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BRIEF REPORT

Breeders management and reproductive traits in three heritage rabbit (*Oryctolagus cuniculus*) breeds: a preliminary study

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ABSTRACT

The aim of the present research is to investigate breeders' management strategies and their effects on reproductive performances in heritage breeds. A total of 468 litters were analysed: Belgian Hare ($N = 151$), Burgundy Fawn ($N = 105$), Californian ($N = 212$). Litter size (born alive), percentage of weaned kits and percentage of selected kits were analysed using a model that included the effects of breed, year of birth, litter's origin (with three levels: both internal parents = 0, one outside parent = 1 both outside parents = 2) and their interactions (breed*year of birth, breed*litter's origin, year of birth*litter's origin, breed*year of birth*litter's origin). Besides, number of litters per buck and number of litters per doe were analysed using a model with only effect of breed. All these analyses were carried out with SPSS software. No effects of breeds on litter size, percentage of weaned and percentage of selected kits were found. Year of birth presented significant effects on litter size and percentage of weaned kits ($p \leq 0.05$). The inclusion of external breeders didn't significantly influence analysed reproductive data. The number of litters per buck and per doe were not influenced by breed. The frequency of external breeders' inclusion is breed specific. Data recording is a basic step in phenotypical characterization, our results supply some information about breeders' management strategies and their effects on some reproductive parameters. Our results show breed specific frequencies of inclusions of external breeders and a positive effect of management procedures (genetic plus environment) on percentage of weaned kits according to the year of birth.

HIGHLIGHTS

- Breeders management and reproductive parameters have been described
- The most frequent combination is a home bred doe mated to an external male
- A mean of 2 litters per doe and per buck have calculated in all the breeds
- The frequency of use of external breeders is breed specific

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Introduction

Rabbit domestication started in the southern part of France and close areas of Spain almost 1500 years ago; the wild ancestors still lives in the these regions and a high number (≈ 200) of heritage breeds and local populations differentiated from the first domesticated stock (Monnerot et al. 1994; Whitman 2004; Carneiro et al. 2011; Fontanesi 2021). Rabbit production in Europe is mainly based on commercial hybrids selected for high reproductive and productive performances, extinction of low productive heritage breed is an effective risk, as a consequence, an accurate characterization of European rabbit (*Oryctolagus cuniculus*) breeds and populations under a phenotypical and genomic point of view plays a pivotal role in genetic resources management and conservation (Bolet et al. 1999; Badr et al. 2019; Ren et al. 2019).

Rabbit breeds conservation strategies are mainly finalized to maintain genetic variability, to study and to preserve useful genes and to maintain cultural legacies; in addition, low productive breeds could be oriented to extensive rearing systems and marginal areas utilization (breed specific adaptability and feed utilization) and traditional and niche productions (product qualities, consumers' perception) (Ruane 1999; Gandini and Villa 2003; Blasco 2008; Dalle Zotte and Paci 2014). Furthermore, proteins supply, food production and security and productive systems' adaptability and

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resilience are rooted in livestock biodiversity which is fundamental in the process of development of sustainable animal productions (Blasco 2008; Groeneveld et al. 2010; Pilling et al. 2020).

Considering heritage breeds we have to move the focus from rabbit meat production breeders to fancy breeders who choose their selection targets according to the conformational standard of perfection (national breed standard). In Italy rabbit breeders are represented on behalf of the Ministry of Agriculture by ANCI-AIA association (Associazione Nazionale Coniglicoltori Italiani – Associazione Italiana Allevatori) which shares similar standards with the European Association of Poultry, Pigeon, Cage Bird, Rabbit and Cavy Breeders. Breeds standard very carefully describe morphological traits with no references about breed' productivity and reproductive efficiency (Bolet et al. 1999).

The productive interest of native breeds and, in addition, of coloured (purebred or crosses) rabbits could be linked to extensive and organic production systems in particular being their reproductive ability quite good in unstandardized condition typical of small farms (Szendrő et al. 2012). In organic rabbit production only coloured pure breed rabbits, local populations and first generation crosses are admitted, no red eyed animals are used (Dalle Zotte and Paci 2013).

Highly productive hybrids descend from a very reduced number of breeds which created the foundation stocks of all the worldwide existing commercial strains. Nowadays rabbit biodiversity is protected thanks to the work and dedication of fancy breeders (Bolet et al. 2004).

Rabbit genetic improvement is based on genetic selection and reproductive abilities (Odubote and Somade 1992) but the importance given by fancy breeders to reproductive parameters is not very high being them mainly oriented to obtain show prospect subjects. Little size litters of large kits born in the first month of the year to reach perfect development condition during the exhibition season (late summer, autumn winter) are the preferred conditions.

So, like in companion animal (dog and cats), reproductive traits run the risk to miss their central role in animal breeding and their zootechnical function (Bolet et al. 2004; Marelli et al. 2020), furthermore, a constant recording of zootechnical data in fancy rabbitry should be improved to ensure an accurate phenotypical characterization of rabbit genetic resources (Bolet et al. 2004; Dalle Zotte and Paci 2013).

The aim of the present research is to investigate breeders' management and reproductive performances to better characterize heritage breeds reproductive traits and selection protocols.

Materials and methods

Animals and data collection

A total of 468 litters from 3 different heritage breeds selected for conformation shows purposes were analysed. Studied breeds were: Belgian Hare (BEH), Burgundy Fawn (BUF), Californian (CAL). Main breeds' standard characteristics, number of buck and does and number of litters per breed are listed in Table 1. All data were recorded in a fancy rabbitry in norther Italy with three different facilities where standard husbandry procedures are applied. Rabbits breeders (males and females) are housed in single wire mesh cages (60.00*80.00*60.00; L*W*H; cm*cm*cm; 1/3 of the floor is covered with a wooden platform). Rabbits are fed Purina® Complete Rabbit feed, water is *ad libitum* available (nipple drinkers). All-over the year polyphite meadow hay is given to animals in good quantity so it is constantly present in the cage both for nutritional purposes and for environmental enrichment and as nesting material. Internal plastic nests are used (35*45*10; L*W*H; cm*cm*cm). Natural mating system is used. Kits are weaned at 8 weeks of age. Data were collected over an 11 years period (2010–2020).

Every breeder entered in ANCI-AIA studbook is singularly identified with ear tattoos. Breeders were classified according to their origin: born in the rabbitry (internal) or coming from other rabbitries (external). The level of inclusion of external breeders was calculated too according to rabbits' identification codes: no external breeders = 0; external buck or external doe = 1; external buck and external doe = 2. Data recorded by the breeder for each litter, together with doe and buck identification number were: year of birth, number of kits born alive (litter size), number of weaned kits and number of selected kits according to the potential correspondence to the breed standard. Proportions of weaned kits on born alive kits were calculated (%; weaned), proportions of selected kits on weaned kits (%; selected) were calculated too.

Table 1. Range of weight (Kg), coat colour, numbers of bucks (*N*), number of does (*N*), number of litters (*N*) in Belgian Hare (BEH), Burgundy Fawn (BUF) and Californian (CAL) breeds.

Breed	Standard weight (Kg)	Coat colour	Bucks (*N*)	Does (*N*)	Litters (*N*)
BEH	3.5–4.0	Chestnut agouti	72	77	151
BUF	4.0–4.5	Fawn	66	55	105
CAL	3.7–4.3	Colourpoint	120	91	212

Table 2. Frequencies (%) distributions of internal (I) and external (E) breeders in Does origin (B), Bucks origin (D) and litters' origins (DB) of Belgian Hare (BEH), Burgundy Fawn (BUF) and Californian (CAL) breeds.

	Doe origin (B)		Buck origin (D)		Litter origin (DB)		
Breed	I	E	I	E	II	EI–IE	EE
BEH	74.17	25.83	39.74	60.26	31.79	50.33	17.88
BUF	58.10	41.90	22.86	77.14	10.48	60.00	29.52
CAL	93.40	6.60	38.68	61.32	36.79	58.49	4.72
Tot	79.27	20.73	35.47	64.53	29.27	56.20	14.53
p	≤0.05		≤0.05			≤0.05	

Tot: total frequency; p: Pearson Chi square probability.

Statistical analysis

Frequencies distribution of doe origin, buck origin and litter origin per breed were analysed using proc freq procedure of SAS 9.4 statistic package, Chi Square test was used to investigate significant differences ($p \leq 0.05$).

Litter size (born alive), percentage of weaned kits and percentage of selected kits were analysed using a model that included the effects of breed, year of birth, litter's origin (with three levels: both internal parents = 0, one outside parent = 1, both outside parents = 2) and their interactions (breed*year of birth, breed*litter's origin, year of birth*litter's origin, breed*year of birth*litter's origin). Besides, number of litters per buck and number of litters per doe were analysed using a model with only effect of breed. All these analyses were carried out with SPSS software. Post hoc Bonferroni test was applied to investigate differences' significance ($p \leq 0.05$). Linear regressions of the number of kits born and the percentage weaned per year of birth were studied, and coefficients of determination were reported.

Results and discussion

Breeders management analysis (Table 2) reveals some interesting information. Breeds frequencies distribution in does' origin defines breed specific percentages with CAL being characterized by the highest frequencies of internal does utilization (93.40%), on the contrary BUF showed the highest percentage of does from other rabbitries. In general, breeding protocols in the studied rabbitry are based on internal females (79.27% *vs.* 20.73%). A different situation has been recorded in bucks where the external origin is the prevailing one (64.53 *vs.* 35.47). BEH is the breed where internal bucks are more frequent (39.74%). The effects of purebreed sires on reproductive traits in hybrid rabbits creation are important, BUF bucks were, for example, used to improve reproductive production in a hybrid female line for organic production, a high litter size of 8.38 (*N*) kits born was recorded (Dalle Zotte and Paci 2013).

Litter origins reveals different breed-based combinations with the inclusion of one external parent per litter being the most common breeding strategy (56.20%). The breed with the most frequent combination of exclusively internal breeders is CAL (36.79%), on the contrary, in BUF the 29.52% of the litters is out of both external parents. Parents origin together with the high number of males present in the rabbitry could reveal selection plans based on the addition of external 'blood' to add positive morphological traits and to limit inbreeding levels' increase as direct or indirect goal. (Odubote and Somade 1992; Bolet et al. 2004; Szendrő et al. 2012; Leroy et al. 2013; Ren et al. 2019).

Table 3 reports the least square means and standard errors of the number of litters per doe and per buck, no significant differences have been calculated. The main part of the parents produces less than two litters in their reproductive life.

A significant effect of the year of birth on litter size and on percentage of weaned kits has been recorded ($p \leq 0.05$; Figure 1). A trend to a slight reduction of the number kits born alive per litter has been calculated, anyway, the coefficient of determination is poor ($R^2 = 0.26$). On the contrary the coefficient of determination of the linear trend of the percentage of weaned kits per litter is strong ($R^2 = 0.81$) and reveals a clear trend to the increase of the weaning percentage in the last years. Table 4 shows similar litter size among BEH, CAL and BUF breeds (6.06, 5.77 and 5.75 kits). Bolet et al. (2004) calculated very similar results in the same breeds: the number of born alive kits/litter was 5.44 kits in BEH and 5.17 kits in BUF. The same results are reported in a paper considering reproductive performances in four different heritage breeds, average litter size in BUF was recorder to be 5.25 in natural mating systems (Jimoh and Ewuola 2016). About BUF litter size: some authors report a number of 8 kits born alive per litter (Bolet et al. 2002).

Litter size is a selection target in commercial hybrid strain, and a characterising trait in heritage breeds: the Ibizan breed, for example, is characterized by litters averagely composed by 3.5 live kits (Formoso-Rafferty et al. 2016). In CAL an average litter size at birth was registered to be 4.78 (Odubote and Somade 1992). In C77 hybrid strain an average litter size of 7.27 live kits was calculated in the same rearing conditions of heritage breeds (Bolet et al. 2004).

The percentages of weaned kits are high and comparable with hybrid strains. In BEH, BUF and CAL

weaning percentages have been calculated to be 89.86, 87.18% and 88.89% respectively. In the same conditions C77 hybrid registered a percentage of weaned kits per litter of 93.67% (Bolet et al. 2004). In CAL breed a weaning percentage of 72.38% was calculated in a study considering pure breeds and their crosses, significant effects of parents' genetic were recorded (Odubote and Somade 1992).

Table 3. Least square means ± standard error for number of litters per doe and buck in Belgian Hare (BEH), Burgundy Fawn (BUF) and Californian (CAL) breeds.

Breed	Litter/doe (*N*)	Litter/buck (*N*)
BEH	2.10 ± 0.16	1.94 ± 0.11
BUF	1.61 ± 0.17	1.91 ± 0.21
CAL	1.77 ± 0.13	2.34 ± 0.16
p	N.S.	N.S.

N.S.: non-significantly different.

Table 4. Least square means ± standard error for litter size, percentage of weaned kits on born alive, percentage of selected kits on weaned kits in Belgian Hare (BEH), Burgundy Fawn (BUF) and Californian (CAL) breeds.

Breed	litter size (*N*)	weaned kits (%)	selected kits (%)
BEH	6.06 ± 2.03	89.86 ± 1.97	79.40 ± 2.85
BUF	5.75 ± 0.25	87.18 ± 2.45	84.98 ± 3.55
CAL	5.77 ± 0.18	88.89 ± 1.74	81.56 ± 2.52
p	N.S.	N.S.	N.S.

N.S.: non-significantly different.

The number of kits selected on weaned kits per litter show high numbers in particular in BUF breed (84.98%). The high percentages of kits per litter considered "show-quality" are in accordance with the finding of Bolet et al. (2004) who described how small litters of large kits are the preferred condition in fancy rabbit breeding. It is important to underline the low heritability of reproductive traits, litter size (kits born alive) and percentage of weaned kitss heritability (h^2) in a commercial hybrid were recorded to respectively be 0.05 and 0.03 (Ezzeroug et al. 2019).

No effects of the level of inclusion of external breeders have been recorded being the litter size around 6 (*N*) kits in every combination, breed specific analysis should be carried out considering breeds' genetic make-up (Kardos et al. 2015; Ren et al. 2019). No significant effects of the interactions between independent variables have been recorded.

Conclusions

Reported results show breed specific frequencies of inclusions of external breeders even though no significant effects on the tested reproductive parameters have been found. A positive effect was recorded in the percentage of weaned kits in the last years of

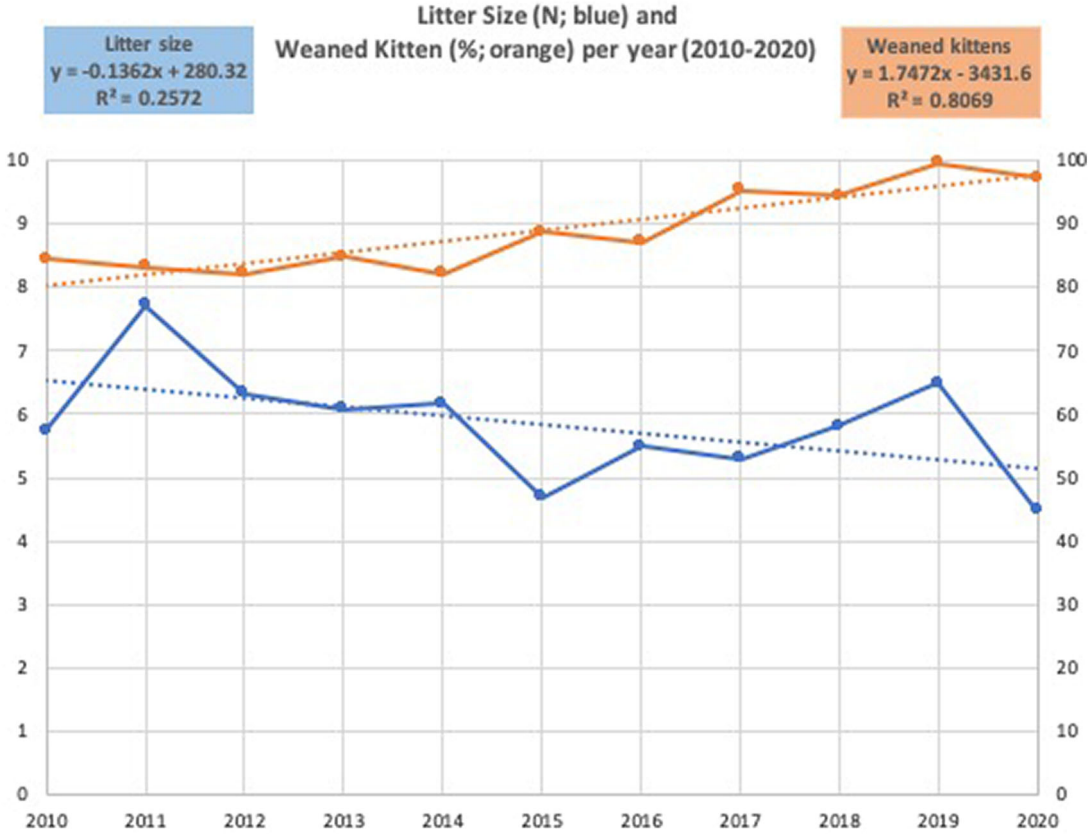

Figure 1. Least square means for litter size (*N*) and weaned Kittens (%) per year of birth (2010–2020).

production, a beneficial combination of genetic and environmental factors could be supposed. The percentages of weaned kits are close to those reported for hybrid strains when reared in the same conditions. Almost all the produced kits were considered to be show-quality, the selection target for conformation traits has been reached in all the considered breeds.

Phenotypical characterization is a basic step in conservation programmes determination, reproductive traits descriptions and breeder's management protocols definition represent basic ingredients in rabbit biodiversity protection through reproductive efficiency improvement. An accurate characterization of reproductive phenotypes in heritage breeds could supply important data for genomic investigation and breeds genetic landscape description too.

In addition, objective data about reproductive traits recorded in standard environment represent a powerful tool in heritage breeds characterization and in breed's fitness evaluation.

A complete reproductive data record sheet could be very effective in reproductive traits monitoring and objective data supplying aimed to characterize and preserve domestic rabbit biodiversity.

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Ethical approval

The paper is exclusively based on genealogical and farm management data analysis.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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