and/or pastures. During the 7 weeks of the experiment the mares where identified by either their coat colours and markings, their brand or their halters with name tag. Each week the mares where given a body condition score (BCS) and their individual grazing behaviour was monitored, which parameters are further explained in respectively paragraph 2.4.2 and 2.4.3.

2.4. Data collection

2.4.1. Pasture dry matter

During the 7-week period of data collection the pasture mass was estimated weekly with the use of a Jenquip Rising Plate Meter (RPM) (Figure 2). Total pasture mass was estimated by either an L transect in the middle of the pasture or a diagonal line if the pasture was too large. This estimation consisted of 40 readings without differentiation between roughs and lawns (MacAdam & Hunt, 2015). Total mass in pastures that were too small for the L transect was estimated using a C transect.

Pasture mass of the roughs and lawns were estimated separately by carrying out 30 readings, spread out across the pasture, in either the roughs or lawns. The roughs were defined as areas consisting of tall grasses. The lawns were defined as areas that were low grazed with the sward height below 4 cm (Fleurance et al., 2007).

On location, the numbers on the RPM would be read before and after the readings and noted on the 'pasture measurements form' (8.2 appendix 2). The difference between those two numbers is the amount of clicks. When we divide the number of clicks by the number of readings (either 30 or 40) we calculate the average compressed pasture height per sample. Using the standard Manawatu pasture equation, described below, pasture mass could be calculated in kg dry matter (DM) per hectare for either the total pasture, the lawns or the roughs (Donaghy, McCarthy, Wims & Lee, n.d.).

$$2nd\ RPM - 1st\ RPM = Clicks$$

$$\frac{Clicks}{Readings} = Averige\ compressed\ pasture\ height$$

$$DM\,\frac{kg}{ha} = Averige\ compressed\ pasture\ height * 158 + 200$$

Figure 2. The Jenquip Rising Plate Meter (left) and it's reading plane (right).

2.4.2. Individual grazing behaviour

During the observational trials the mare's individual faecal avoidance behaviour and grazing behaviour was measured by scan sampling the mares in their paddocks. The individual grazing behaviour was observed and scored using an ethogram during the sampling. The ethogram followed the guidelines of previous research by Van Dierendonck *et al.* (1996) and Fleurance *et al.* 2007). The ethogram was used during the half hour observational trial per horse and time intervals were set at 1 minute. The ethogram used in this experiment consisted of an inventory of

9 behaviours or actions the mares could exhibit (Table 3). During the half hour observational trial, the exhibited behaviour would be noted on the 'behaviour scan form' (8.1 Appendix 1).

Table 3. Ethogram used to score individual horse behaviour (Van Dierendonck et al., 1996; Fleurance et al., 2007).

Ethogram; behaviour or actions scores and their description	
Score	**Description**
Grazing Lawns (GL)	Eating grasses and herbs > 1 meter away from roughs, not separated by more than 10 seconds of rest, move or other.
Grazing Roughs (GR)	Eating grasses and herbs within 1 meter of faeces, not separated by more than 10 seconds of rest, move or other.
Moving (MO)	All kinds of moving, longer than 10 seconds.
Resting (RE)	Standing or lying relaxed
Drinking (DR)	Drinking water
Positive social interaction (PSI)	Playing, grooming another horse, etc.
Negative social interaction (NSI)	Fighting, chasing, kicking, etc. normally with ears flattened.
Out of sight (OS)	If horse cannot be seen.
Other (X)	All behaviours not described above.

2.4.3. Body condition scores

For each of the followed mares their BCS would be determined during the weekly stud farms visits. A total of 7 BCS assessments were collected for each mare, if she was present during all the stud farm visits. Body condition scores were given according to the guidelines of a condition scoring system from Henneke et al., 1983. Which consist of a 1-9 scale (Table 4).

Table 4. BCS and their description. Adapted from Henneke et al., 1983.

Body condition scores and their description	
Score	**Description**
1 Poor	Animal extremely emaciated. Spinous processes, ribs, tailhead, tuber coxae and ischii projecting prominently. Bone structure of withers, shoulders and neck easily noticeable. No fatty tissue can be felt.
2 Very thin	Animal emaciated. Slight fat covering over base of spinous processes, transverse processes of lumbar vertebrae feel rounded. Spinous processes, ribs, tailhead, tuber coxae and ischii prominent. Withers, shoulders and neck structures faintly discernible.
3 Thin	Fat build up about halfway on spinous processes, transverse processes cannot be felt. Slight fat cover over ribs. Spinous processes and ribs easily discernible. Tailhead prominent, but individual vertebrae cannot be visually identified. Tuber coxae appear rounded, but easily discernible. Tuber ischia not distinguishable. Withers, shoulders and neck accentuated.
4 Moderately thin	Negative crease along back. Faint outline of ribs discernible. Tailhead prominence depends on conformation, fat can be felt around it. Tuber coxae not discernible. Withers, shoulders and neck not obviously thin.
5 Moderate	Back level. Ribs cannot be visually distinguished but can be easily felt. Fat around tailhead beginning to feel spongy. Withers appear rounded over spinous processes. Shoulders and neck blend smoothly into body.
6 Moderately fleshy	May have slight crease down back. Fat over ribs feels spongy. Fat around tailhead feels soft. Fat beginning to deposit along the side of the withers, behind shoulders and along the sides of the neck.
7 Fleshy	May have crease down back. Individual ribs can be felt, but noticeable filling between ribs with fat. Fat around tailhead is soft. Fat deposited along withers, behind shoulders and along the neck.
8 Fat	Crease down back. Difficult to feel ribs. Fat around tailhead is very soft. Area along withers filled with fat. Noticeable thickening of neck. Fat deposited along inner thighs.
9 Extremely fat	Obvious crease down back. Patchy fat appearing over ribs. Bulging fat around tailhead, along withers, behind shoulders and along neck. Fat along inner thighs may rub together. Flank filled with fat.

During the farm visits, the mares given BCS would be noted on the previously mentioned 'behaviour scan form' (8.1 Appendix 1). The BCS scores were given to the mares by a total of 2 research interns during the 7 weeks, both having studied the article by Henneke et al., 1983. And thus, familiar with the specific areas on which the body condition scoring is based (Figure 3).

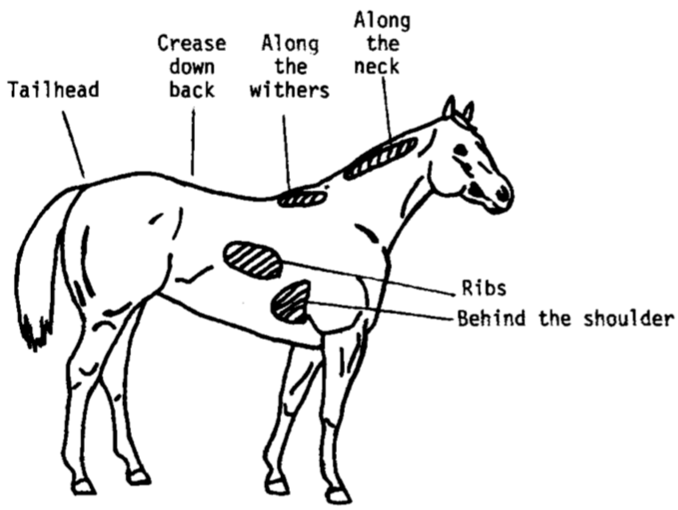


Figure 3. From Henneke et al., 1983. Diagram of areas palpated to estimate body fat and condition score.

2.4.4. Faecal Egg Counts

During the scan sampling of the mares' individual grazing behaviour, faecal samples were opportunistically collected. Whenever the observer saw one of the followed mares defecating the exact place would be notated. As soon as possible without disturbing the mare, the fresh faeces would be collected from the pasture, no later than 15 minutes after defecating. Faecal samples were collected using gloves and a plastic sampling container (Taylor, Coop & Wall, 2007). Approximately 5 grams of faeces were collected.

After visiting the stud farms the faecal samples were brought to the Massey University Parasitology department for the faecal egg count (FEC) of Strongylid types using the McMaster method. If faeces samples could not be examined within a day, they were stored in a refrigerator to slow down the otherwise very fast embryonating of the parasite eggs and measured the following day (Nielsen et al., 2010; Taylor et al., 2007).

2.4.5. Faeces load on pasture

During the last two weeks of sampling the faeces load on the pasture was assessed. The pasture vegetation's sward height became so short during the last weeks that in some pasture it seemed that almost the entire pasture was defined as lawns, but faeces were accumulating in the pastures. Therefore, a 5 by 5-meter patch of the pasture, in both the roughs and lawns, was examined and the number of faeces it contained counted. A measuring tape was used to define the 5 by 5-meter patches.

2.5. Data analysis

The data of the study was analysed using descriptive statistics to better understand and display the acquired data, which was performed using Excel® and Stata® software. Subsequently, the Friedman test was used as a non-parametric alternative for multiple repeated measurements. The Friedman test assesses whether there are statistical differences (P-values < 0.05) between de different groups of mares (dry, pregnant and with foal) between both stud farms. If statistical differences were present, the Friedman test does not further specify these. *Post Hoc* the Wilcoxon test can be used to analyse between which groups statistical differences exist. The statistical software used to analyse the data was R Studio® and Stata®.

3. Results

3.1 Stud Farms

On stud farm 1 the number of paddocks where measurements were taken was 16, and the number of paddocks for stud farm 2 was 7. The paddock size ranged from 1.35 to 5ha for stud farm 1 and between 2.5 and 7ha for stud farm 2. Paddock sizes for both the dry mares (not covered) and the pregnant mares were significantly different between both stud farms. The paddock size for mares with their foals did not significantly differ between the two stud farms (Table 5). Horse Density [HD] is significantly different between the two stud farms, for both total HD and HD per State (dry, pregnant and mares with foals) (Table 5).

Table 5. Summary of differences in paddock size (ha) & horse density (horses/ha) between the two stud farms (from Stata).

	Stud Farm 1	Stud Farm 2	P-value
No of paddocks	16	7	
Paddock size All	2.63 (1.35-5)	5.02 (2.5-7)	0.0001
Paddock size dry	1.87 (1.7-2.5)	6.67 (6.5-7)	0.0001
Paddock size preg	3.22 (0.9-5)	4.97 (1.9-7)	0.0001
Paddock size mares&foals	2.8 (0.8-5)	2.36 (2.1-2.5)	ns
Horse density All	4.03 (2.4-4.4)	1.72 (1.14-1.8)	0.0001
HD dry	3.78 (2.4-6.11)	1.29 (1.08-1.43)	0.0001
HD preg	4.63 (3.33-4.4)	3.07 (1.18-4)	0.0001
HD mares&foals	2.94 (1.76-4)	1.55 (0.95-1.2)	0.0211

3.2 The Mares

Of the 40 mares followed during the experiment, 7 did not changes pastures during the 7 weeks of the experiment, while 15 mares changed pastures once during the 7 weeks of the experiment, and 18 mares changed pastures multiple times (15 mares changed pastures twice and 3 mares changed pasture three times) (table 6).

During the experiment 5 mares were followed the entire 7 weeks of the experiment while the others were not present for the entire 7 weeks of the experiment. This could be due to leaving the farm, or not being present in the pasture during the time we visited the farm. Nineteen mares were not present during 1 week of the experiment, 4 mares were not present for 2 weeks of the experiment, 7 mares were not present for 3 weeks of the experiment, 1 mare was not present for 4 weeks of the experiment and 3 mares were not present for 5 weeks of the experiment (table 6).

Unfortunately, one mare (horse ID 20) was only followed for one week of the experiment. This is due to the random choosing of the study objects and her leaving the farm after week 1 without our knowledge of this beforehand.

Table 6. The mares followed during the experiment, the number of weeks present during the experiment and the pastures they were in during the weeks of the experiment.

Horse ID	Stud Farm	Pasture wk 1	Pasture wk 2	Pasture wk 3	Pasture wk 4	Pasture wk 5	Pasture wk 6	Pasture wk 7
1	1	2	2	7	7	7	3	
2	1	2	2	7	7			
3	1	7	9	9				
4	1	4	10					
5	1	4	10	10	10	10	10	
6	1	7	7	7	9	3	3	
7	1	7	7		9	9	9	3
8	1	2	7	7	9	6		
9	1	8	7					
10	1	8	7	7	7	7	7	
11	1	8	7	7	7	7		4
12	1	8	7	7	7	7		
13	1	1	1	1	5		1	
14	1	1	1	1	6	6	13	13
15	1	1	1	1		11	11	11
16	1	5	1		12			11
17	1	5	1	1	6	6	12	12
18	1	5	5	5	5			
19	1	5	5	5	5			
20	2	14						
21	2		18	18	18	18	18	18
22	2	16	16	16	14			
23	2	16	16	16	20	20	20	
24	2	16	16	16	20		14	
25	2	17	17	17	20	20		14
26	2	17	17	17	17	17	17	17
27	2	17	17	17	17	17	17	17
28	2		19	15	15	19	19	19
29	2		19	15	15	19	19	19
30	2		19	15	15	19	19	19
31	2		19	15	15	19	19	19
32	2		19	15				
33	2		19	15	15	19	19	19
34	2	16	16		14	18		
35	2	16	16	16	20	20		14
36	2	16	16	16		18		
37	2	14	18	18	18	18	18	18
38	2		17	17	17	17	17	17
39	2		17	17	20	20	20	20
40	2		17	17	20	20	20	20

	Missing
	First pasture
	Second pasture
	Third pasture
	Fourth pasture

3.3 Pasture Dry Matter

Pasture dry matter measurements between the two farms were significantly different, both total pasture dry matter ('Total DM All') and dry matter of the roughs ('DM rgh All') (Table 7). When looking at pasture dry matter and which group of mares were on the pasture, the significant difference between total pasture dry matter was seen for the pastures of the pregnant mares and the pastures with mares & foals. The pastures standing dry mares were not significantly different in total dry matter between the two stud farms (table 7). Concerning pasture dry matter of the roughs the significant difference between the two stud farms was seen in the pastures accommodating the dry mares and mares with foals (table 7). There was no significant difference between the two stud farms concerning the dry matter of the roughs of the pastures accommodating pregnant mares (table 7). Between the two stud farms there was no significant difference between the measured pasture dry matter of the lawns ('DM lwn all') and thus there was no significant difference between pastures accommodating different groups of mares concerning dry matter of the lawns (table 7).

Table 7. Comparison between the two stud farms in total pasture dry matter, pasture dry matter of the roughs & pasture dry matter of the lawns divided by the different mare groups.

	Stud farm 1	Stud farm 2	P-value
Total DM All	1606 (1373-2084)	2257 (1736-2368)	0.0001
Total DM dry	1661 (1467-2139)	1736 (1460-2317)	ns
Total DM preg	1606 (1282-1985)	2325 (1795-2491)	0.0001
Total DM mares&foals	1513 (1373-2202)	2024 (1829-2299)	0.0458
DM rgh All	2680 (2206-3686)	3733 (3215-4081)	0.0006
DM rgh dry	2567 (2027-3686)	3733 (3223-4081)	0.0005
DM rgh preg	3228 (2448-4845)	3823 (3265-4092)	ns
DM rgh mares&foals	2720 (2538 - 3907)	3217 (3107-3602)	0.0254
DM lwn All	1587 (1153-1795)	1606 (1342-1885)	ns
DM lwn dry	1424 (1045-1687)	1411 (1269-1669)	ns
DM lwn preg	1795 (1421-2922)	1727 (1369-1916)	ns
DM lwn mares & foals	1361 (1140-1906)	1706 (1311-1706)	ns

3.3.1 Stud farm 1

Looking at stud farm 1 it is visible that horse density fluctuated during the 7 weeks of the experiment (Figure 4). Dry matter of both the lawns and the roughs (and thus total dry matter) decreased during the experiment. And the decline in total kg dry matter/ha was mostly due to a decrease in dry matter of the roughs during the last two weeks of the experiment, as seen in Figure 4. Horse density (number of horses/ha) at the pastures at stud farm 1 differed over the 7 weeks of the experiment.

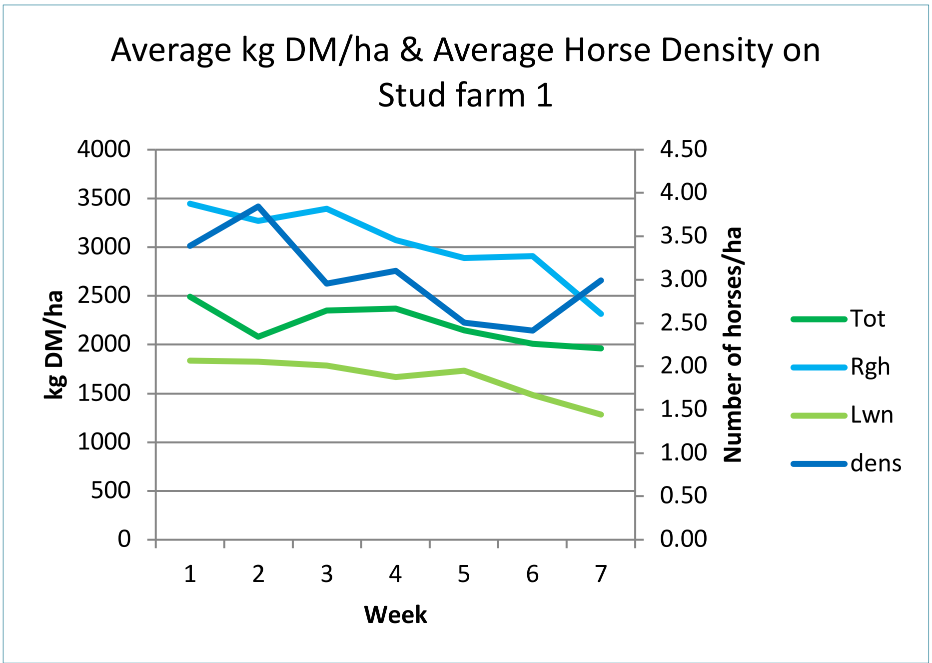


Figure 4. The average kg DM/ha (total, roughs and lawns) & average horse density (horses/ha) on stud farm 1.

The grazing behavior of dry mares at stud farm 1 consisted mostly of grazing roughs (between 63-88%). Only 12-37% of the grazing time was spent grazing the lawns (Figure 5). An individual grazing behavior scan was not carried out in week 3 for dry mares, therefore the missing data in figure 5. During week 4 the least amount of time was spent grazing in the lawns (12%) and it coincides with a higher amount of dry matter of both the lawns and the total pasture dry matter (Figure 5).

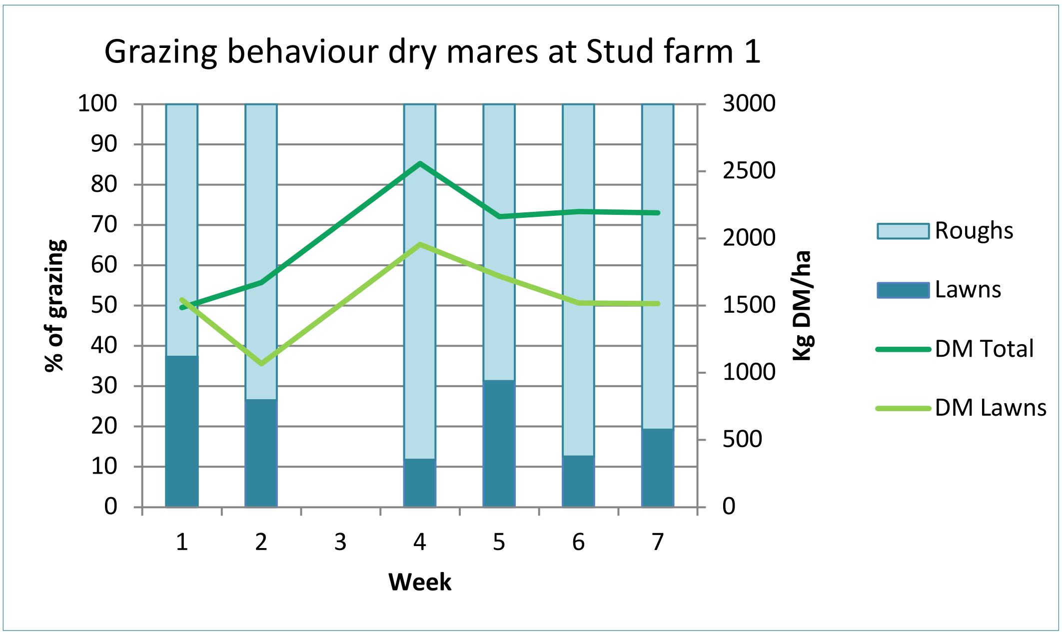


Figure 5. Percentage of grazing roughs and lawns carried out by dry mares at stud farm 1, per week and the pasture dry matter and hand (total and lawns) in kg DM/ha.

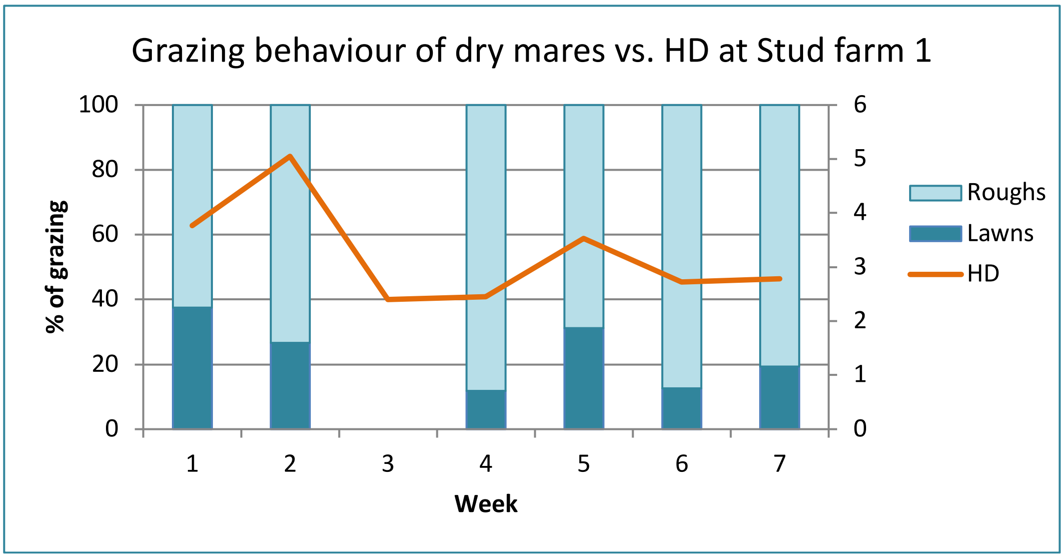


Figure 6. Percentage of grazing roughs and lawns carried out by dry mares at stud farm 1 per week and the horse density (horses/ha).

In Figure 6 the grazing behaviour of the dry mares at Stud farm 1 is plotted against the horse density (HD) present at stud farm 1. The horse density at the pastures containing dry mares ranged between 2.4 to 5.05 horses/ha (Figure 6).

The grazing behavior of pregnant mares consisted of mostly grazing in the roughs. In the first week the amount of time spent grazing roughs and lawns was almost similar. However, in the following weeks the percentage of grazing time spent grazing roughs was between 92-100% (Figure 7). There was no individual grazing behaviour scan carried out in week 3, hence the missing bar in both Figure 7 and 8. Total pasture dry matter was between 1500-1800 kg DM/ha for the entire 7 weeks of the experiment. Dry matter of specifically the lawns was less consistent and differed more for each of the 7 weeks of the experiment. The maximum being 2770 kg DM/ha and the minimum 874 kg DM/ha (Figure 7).

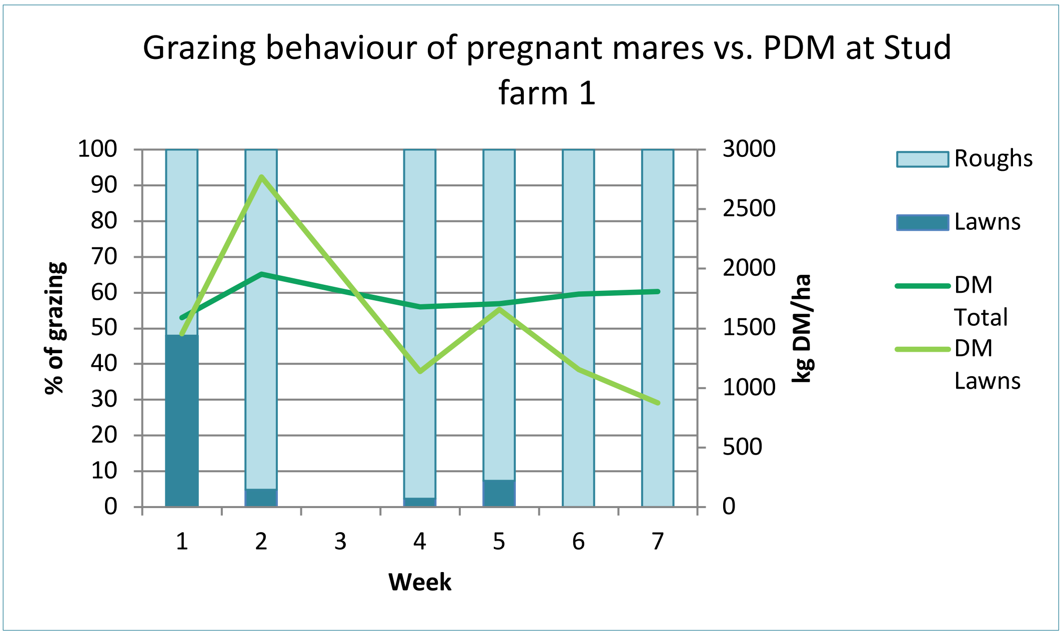


Figure 7. Percentage of grazing spent grazing roughs and lawns carried out by pregnant mares at stud farm 1, per week and the pasture dry matter (PDM) at hand (total and lawns) in kg DM/ha.

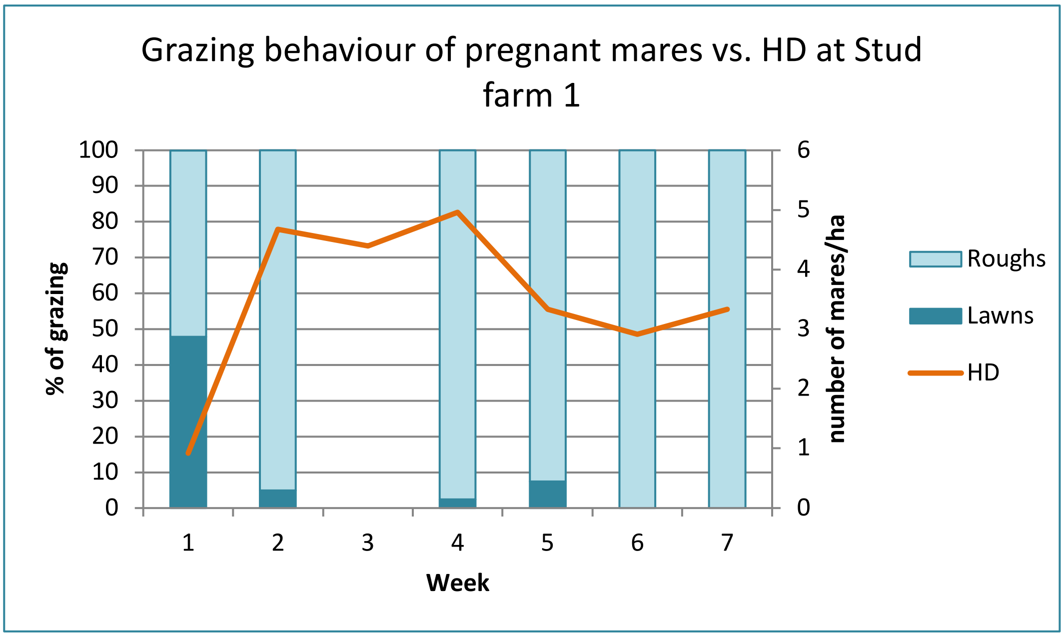


Figure 8. Percentage of time spent grazing roughs and lawns carried out by pregnant mares and the horse density (HD, horses/ha) present at stud farm 1.

The same bar graph of the grazing behavior (grazing either roughs or lawns) of the pregnant mares at stud farm 1, set against the horse density present at the pastures shows that horse density ranged between 0.92- 4.96 horses/ha (Figure 8).

The mares with foals at stud farm 1 spent most of their time grazing in the roughs (between 73-100%). The time spent grazing lawns started off at 27% in the first week of the experiment and decreased each week to only 4% in week 4. During weeks 5-7 all the grazing time was spent grazing the roughs (Figure 9). In week 1 both the total pasture dry matter and the dry matter of the lawns were at their highest, respectively 3936 kg DM/ha and 2749 kg DM/ha. The total pasture dry matter and dry matter of the lawns decreased during the experiment (Figure 9).

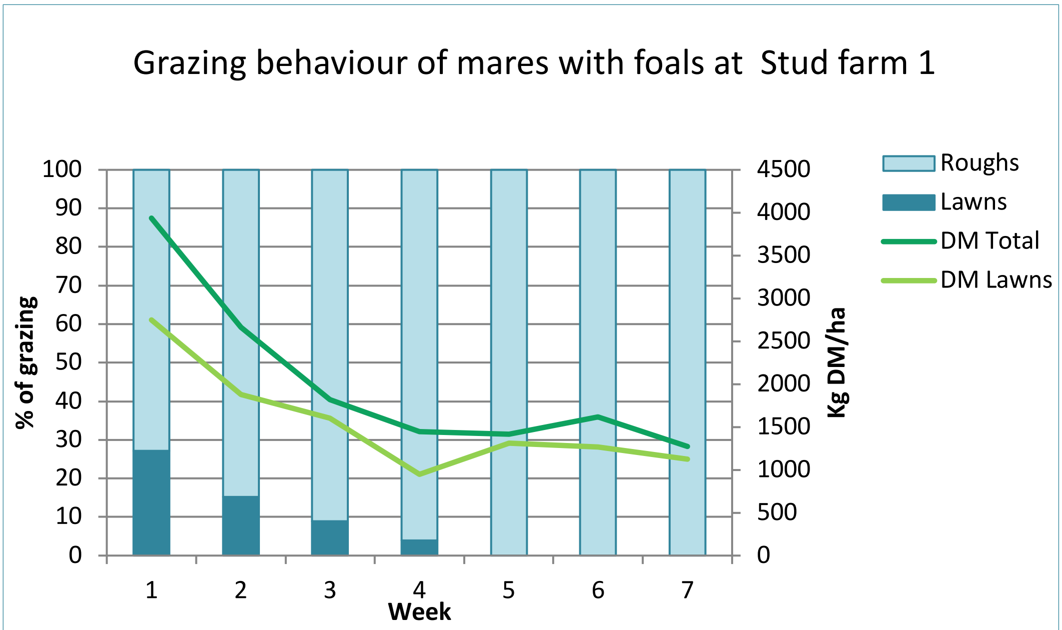


Figure 9. Distribution of percentage of time spent grazing in 'roughs' or 'lawns' by dry mares vs. pasture dry matter (PDM) at hand (total and lawns) in kg DM/ha at stud farm 1.

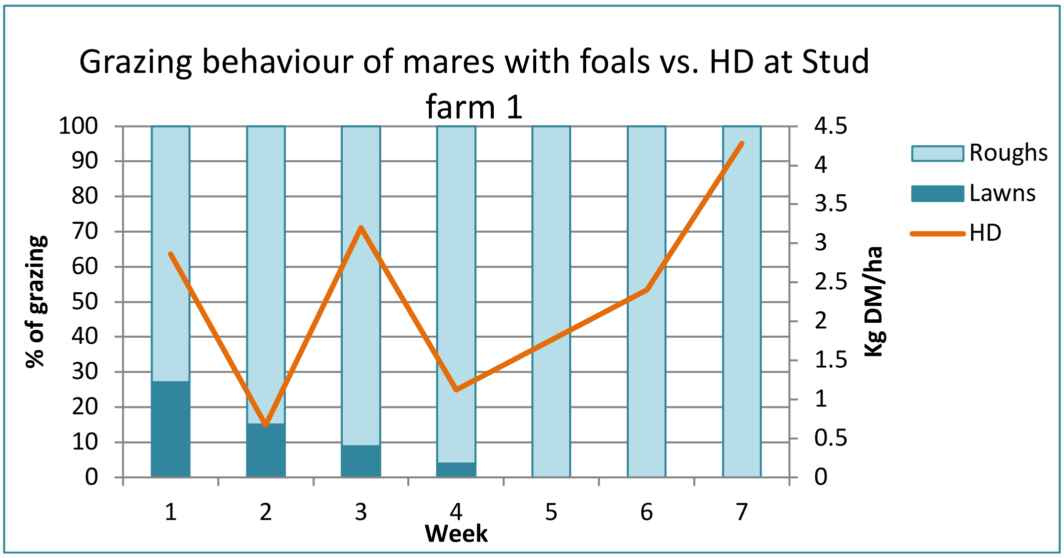


Figure 10. Percentage of time spent grazing in 'roughs' or 'lawns' by dry mares vs. horse density (horses/ha) at stud farm 1.

Horse density at pasture at stud farm 1 was also set against the percentage of grazing either roughs or lawns by mares with foals, as showed by Figure 10. Horse density ranged from 0.67 to 4.28 horses/ha (Figure 10).

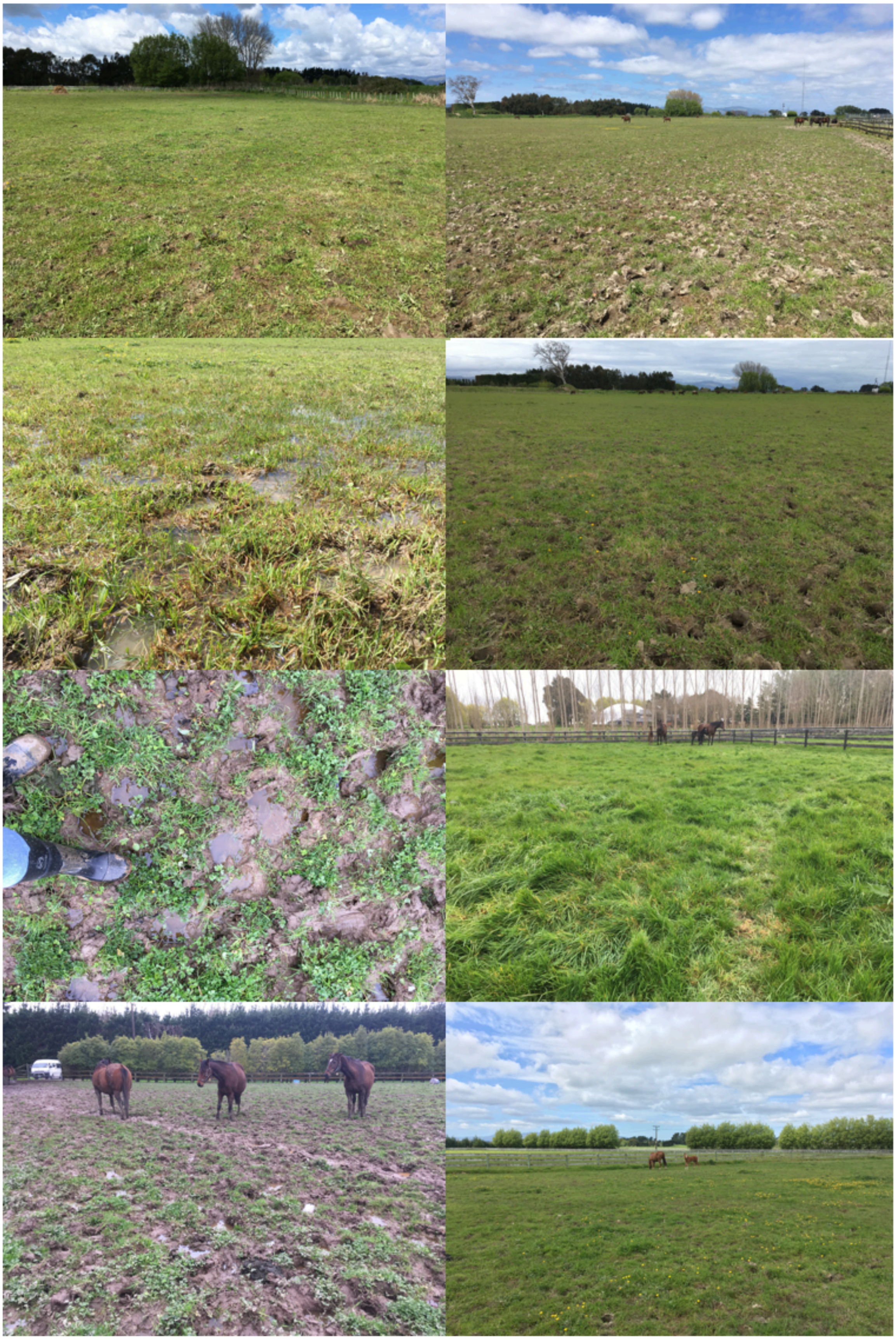


Figure 11. Examples of pastures and their vegetation, during the 7 weeks of the experiment on stud farm 1.

As mentioned before, the average total dry matter and average dry matter of the lawns decreased during the 7 weeks of the experiment (Figure 4). Pastures differed a lot, some pastures were quite muddy in certain weeks and in other weeks really dry. Further, some pastures contained vegetation with a much higher sward height. Figure 11 shows examples of how the pastures looked vegetation wise.

3.3.2 Stud farm 2

At stud farm 2 the average horse density fluctuated during the 7 weeks of the experiment (Figure 12). Average dry matter of both the lawns, the roughs and total dry matter fluctuated, but overall showed an increase in dry matter (kg DM/ha). The increase in total dry matter is mostly due to an increase in dry matter of the lawns (Figure 12).

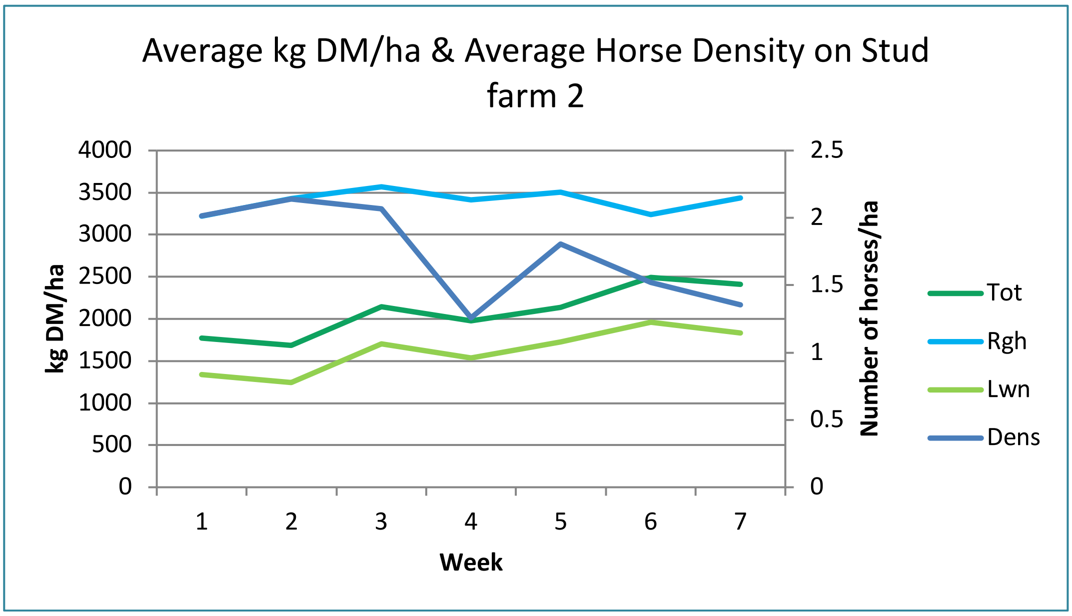


Figure 12. The average dry matter in kg DM/ha (total, roughs and lawns) & average horse density (horses/ha) on stud farm 2.

During the 7 weeks of the experiment the dry mares at stud farm 2 spent around 38-97% of their time grazing the roughs (Figure 13). During week 1 the grazing behavior scan was not carried out, thus explaining the missing bar in Figure 12. The total pasture dry matter ranged between 776 kg DM/ha to 2285 kg DM/ha. The dry matter of the lawns ranged between 821-2680 kg DM/ha (Figure 13).

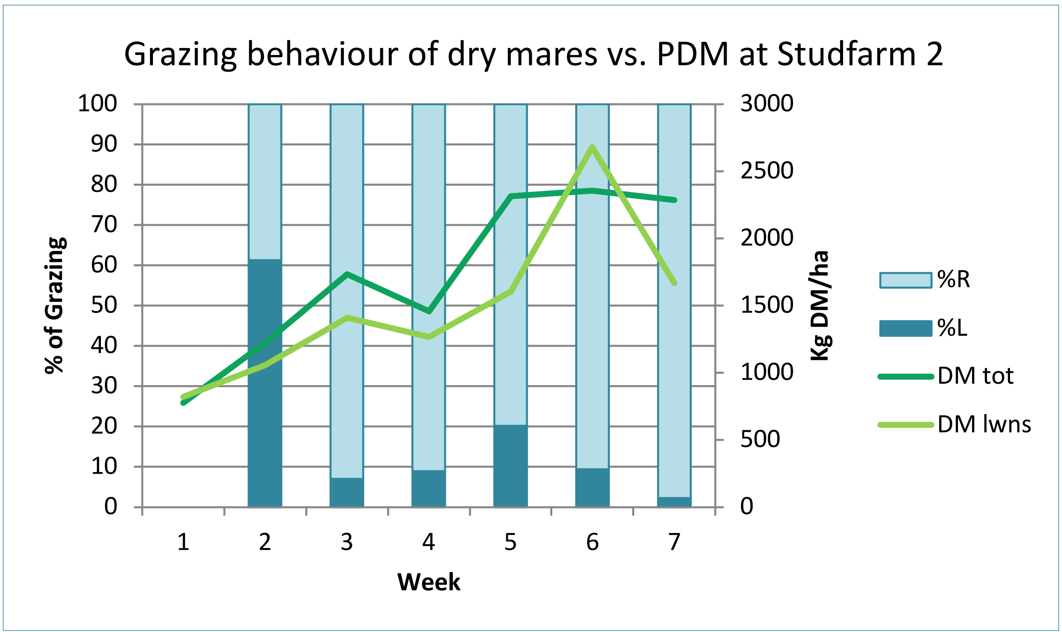


Figure 13. Distribution of percentage of time spent grazing in 'roughs' or 'lawns' by dry mares vs. pasture dry matter (PDM) at hand (total and lawns) in kg DM/ha.

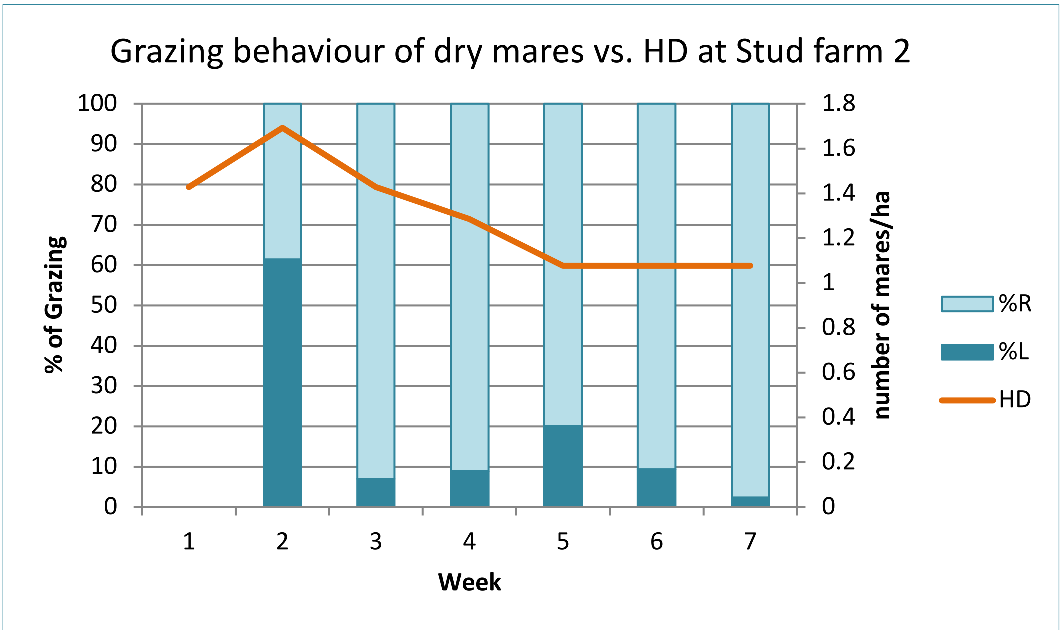


Figure 14. Percentage of time spent grazing in 'roughs' or 'lawns' by dry mares vs. horse density (HD, horses/ha) at stud farm 2.

Figure 14 is showing the same grazing behavior of the dry mares as Figure 13 but this time set against the horse density (HD) present at stud farm 2. The horse density present at the pasture containing dry mares ranged between 1.69 and 1.08 horses/ha (Figure 14).

The grazing time of the pregnant mares at stud farm 2 was mostly spent grazing roughs (between 64-97%). The total pasture dry matter differed between 1861 kg DM/ha at its lowest and 2568 kg DM/ha at its highest (Figure 15). Pasture dry matter of the lawns ranged between 1429 and 2201 kg DM/ha.

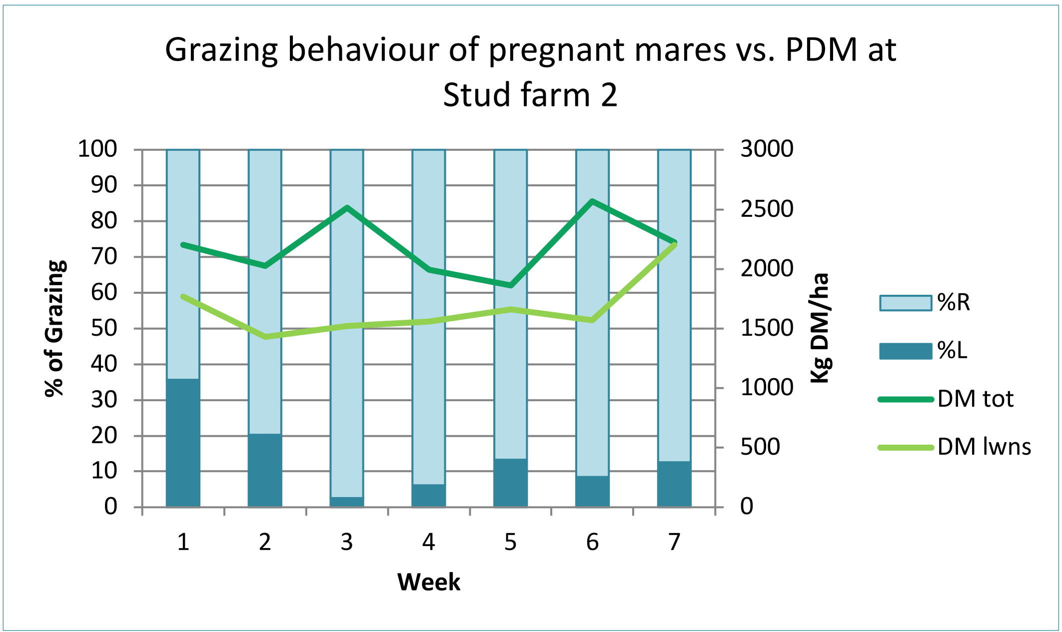


Figure 15. Percentage of time spent grazing in 'roughs' or 'lawns' by pregnant mares vs. pasture dry matter (PDM) at hand (total and lawns) in kg DM/ha.

The same bar graph of the grazing behavior of the pregnant mares at stud farm 2, but this time set against the horse density present at the pastures shows that HD ranged between 1.27- 2.84 horses/ha (Figure 16).

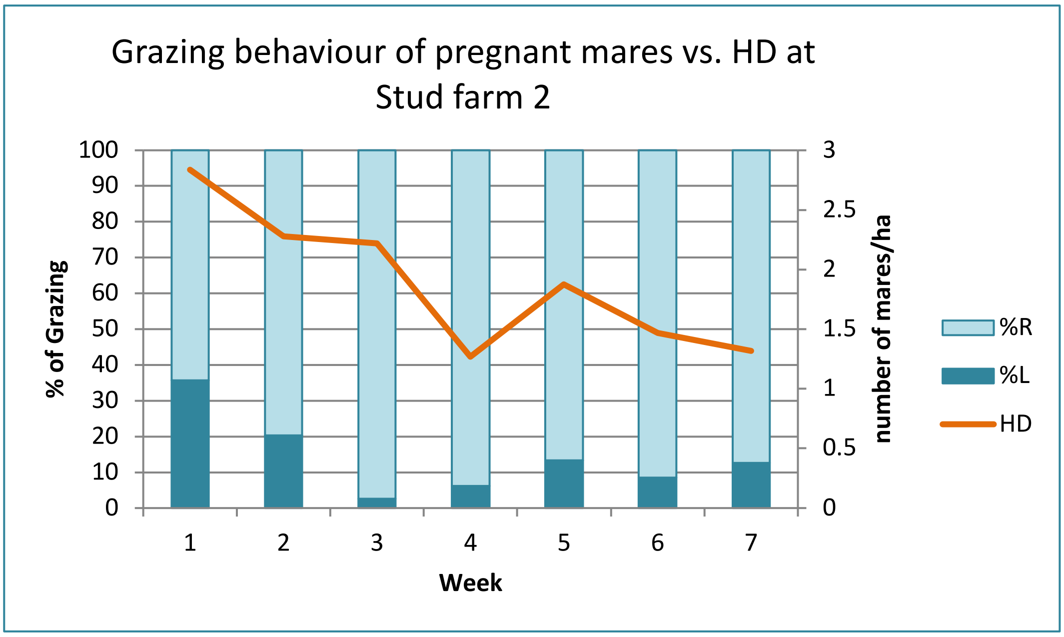


Figure 16. Percentage of time spent grazing in 'roughs' or 'lawns' by pregnant mares vs. horse density (HD, horses/ha) at stud farm 2.

The mares with foals grazed the roughs for 27-43% of the grazing time during week 1 and 2. During week 3-7 the time spent grazing the roughs ranged between 93 and 98% (Figure 17). The total pasture dry matter started at 1961 kg DM/ha in week one, dropped to 1392 kg DM/ha in week 2 and then started increasing during week 3-6 to 2479 kg DM/ha, with a small decrease to

2323 kg DM/ha in the final week of the experiment (Figure 17). The dry matter of the lawns ranged between 1058 kg DM/ha and 2022 kg DM/ha (Figure 17).

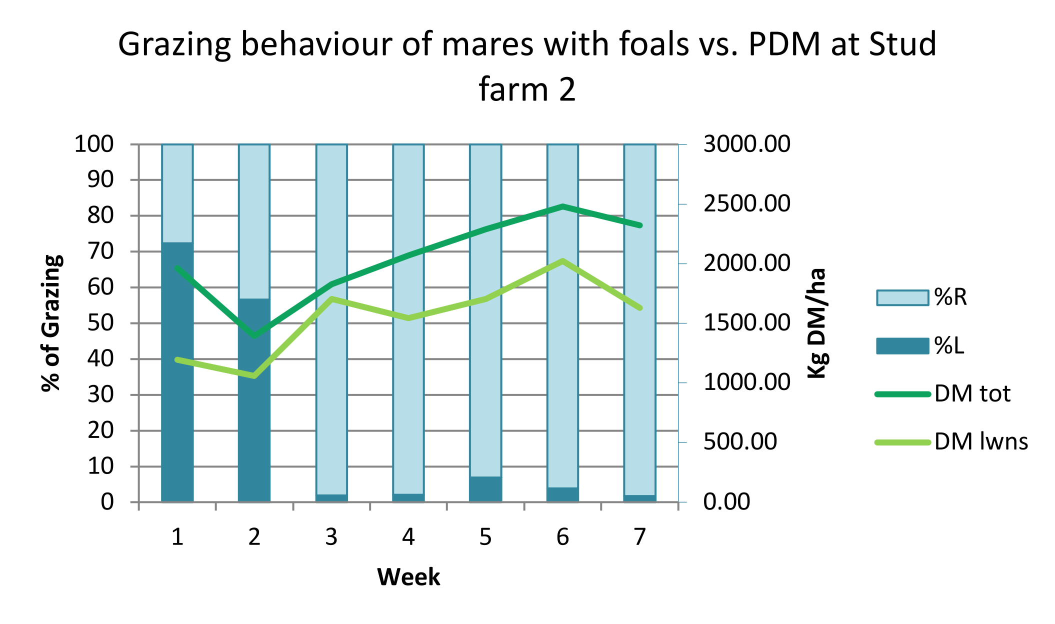


Figure 17. Percentage of time spent grazing in 'roughs' or 'lawns' by mares with foals vs. pasture dry matter (PDM) at hand (total and lawns) in kg DM/ha.

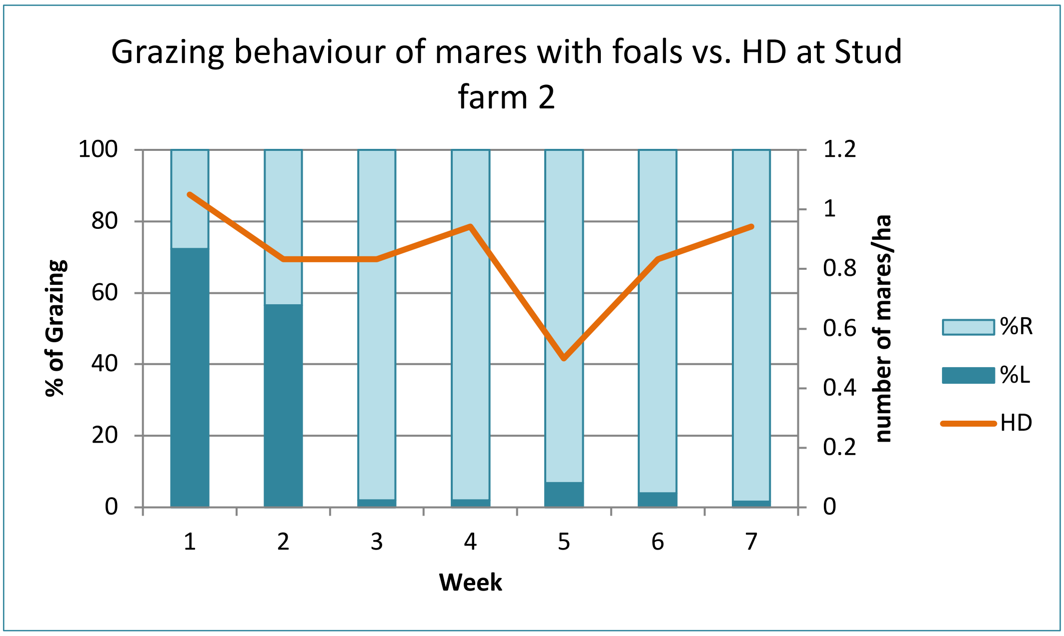


Figure 18. Percentage of time spent grazing in 'roughs' or 'lawns' by mares with foals vs. horse density (HD, horses/ha) at stud farm 2.

The HD in the pastures containing the mares with foals on farm 2 ranged between 0.5 and 1.05 mares/ha during the 7 weeks of the experiment (Figure 18).

Figure 19. Examples of the pastures and their vegetation during the 7 weeks of the experiment, as seen on stud farm 2.

On stud farm 2 the total dry matter (kg DM/ha) and dry matter of the lawns did not decrease as was the case on stud farm 1 (Figure 4), but there was a slow but steady increase in pasture dry matter (both total and lawns) (Figure 11). This was also visible on the pastures at stud farm 2, where sward height was lower during the first week of the experiment and higher during the end of the experiment. Figure 19 shows these differences (from left to right, from top to bottom it shows the increase of sward height of the pasture during the 7 weeks of the experiment).

3.4 Grazing Behaviour

The mares grazed on average 69% of the time while recorded for the ethogram. On stud farm 1 the average time spent grazing was 63% vs. 74% on stud farm 2. Between mare states the % of grazing the roughs differed and was the highest in the mares with foals (Figure 20, 21).

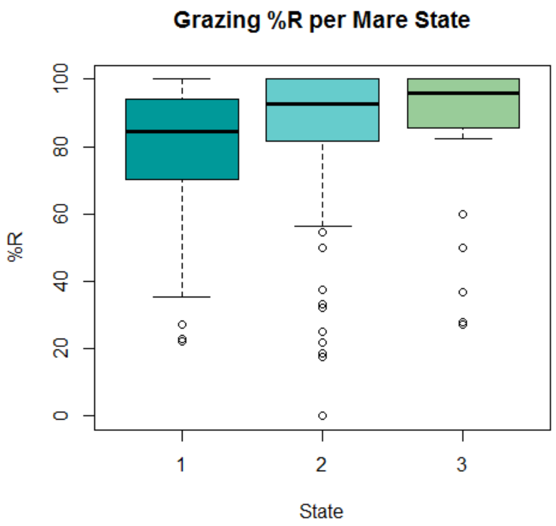


Figure 20. Percentage of time spent grazing per mare State (1 = dry mares, 2 = pregnant mares, 3 = mares with foals).

The percentage of grazing in the roughs per mare state was respectively 79% on average for mare state 1 (dry mares), 84% on average for mare state 2 (pregnant mares) and 87% on average for mare state 3 (mares with foals) (Figure 21).

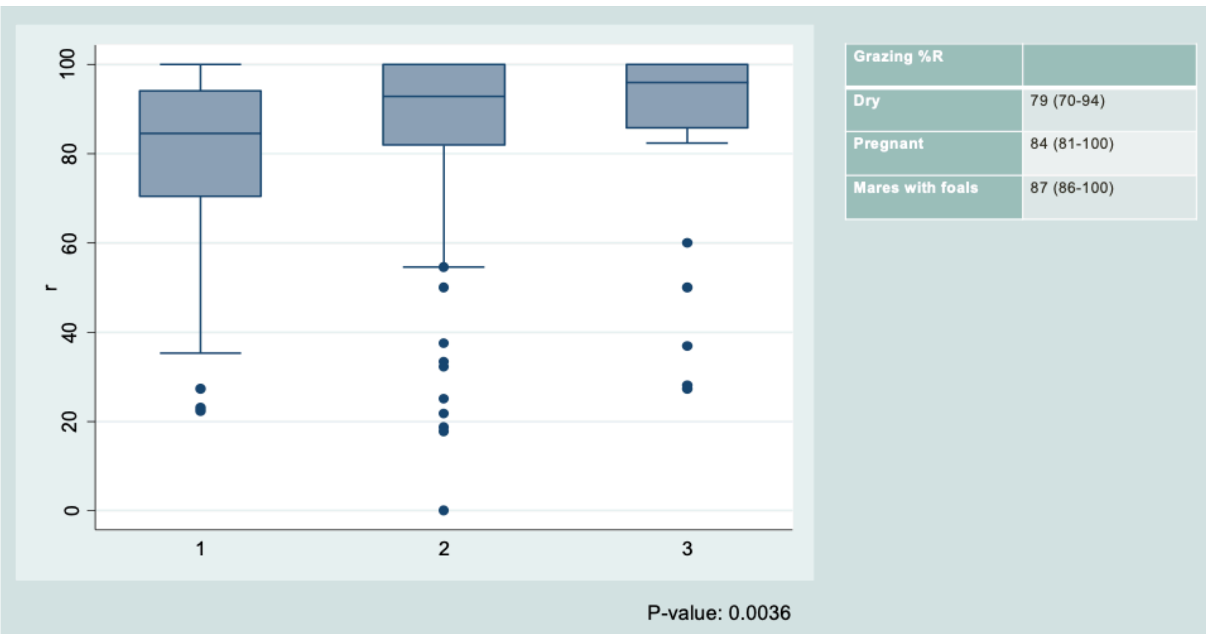


Figure 21. Boxplot of the mare grazing behaviour grouped by mare state (dry, pregnant, with foal).

Figure 20 and figure 21 show that the percentage of grazing increased over the period the length of the experiment for both farms, and that these increases in the percentage of time grazing were seen in all the mares, independent on mare state (Figure 22, 23).

As seen previously, most horses spent their time grazing in the roughs during the 7 weeks of the experiment and for both stud farm 1 and stud farm 2 time spent grazing in the roughs increased (Figure 22).

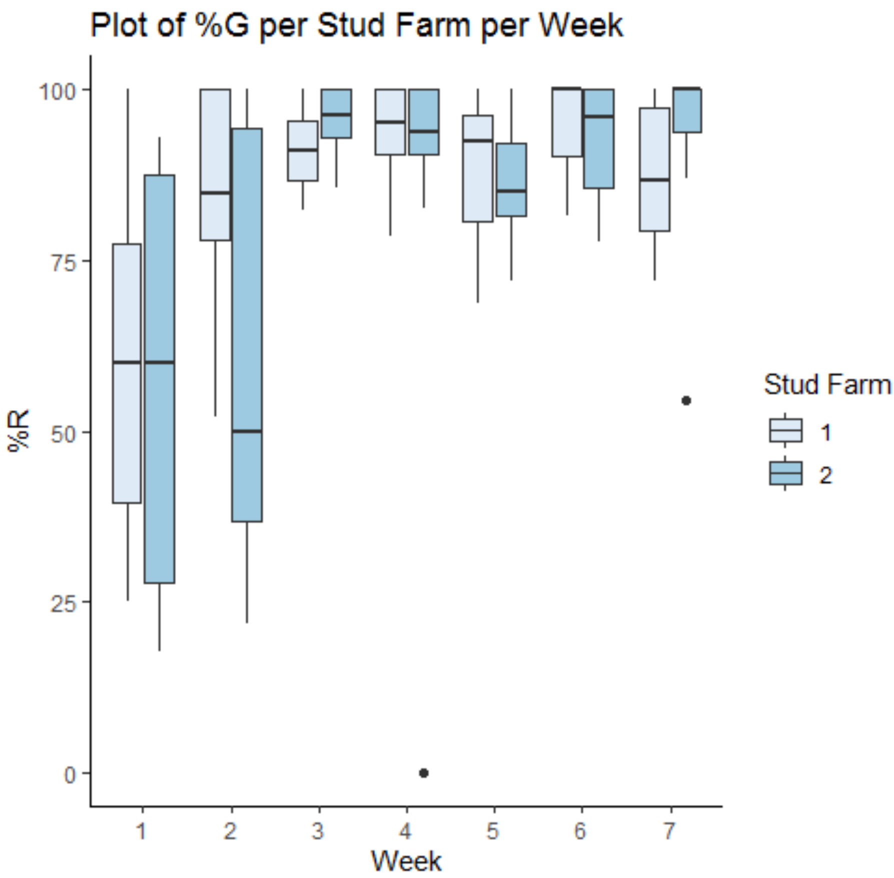


Figure 22. Boxplot of the percentage of time spent grazing in the roughs for each week of the experiment per Stud farm.

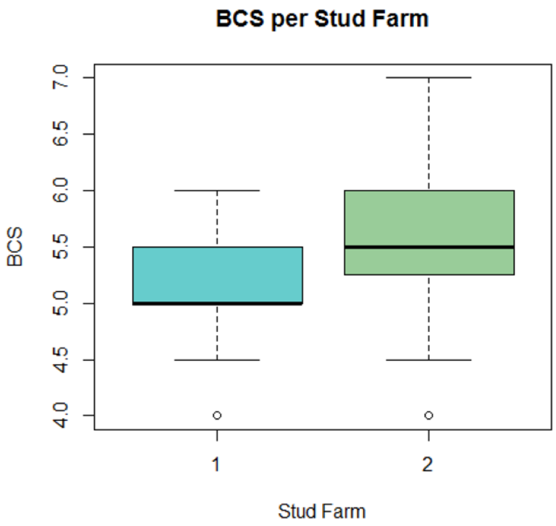
3.5 Body Condition Scores

The mean BCS of the total of 40 mares followed in this study was 5.5, ranging from 4 to 7, with a median of 5.5 (table 9). Between the different states mean BCS differed and were respectively BCS 4.99 for State 1 (dry mares), BCS 5.7 for State 2 (pregnant mares) and 5.43 for State 3 (mares with foals) (table 8).

Table 8. Mean and median BCS per mare state.

	State 1	State 2	State 3
BCS mean (min-max)	4.99 (4-5.5)	5.7 (4-7)	5.43 (5-6)
BCS median	5	6	5.5

Between the two stud farms the BCS differed too. The spread in BCS measurements was larger for stud farm 2, and its median was higher too (5.5 compared to 5 for stud farm 1) (Figure 22). On average mares, from stud farm 2 had a higher BCS than mares from stud farm 1 (Figure 22).



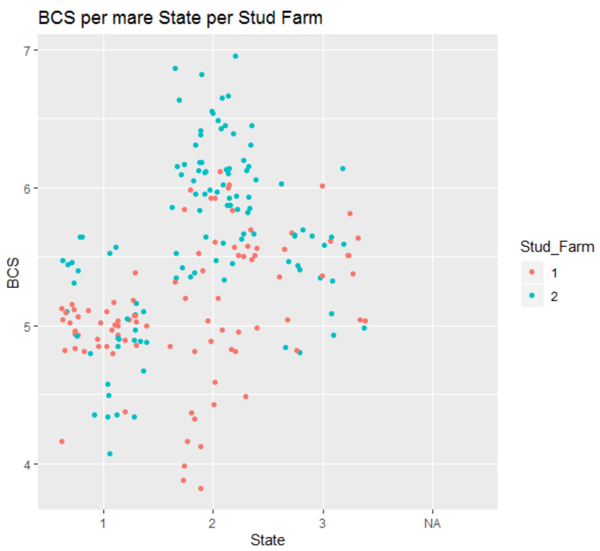


Figure 23 (left). Boxplot of the BCSs scored on each farm.

Figure 24 (right). Scatterplot of the scored BCSs per mare State (1 = dry, 2 = pregnant, 3 = with foal) divide by Stud farm.

Looking at both stud farm and mare state it is visible that the biggest difference in BCSs of the mares is in mare State 2 (pregnant mares). For State 1 and State 3 the scatter is more evenly distributed, where the scatter of mare state 2 has a larger spread in which there is a bit of a division visible in scatter of stud farm 1 (lower BCSs) and stud farm 2 (higher BCSs) (Figure 23). During the 7 weeks of the experiment BCSs ranged from 4 to 7 with the average BCS per week ranging between 5 and 6 (Table 9).

Table 9. Mean, minimum and maximum BCS per week of the experiment.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Mean BCS	5.22	5.23	5.35	5.5	5.57	5.57	5.63
Minimum BCS	4	4	4.5	4.5	4.5	5	5
Maximum BCS	6	6.5	6.5	6.5	6.5	7	7

3.6 Fecal Egg Counts

During the experiment a total of 24 faecal samples were opportunistically collected. Of those 24 samples only 2 were positive for Strongylid types. The FE's were 50 eggs/gram for the positive sample, sampled 4-Oct'17 from mare ID 37 and 400 eggs/gram for the positive sample, sampled 18 Oct'17 from mare ID 38. Both mares were stabled at stud farm 2 but did not share a pasture at any point in the experiment.

3.7 Faeces load on pasture

During the last two weeks of the experiment the faeces load on pasture was determined for pastures where the lawns and roughs were no longer distinguishable due to short sword height of the roughs, but were faeces was accumulating (Figure 26). The faeces load on pasture for the concerning pastures ranged between 3 and 8 piles of faeces per 25m^2.

Figure 25. Example of the faeces load on pasture near the end of the experiment.

4. Discussion

4.1 Research problem & key findings

As stated in the introduction, a higher horse density on pasture translates to more pressure on the pasture (Rogers et al., 2007; Rogers et al., 2017). In the breeding season there is an increased horse density, stressing the importance of good farm management and pasture management. This importance is even more pressing in the production system on thoroughbred stud farms in New Zealand, as this is mostly pasture based (Avery, 1997; Rogers et al., 2007). Additionally, high stocking densities pose a risk for parasite (re)infections. Therefore, adequate pasture management and deworming management are called for, especially while bearing in mind the knowledge of upcoming global resistance against anthelmintics and the previously described high dependency on anthelmintics on New Zealand's stud farms (Bishop et al., 2014; Rosanowski et al., 2017; Scott et al., 2015).

The aim of this study was to obtain a better insight in the individual grazing behaviour of horses and to gain more insight in possible parasite re-infestation due to grazing behaviour and pasture management. Management differences and their potential effect on pasture dry matter and the individual mare grazing behaviour where investigated by including two different Thoroughbred stud farms in this study. The key findings were that the data suggested an overall decline of pasture dry matter on stud farm 1, and that only in pastures where dry matter declined horses started eating more in the roughs. On stud farm 2, pasture dry matter increased during the experiment, potentially due to a decline in horse density on the farm during the 7-weeks of the experiment. A higher horse density probably leads to less faecal avoidance behaviour because horses eat less selective with higher horse density at pasture. In regard to parasite reinfestation the present study does not provide an answer but does shed light on the possible presence of anthelmintic resistance and the high dependency on drenching, calling for a more modern and sustainable parasite control strategy.

4.2 Pasture management & grazing behaviour

The two farms differed significantly in their paddock sizes (for dry mares & pregnant mares) and in the horse density (HD) on the farms. This is logical, since stud farm 1 is a large commercial stud farm, while stud farm 2 is more of a boutique stud farm. The expectation beforehand was that the HD would be higher on stud farm 1. The differences in management are probably partly due to being such different enterprises. Following the mares on both stud farms, the data suggest that there is more movement on stud farm 1 (table 6), which can be explained by them standing stallions and thus mares from outside visiting the farm in the breeding season. Between the stud farms there was no significant difference between the pasture dry matter of the lawns. This comes as a surprise, because during the 7 weeks of the experiment the visual impression of the pastures on both farms was that there was a higher sward height on stud farm 2. Thus, the expectation was that the pasture dry matter of the lawns would be significantly different between both farms. However, the higher sward height seen on stud farm 2 did translate into a significant difference in total dry matter between the two stud farms (except for the pastures containing dry mares). And there was also a significant difference in the dry matter of the roughs between the two farms (concerning the pastures accommodating the dry mares and mares with foals) (table 7).

The expectation was that during the 7 weeks of the experiment pasture dry matter would decline, thus forcing horses to spend more time grazing in the roughs. On average (figure 4) the pasture dry matter (kg DM/ha) on stud farm 1 did decline, which was very logical, especially when taking into account that at the time of the experiment the farm was overcrowded compared to their normal stocking density. On stud farm 2, however, the average pasture dry matter (kg DM/ha) showed an increase. An explanation for this increase could be the heavy rains in first few weeks of the experiment followed by more sun hours in the later weeks of the experiment in combination with a lower stocking density at stud farm 2, giving the pasture time to regrow. This explanation is purely speculative, though, since weather and rainfall where not taken into account in this experiment.

Additionally, the amount of time spent grazing in the roughs did not increase due to the decline of pasture dry matter on stud farm 1, in contrast to the expectation that the horses would be forced to graze in the roughs. Apparently, either the duration of the experiment was too short to actually see the shift to grazing more in the roughs due to a decline in pasture dry matter, or it is due to grouping all the different mares together. When dividing the horses in three groups (dry mares, pregnant mares and mares with foals) the group of pregnant mares on stud farm 1 does show that a decline in dry matter of the lawns is accompanied by spending more, if not all, their time grazing in the roughs (Figure 7, 8). The same trend is seen in the grazing behavior of the mares with foals on stud farm 1, who also end up grazing more in the roughs simultaneous with a decline in both total dry matter and dry matter of the lawns (Figure 9, 10). It seems as though the data of the dry mares on stud farm 1, which showed an increase in pasture dry matter and no difference in eating lawns or roughs during the experiment, overshadowed the data in the other groups and pastures. So, looking back the group of dry mares (third group) should not have been included, because the condition 'decline of pasture dry matter' was not met. When excluding the third group, pasture dry matter did decline on average on stud farm 1, and in those pastures, horses started grazing more in the roughs during the 7 weeks of the experiment.

In contrast, on stud farm 2 total dry matter increased, possibly due to favorable weather for pasture growth, as stated before. Another reason might have been the decline in horse density during the 7 weeks of the experiment. When looking at the results, horse density did decline on average on stud farm 2, but when again dividing the horses in groups this argument doesn't hold. The mares with foals on stud farm 2 started grazing more in the roughs, while total pasture dry matter increased. However, this can't be attributed to horse density since HD fluctuated a little but stayed roughly the same during the 7 weeks of the experiment. There must have been other factors explaining why the horses started grazing more in the roughs, even though pasture dry matter increased, and HD did not change over time. Mares with foals need a lot of energy since they are lactating, but that too does not explain grazing more in the roughs since the roughs are mostly consisting of matured grasses, which are often of less nutritional value (Williams et al., 2020).

Furthermore, Hoskin & Gee (2004) reported that pregrazing pasture mass of 1,800-2,000 kg DM/ha is not limiting for feed intake. In this study the pre-grazing pasture mass was not known, since the mares were already turned out at pasture on both farms. And the pastures measured in this study were already in use. However, pasture mass (total dry matter) was > 2,000 kg DM/ha on stud farm 2 for pastures accommodating the pregnant mares and the mares with foals. For dry mares the pasture mass was just below 1,800 kg DM/ha (table 7), but as already mentioned, it might have been higher before the pasture was taken into use, since this measurement is average dry matter and not total dry matter at the start of the experiment. For stud farm 1 the total pasture dry matter (kg DM/ha) was around 1,600 (table 7). This is due to a large difference between pastures at the start of the experiment, ranging in total dry matter from 1,200 to 4,100 kg DM/ha. It could be that total pasture dry matter of certain pastures was insufficient on stud farm 1. It is difficult, though, to determine what the effect of a limited feed intake has been on grazing behaviour in this study. Except for the previously mentioned trend of the mares grazing more in the roughs throughout the 7-week experiment. Previous research has shown that a low sward height coerces horses to start eating in the roughs, thus showing less fecal avoidance behaviour (Leathwick, Pomroy & Heath, 2001; Rogers et al., 2007; Rogers et al., 2017). The effect of limited feed intake was difficult to determine though in this research due to the additional feeding of haylage on both stud farms, which was not anticipated and thus not included in the study design (see 4.4 strength & limitations).

Comparing the two farms there is no clear difference in fecal avoidance behaviour by the mares. It would have been interesting to see at which stocking density mares display less fecal avoidance behavior. At both farms, mares started eating in the roughs, so no clear fecal avoidance behavior was displayed. It could be that at both farms the stocking density was high, making the fecal avoidance behavior less obvious (Hoskin & Gee, 2004). Another factor that comes into play is the definition of the lawns. They were defined as areas that were low grazed with the sward height below 4 cm (Fleurance et al., 2007). In the ethogram grazing roughs (GR) is described as eating grasses and herbs within 1 meter of faeces, not separated by more than 10 seconds of rest, move or other. When looking at the pictures of the pasture on stud farm 2 (Figure 19) there seems to be abundant pasture cover, compared to the pastures on stud farm 1 (Figure 11). The question is whether on those pastures with an abundance of vegetation, grazing roughs has been seen as grazing tall grass near faecal piles or whether the mares were just not eating the short grass, since the entire pasture consisted of taller grasses. Because of these uncertainties the actual effect of horse density on faecal avoidance behaviour can't be explained using the data of this study. On the other hand, previous studies concerning the effect of high stocking densities on grazing behaviour have shown that when horse density increases and pastures are heavily grazed horses will start grazing more in the roughs to meet their nutritional needs (Leathwick et al., 2001; Rogers et al., 2007; Rogers et al., 2017). A study by Fleurance, Farruggia, Lanore, & Dumont (2016) showed that when comparing moderate with high stocking density, the amount of time spent grazing during the day did not differ between the two stocking densities. But there was a lower bite-to-step ratio (bite rate and step rate during 1 minute of uninterrupted grazing), showing that horses do graze more selectively when grazing intensity is lower (Fleurance et al., 2016). This selective grazing attributes to being able to select favoured grass/herbage but could also mean more faecal avoidance behaviour being displayed.

4.3 Prevention of parasite infections

During this study the idea was to get a better insight in the possibility of parasite reinfestation due to grazing behaviour and pasture management. During the experiment faeces were opportunistically collected and multiple FECs were carried out. Of those 24 faeces samples, only 2 were positive for Strongyle types. These 2 positive faeces samples were both from stud farm 2. The question is: what is the meaning of those two positive faeces samples? In short, it can either mean that on stud farm 1 the deworming products are still effective. Or it can be that on stud farm 2, there is resistance against anthelmintics, however the exact time of the last deworming treatment was not known and the egg counts were low, below the threshold often used to identify the mares needing another treatment. The following paragraphs will address these possible reasonings in further depth, will address adequate surveillance and prevention of parasite (re)infestation on stud farms and the difficulties faced in adequate worm control.

The difference in deworming management between stud farm 1 and 2 is that on stud farm 1 the mares get drenched every 6-8 weeks, while on stud farm 2 the drenching interval is 10 weeks. Drenching the mares every 6-weeks is an intensive use of anthelmintics, risking provoking resistance against anthelmintics (Eysker et al., 2006; Scott et al., 2015). As mentioned previously, it also interrupts with the establishing of so-called refugia (Eysker et al., 2006).

Even though it seems that on stud farm 1 there is not yet resistance against the used deworming products, since there were only negative FECs, one should bear in mind that the circumstances on stud farm 1, in regard to their deworming management, do pose a threat. Factors aiding the selection of resistant worms on stud farm 1, are the short deworming interval used, the deworming of the entire herd, and no rotation of the used anthelmintic product (Kaplan & Nielsen, 2010; Scott et al., 2015).

What became clear during the experiment and after speaking with both stud farm owners is that both farms are still highly depended on frequent deworming. This, together with the knowledge obtained from previous questionnaires and research by Bolwell et al., (2015), shows that New Zealand's deworming management is still largely based on interval drenching, mostly without previous faeces collecting and conducting fecal egg counts (Bolwell et al., 2015; Stowers et al., 2009). The described short drenching interval (6-8 weeks) between deworming treatments on stud farm 1 is no exception but rather the norm in New Zealand (Bolwell et al., 2015). As stated, worldwide resistance against anthelmintics is rising, underlining the importance of a different strategy consisting of more surveillance and less frequent and more selective use of anthelmintics (Nielsen, Pfister, & von Samson-Himmelstjerna, 2014). Surveillance is generally conducted by performing FECs and by treating only horses having FECs above a certain threshold, or those known has high shedders. What both farms are doing at the moment is treating all their horses with anthelmintics, and not making a distinction between high and low shedders. Stud farm 2, unlike stud farm 1, does carry out a dozen FECs a year but does this with the aim of checking the effectivity of the used anthelmintic products (via FECRT: fecal egg count reduction tests). It is known, however, that horses that do not classify as high shedders most of the time remain low shedders even without anthelmintic treatment (Döpfer et al., 2004; Nielsen et al., 2006; Reinemeyer, 2009). It is thus unnecessary to treat those horses. The risk of them turning into high shedders is reduced by carrying out frequent fecal egg counts to identify possible high shedders that do need anthelmintic treatment (Scott et al., 2015; Nielsen et al., 2014). This advocates for a far more individual approach of worm control (Reinemeyer, 2009).

Besides in the interval there is also a difference in the anthelmintic products used on both farms. The use of the broad spectrum anthelmintic Strategy-T ® (Virbac) (a combination of benzimidazole (oxfendazole) and tetrahydropyrimidines (pyrantel)), on stud farm 1 provides good protection against *Strongyloides Westeri* (foal worm) and *Parascaris Equorum*. The oxfendazole works against all stadia of both the small (*Cyathostominae*) and large strongyles (*Strongylus* spp.) In order for oxfendazole to have a high efficiency against larval stadia (either in mucosa or migrating) of both small and large Strongyles it is advised to treat the horses for 5 consecutive days (Corning, 2009). Though, worldwide there is a widespread resistance against benzimidazoles, this has not yet been seen in New Zealand, in contrast to the upcoming resistance (less efficiency) against ivermectine, which has been documented in New Zealand (Bishop et al., 2014; Rosanowski et al., 2017). Both farms are dependent on benzimidazoles, posing a possible problem for the future (Corning, 2009). The administration of pyrantel poses an additional risk. In combination with oxfendazole it has no additional value, since it does not work against *Strongyloides Westeri*, is only effective against the adult stages of *Parascaris Equorum* and has a known efficacy of below 90% against the adult stages of both small and large strongyles. Thus, presenting a risk for the further increase of resistance (Scott et al., 2015). These products do not protect the horses against tapeworms, and there is also no surveillance in place, posing a risk for tapeworm infections. It is known that at a double dose pyrantel does work against *Anoplocephalo perfoliate*, but overdosing risks developing resistance in the other worm species (Gasser, Williamson & Beveridge, 2005; Lyons, Drudge, Tolliver, Swerczek & Collins, 1989; Owen & Slocombe, 2004).

On stud farm 2 the deworming product Equitak Excel® (Bayer) was used, this is a combination of abamectin (macrocyclic lactones), oxfendazole (benzimidazole) and praziquantel, thus providing protection against *Strongyloides Westeri*, *Parascaris Equorum*, and both small and large strongyles. The abamectin provides protection against all adult and larval stages of *Strongylus* spp. and against adult and developing stages of *Cyathostominae*, except for larval stage 3 which is encapsulated in the mucosae (Scott et al., 2015). Praziquantel provides protection against tapeworms. Equitak Excel is used for two years and then alternated for one year with Ultramax equine® (Pharmachem) (containing ivermectin and praziquantel). Rotating anthelmintics likely masks resistance and more importantly can't replace the necessary routine check of anthelmintic efficiency (Kaplan & Nielsen, 2010). Combination products combining an anti-tapeworm product with a product from other anthelmintic groups is not advised, because the time of treatment is different for tapeworms, thus encouraging resistance in other worm species. The elaboration of the products above, shows the difficulty to apply the correct anthelmintic with a high enough efficacy, further underlining the importance of moving towards a more sustainable approach (Kaplan & Nielsen, 2010; Nielsen, 2012; Reinemeyer, 2009; Scott et al., 2015). It also shows that there is an added value of determining the level of efficacy deworming products still have on a particular farm to not further the development of anthelmintic resistance. And more so, it shows how FECs (individual or grouped) could reduce the number of horses receiving treatment, reduce the amount of times receiving treatment and make the treatment more specific, all contributing to a more surveillance based, individual and sustainable approach to worm control (Nielsen, 2012; Nielsen, 2021; Reinemeyer, 2009; Scott et al,. 2015; Stowers et al., 2009). And of course, also implementing faecal egg count reductions test (FECRT's) in the parasite control program to regularly check anthelmintic efficacy (Nielsen, 2021; Scott el al., 2015).

The positive FECs on stud farm 2 can point towards resistance or lower efficacy of the deworming product used. They could also be due to the longer deworming interval, or it could be that the egg reappearance period (ERP) is shortened, but this cannot be confirmed since the time of the last deworming was not known. The advice would be to keep checking the efficacy of the used products via FECRT, to ensure the use of anthelmintics with high efficacy. And to further define, as mentioned, the high and low shedders on the farm. The positive FECs had an EPG of 50 and 400, so the latter horse would be a candidate for deworming.

There is clearly a need for a more selective, individual and sustainable approach to parasite control. What is the reasoning then behind this holding onto 'old-fashioned' methods instead of choosing a more modern approach? An argument is that it stems from a period where the biggest challenge in worm control was to target large strongyles. However, these are not the challenges faced today, since on most large strongyles are no longer present on well managed farms and cyathostomins are now the main target. For this reason it is no longer an acceptable method of parasite control to just rely on interval programs (Reinemeyer, 2009). Another argument could be the cost, or lack of financial benefits. However, implementing FECs decreases the amount of treatments administered each year, as some horses do not need treatments because of being low shedders (Nielsen, 2021; Reinemeyer, 2009; Scott et al., 2015). The long-term benefits are most important, safeguarding anthelmintic efficacy and lowering the chance of occurrence of anthelmintic resistance (Kaplan & Nielsen, 2010; Nielsen, 2021; Reinemeyer, 2009). Looking at countries were this type of more sustainable antiparasitic management is in place and working, it seems that legislation plays quite a role. In Denmark for example anthelmintic products can only be obtained via prescription. It has been this legislation which ensured a close involvement of veterinarians in parasite control, by prohibiting prophylactic use of anthelmintics and warranting correct diagnosing (Kaplan & Nielsen, 2010). This practice has motivated owners and veterinarians alike to shift towards a selective approach and selective therapy based on regular FECs, resulting in in a lower treatment intensity in the country (Kaplan & Nielsen, 2010). A study by Nielsen, Gee, Hansen, Waghorn, Bell & Leathwick (2020) showed that a treatment strategy with less frequent treatments then the usual interval drenching on stud farms in New Zealand for one calendar year/foaling season did not affect equine health negatively, further promoting and strengthening the case for the implementation of a less frequent, more sustainable and more selective control strategy against equine parasites.

4.4 Strengths & limitations

The most crucial limitation of this research is the randomness of the measurements. Even though the research design was well structured, in practice it proved difficult to implement this design on a working stud farm. The horses were picked randomly for the study, but it was not taking into account beforehand that it was unknown how long they were at the farm, how long they were staying and when they would be moved from one pasture to another. The farms were large and therefore not all pastures could be measured in terms of pasture measurements (dry matter), which was a problem encountered during the gathering of the data. It meant that some pastures only accommodated mares that were followed for a very limited time of the experiment, and thus those pastures measurements were not continuously taken throughout the full 7 weeks of the experiment. When analyzing the data another problem occurred: repeated measurements in time, on the same research subjects resulting in quite a total of measurements but they are not independent measurements. So, even though it seems like a lot of measurements, they are repeated and not independent, thus the sample size and respectively power is smaller than first anticipated. This hinders the actual generalizability of the findings. To add to that, there was also an inconsistency in the measurements, with missing mares or missing pasture measurements during certain weeks making it a difficult datasheet to analyze statistically. Nevertheless, the results of this study, which can't be used to apply to the larger population, do give an idea of how much comes into play with the management of a stud farm and how important it is to maintain

both good pasture management and to keep an eye on parasite (re)infestation with proper surveillance, and preferably have measures in place to prevent this.
Another problem that arose during analysis of the data was that possible effects of confounding variables couldn't be controlled, thus maybe influencing the findings. An example of a confounding variable is the supplementary feeding of haylage due to some of the pastures being trampled during the heavy rainfall, which was an unanticipated event. It could be that the additional feeding of haylage had an influence on the grazing behavior of the mares, on the herbage available at pasture and on fecal avoidance behavior of the mares.

Despite these limitations the main research goals were attained with regard to getting a better insight in the grazing behaviour of the horses, the changes in horse density on the farm and its effect on grazing behaviour and pasture quality. Future research would preferably involve a more structured follow up of the horses, in which confounding variables such as additional feeding, weather influence on pasture, faeces load on pasture and preparatory pasture measurement (before pastures are taken into use) are included.

5. Conclusion

This research project aimed to obtain insight into the individual grazing behaviour of horses and to get a better idea of the possibility for parasite re-infestation due to grazing behaviour and pasture management. Horses start eating less selectively when pasture pressure is higher, due to higher horse density. And therefore, faecal avoidance behaviour can be less clear. Additionally, when sward height declines and pasture dry matter is lower, horses spend more time grazing in the roughs. Based on the results of this study both a higher horse density and lower sward height at pasture, do not immediately translate to higher parasite infestation, mainly because the anthelmintic products used are still effective. However, upcoming global anthelmintic resistance underlines that being dependent solely on anthelmintics is not sustainable. On stud farms there should be a sustainable approach to anti-parasitic management. This translates to the use of rotational grazing on the farms, the use of FECs for determining high and low shedders and thus knowing which horses need antiparasitic treatment, and FECRTs to maintain insight in the efficacy of the used anthelmintic products. All these measures serve for maintaining equine health, but also to not further select for anthelmintic resistance. For this, a more selective, individual and sustainable approach is needed.

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7. Appendix

8.1 Appendix 1 “Behaviour scan form”

Paddock #: **Studfarm: 1/2**				
Total # of mares =				
Date:				
Name followed Mares	BCS	Colour	Dry/Preg/With Foal	Notes

1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Faeces collected from:

8.2 Appendix 2 “Pasture measurements form”

Date					
Pasture number					
Stud farm					
	First RPM	Second RPM	Clicks	Reading	Total DM (kg/ha)
Total					
Roughs					
Lawns					