Endozoochory has been extensively studied in the past, and has recently gained new momentum. The role of herbivorous mammals as endozoochorous seed dispersers has been recently highlighted (Willson, 1993; Pakeman et al., 2002; Myers et al., 2004), and several studies have proved the presence of seeds in the dung of wild and domestic herbivores (Sánchez & Peco, 2002; Manzano et al., 2005; Ramos et al., 2006; Kuiters & Huiskes, 2010; De la Vega & Godínez-Álvarez, 2010; Mancilla-Leytón et al., 2011, 2012). In addition, several seed characteristics such as size, hardness, shape, and the fruit in which they are contained are very important factors that also affect seed dispersal by animals (Janzen, 1986). Since herbivorous mammals have a long seed residence time in guts (24 to 72 h) (Olson & Wallander, 2002; Mancilla-Leytón et al., 2011) and make long-distance routes (Cory, 1972; Klein, 1981), they can promote the rapid dispersal of plant populations. Due to the particular feeding habits and ranging behavior of browsers (Morand-Fehr et al., 1983; Devendra, 1990; Milne, 1991), herbivores such as domestic goats can be seed dispersers.

It has been documented that goats can disperse the seeds of shrub species in arid and semiarid regions of Mexico (Baraza & Valiente-Banuet, 2008; Giordani, 2008), and various herbaceous species in New Zealand.
(Harrington et al., 2011) or the United States (Lacey et al., 1992). In Spain, its dispersal role has been studied for legume shrubs such as *Adenocarpus decorticans* and *Retama sphaerocarpa* (Robles et al., 2005), or Mediterranean shrubs such as *Cistus salvifolius*, *Halimium halimifolium*, *Myrtus communis* and *Pistacia lentiscus* (Mancilla-Leytón et al., 2011). Nevertheless, the available information related to other common Mediterranean shrubs that goats eat is limited, and little attention has been given to its role as seed dispersers of the browsed shrub species.

The aims of this study were to determine if goat gut passage affected the germination of seeds from five common Mediterranean shrub species, and if seed inclusion in faeces had effects on seedling emergence and growth. The following questions were therefore addressed: i) which is the percentage of recovery seed after the digestive process?, ii) which seed properties influence recovery?, iii) what is the temporal pattern of seed recovery after ingestion?, and iv) how does ingestion by goats affect the recruitment of the studied species?

**Material and methods**

**Seed selection and biometric characteristics**

Five common Mediterranean shrub species of high forage value and widely spread in the Mediterranean region (Valdés et al., 1987) were selected: *Cistus albidus* L. (Cistaceae), *Phillyrea angustifolia* L. (Oleaceae), *Calicotome villosa* (Poir.) Link. (Fabaceae), *Rhamnus lycioides* L. (Rhamnaceae) and *Atriplex halimus* L. (Chenopodiaceae). The seeds were obtained from a forestry nursery (Semillas Silvestres, S.L.) in Cordoba, Spain.

In order to determine average seed volume, 100 seeds of each species were measured with an electronic vernier caliper. Rupture strength (hardness) of each seed was also measured with a digital force gauge (PCE-FM50).

**Seeds retrieved after gut passage**

Six adult female Payoya goats of similar size and age (3-year old, 40-45 kg average weight) were individually housed at the Teaching and Experimental Farm of the Faculty of Agriculture, University of Seville. Goats were kept in individual metabolic pens with a collector system for faeces, where they were fed. At the beginning of the experiment, each goat was offered a high number of seeds from each species (21,388 seeds: 5,000 seeds of the species *C. albidus*, *P. angustifolia*, *R. lycioides* and *A. halimus*, plus 1,388 seeds of *C. villosa*) in order to ensure that some passed the goats guts. Seeds were mixed with barley grains (250 g) to facilitate intake (Mancilla-Leytón et al., 2011), and offered for roughly one hour until fully consumed by goats. From then on, goats were fed alfalfa hay and barley grain, and had free access to water. All dung pellets produced by each goat were collected every 24 h for five days (0-24, 24-48, 48-72, 72-96 and 96-120 h after seed ingestion), and dried at room temperature for 72 h in a bell jar with silica gel to avoid seed fermentation and damage. The dung was then broken down for seed retrieval: 20 subsamples of 4 g of dung were daily taken per goat, and the number of seeds recorded. The average number of seeds retrieved from daily subsamples was extrapolated to the total daily dung amount per animal, thus providing an estimate of the daily percentage of seed recovery (PR) through the following expression: 

\[
PR = \left( \frac{Mf \cdot Sr}{4S} \right) \times 100
\]

where \(Mf\) is the total daily mass of faeces (time interval), \(Sr\) is the average number of seeds retrieved per subsample (4 g of pellet), and \(S\) is the number of seeds ingested per goat (Mancilla-Leytón et al., 2012).

**Seed germination after gut passage**

The germination of seeds retrieved from goat dung during the two time intervals of greatest seed recovery rates was compared to the germination of seeds that remained uneaten. Each species seeds ingested during the same time interval (day) by every goats were pooled for this experiment. Seeds from *C. albidus*, *C. villosa* and *A. halimus* were classified under three categories: (1) control, seeds that were not eaten; (2) 24-48 h, seeds retrieved between 24 and 48 h after ingestion; (3) 48-72 h, seeds retrieved between 48 and 72 h after ingestion. In the case of *R. lycioides* and *P. angustifolia* seeds, categories were: control, 48-72 h and 72-96 h. Very few seeds were retrieved during the other time intervals, and thus were not tested.

Some of the seeds retrieved were partially broken, missing part of the cotyledons but with an intact embryo. Since the number of broken seeds was very low in all species (< 0.02% retrieved seeds), they were not
tested for germination. Only seeds with no evidence of apparent external damage after examination under a microscope were used for the germination experiment.

Seeds of all treatments were disinfected by a 2-min immersion in a 1% sodium hypochlorite solution, and thoroughly rinsed with sterile distilled water (10 min). Each species seeds were then placed on filter paper in 5-cm Petri dish. Each Petri dish contained 25 seeds, with 4 replicates per treatment. Distilled water (3 mL) was added to each dish, which were then wrapped with parafilm and placed in a germinator (ASL Aparatos Científicos M-92004, Madrid, Spain) for 60 days with a regime of 12 h of light (25°C, 35 µmol m−2 s−1, 400-700 nm) and 12 h of darkness (12°C). This temperature regime was chosen to resemble the end of autumn temperatures in Mediterranean climates, when these species germinate. The dishes were inspected daily and germinated seeds were counted and removed. We considered that seeds had germinated after root emergence (1-2 mm). The water level was also adjusted daily with distilled water.

Three germination parameters were determined: final germination percentage, time of first germination and mean time to germination (MTG), calculated as: 

\[ \text{MTG} = \frac{\sum (n_i \cdot d_i)}{N} \]

where \( n_i \) is the number of seeds germinated at day \( i \), \( d_i \) the incubation period in \( i \) days, and \( N \) is the total number of seeds that germinated in the whole treatment (Brenchley & Probert, 1998).

**Viability test**

The tetrazolium test was applied to four 20-seed replicates of each species collected both from pellets and from uneaten seeds (control), to determine the viability of the embryos (MacKay, 1972). Seeds were kept in water during 16 h at a constant 25°C temperature, and then submerged in a 1% aqueous solution of 2,3,5-triphenyl-tetrazolium chloride, pH 7, in darkness for 24 h at a constant temperature of 25°C. Seeds were then dissected and embryo analysed with a magnifying glass (Bradbeer, 1998).

**Seedling emergence from dung**

The effect of being contained in dung for seedling emergence was tested in a greenhouse experiment. Three treatments were applied: 1) seeds retrieved from intact dung, 2) seeds retrieved from broken-down dung, simulating crumbling of pellets under natural conditions (i.e. rainfall or animals trampling the pellets) (Mancilla-Leytón et al., 2012) and 3) seeds not ingested by goats. In each of the dung treatments (1 and 2), 16 pots with 12 g of dung were placed on the surface of a sand/vermiculite mixture (1:1), eight pots with dung collected in the first time interval of greatest seed recovery, and another eight with dung collected during the second greatest seed recovery time interval (24-48 and 48-72 treatments for C. albidus, C. villosa and A. halimus; 48-72 and 72-96 h treatments for R. lycoides and P. angustifolia). In the third treatment (control group), eight pots each containing 20 seeds which had not passed through the goats guts were also placed on the surface of the sand/vermiculite mixture. All pots were randomly placed in the greenhouse with day/night temperature of 25/15°C and watered by imbibition with tap water, providing the same amount of water to all replicates. Emergence of seeds was daily monitored for 60 days. The biomass and height of the seedlings emerged in each treatment were measured at the end of the experiment.

The percentage of seedlings established (PE) at the end of the sampling period was estimated for each species by a similar procedure to seed recovery: 

\[ \text{PE} = \frac{100 \cdot \text{Se}}{3 \cdot \text{Sr}} \]

where \( \text{Se} \) is the average number of seedlings established of a species, and \( \text{Sr} \) is the average number of seeds found in 4 g of pellets (based on 20 subsamples).

**Data analysis**

To assess whether seed recovery is related to characteristics of the seeds (length, width, volume, hardness), a multiple regression model was performed. Differences among biometric characteristics, total number of seeds retrieved from dung between treatments, total number of germinated seeds, time to first germination, mean germination time, seed viability and number and sizes of seeds emerged from uneaten seeds, and retrieved from intact and crumbled dung collected at different time intervals were statistically evaluated through performance of one-way ANOVA analysis. After testing the variables for normality using the descriptive statistics of asymmetry and kurtosis, ANOVAs were performed with either log-transformed data (mean time of germination or MTG, mean time of emergence or MTE) or raw data (rest of variables). Tukey test was performed to evaluate significant differences among
treatments. All statistical analyses were carried out with SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA).

**Results**

**Seed biometric characteristics and recovery after gut passage**

The characteristics of seeds are listed in Table 1. All biometric variables showed significant differences between species. *R. lycioides, P. angustifolia* and *C. villosa* seeds were significantly longer, wider and showed larger volumes than the rest of the seeds (F = 54.58, F = 26.97 and F = 17.64, p ≤ 0.05, respectively). *C. salviifolius* and *C. villosa* seeds displayed the greatest resistance to breakage (F = 56.292, p ≤ 0.05).

The total percentage of seeds retrieved from goat faeces widely varied among species with *R. lycioides* registering the lowest recovery rate (1.3%) and *C. albidus*, the highest (35.8%) (Fig. 1). The largest total amounts of retrieved seeds correspond to *C. albidus* (1795) and *C. villosa* (330), accounting for 35.8 and 23.7% of the seeds eaten by the goats, respectively, while the amounts of seeds retrieved of *A. halimus* (4%), *P. angustifolia* (2.7%) and *R. lycioides* (1.3%) were significantly lower (Fig. 1). The number of seeds retrieved per time interval differed among all species, with most species registering seed recovery between 48-72 h after ingestion, although goats defecated seeds of *C. albidus, P. angustifolia* and *C. villosa* until the end of the experiment (fifth day of sampling)

After verifying the normality, homoscedasticity and absence of autocorrelation, the results of multiple regression model showed the existence of a significant relationship between seed recovery and hardness and length of the same ($R^2 = 0.71$, F = 28.14; $p ≤ 0.001$) described by the following equation: % recovery = 9.64 + + (1.34 · hardness) – (4.92 · length).

**Seed germination after gut passage**

Passage through the goat gut only significantly increased seed germination in *P. angustifolia* (Tukey test, $p ≤ 0.05$) (Fig. 2). In contrast, it decreased seed germination in *C. villosa, A. halimus* and *C. albidus*, although no statistical differences were found (Tukey test, $p ≥ 0.05$). Finally, none of the *R. lycioides* seeds eaten by goats germinated as opposed to the control seeds (4%), proving that goat gut passage had an inhibitory effect in seed germination of this species (Fig. 2).

The number of days to first germination and mean time of germination (MTG) and viability are shown in Table 2. Only seeds retrieved from *A. halimus* (24-48 h)

![Figure 1. Percentage of seeds (mean, n = 6) retrieved from goat faeces 24, 48, 72, 96 and 120 hours after consumption in the five species studied. Different letters indicate significant differences among species in the total number of seeds retrieved (Tukey test; $p ≤ 0.05$).](image)

**Table 1. Seed biometric characteristics of the five species studied (mean ± SE, n = 100)**

| Species          | Length (mm) | Width (mm) | Volume (mm$^3$) | Hardness (N) |
|------------------|-------------|------------|-----------------|--------------|
| *Cistus albidus* | 1.36 ± 0.07a| 0.95 ± 0.08a| 0.63 ± 0.09a    | 25.60 ± 2.59a|
| *Calicotome villosa* | 3.31 ± 0.06b| 2.64 ± 0.08b| 11.59 ± 0.93a   | 20.48 ± 1.38a|
| *Atriplex halimus* | 1.34 ± 0.12a| 1.24 ± 0.15a| 1.03 ± 0.03a    | 3.08 ± 0.38a |
| *Phillyrea angustifolia* | 4.75 ± 0.02c| 2.98 ± 0.02c| 22.01 ± 2.56c   | 16.03 ± 0.66d|
| *Rhamnus lycioides* | 4.47 ± 0.03c| 2.30 ± 0.11b| 11.88 ± 0.91b   | 7.83 ± 0.34c |

Different letters indicate significant differences among treatments within each species (Tukey test; $p ≤ 0.05$).
and 48-72 h) and *C. villosa* (24-48 h) showed significantly lower time to first germination than control seeds. Also, passage through the goat gut significantly shortened germination time of retrieved seeds from *A. halimus* and had no effect in rest of species (Table 2). Finally, the tetrazolium test showed no significant differences in the viability percentages among control seeds and seeds retrieved from goat faeces in *C. albidus* and *C. villosa*. In the case of *A. halimus, P. angustifolia* and *R. lycioides*, control seeds were significantly more viable than defecated ones (*p* ≤ 0.05) (Table 2).

### Seedling emergence

The seedling emergence rate and MTE are shown in Table 3. There was seedling emergence from control seeds of all species except *P. angustifolia*. The lowest percentage of emergence in the control treatment was found in *C. albidus* seeds (6.2%), while the largest was registered in *A. halimus* seeds (57.5%). There was no seedling emergence in intact faeces for any species (Table 3). Seedling emergence in crumbled faeces was only registered in *C. villosa* and *A. halimus* seeds retrieved 24-48 and 48-72 h after ingestion.

Seedling emergence in *C. villosa* seeds retrieved from crumbled faeces at the 24-48 h interval (55%) was slightly higher than control seeds (51.2%), although no significant differences were found (Tukey test; *p* ≥ 0.05). Meanwhile, this species showed a significantly lower emergence of seedlings in seeds retrieved at the 48-72 h interval (7.9%) (Table 3). On the other hand, seedling emergence was significantly lower in *A. halimus* seeds retrieved at the 24-48 h (6.9%) and 48-72 h (3.7%) intervals when compared to control seeds (57.5%) (Table 3).

### Table 2. Number of days to first germination, mean time of germination (MTG) and viability of the control and defecated seeds. Values are mean ± SE (n = 4)

| Species          | Treatment                  | 1st Germination (d) | MTG (d) | Viability (%) |
|------------------|----------------------------|---------------------|---------|---------------|
| *Cistus albidus* | Control                    | 30.0 ± 6.8 a        | 28.3 ± 7.7 a | 82.0 ± 2.6 a |
|                  | Retrieved 24-48 h          | 30.2 ± 12.4 a       | 35.2 ± 10.7 a | 80.1 ± 2.7 a |
|                  | Retrieved 48-72 h          | 36.0 ± 8.0 a        | 40.2 ± 10.0 a | 80.2 ± 6.1 a |
| *Calicotome villosa* | Control                  | 8.0 ± 1.7 a         | 23.9 ± 0.7 a  | 94.1 ± 1.2 a |
|                  | Retrieved 24-48 h          | 12.0 ± 0.5 b        | 26.8 ± 1.0 b  | 91.6 ± 4.2 a |
|                  | Retrieved 48-72 h          | 8.2 ± 1.0 a         | 27.5 ± 1.2 a  | 91.6 ± 3.2 a |
| *Atriplex halimus* | Control                   | 4.0 ± 0.2 a         | 6.4 ± 1.4 a   | 86.1 ± 2.0 a |
|                  | Retrieved 24-48 h          | 1.0 ± 0.1 b         | 2.3 ± 0.5 b   | 60.7 ± 5.8 b |
|                  | Retrieved 48-72 h          | 1.7 ± 0.7 b         | 4.5 ± 1.1 b   | 42.5 ± 13.8 b |
| *Phyllirea angustifolia* | Control                | NG                  | NG          | 94.3 ± 2.0 a |
|                  | Retrieved 48-72 h          | 4.7 ± 2.4 a         | 9.5 ± 2.4 a   | 65.9 ± 6.5 b |
|                  | Retrieved 72-96 h          | 5.2 ± 6.3 a         | 10.5 ± 5.2 a  | 60.7 ± 3.6 b |
| *Rhamnus lycioides* | Control                   | 4.7 ± 3.8           | 9.5 ± 3.8 a   | 89.0 ± 1.9 a |
|                  | Retrieved 48-72 h          | NG                  | NG          | 35.7 ± 1.7 b |
|                  | Retrieved 72-96 h          | NG                  | NG          | 33.3 ± 2.7 b |

Different letters indicate significant differences among treatments within each species (Tukey test; *p* ≤ 0.05). NG: not germinated.
The MTE in seedlings of *C. villosa* emerged from seeds retrieved 24-48 h (23.7 days) and 48-72 h (17.4 days) after ingestion were shorter than that of seedlings from control seeds (28.1 days), although no significant differences were found. The same tendency was observed in seedlings of *A. halimus* at 24-48 and 48-72 h intervals, including the lack of significant differences with the control treatment (Table 3).

In *C. villosa* seedlings emerged from seeds recovered at the 24-48 and 48-72 h intervals, a tendency to higher biomass and height of the aerial portion was registered when compared with control seeds, with no significant differences found; the same pattern was also observed in seedlings of *A. halimus* emerged from seeds retrieved from crumbled faeces 24-48 and 48-72 h after ingestion (Table 3). On the other hand, the biomass and length of the roots of *C. villosa* seedlings emerged from seeds retrieved at the same sampling times were also generally larger than those of the control treatment, although less prominently than in the aerial part case. Contrastingly, the biomass and length of the roots of *A. halimus* seedlings showed a clear tendency to increase along the subsequent recovery intervals when compared with the control treatment, although no significant differences were found (*p* ≥ 0.05) (Table 3).

**Discussion**

The percentages of *C. albidus* seeds retrieved (35.8%) from goat dung are similar to those obtained for *C. salvifolius* (30%) by Mancilla-Leytón et al. (2011). This can be related to the hardness of their seeds, characteristic of Cistaceae family, in addition to its small size (see Table 1), which increased their resistance to mastication and rumination (Castro & Robles, 2013).

**Table 3.** Seedlings emergence rate, mean time of emergence (MTE), biomass and height or length of seedlings emerged from intact and crumbled faeces collected 24-48 and 48-72 hours after ingestion. Values are mean ± SE (n = 8)

| Species         | Treatment               | Emergence (d) | MTE (d) | Aerial portion | Roots          |
|-----------------|-------------------------|---------------|---------|----------------|----------------|
|                 |                         |               |         | Biomass (mg)   | Height (cm)    |
|                 |                         |               |         | Biomass (mg)   | Length (cm)    |
| *Cistus albidus*| Control                 | 6.2 ± 2.3     | 28.1 ± 12.0 | 10.0 ± 0.0 | 1.6 ± 0.4 | 9.3 ± 0.0 | 2.8 ± 0.4 |
|                 | 24-48 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 24-48 h crumbled faeces  | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h crumbled faeces  | NE            | NE      | NE             | NE             | NE        | NE        |
| *Calicotome villosa*| Control               | 51.2 ± 4.2a   | 28.1 ± 4.1a | 29.2 ± 2.9a | 7.4 ± 2.6a | 12.2 ± 1.2a | 17.6 ± 1.3a |
|                 | 24-48 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 24-48 h crumbled faeces  | 55.0 ± 10.3a  | 23.7 ± 2.0a | 37.2 ± 6.2a | 11.5 ± 0.8a | 15.7 ± 1.7a | 12.7 ± 0.9a |
|                 | 48-72 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h crumbled faeces  | 10.8 ± 3.3a   | 17.4 ± 7.6a | 37.5 ± 9.6a | 7.4 ± 2.2a | 12.5 ± 2.5a | 11.2 ± 4.0a |
| *Atriplex halimus*| Control                 | 57.5 ± 9.2a   | 4.5 ± 0.4a  | 16.7 ± 4.1a | 3.9 ± 0.4a | 4.6 ± 0.9a | 14.8 ± 2.3a |
|                 | 24-48 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 24-48 h crumbled faeces  | 6.9 ± 3.4a    | 3.5 ± 1.0a  | 29.3 ± 4.4a | 2.0 ± 1.1a | 6.0 ± 2.9a | 13.8 ± 1.9a |
|                 | 48-72 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h crumbled faeces  | 3.7 ± 4.9b    | 1.5 ± 1.8a  | 26.8 ± 5.9a | 4.5 ± 1.9a | 5.8 ± 2.2a | 14.0 ± 0.9a |
| *Phyllirea angustifolia* | Control           | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h crumbled faeces  | NE            | NE      | NE             | NE             | NE        | NE        |
| *Rhamnus lycioides*| Control                | 5.0 ± 3.3     | 9.3 ± 1.3  | 4.4 ± 0.6     | 2.6 ± 0.2     | 4.4 ± 0.6 | 8.8 ± 1.1 |
|                 | 48-72 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 48-72 h crumbled faeces  | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 72-96 h intact faeces    | NE            | NE      | NE             | NE             | NE        | NE        |
|                 | 72-96 h crumbled faeces  | NE            | NE      | NE             | NE             | NE        | NE        |

Different letters indicate significant differences among treatments within each species (Tukey test; *p* ≤ 0.05). NE: no emergence.
plained by the primary seed dormancy (physical dormancy) imposed by the hard seed coat (Thanos et al., 1992; Baskin et al., 2000), characteristic of this botanical family. The passage through the goat gut did not soften C. villosa seeds coat, therefore not improving germination, but neither caused damage to the embryo which would have adversely affected seed germination, as evidenced by the viability percentages of seeds obtained in the tetrazolium test (Table 2). On the contrary, the passage through the goat gut did soften the seed coat of A. halimus, decreasing the viability of ingested seeds.

The germination enhancement registered in P. angustifolia seeds after goat gut passage is remarkable, since this species seeds show a primary dormancy (physical dormancy) imposed by a hard seed coat (Table 1 and Takos & Efthimiou, 2003). As a consequence, various pre-germination treatments have been suggested to promote this species germination including sulfuric acid or hot water immersion, or a combination of either methods, or stratification in wet sand for several months (Takos & Efthimiou, 2003). In the case of R. lycioides seeds, goats behaved as seed predators, this finding also being reported for other shrub species such as P. lentiscus (Mancilla-Leytón et al., 2011).

The complete absence of seedling emergence in the intact faeces could be explained by the tight structure of goat dung pellets, which can act as a mechanical barrier to seedling emergence, and fades out when pellets are broken-down. Consequently, trampling by grazing animals, rainfall and coprophagous insects that break-down the dung are necessary for seedling establishment, especially for species that cannot emerge from intact dung (Mancilla-Leytón et al., 2012). The clear tendency to higher biomass and height of the C. villosa and A. halimus seedlings emerged from crumbled faeces compared with control seedlings, could be related to the higher nutrient content of organic matter in faeces than in the vermiculite substrate and to a higher water retention capacity of crumbled faeces (Malo & Suárez, 1998; Traveset & Verdú, 2002).

As conclusion, the size and hardness effect of seeds, the goat’s gut passage effect and the mechanical effect of pellets, are important criteria to consider the dispersion of seeds, and these have been evident in this study. Unravelling zoocorous dispersal mechanisms in a semi-natural environment may therefore offer both fundamental and necessary applicable ecological knowledge. The incorporation of wild plant Mediterranean
species into the diet of domestic grazers can be an important step to disperse those species in Mediterranean areas. Goats can potentially favor or inhibit seed dispersion of the plants that they eat. Goat grazing could also be used as a management tool for spreading populations of target shrub species or to prevent shrub encroachment in undesired areas. Therefore, these results should be considered when developing conservation and restoration plans of natural vegetation after major disturbances (fire, tillage, crop abandonment, etc).

Acknowledgements

The authors thank Mr. Jose Ardila and Dehesa de Gatos S.L. for their help and collaboration. Special thanks to Ms. Yolanda Paz for her great support and dedication in processing the samples in the laboratory, and Mr. Oscar Andrade for field assistance. This study was partially supported by the Consejería de Medio Ambiente (Junta de Andalucía, OG-052/07). J.M. Mancilla-Leytón gratefully acknowledges an FPDI grant (Junta de Andalucía). Dra. Raquel Fernández lo Faso revised the English version of the manuscript.

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