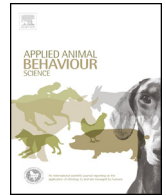




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Targeted grazing of milk thistle (*Silybum marianum*) and Syrian thistle (*Notobasis syriaca*) by goats: Preference following preconditioning, generational transfer, and toxicity

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ABSTRACT

Nitrophilic thistles such as milk thistle (*Silybum marianum*) and Syrian thistle (*Notobasis syriaca*) encroach rangeland areas where animals gather and defecate, in particular around watering and feeding points. High densities of milk and Syrian thistles (MST) diminish forage yields and detract from the amenity value of these areas. The aims of the present study were: (i) to test the safety of feeding MST to adult goats; (ii) to determine if preconditioning adult goats to MST, by feeding it indoors together with concentrate, enhances preference for MST when they graze MST-rich pastures; and (iii) to test for generational transfer by comparing the propensity to consume MST and the preference for MST over clover hay for weaned kids that previously suckled from does that were, or were not, preconditioned to consume MST fed as green fodder. We found that eating MST was not toxic to adult goats. Over six observation sessions of one hour, preconditioned goats devoted 50% more time to consuming MST than non-conditioned counterparts (30.3% versus 20.6%, respectively; $P = 0.0005$), and kids that experienced the preconditioning period together with their does tended ($P = 0.08$) to show a greater preference for MST over clover hay than their counterparts born to non-conditioned adults. Although the efficacy in depleting the seed bank has yet to be verified, from the point of view of the animal, goats may be used in targeted grazing of milk and Syrian thistles.

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1. Introduction

Annual and bi-annual thistles from the Compositae family decrease yields of crops (Khan et al., 2009) and pastures (Grekul and Bork, 2004) and detract from the amenity value of rangelands (Gutman et al., 2000). Some East-Mediterranean species, such as milk thistle (*Silybum marianum*) and Syrian thistle (*Notobasis syriaca*), are common in the nutrient-rich, eutrophised areas of rangelands such as those close to gazelle latrines and nutrient-rich ant nests (Danin and Yom-Tov, 1990), to watering points where cattle gather and defecate (Gutman et al., 2000), and to active or abandoned sheep corrals (Vinograd et al., 2011). Following the finding that milk thistle is highly tolerant to salinity (Ghavami and

Ramin, 2008), a recent hypothesis is that outbreaks of “nitrophilic” milk thistle and Syrian thistle in nutrient-rich areas of rangelands do not result from the abundance of N alone, but also from the resilience of these species to excess Na and K in the soil (Vinograd et al., 2011).

The fact that the seed-banks of *S. marianum* and *N. syriaca* are small (Sofer-Arad et al., 2007) suggests that grazing might control these species within a few years. Indeed, the density of thistles is affected by cattle grazing management, such as continuous versus rotational grazing (De Bruijn and Bork, 2006), but generally in mid-Eastern rangelands, increased cattle grazing density is associated with a higher frequency of thistles (Sofer-Arad et al., 2007). Danin and Yom-Tov (1990) claimed that spines in milk thistle deter cattle from grazing this species. Wilson et al. (2006) provided guidelines for controlling Bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), Musk thistle (*Carduus nutans*), Scotch thistle (*Onopordium acanthium*) and yellow starthistle (*Centaurea solstitialis*) in the

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U.S.A. by means of grazing. Livestock generally avoid entering dense stands of mature thistle but they will graze young, immature plants. Cattle will not graze bull thistle and musk thistle beyond the late bud stage and grazing milk thistle is deemed dangerous for cattle because of high and possibly lethal contents of nitrates (Kendrick et al., 1955; CCNWP, 2015). In contrast, musk thistle is readily grazed by sheep and goats from rosette to bolting stage (Wilson et al., 2006). Khan et al. (2009) reported on goat grazing to prevent milk thistle invasion in crops in Pakistan, but in Bedouin camps in Israel, where milk thistle is dominant, there is no evidence that it is consumed by sheep or goats (Vinograd et al., 2011).

Individuals behave, and in response to their behavior they experience consequences, which in turn modify the likelihood of future behaviors (Skinner, 1981). In the case of foraging, behavior by consequences is driven by the interrelationship between a food's sensorial characteristics and its postingestive feedback (Provenza, 1995; Provenza and Villalba, 2006). The senses of smell, taste and sight enable animals to discriminate among foods and they generate pleasant or unpleasant sensations associated with ingestion (Provenza and Villalba, 2006). Negative feedback can be used to deter animals from consuming a poisonous plant and positive feedback can encourage them to accept a non-preferred species. In particular, mixing undesirable with more preferred feeds, thereby associating them with familiar flavors, and providing adequate supplements are ways to increase feed acceptance (Burrill and Frost, 2006).

Volatile molecules absorbed by animals reach placental circulation and affect feed preferences of kids post-weaning (Hai et al., 2012). The odor of milk is very much affected by the neutral volatile compounds ingested at pasture (Fernandez et al., 2003). Heifers that suckled mothers fed ammoniated wheat straw throughout wintering performed better when later exposed to straw as adults than heifers naïve to straw (Wiedemeier et al., 2002). Therefore, young animals are exposed to food flavors pre- and post-partum, which induces a generational transfer of grazing behavior. Hence goats adopt preferences for foods that are eaten by their mothers (Provenza et al., 1993) and these behaviours may endure for at least two generations (Biquand and Biquand-Guyot, 1992).

The objectives of the present study were: (i) to test the safety of feeding milk and Syrian thistles (MST) to goats; (ii) to determine if preconditioning adult goats to MST, by feeding them together with a small amount of concentrate to establish a positive feedback, enhances preference for MST of goats when turned to MST-rich pastures; and (iii) to establish whether goat kids exposed to MST while suckling preconditioned (PC) or non-conditioned (NC) does differ in their propensity to consume MST fed as green fodder, or in their preference for MST over clover hay.

2. Materials and methods

2.1. Experimental area

The study was conducted at the Ramat Hanadiv Nature Park, south of the Mount Carmel ridge, Israel (32°25' N, 34°52' E). Average yearly rainfall is 600 mm which falls from October to April. The ecosystem is a disturbed Mediterranean woodland (garrigue), characterized by steep, rocky slopes with sparse patches of shallow soil. The growing season of the highly diverse herbaceous vegetation extends from January to mid-May. The woody vegetation is dominated by low trees (mainly *Phillyrea latifolia* L.) and tall shrubs (*Pistacia lentiscus* L. and *Calicotome villosa* Poir. Link). Bushes of *Ephedra foemina* Forsk., *Asparagus stipularis* Forsk., *Sarcopoterium spinosum* L. Spach grow between the coppices. Large areas of the park are grazed by beef cattle, primarily to reduce fire hazards in the dry summer period, and their watering trough is located in a

15-ha area of cypress groves. The area around the watering trough is heavily encroached by *S. marianum* (L.) Gaertn. (milk thistle) and *N. syriaca* (L.) Cass. (Syrian thistle).

2.2. Adult goat experiment

All experimental procedures were conducted in accordance with the Israel Council on Animal Care Guidelines (ICACC, 1994).

2.2.1. Animals and treatments

Forty-two local (Mamber and Damascus) goats, each with at least one suckling female kid, were used. Goats were, on average, 24 days post-partum when selected. Twenty-two of them were subjected to preconditioning (PC), while the remaining 20 goats served as non-conditioned control (NC). Goats were allocated to treatments according to breed, parturition date and body weight (BW). Average BW was 46.1 ± 2.1 and 46.6 ± 1.9 kg for PC and NC goats, respectively.

Milk and Syrian thistle thrive in the same environments. Their chemical composition is very similar (reported in Results) and distinguishing between the two species before they flower is very time-consuming. We therefore grouped them together under the term milk/Syrian thistles (MST) throughout this study. Animals in the PC group were preconditioned to MST in March 2012 for 14 days during which they were offered every morning 0.9 kg/head (fresh matter) of freshly collected MST foliage that was chopped to 4 cm in length and mixed with 70 g/head of a commercial concentrate (16% crude protein; Ambar, Hadera, Israel). Residues were weighed daily 1 h after exposure. The amount of MST offered ensured at least 15% of residue. For all tests, an aliquot of fresh MST was kept outside the pen in order to evaluate weight loss by evaporation over the course of one hour and correct intake values accordingly.

Following each day's preconditioning, all animals (PC and NC) were shepherded together to an area devoid of the target species, where they grazed for four hours. In addition, all animals received daily 1 kg/head of concentrates (fresh matter) divided over two meals.

2.2.2. Time spent grazing milk/Syrian thistles

The thistle-infested area designated for the grazing trials was located 80–180 m from the cattle watering trough and had been grazed by cattle in previous years. In November 2011, before seed emergence, the area was divided into six adjacent plots of 0.186 ha (31 × 60 m) each which were then fenced. The initial density of milk and Syrian thistles in each plot was established by counting plants within 1 × 1 m² quadrats located every two meters along two transects, each 70–80 m in length.

After the preconditioning period, animals in each treatment were allotted to three groups, which served as replicates (7 animals per replicate). Grazing of the experimental plots and associated observations occurred during the second half of March 2012. On each of these days, two groups, one from each treatment, grazed their respective plots for one hour in the morning (starting at 08:00) and for one hour in the afternoon (starting at 13:00). Each of the six groups was assigned to one of the six plots for the duration of the experiment and grazed its plot three times in the morning and three times in the afternoon. The grazing order was structured as six cycles, with group randomized within cycle, with the single constraint that the NC and PC groups should belong to non-adjacent plots in order to avoid social facilitation between them.

During the one-hour grazing sessions, an observer in each plot recorded the behavior of each goat every 5 min using the scan sampling method (Altmann, 1974). Behavioral categories were walking, searching for food, and grazing. When the recorded behavior was grazing, the vegetation selected was recorded according to the five main plant categories that were found on the plots: milk or

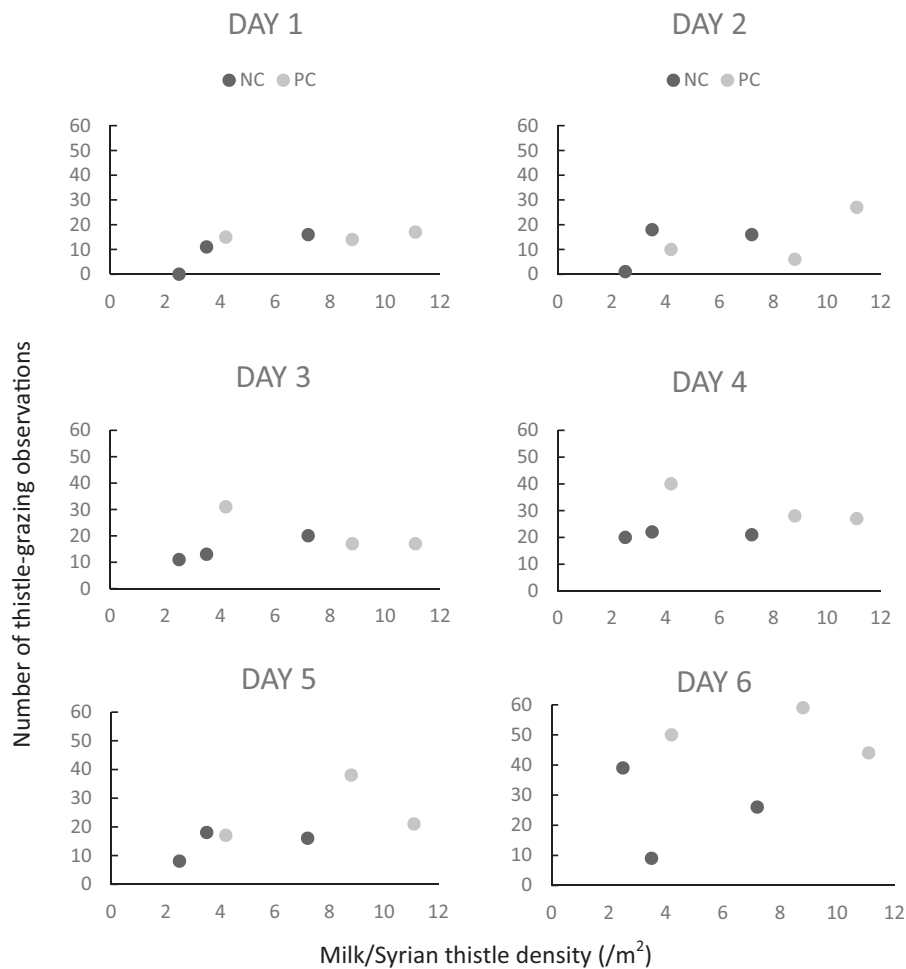


Fig. 1. Number of milk and Syrian thistle-consuming observations as a function of the initial density of thistles in plots over 6 sessions of 1 h observation.

Syrian thistles, cypress (*Cupressus sempervirens*), prickly burnet (*S. spinosum*), white hedge-nettle (*Prasium majus*) and annual grasses (as one category). No details concerning consumed part plants (leaves and stems) were recorded.

Goats had no access to feed before the morning grazing session. After each grazing session, goats were returned to their pen where clover hay was available. Groups that did not graze the experimental plots on any given day were taken out to graze the park woodland with the main herd. Kids were weaned during the observation period and did not accompany their mothers to graze the experimental plots or the park woodland.

2.2.3. Chemical analyses

2.2.3.1. Blood analyses. Jugular blood was sampled at 08:00 immediately before the preconditioning period commenced (day 0) and on its last day (day 14). A sub-sample was retained on site in order to estimate hematocrit and the remainder was immediately cold-transported to the Kimron Veterinary Institute (Bet Dagan, Israel) for additional analyses. For hematocrit (%) determination, the samples were drawn into heparin capillaries which were then centrifuged and read using an Adams Micro Hematocrit Reader. Analyses at the Kimron Veterinary Institute were performed within two hours of sampling and comprised: white and red blood cell counts, with eosinophil count (Technicon H-I, Diagnostic Division, Miles Inc., Tarrytown, NY) expressed as a percentage of white blood cells, as an indicator of stress (Dantzer and Mormède, 1983); aspartate transaminase (AST) in blood serum as an indicator of tox-

icity (liver damage) as described by Bergmeyer et al. (1978); and hemoglobin.

2.2.3.2. Chemical composition. The in vitro DM digestibility and the contents of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (ADL) were determined on MST samples offered during the preconditioning period (n = 14) and on samples of milk/Syrian thistles clipped in each plot during the observation period (n = 48) using Near Infrared Spectroscopy (Foss NIRsystems 5000, Foss Tecator, Höganäs, Sweden). These samples were identified as milk or Syrian thistles. The nitrate content of MST sampled during the preconditioning period was assessed using Reflectoquant nitrate test strips (Merck-Serono, Herzlyia Pituah, Israel) quantitated with a RQflex Plus Reflectometer (Darmstadt, Germany) as described by Bar-Tal et al. (2008).

2.3. Weaned kid experiment

2.3.1. Animals and treatments

The weaned kid experiment used 55 female kids. Of these, 42 kids were born in January–February 2012 to the goats of the adult goat experiment and were weaned on March 20 (± 1.3 d). Kids born to adults of the PC treatment (23 kids divided into 4 groups designated PC) had been exposed to MST, both directly (together with their mothers) for the 14 consecutive days of the preconditioning period, and indirectly through milk flavors produced by PC mothers exposed to thistles when they grazed the experimental plots. Kids born to adults of the NC treatment (19 kids divided into 4 groups),

Table 1
Chemical composition, nutritional attributes and nitrate concentration of milk and Syrian thistle samples taken during the preconditioning and observation periods. Values are means \pm S.E. and expressed as% of dry matter. Abbreviations: CP, crude protein; IVDMD, in vitro dry matter digestibility; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin.

	CP	IVDMD	NDF	ADF	ADL	NO ₃
Milk thistle						
Leaves	12.4 \pm 1.6	71.2 \pm 4.0	29.5 \pm 2.4	20.9 \pm 2.2	11.2 \pm 1.3	0.83 \pm 0.2
Stems	3.9 \pm 0.9	48.8 \pm 3.9	56.1 \pm 1.5	38.7 \pm 0.9	4.5 \pm 1.0	0.86 \pm 0.2
Flowers	9.0 \pm 0.7	61.3 \pm 4.9	49.0 \pm 5.0	31.8 \pm 3.1	6.5 \pm 0.8	0.15 \pm 0.1
Syrian thistle						
Leaves	14.1 \pm 1.6	73.2 \pm 2.7	34.3 \pm 0.5	22.7 \pm 0.6	8.9 \pm 0.9	0.58 \pm 0.2
Stems	5.0 \pm 0.6	55.2 \pm 6.1	56.7 \pm 3.3	39.7 \pm 2.0	5.5 \pm 0.7	0.49 \pm 0.4
Flowers	10.0 \pm 1.0	64.9 \pm 2.1	46.1 \pm 2.9	29.6 \pm 2.4	7.9 \pm 0.7	0.13 \pm 0.0

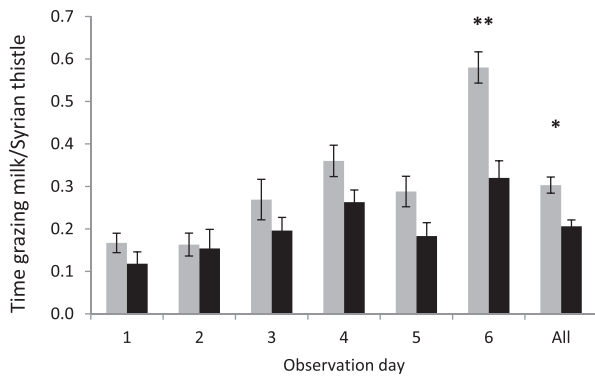


Fig. 2. Proportion of time devoted to grazing milk/Syrian thistles in preconditioned (PC; n=3; grey columns) and control (NC; n=3; black columns) groups of goats over 6 observation days. Goats were observed for one hour daily (average \pm SE; significance refers to arcsine-transformed data).

plus additional contemporaries selected from the flock (13 kids divided into 3 groups), were designated NC. Although NC kids had no direct exposure to thistles, they did have indirect exposure (via milk flavors) because NC mothers grazed the experimental plots and may have encountered occasional patches of MST on days they grazed with the main herd. All weaned kids were kept together when not being tested. They received concentrate feed (16% CP; Ambar, Hadera, Israel) ad libitum and had free access to medium-quality clover hay (8.7% CP, 65.5% NDF, 42.3% ADF, 4.2% ADL, 44.7% DM digestibility, 13.3% ash, on DM basis).

2.3.2. Propensity and preference tests

The propensity of weaned kids to consume MST and the preference for MST over hay were determined over 6 consecutive days (days 1–6). Tests were carried out in six 2 m \times 2 m pens. For each group, propensity to consume MST was measured once on each of the first three odd days, and preference was measured once on each of the three even days. For propensity, pens were equipped with two troughs, one containing water and the other containing 1.5 kg freshly cut MST (fresh matter basis). The relative positions of troughs were randomized among days. Test duration was one hour. The intake of each group was calculated as the difference between offer and residue, corrected for evaporation losses, and expressed per unit body weight.

For preference tests, the same six pens were equipped with four troughs: one containing water, one containing 1.5 kg freshly cut MST (fresh matter basis), and two containing 150 g chopped clover hay each. Test duration was one hour. Intake, corrected for evaporation losses, was calculated as above. Preference was defined as the ratio between MST and total forage intake, on DM basis.

2.4. Data analysis

Statistical analyses were performed using SAS 9.2. Comparison of treatments was performed using PROC MIXED.

2.4.1. Goat experiment

In order to test the significance of differences in blood-test variables before and after conditioning to MST within the PC and NC treatment groups, an analysis of covariance was conducted with treatment as categorical factor, initial (before pre-conditioning) values as covariates and goat (group) as subject.

Values of the proportion of time grazing a plant species category were arcsine-transformed before statistical analysis. For the analysis of proportion time spent grazing MST and the number of plant species categories consumed, a repeated measures analysis of variance was used with a first-order autoregressive covariance structure. The factors in the model were treatment, grazing session (morning/afternoon), animal group/plot, and the interactions between treatment \times grazing session and treatment \times day. The experimental unit was group nested within treatment, and day was the repeated measurement.

2.4.2. Weaned kid experiment

Untransformed measurements of intake were tested at the group level (n=4 and 7 groups for PC and NC, respectively). A repeated measures procedure for the propensity of consuming MST given as sole fodder, and preference of MST over hay was applied in which the experimental unit was group nested within treatment, and day was the repeated measurement.

3. Results

3.1. Adult goat experiment

3.1.1. Nitrate content and toxicity of milk and syrian thistles during preconditioning

The nitrate contents of MSTs (Table 1) were lower than 1%, on DM basis, and ranked leaves = stems > flowers.

During the 14 days of the preconditioning period, goats ingested, on DM basis, a total of 568 \pm 28 g fresh matter of MST per head (90 g/d of dry matter, on average).

Initial values for blood attributes did not differ between NC and PC treatments. Feeding MST to goats in the PC group did not impair their health (Table 2): AST did not increase, showing no evidence of liver damage. Eosinophil count did not decrease in the PC group, but increased in the NC group ($P < 0.05$); no effect was noted for neutrophils; the hematocrit and red blood cell counts were not affected by preconditioning to thistles; moreover, hemoglobin was not reduced, as would happen if methaemoglobin was produced as a result of nitrite poisoning.

Table 2

Blood test results (mean ± S.E.) for adult goats of the control group (NC) and of the group preconditioned to MST (PC), before and after the preconditioning period. Abbreviations: AST, serum aspartate transaminase; HGB, hemoglobin; EOS, eosinophils; NEUT, neutrophils; HCT, hematocrit; RBC, red blood cell count. EOS and NEUT are expressed as% of white blood cells.

Blood measure	Treatment	Before (B)	After (A)	Change (A–B)	P (change differs from 0)
AST (u/L)	NC	81.1 ± 5.2	86.4 ± 4.7	5.3 ± 2.0	NS
	PC	87.3 ± 9.4	88.1 ± 6.2	0.8 ± 4.9	NS
HGB (g/dL)	NC	9.7 ± 0.5	8.9 ± 0.2	–0.8 ± 0.4	NS
	PC	8.2 ± 0.4	8.1 ± 0.4	–0.1 ± 0.2	NS
EOS (%)	NC	2.7 ± 1.0	4.6 ± 0.9	1.9 ± 1.0	0.05
	PC	2.3 ± 0.9	2.6 ± 0.4	0.3 ± 0.9	NS
NEUT (%)	NC	57.2 ± 2.3	55.8 ± 2.1	1.4 ± 1.7	NS
	PC	59.1 ± 5.2	58.7 ± 4.5	–0.4 ± 2.2	NS
HCT (%)	NC	30.6 ± 1.5	28.2 ± 0.9	–2.4 ± 1.2	NS
	PC	25.6 ± 1.2	25.3 ± 1.6	–0.3 ± 0.6	NS
RBC (× 10 ⁶ /uL)	NC	17.5 ± 0.9	16.8 ± 0.8	–0.7 ± 0.5	NS
	PC	15.3 ± 0.4	15.5 ± 0.7	0.2 ± 0.4	NS

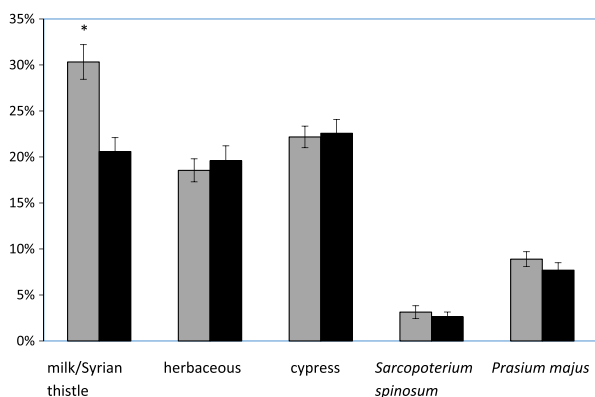


Fig. 3. Proportion of total grazing time among the five major species categories by groups of goats that were preconditioned (PC; n = 3; grey columns) or not (NC; n = 3; black columns) to milk/Syrian thistles over 6 observation days. Goats were observed for one hour daily (average ± SE; significance refers to arcsine-transformed data).

3.1.2. Time spent grazing milk/Syrian thistles

The initial (pre-grazing) density of milk/Syrian thistles in the experimental plots was 11.0, 8.8, and 4.2 plants/m² in those grazed by goats of treatment PC, and 7.2, 2.5, 3.5 plants/m² in those grazed by goats of treatment NC. The mean thistle density did not differ between the two sets of plots (PC = 8.0 ± 2.0, NC = 4.4 ± 1.4 plants/m²; P = 0.21) and the number of MST-eating events was not related to initial thistle density (Fig. 1). No difference was found between groups in the average number of plant species categories grazed during observation sessions (3.5 and 3.4 in PC and NC goats, respectively).

The proportion of time devoted to grazing MST increased significantly over observation days (Fig. 2, P < 0.0001). Overall, preconditioned (PC) goats devoted 50% more time to consuming MST than non-conditioned (NC) counterparts, i.e., 30.3% and 20.6%, respectively (P = 0.02). The difference between the treatments was even more pronounced in the afternoon grazing sessions, for which respective averages were 38.3% and 23.2% of time in PC and NC goats, respectively. The difference between PC and NC treatments tended (P < 0.10) to be significant on days 1, 4 and 5 but reached significance only on day 6, when PC devoted almost twice as much time grazing MST as the NC counterparts (P < 0.01). Preconditioning to MST had a specific effect, as only the proportion of time spent grazing MST, and not the other four plant categories, was affected by the treatment (Fig. 3). This means that the increase in time allocated by PC goats to grazing MST was at the expense of idling.

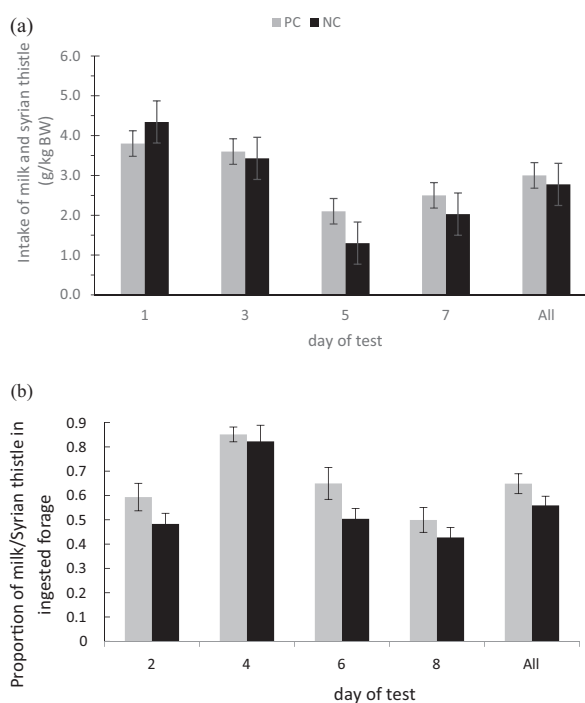


Fig. 4. Propensity and preference results for tests conducted on weaned kids of the PC and NC adult goat treatment groups. (a) Intake of milk and Syrian thistle during the propensity test (averages ± SE); (b) Proportion of milk/Syrian thistle in total fodder ingested during the preference test (averages ± SE).

3.2. Weaned kid experiment

PC and NC kids did not differ in their propensity to consume MST when given as a sole fodder (P = 0.91; Fig. 4a). However, the proportion of MST in total fodder ingested during preference trials tended to be higher in PC than in NC kids (0.65 and 0.55, respectively; P = 0.08; Fig. 4b).

4. Discussion

During the preconditioning period, goats ingested less than 100 g/day of MST (DM basis). In addition, the contents of nitrates in milk and Syrian thistles collected in the experimental plots was <1% (Table 1), i.e., lower than the level that triggers nitrite poisoning (Pfister, 1988). According to Bruning-Fann and Kaneene (1993), hematologic changes seen with chronic high nitrate exposure include both compensatory increases in red blood cells and anemia, along with increased neutrophils and eosinophils. All esti-

mates of red blood cells and anemia were not affected by eating MST (Table 2). Not only can it safely be assumed that animal health was not jeopardized by exposure to MST, but goats could derive special health benefits from ingesting milk thistle because it contains silybinin, a flavonoid complex that acts as an anti-oxidant, decreases activity of tumor promoters, reduces oxidative damage to kidneys, and, most importantly, protects liver cells against toxins (Wynn and Fougere, 2007).

Goats consumed MST in the experimental plots and allocated 20–30% of grazing time to thistles, on average. Although a goat may not have ingested MST during a single observation session, no goat rejected MST over all observation days. This is in agreement with Khan et al. (2009), who showed that goats are willing to consume milk thistle, but it contrasts with Vinograd et al. (2011), who found the opposite.

There are several factors that may be relevant in resolving the conflicting reported findings. Firstly, one cannot extrapolate that MST consumption never poses a risk of nitrate poisoning: in a recent soil survey at Ramat Hanadiv (Arviv, 2015), the nitrate content varied from 47 mg/kg in the vicinity of the cattle water trough to 3 mg/kg in the plots used in this study located 80–180 m from the watering point, suggesting that there are times when nitrate contents could be high enough in MST to endanger animals and deter them from eating MST. Secondly, animals avoid grazing in feces-rich areas that may be infested with parasites (Hutchings et al., 1999). The warm and moist conditions in March to May increase the survival of infective helminth larvae and the chances of being infected (Shimshoni, 1974). As nitrophilic species are abundant in feces-rich patches, they may be avoided by animals. And thirdly, botanical diversity is low in areas encroached by nitrophilic plant species. The experimental plots were fenced, not allowing for goat to roam, and the number of species ingested was <4, on average, compared to >10 in other areas of the park (Glasser et al., 2008). A prerequisite for goats to safely consume plants rich in secondary compounds is botanical diversity (Rogosec et al., 2006), which suggests that MST intake probably would be increased if dietary variety was increased by shepherding, as proposed by Meuret and Provenza (2015).

Finally, the proportion of time devoted to MST grazing increased over observation days and reached 58% in goats from the PC treatment. As foraging behavior is shaped by consequences (Provenza, 1995), time spent consuming a toxic plant would be expected to decrease rather than increase over days. Our results suggest that goats increased their intake of MST following positive feedbacks. Also, the nutritional value of MST is high (Table 1). All these findings strongly suggest that grazing MST in this study did not impair goat health and wellness.

Preconditioning seeks to create an association by goats between a nutrient bonus and the targeted species, and this is stored in cognitive memory as flavor, encompassing texture, smell and taste (Provenza, 1995). Time devoted to consuming MST was increased by preconditioning in goats (Fig. 2). Burritt and Frost (2006), who pre-conditioned goats during the first days of exposure terpene-rich juniper and tannin-rich sagebrush, also reported that pre-conditioning increased the intake by goats of these unpalatable plants.

In the present study, concentrate was used to elicit positive feedback following MST feeding. Goats had no synchronous access to concentrate when they grazed the experimental plots but it was fed 2–4 h later when goats returned to the shed. Therefore, one cannot determine to what extent the relative preference for milk and Syrian thistles (Fig. 2) was due to continued concentrate feeding as opposed to cognitive recognition by goats that eating thistles is beneficial. The finding that the relative preference for MST grew stronger as the trial progressed (Fig. 2) leans toward the latter alternative.

Preconditioning to MST was shared by PC goats and their kids, but not by NC goats. As young kids prefer what their mothers prefer (Mirza and Provenza, 1992; Provenza et al., 1993), it was expected that PC kids would exhibit higher preference for MST than NC counterparts. Although this was not found for propensity (Fig. 3a), PC kids tended to show a greater preference for MST over clover hay than did NC kids (Fig. 3b). We have shown previously (Glasser et al., 2009) that propensity and preference tests may yield different results. In a propensity test, kids raised by a Damascus or a Mamber goat did not differ in their intake of a shrub of high (*P. lentiscus*) versus low (*P. latifolia*) tannin content. However, when given a choice between the two species, kids raised by a Mamber goat showed lower preference for *P. lentiscus*. As MST contain flavonoids (Wynn and Fougere, 2007), it may be assumed that consuming MST and clover hay in synchrony can alleviate negative feed-back, lifting the intake limitation. Our results suggest that acquired preferences in young kids are expressed only if nutritional benefits can still be felt after weaning, when a kid learns to make its own foraging decisions (Mirza and Provenza, 1990, 1992).

Most of the field observations were made before flowering. A prerequisite to reducing the density of thistles is depleting their seed banks. This can be done only if plants do not reach the flowering stage or if flowers are consumed before seeds are dispersed. Wilson et al. (2006) claim that goats are the preferred herbivore to combat Canada thistle (*C. arvensis*) encroachment because cattle and sheep stop consuming it after spines develop. This has yet to be determined for milk and Syrian thistle.

5. Conclusions

Goats ingest the nitrophilous Compositae thistles readily. Preconditioning goats to thistles prior to grazing increases their intake of these plants and tends to increase the preference for thistles of their kids.

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