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APPLICATION OF TARGETED GOAT GRAZING IN OIL PALM PLANTATIONS: ASSESSMENT OF WEED PREFERENCE, SPATIAL USE OF GRAZING AREA AND LIVE WEIGHT CHANGE

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ABSTRACT

Targeted goat grazing is a promising tool to control competing weeds in crop plantation systems without causing adverse effects on the environment. Here, we investigated the effectiveness of targeted grazing for weed control involving 11 Katjang crossbreed goats in a mature oil palm plantation. We assessed the animal behaviour and management aspects including weed preference, spatial use of grazing area, and body weight change. Asystasia gangetica *was the most preferred weed species, followed by* Clidemia hirta. *Time spent grazing on* A. gangetica *(45.83-282.91 s) and* C. hirta *(10.04-49.82 s) by the female goats were different between grazing days (*p*<0.05). Spatial use between edge and interior areas of grazing plots were not different (*p*=0.718), meaning goats grazed evenly throughout the grazing plots. Our results revealed that goats fed evenly on the diverse weed community throughout the grazing plots and maintained similar body weight (*p*=0.488) before and after grazing. Livestock integration with oil palm agriculture in the manner of targeted grazing should be promoted as a part of integrated pest management for reducing weeds. Targeted grazing might be the solution for environmentally sound weed management in sustainable oil palm plantations.*

Keywords: biological control, integrated pest management, livestock integration, sustainable palm oil.

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INTRODUCTION

Sustainable palm oil production demands producers to improve current agricultural practices, with the intention of compatibility with environmental protection and worker health (Abdul Majid, 2021; Azhar *et al*., 2017; Saadun *et al*., 2018). Palm oil certification schemes such as the Roundtable on Sustainable Palm Oil (RSPO) and Malaysian Sustainable Palm Oil (MSPO) require producers to implement the use of biological control methods in palm oil production (Kalidas, 2012). For instance, biological control such as cover crop management has shown to be effective in reducing weeds and has the potential to be included in sustainably managed oil palm plantations to reduce the use of commercial herbicides (Baumgartner *et al*., 2008; Gago *et al*., 2007; Samedani *et al*., 2015; Tohiran *et al*., 2019a; 2019b). In Malaysia, leguminous cover crops species commonly used are *Pueraria phaseloides* (synonym for *Pueraria javanica*), *Centrosema pubescens*, *Calopogonium mucunoides*, *C. caeruleum* and of late, *Mucuna bracteata* as they reduce the growth and cover of weed species (Mathews and Saw, 2007). This improvement of agricultural practice is inevitable

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due to the increasing market demand for certified palm oil-based products globally (CPET, 2015). It is forecasted that the scale of oil palm plantation land use will continue to expand in Southeast Asia, Western Africa and South America (Vijay *et al*., 2016). To date, there is a lack of empirical evidence on biological control as an effective alternative to manage weeds in oil palm plantations.

Weed species such as *Chromolaena odorata* and *Asystasia gangetica* are mainly controlled by chemical herbicides in oil palm plantations because they compete with the palm oil crop for water and nutrients, reducing crop health and productivity (Ali *et al*., 2021; Nchanji *et al*., 2016; Satriawan *et al*., 2021; Sidik *et al*., 2018). Chemical herbicides such as paraquat (600 or 800 g ha^{-1}), gluphosinate-ammonium (200 g ha^{-1}) and glyphosate (400 g ha^{-1}) are commonly used to control weeds in oil palm plantations (Dilipkumar *et al*., 2017; Mohamad *et al*., 2010; Wibawa *et al*., 2010). Major palm oil producing countries such as Malaysia have banned the use of herbicides such as paraquat (Wibawa *et al*., 2007), deemed hazardous to human health and the environment (Ferramosca *et al*., 2021; Pochron *et al*., 2021; Van Bruggen *et al*., 2018; Weisenburger, 1993; Zaller *et al*., 2021). An alternative to using the remaining permitted chemical herbicides for controlling weeds in oil palm plantations is the application of targeted grazing with livestock animals (Tohiran *et al*., 2017; 2019a; 2019b).

Targeted grazing is grazing by ruminant livestock for a set duration and intensity during a specified stage in the growing season to achieve specific vegetation management goals (Frost and Launchbaugh, 2003; Launchbaugh *et al*., 2006; Walker, 1994). It is an under-exploited tool that is fast proving very potent for weed control in expansive rangeland scenarios (Bailey *et al*., 2019; Frost and Launchbaugh, 2003). Using targeted grazing effectively demands site-specific knowledge of plant growth, animal nutrition, grazing behaviour, ecosystem function and public relations (Macon, 2014). Compared with herbicide application, targeted grazing can be inexpensive, with very light targeted grazing by sheep reducing weeds and increasing desired plant species (Bailey *et al*., 2019; Rinella and Hileman, 2009).

Goat grazing can be an important tool for biodiversity conservation in agroecosystems if managed appropriately (Azhar *et al*., 2021; García *et al*., 2012). The integration of rotationally grazed livestock in oil palm plantations has been promoted in order to manage weeds, supplement crop growth with organic manure, and improve farmland biodiversity (Azhar *et al*., 2013; Jambari *et al*., 2012; Tohiran *et al*., 2017). In established oil palm plantations, noxious weeds such as *Asystasia gangetica*, *Clidemia hirta, Centhotheca lappacea* and *Cyrtococum accrescens* strongly compete with oil palm trees for nutrients, moisture and sunlight and eventually cause yield depression (Azahari *et al*., 2004). At establishment and early growth stages of oil palm trees, weeds compete for resources, negatively affecting tree growth and yield and obstructing routine estate practices such as harvesting (Azahari *et al*., 2004; Rosli *et al*., 2010). Eradication of a very dense stand of *A. gangetica* in an oil palm plantation resulted in a 12% increase in FFB production (Kustyanti and Horne, 1991). Although the most common cost-effective practice to remove oil palm plantation weeds is herbicide application (Wibawa *et al*., 2010), this method is becoming unfavourable and increasing unpopular with the public due to the toxic and hazardous effects (Farooq *et al*., 2011). Biological weed control using grazing animals offers an economically cheaper alternative compared to herbicides in crop-livestock integration systems (Sánchez, 1995; Tohiran *et al*., 2014; 2017).

Feeding behaviour of goats in both open and confined areas influence their diets (Araújo *et al*., 2018; Goetsch *et al.,* 2010). Previous research has reported that feeding behaviour can be influenced by genotype, environmental conditions (site), differences in vegetation conditions (quality), and preference for different plant species (Goetsch *et al*., 2010; Mphinyane *et al*., 2015). However, feeding behaviours of goats raised in the field were almost the same as those raised in a confined area (Silva *et al.,* 2013). Most goat feeding behaviours appear to be influenced by the level of concentrate in the ration (Lu *et al*., 2008) and the physical characteristics of the fibre (Lu *et al*., 2008; Zhao *et al*., 2014). Additionally, goat feeding behaviour varies differently with the body size of different genotypes (Koluman *et al*., 2016).

Animal feeds of natural grass and total mixed rations have different crude fibre content and texture which influence feeding, rumination and chewing activity of goats (Adiwinarti *et al*., 2019). The more dietary fibre intake by goats, the longer the chewing time required (Lu *et al*., 2008). Goats fed with high fibre feed needed more time to eat and had longer feeding bouts, causing lower feed intake than goats fed low fibre feed (Adiwinarti *et al*., 2019). In comparison, goats fed with total mixed rations require more drinking water than goats fed on natural grass (Adiwinarti *et al*., 2019).

In a grassland environment, grazing has a profound influence on the diversity and spatial distribution of plant species (Adler *et al*., 2001). Selective grazing of particular species can lead to local extinction or colonisation of plant species, and changes in the within-community spatial organisation of vegetation (Pazos *et al*., 2007). Additionally, the heterogeneous spatial distribution of local disturbances induced by

livestock grazing, such as trampling, gap creation, or nutrient deposition, can also create spatial heterogeneity in plant species composition (Adler *et al*., 2001; Augustine and Frank, 2001). Similar approaches can be applied to crop production, especially in oil palm plantation scenarios. Understanding the spatial distribution of livestock movement around a plantation site can provide significant management tools for farm managers (Sanderson *et al*., 2010).

Our study assessed the grazing and browsing behaviour and management aspects of targeted goat grazing in an oil palm agro-ecosystem. Specific objectives of the study were: (i) to determine weed preference by local goats (Katjang crossbreed), (ii) determine spatial use of grazing plots by goats, and (iii) measure live weight of goats gain in response to targeted grazing on understory weeds. This study sheds new light on the application of grazing livestock as a potential biological weed control method in sustainable palm oil production.

MATERIALS AND METHODS

Study Site

This single livestock species grazing study was conducted at the Malaysian Palm Oil Board (MPOB) Keratong Research Station, Pahang, Malaysia (N 02º47′56.1″ E 102º55′37.6″) between July and August 2016. The research station is located in a 700 ha oil palm plantation, with a planting density of 136 palms per ha. The oil palm stand was 17 years old. Weed control using chemical herbicide is sprayed three to four times per year and has been the standard practice for more than 25 years.

Experimental Design and Animals

Seven, 25.0 m × 25.0 m randomly allocated grazing plots within the 700 ha plantation were erected using portable net-type electric fences, powered by 12 volt rechargeable lead battery. Individual grazing plots were divided into three rectangular strips (8.3 m × 25.0 m) with each strip allocated for one day of grazing. The grazing plots were characterised by a flat area of nine oil palm trees. A total of 11 healthy Katjang crossbreed (*Capra hircus*) goats, comprising one buck and 10 does, aged between 12 to 24 months were used in this study. The goats were fed with commercial pellets (soybean hull) and oil palm fronds leaves before the grazing commenced. Each individual goat was ear tagged for identification. Goats were released from their shelter and herded to their allocated sub-plot at 10.00 am and then herded back to their shelter at 2.00 pm daily (approximately 4 hr of grazing daily). Each goat was supplemented with 200 g soybean hull pellets and *ad libitum* supply of chopped palm oil fronds, after returning to their shelter. Goats were allowed to graze in each grazing sub-plot for one day before moving to an adjacent plot. Each goat was first weighed prior to grazing and re-weighed every seven days using a portable digital weighing scale. The mean initial doe body weight was 17.67 kg, while the buck was 31.40 kg. Prior to commencement of the targeted grazing experiment, goats were trained to familiarise with the live electric fencing. During the study period, the grazing plot areas were not sprayed with herbicides. Out of the 11 animals used in this study, unfortunately three had died due to parasite infection.

Goat Grazing Preference for Weed Species

We used scan sampling to randomly select seven individual goats and recorded the types of weed species they selected during a 15 min browsing bout. We used a digital stopwatch to record the duration of time spent browsing a particular weed species. This 15 min duration was counted as a visual observation. In this study, we recorded a total of 147 visual observations.

Spatial Use of Grazing Plot

At 15 min intervals, we determined the specific location of each goat, either at the edge (within 5 m from the fence) or at the interior (beyond 5 m of the fence) of the grazing plot. This 15 min interval was counted as a visual observation adapted from Parsons and Dumont (2003). A total of 378 visual observations were recorded.

Data Analysis

Prior to data analyses, Shapiro-Wilk's tests were performed to determine the distribution pattern of collected data. To improve the linearity of data distribution, data was either square root or log transformed. To compare the number of weed species browsed by different individual animals and grazing days (day 1-21), we performed a balanced one-way analysis of variance (ANOVA). We used *post hoc* analysis (*i.e*., Tukey's test) to conduct multiple comparisons of different treatment (grazing day) levels. To compare the grazing time between different spatial areas (edge or interior of grazing plot), we conducted an unbalanced one-way ANOVA. To compare the body weight of does, we performed a balanced one-way ANOVA and *post hoc* analysis (*i.e*., Tukey's test). The buck was excluded from the data analyses. We performed all statistical analyses in GenStat version 15 (VSNI, Hemel Hempstead United Kingdom).

RESULTS AND DISCUSSION

Weed Preference and Control

Thirteen weed species were grazed and browsed by goats (*Table 1*). Within each grazing plot, the weed cover was completely cleared after three days of grazing (*Figure 1*). There was no significant difference in the number of browsed weed species between the seven different individual goats (df=6; variance ratio=0.75; p=0.607; *Figure 2*). This result indicates that each doe was consistent with respect to the number of weed species that it could control in oil palm plantations. However, there was a significant difference in the number of weed species browsed by goats between different days (df=20; variance ratio=2.29; p=0.003; *Figure 3*).

Based on the cumulative data of time spent grazing, *Asystasia gangetica* was the most preferred weed species during the first day at each grazing plot, followed by *Clidemia hirta* (*Table 1*). There was a significant difference in time spent grazing *A. gangetica* (df=6; variance ratio=5.86; p<0.001) and *C. hirta* (df=6; variance ratio=2.29; p=0.039) between the seven individual female goats (*Figure 3*). Similarly, time spent grazing *A. gangetica* (df=20; variance ratio=5.21; p<0.001) and *C. hirta* (df=20; variance ratio=5.28; p<0.001) by the female goats was different between grazing days (*Figure 3*). Our results show that time spent browsing on *Centhotheca lappacea* (df=20; variance ratio=5.29; p<0.001) and *Ischaemacum muticum* (df=20; variance ratio=1.95; p=0.014) was significantly different between days (*Figure 3*).

Time spent grazing *Cyrtococum accrescens* was not significantly different between the seven individual does, nor between the grazing days (*Figure 3*). There was also no significant difference in time spent grazing *C. lappacea* and *I. musticum* between the seven individual does (*Figure 3*).

TABLE 1. CHECKLIST OF WEED SPECIES GRAZED BY GOATS IN AN OIL PALM PLANTATION

Species	Family	Growth habit	Duration	Cumulative time spent on feeding by goats (s)
Asystasia gangetica	Acanthaceae	Forb/herb	Perennial	31 054
Clidemia hirta	Melastomataceae	Shrub	Perennial	7 171
Centotheca lappacea	Poaceae	Graminoid	Perennial	3 558
Cyrtococum accrescens	Poaceae	Graminoid	Annual	2 518
Ischaemum muticum	Poaceae	Graminoid	Perennial	1 410
Stenochlaena palustris	Blechnaceae	Forb/herb	Perennial	250
Chromolaena odorata	Asteraceae	Shrub	Perennial	185
Nephrolepis biserrata	Lomariopsidaceae	Forb/herb	Perennial	96
Davallia denticulata	Davalliaceae	Forb/herb	Perennial	84
Adiantum latifolium	Pteridaceae	Forb/herb	Perennial	75
Vittaria elongata	Pteridaceae	Forb/herb	Perennial	46
Paspalum dilatum	Poaceae	Graminoid	Perennial	3
Paspalum conjugatum	Poaceae	Graminoid	Perennial	1

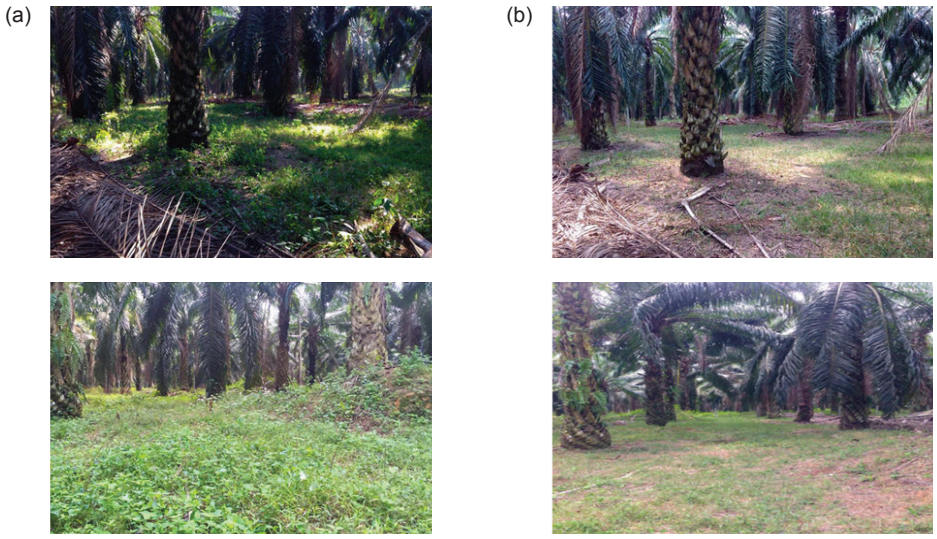

Figure 1. (a) Weed cover in oil palm plantations before, and (b) after targeted goat grazing over three days.

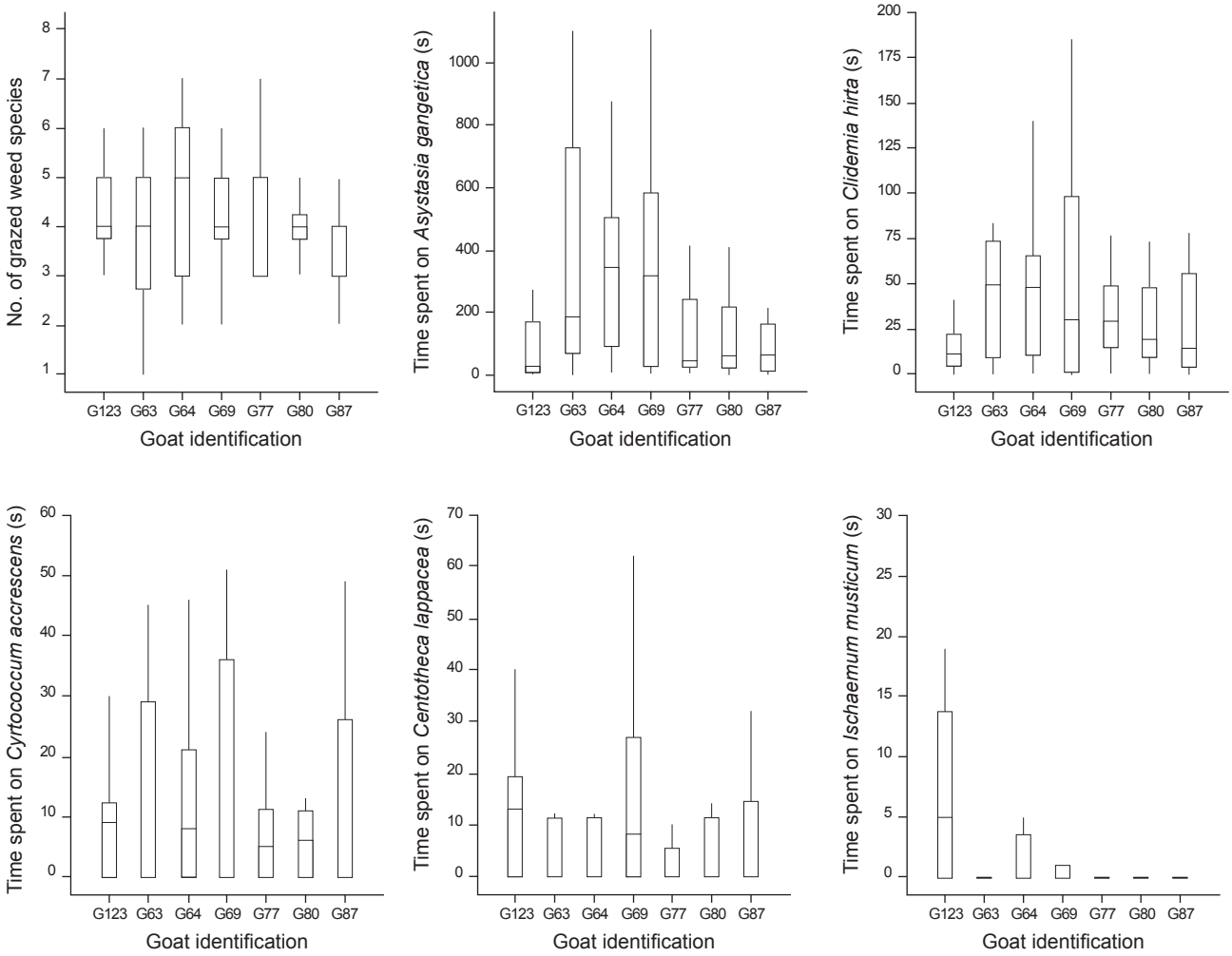

Figure 2. Boxplots of the number of weed species grazed, and top five weed species preferred by goats with respect to individual animals grazing time within grazing plots in an oil palm plantation.

Spatial Use of Grazing Plots

No significant difference in spatial use between edge and interior areas of grazing plots was observed (df=1; variance ratio=0.13; p=0.718). The goats grazed evenly throughout the grazing plots without displaying spatial bias towards the edge or interior areas. In addition, grazing days had no significant effect on spatial use (df=2; variance ratio=1.04; p=0.355).

Live Body Weight Gain

There was no significant difference in body weight, before and after grazing, among the 10 does (df=4; variance ratio=0.87; p=0.488; *Figure 4*). Our data indicate that the body weights decreased in the first week ($\bar{x}$=16.82 kg; day 7) and second week ($\bar{x}$=17.19 kg; day 14), but gradually increased in the third week ($\bar{x}$=17.83 kg; day 21) and fourth week ($\bar{x}$=18.25 kg; day 28; *Figure 4*).

Goat Preferences for Weed Species

Our data indicate Katjang crossbreed goats consume ground level weeds, but they also browse taller and woodier vegetation. As efficient browsers, goats have a unique character that distinguishes them from almost all other types of livestock. Browsing makes up approximately 60% of a goat's activity but only about 10%-15% of a cow's activity (Bull, 2000). In oil palm plantations, prevalent weeds species such as *A. gangetica*, *C. hirta* and *C. odorata* are readily available and have become the common plant species of the understory ground layer of Malaysian oil palm plantations (Wibawa *et al*., 2009). This study suggests that these three weed species have lower fibre content. Goats prefer to browse weed species with greater palatability and lower fibre content (Nampanzira *et al*., 2015), with *A. gangetica* being the most preferred species (Achonwa *et al*., 2017).

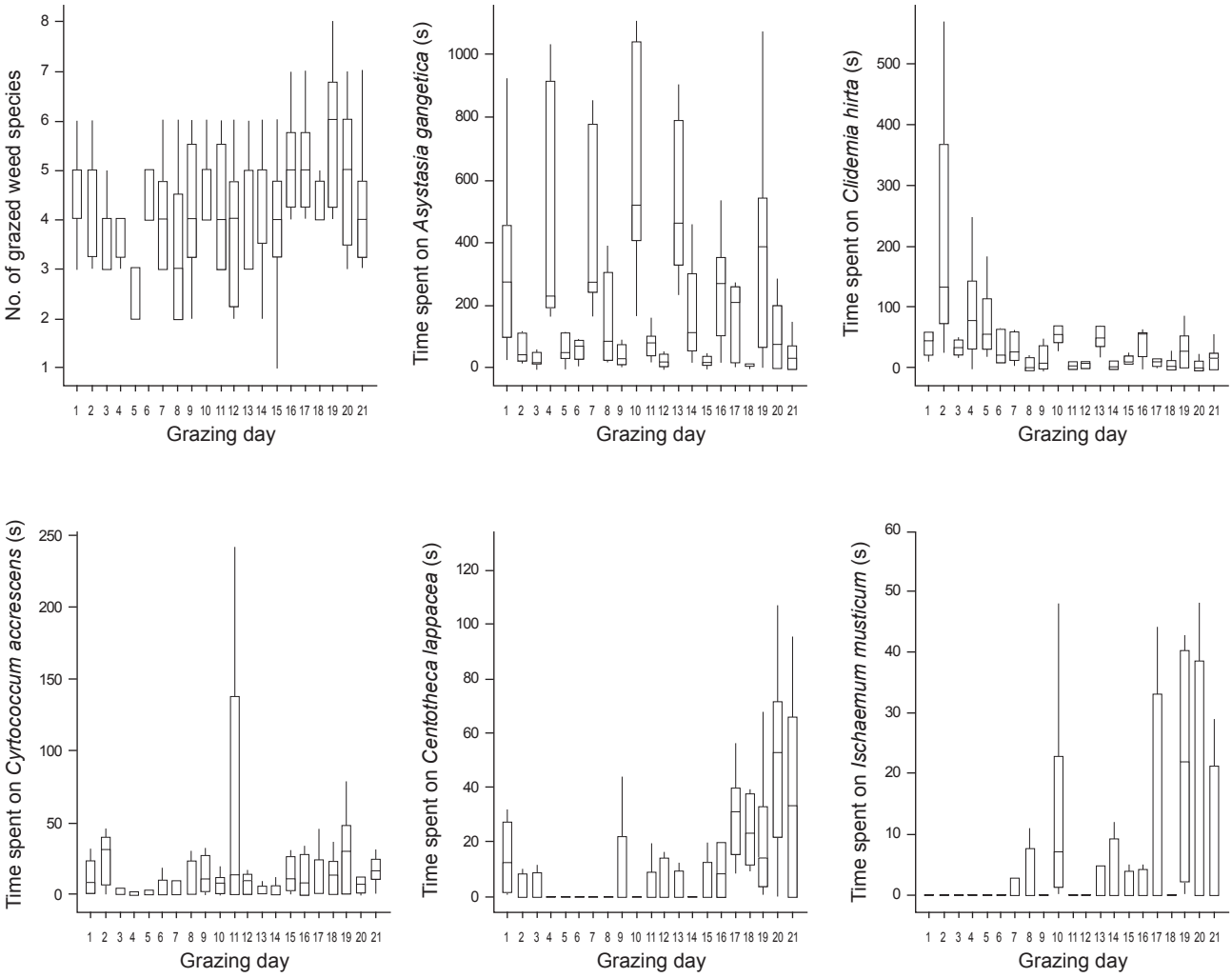

Figure 3. Boxplots of the number of weed species and top five weed species preferred by goats with respect to grazing day in an oil palm plantation.

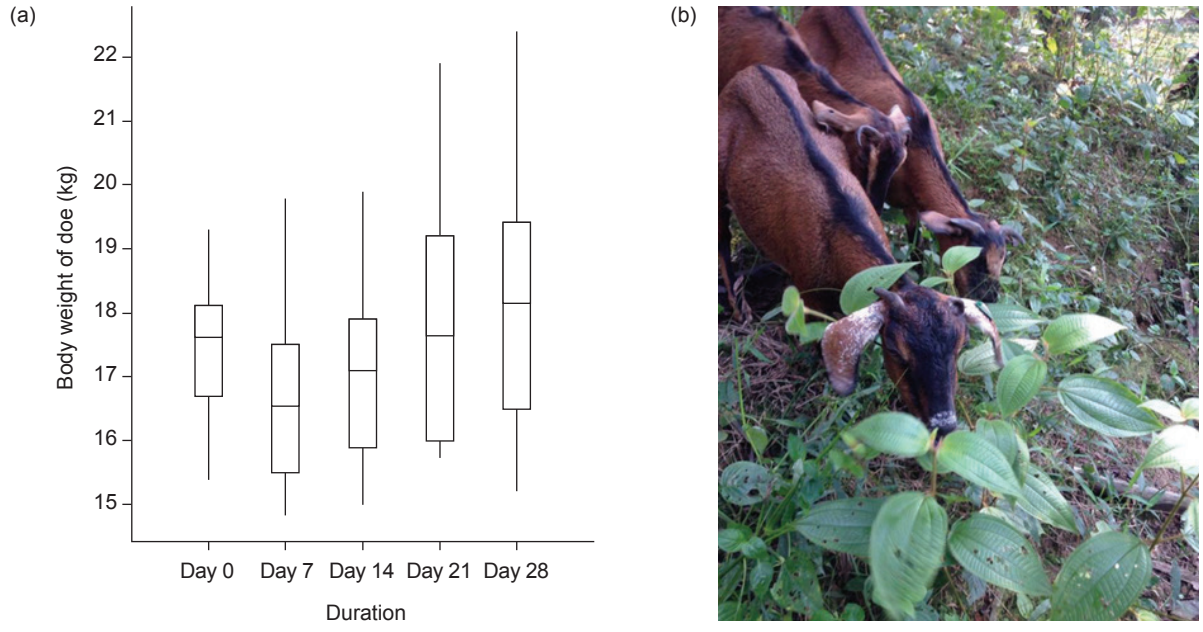

Figure 4. (a) Goat performance during the implementation of targeted grazing and (b) goats browse weeds that would be conventionally controlled by herbicides in oil palm plantations.

Understanding goat grazing behaviour in oil palm plantation areas is important knowledge for a plantation's manager if they wish to practice targeted grazing for weed control as an alternative to herbicide application. Goats and sheep have been shown to graze or browse in cyclic patterns, devouring substantial amounts of weed species during one grazing period, followed by low weed consumption in the following period (Launchbaugh *et al*., 2006). Our results indicate that goat selection was consistent across all scales which is consistent to the finding of Skarpe *et al*. (2007). Of the weed species present, goats selected to browse from relatively high trees and from trees with signs of previous browsing which is also consistent with Skarpe *et al*., 2007. Goats are known to be agile compared with cattle and sheep, frequently using a bipedal stance and climbing to gain access to vegetation of interest (Animut and Goetsch, 2008).

Goats prefer to browse several plant species that are considered weeds in typical oil palm plantation, *e.g*., *C. hirta* and *C. odorata*. In addition, goats are known for their consumption of seeds and reproductive stems, and the ability to decrease spread of some undesirable plant species (Animut and Goetsch, 2008). By using goats, control of unwanted weed species in oil palm plantations can be achieved via frequent defoliation of the undesirable species, removal of active growing points, and at high and frequent enough intensities to deplete root energy reserves. However, this may require standard or even higher stocking rates (Gabdo and Abdlatif, 2013).

The first objective of the study was to investigate weed species preferences by local Katjang crossbreed goats as a potential management practice to control weeds in the oil palm plantation. In our study, most of the weeds selected by goats were as nutritious as some common grass species available at the plantation *i.e*., *Centotheca lappacea, Cyrtococum accrescens* and *Paspalum dilatum* (Gibson, 2009). Careful planning for utilising the weeds will produce reasonable goat performance. It is reasonable to maintain and leave some weed cover for the next defoliation. Appropriate utilisation of the weeds so as not to kill them may result in underutilisation of the weeds biomass, due to goat browsing preferences.

Spatial Use of Grazing Plots

Our findings highlight that targeted goat grazing controls weed cover consistently throughout the grazing plots. It also indicates that goats are an effective biological control agent for weeds in an oil palm plantation and that portable net electric fencing is indispensable in managing the movement of goats during grazing. The stocking density (*i.e*., approximately 5 m^2 per goat per hr) is sufficient to clear the weeds in oil palm plantation. High stocking density stimulates feeding behaviours that increase utilisation of weed biomass by goats (Utsumi *et al*., 2010).

Goat Performance

The goats used in this study did not show an overall increase in body weight. The goats lost weight in the first half of the experiment and regained body weight again in the latter half of the grazing period. Our results indicate that goats can browse on weeds in oil palm plantations, without a severe decrease in live weight gain. Goat's live weight gain may be improved by adjusting stocking rates and the intensity and frequency of defoliation of the target weed species. The information gained here from the first objective, that goats show higher browsing preferences for the most prevalent weed species, which can help to refine future studies on managing goat browsing of weeds to achieve live weight gain targets as well as desired weed control.

Common weed plants in oil palm plantations can provide high forage value for livestock (Tohiran *et al*., 2014; 2017; 2019a; 2019b). The leaves and parts of woody plants browsed by the goats in oil palm plantations can be highly nutritious (Tohiran *et al*., 2014). Animal body weight indicates the type and amount of vegetation present (Launchbaugh *et al*., 2006). Hence, goat performance depends on stocking density allowing for selection of most nutritious weeds, grazing time, and on the level of supplementary stall feeding.

Future of Targeted Grazing for Weed Management

Targeted goat grazing practice is an environmentally sound method for controlling weeds in mature (*i.e*., more than five years) oil palm plantations. Moreover, this practice of using livestock grazing or browsing for short periods at high intensity can reduce the presence of pest plants (Launchbaugh *et al*., 2006). This agricultural practice, which integrates commodity crop and livestock production, inclines toward integrated pest management and reduced synthetic herbicide inputs. Our study revealed that goats fed on a diverse weed community, grazed weeds evenly throughout the grazing plots, and overall maintained similar body weight over the course of grazing in the plantation. This can address a number of the criteria for sustainability defined by the MSPO and other palm oil certification schemes (*e.g*., the RSPO). These include safe (or reduced) use of agrochemicals to protect human health and the environment, and application of integrated pest management systems to control weeds. In addition, oil palm-livestock integration practice in

the manner of targeted grazing is compatible with the United Nations Sustainable Development Goals (SDGs).

Targeted grazing can be used to accomplish vegetation management goals (*e.g.*, lowered costs for management weed control (Frost *et al*., 2012). As such, targeted grazing is being rediscovered as a viable and chemical-free tool to control weeds in Southeast Asia (Tohiran *et al.*, 2014; 2019b) which can be practically applied for sustainable palm oil production and enhanced biodiversity conservation in conventional oil palm agriculture (Tohiran *et al*., 2017; 2019a; 2019b). Further experiments are required to optimise the application of targeted grazing in oil palm plantations. These may include studies on vegetation structure and composition, soil compaction, multiple stocking density and grazer species/breeds, organic carbon level in soil, and wider ecological impacts (Launchbaugh *et al*., 2006).

CONCLUSION

The application of targeted goat grazing to control weeds in oil palm plantations can be agriculturally effective. Our study shows that targetted grazing with livestock can be as effective as herbices application in palm oil plantation (Tohiran *et al*., 2017). We recommend the floristic composition of weeds and ground coverage area to be measured in the future, in order to estimate the stocking density of the animal for weed control application. Livestock integration with oil palm agriculture in the manner of targeted grazing should be promoted as a part of integrated pest management to manage weeds.

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