Factors that affect the success of artificial insemination in cattle of small farmers in the O´Higgins region of central Chile

Factores que afectan el éxito de la inseminación artificial en bovinos de pequeños productores en la región de O´Higgins de Chile central

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Originales: Recepción: 11/11/2019 - Aceptación: 23/09/2020

Abstract

This study analyzes different factors that affect the success of artificial insemination of cows by small farmers involved in a productive and genetic improvement program in the O´Higgins region of central Chile. The success of artificial insemination was modeled as a function of different biological, environmental, and social factors recorded by the program using logistic regression. The model output was the gestational status of the inseminated cows as diagnosed by ultrasound. All predictors were evaluated for unconditional associations with the outcome. The results showed that the pregnancy probabilities in cows from Cardenal Caro Province were higher than those from Cachapoal Province; inseminators with 10 or more years of experience had greater pregnancy success than those with 1-4 years of experience; the pregnancy odds decreased on farms with 30 or more cows compared with farms with 1 to 5 cows; and the pregnancy odds also decreased when AI was performed at a fixed time compared with heat detection. Thus, the province, the number of cows in the herd, the experience of the inseminators, and the type of insemination were associated with the success of the pregnancy.

Keywords

Animal improvement program • small-scale livestock farmers • reproductive technologies • South America

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Resumen

Este estudio analiza diferentes factores que afectan el éxito de la inseminación artificial en vacas de pequeños agricultores adscritos a un programa de mejoramiento productivo y genético en la región de O´Higgins de Chile central. El éxito de la inseminación se modeló en función de factores biológicos, ambientales y sociales registrados por el programa, utilizando una regresión logística. El resultado para este modelo fue el estado gestacional de la vaca inseminada, diagnosticada por ultrasonido. Todos los predictores fueron evaluados para asociaciones incondicionales con el resultado gestacional. Al analizar los resultados, las probabilidades de preñez en vacas de la provincia de Cardenal Caro fue más altas que de la provincia de Cachapoal; los inseminadores con 10 o más años de experiencia tuvieron mayor éxito de preñez que los de 1-4 años de experiencia; las probabilidades de preñez disminuyeron en granjas con 30 o más vacas en comparación con granjas con 1 a 5 vacas; y también disminuyeron cuando la inseminación se realizó a tiempo fijo en comparación con detección de celo. Así, la provincia, el número de vacas, la experiencia de los inseminadores y el tipo de inseminación se asociaron con el éxito del embarazo.

Palabras clave

Programa de mejoramiento animal • pequeños ganaderos • tecnologías reproductivas • América del Sur

Introduction

By 2050, the world population is estimated to reach approximately 9.3 billion people, generating a challenge for the agricultural sector that must produce 60% more food than the current supply to feed this growing population (12, 13, 24). Achieving adequate production levels from a limited natural resource base is critical, and changing our current food and agriculture systems by expanding and accelerating a transition towards a sustainable system that guarantees health levels and food safety, provides economic and social opportunities, and protects the ecosystems on which food depends is crucial (13). According to reports from the Food and Agriculture Organization of the United Nations (FAO), worldwide meat production will increase, especially in countries where grasslands and agricultural land abound, such as South America (14). In this sector, 80% of farms belong to family farming, involving more than 60 million people and representing the main source of agricultural and rural employment. Family farming constitutes a key sector that contributes to the reduction of hunger and the gradual change towards sustainable agricultural systems (29, 31, 34, 35). To increase the sustainability of these processes, elements for the integral development of small farmers, the better use of natural resources, and efficient risk management are necessary. Another fundamental aspect is for family farmers to have access to markets and value chains. Better market opportunities result in greater availability of healthier food at fair prices, benefiting society as a whole (32, 35). This productive sector is key to regional food security but faces important limitations in terms of access to productive resources, social services, basic infrastructure, financing, and extension. With the necessary support, especially from the government, small farmers will be able to fulfill their role as main actors in the dual challenge of improving the world's food security and conserving natural resources (7).

In Chile, the agricultural sector and the food industry are among the main sources of income of the national economy (26, 27), and they are concentrated in the central and south regions of the country, which present excellent and varied climatic conditions for animal production. Among the livestock activities, poultry meat production is the main one in the country, followed by pork, while beef production has experienced a decrease in the last decade (20). The Liberator General Bernardo O'Higgins region (central Chile) is the third region in terms of agricultural exports (19). Of these exports, 21% correspond to livestock, with cattle constituting only 2% (19). This region, the capital of which is Rancagua, covers an area of 16,387.0 kilometers squares, representing 2.2% of the national territory. It is divided into 3 provinces (Cachapoal, Colchagua and Cardenal Caro) and 33 municipalities.

It has a Mediterranean climate (with winter rains), and differences can be established from the sea to the mountain range and from north to south, manifesting in increased precipitation due to the gradual rise of the relief and advance in latitude (10). This allows for the existence of vegetation that needs such a climate to survive. Beef cattle are concentrated in the coastal dry zone, and dairy cattle are concentrated in the central area and near the Andes mountain range.

The National Institute of Agricultural Development (INDAP) assists small farmers in competing in global trade (18), and an INDAP program called "the Bovine Productive and Genetic Improvement Program" (BPGP) exists in the O´Higgins region. This program focuses on giving producers the necessary tools to generate the capacities and conditions to improve productivity, increase livestock, and achieve vertical insertion in the marketing chain. The objective of this program is to benefit as many small farmers as possible through the implementation of techniques and activities oriented towards inputting new genetic material and selecting offspring with superior productive aptitudes. These techniques include artificial insemination (AI) with certified bull semen and technical advice in animal health, traceability, reproduction, and nutrition. The greatest advantage of AI for family farmers is that it provides the opportunity to choose bulls that are proven to transmit desirable traits to the next generation, accelerating favorable selection and eliminating the cost and danger of keeping a bull in the herd. It also minimizes the risk of disseminating sexually transmitted diseases and genetic defects, decreases inbreeding and dystocia, and has a cumulative effect over the years (38).

This report aims to show the variables that have an impact on the pregnancy rate of the cows of small farmers in a breeding program in this region. We studied several variables that could have an impact on pregnancy success such as the owner´s sex; the municipality; the province where the farm was located; the number of cows owned by the farmer; the inseminator´s age and experience; the type of insemination (detected estrus or AI at a fixed time); and the age, body condition, ordinal number of births, date of last birth, breed and biotype (dairy or beef) of the cow. With this information, we performed a statistical analysis using logistic regression to identify factors that affect the success of AI in these cows.

Materials and methods

The BPGP

To participate in the BPGP, smallholders must have the following characteristics: their farm size must not exceed 12 equivalent irrigated hectares, and the farmer's main income must be from farming. An equivalent irrigated hectare is a measurement unit that uses soil and climate variables to establish a production potential equivalent throughout the country (7). Farmers must have their animals traced, which means that each animal must have an official identification device with a unique number; the farmers must also perform an annual declaration of animal stocks to the government agency and be the sole owner of the land where the animals are kept. Finally, they must have the basic infrastructure to inseminate cows, namely, a protective fence for safeguarding both the inseminator and the cow. Farmers must pay a copayment subsidized by the government that covers material expenses (palpation sleeves, lubricants, and straws), bull semen dose, maintenance of the equipment (0.5 mL frozen semen straws were transported and kept in tanks with liquid nitrogen) and transportation to the insemination site. Thus, farmers pay between one-third and one-quarter of what private land-based insemination is worth.

Artificial insemination

AI was performed either at a fixed time (strategic application of hormones to manipulate ovarian follicular growth, corpus luteum life span, and ovulation) or after heat detection (21, 36).

For farmers who had inseminators nearby who could go to where the cows were, AI was performed after heat detection. For farmers who were very far away and outside the reach of the inseminator, AI was performed at a fixed time. When a small farmer in the BPGP detected a cow with heat symptoms, the inseminator was called to inseminate the cow according to the am/pm rule: if the cow was detected to be in estrus during the morning, insemination was performed in the afternoon of the same day, whereas if estrus was detected in the afternoon, insemination was performed the next morning (21, 36). For AI at a fixed-time, the farmer decided the best date to schedule the parturitions according to the food supply. Cows subjected to AI at a fixed time must have an adequate body condition (greater than 2.5) and at least 45 days of a voluntary waiting period and not be pregnant regardless of whether they were cycling. The hormonal protocol used was as follows: on day 0, an ultrasound was performed to confirm that the cow was not pregnant, 2 mg of estradiol benzoate (Syntex ®) was injected intramuscularly (IM), and a bovine intravaginal device (DIB ®) with 0.5 g of progesterone was applied. On day 7, the device was removed, and 1 mg of estradiol cypionate (E.C.P. ®) plus 2 mL of prostaglandin $F_{2\alpha}$ (Ciclase DL ®) equivalent to 500 µg of cloprostenol were injected IM. Finally, 52 to 56 hours after the device removal, AI was performed. The AI technique used was the introduction of bull semen previously thawed at 37 °C for 30 s through the cervix into the uterus of the cow through a rectovaginal technique (2). The inseminators were selected according to their experience or interest in participating in the BPGP, and they were trained in the rectovaginal technique through theoretical and practical courses with professionals from the company that delivers the frozen semen.

Semen selection

The BPGP makes frozen semen from several bovine breeds available to producers. INDAP selected these bovine breeds according to their availability and price and the suitability of the production systems. Frozen semen was provided by ABS Chile (30). Small farmers in this region raise cattle mainly for fattening and dairies in which milk is generally used to make fresh cheese. The farmers who owned dual-purpose cattle were recommended to choose between meat or milk production as this choice promotes more efficient genetic improvement. The cows from the meat systems were breeding when performing AI while the cows from milk systems were not. Based on the needs of the producers, INDAP recommends the use of Aberdeen angus and Red angus breeds for farmers with beef cattle. These breeds are recognized for their ability to gain weight daily, meat quality, and rusticity, among other factors (1, 6, 9, 17). In the case of dairy cattle, INDAP recommends the use of Jersey and Holstein Friesian breeds. The Jersey breed was chosen for its rusticity and small size, its ability to withstand the high summer temperatures of the region, its ease of calving, and high percentage of solids (protein and fats) of its milk, which are favorable for making cheese. Meanwhile, many dairy farmers use the Holstein Friesian breed as it is the breed most commonly used for dairy production in Chile. Farmers who produce cheese as a final product were recommended to switch from Holstein Friesian to Jersey because of the high contribution of protein and fat that is obtained from the milk of these cows and the fewer nutritional requirements they require. Notably, when introducing these breeds to the region, AI was performed in cows that were already adapted to the territory and climate. The inseminators must evaluate the cows subjected to AI according to age and body condition and rule out the ones that are not suitable. They also had special care in choosing bull semen that could be inseminated in heifers when appropriate. These measures were taken to ensure good use of this reproductive technology.

Pregnancy diagnosis

The pregnancy diagnosis was conducted by transrectal ultrasonography. This method was selected because it has high accuracy and because the outcome is known at the time of the test (16). The equipment used was a portable ultrasound scanner with a rectal linear transducer (WED-3100), and the diagnosis was performed with a frequency of 5 MHz (15). A veterinarian with expertise in this field performed all of the ultrasounds. Ultrasound was conducted at least 45 days after insemination for better diagnosis with visualization of the bovine fetus (16). The results were classified as pregnant, nonpregnant, or doubtful. In this study, the pregnancy rate was calculated as the number of pregnant cows out of the total number of cows that underwent ultrasonography. The gestational age was compared with the date of insemination; if there was no agreement, the pregnancy was excluded from consideration in the statistical analysis because it could be due to a natural mount with a bull. The number of cows to be diagnosed by ultrasound was selected based on the availability of the bovines with the aim of performing the diagnosis for most users of the program and covering all of the municipalities with owners in the region.

Data recording and management

The owner´s name and sex, the municipality and province where the farm was located, and the number of cows the farmer owned were recorded for each insemination performed. Concerning the inseminator, the name, age, and experience were registered together with both the insemination date and the type of insemination (detected estrus or AI at a fixed-time). The identification number of the cow, age, body condition (expressed on a scale from 1 to 5 with intervals of 0.25, with 1 corresponding to very thin and 5 to obese) (11), ordinal number of births, and date of last birth of the cow and the breed and biotype (dairy or beef) of the cow and the bull were recorded. The BPGP only subsidized two AIs per cow; thus, only this information was recorded. We also collected information on the offspring born during the BPGP; unfortunately, information was not collected on all of them, so it was not possible to perform a statistical analysis of these data. No preference was found for specific sex in the offspring as sexed semen was not used. All information was recorded in MS Excel spreadsheets. For the representation of the results, we showed a general output summarizing the data as a percentage of the total number of AIs performed.

Descriptive statistics

For the descriptive analysis of the collected data, we only used the information on the cows with ultrasound diagnosis (853 animals), as the number of cows diagnosed with other methods (*e.g.*, presence/absence of calf) was negligible. Continuous variables with a potential effect on insemination success were described using the mean, median, standard deviation, and range for the groups of pregnant, nonpregnant, and total cow diagnoses by ultrasonography (table 1A, page 381). For categorical variables with a potential effect on insemination success, we calculated the number of pregnant and nonpregnant cows along with the percentage of pregnancy for each level (table 1B, page 381).

All variables were screened for missing values, substantial variability, and distribution of values. This analysis revealed that the inseminator's years of experience had a trimodal distribution with modes at 10, 27, and 47 years and with approximately 60% of the data below 10 years; therefore, inseminator experience was categorized as follows: 1-4, 5-9, and 10+ years of experience. Meanwhile, the herd size was categorized as follows: 1-5, 6-10, 11-20, 21-30, and 31+ cows. These categories were selected arbitrarily because the INDAP uses them to categorize the herd size of small farmers.

Statistical modeling

The success of AI was modeled as a function of different biological, environmental, and social factors recorded by the BPGP using logistic regression. The outcome for this model was the gestational status of the inseminated cow, which was diagnosed by ultrasound as nonpregnant [0] or pregnant [1]. The predictors of interest were smallholder sex; the province where the smallholder was located; herd size; the years of experience of the inseminator; insemination type (estrus detected or at a fixed time), age in years, body condition, ordinal number of births, and biotype (dairy or beef) of the cow; and the biotype (dairy or beef) of the bull.

All predictors were evaluated for unconditional associations with the outcome (gestational status) using simple logistic regression. Variables with $p < 0.30$ were included in a multiple logistic regression model (table 2, page 382). All unconditional associated variables were examined for a high correlation between them to prevent collinearity problems in the final model. The final model was built using a stepwise backward elimination process starting with a maximum model containing all unconditionally associated predictors. The least significant variables (high Wald p-value) were removed from the model one at a time until all remaining variables were significant (Wald-test $p \leq 0.05$) unless substantial changes (>20%) in the coefficient of other variables were noticed. Linearity between continuous predictors and the log odds of the gestational status was checked by observing smoothed scatterplots and by categorizing the predictor and evaluating the coefficients associated with indicator variables. Only interactions with biological sense were checked for inclusion in the maximum model. All statistical analyses were performed with Stata version 15 (StataCorp LP).

Table 1A. Descriptive statistics of continuous variables that affect pregnancy efficiency.
Tabla 1A. Estadística descriptiva de variables continuas que afectan la eficiencia de la preñez.

Variable	Cow´s gestational status	n	Mean	Median	Std. Dev.	Range
Inseminator´s age (years)	Nonpregnant	226	42.64	39	11.85	21 - 68
	Pregnant	627	44.69	41	12.20	21 - 69
	Total	853	44.14	40	12.13	21 - 69
Inseminator´s experience (years)	Nonpregnant	226	11.92	9	10.87	0 - 47
	Pregnant	627	13.97	9	11.76	1 - 48
	Total	853	13.43	9	11.56	0 - 48
Cow´s age (years)	Nonpregnant	222	4.60	4	2.08	1 - 10
	Pregnant	607	4.41	4	2.37	1 - 15
	Total	829	4.47	4	2.30	1 - 15
Cow´s body condition (1-5)	Nonpregnant	226	3.33	4	0.43	2.25 - 4.75
	Pregnant	627	3.28	4	0.46	1 - 5
	Total	853	3.30	4	0.46	1 - 5
N° of births	Nonpregnant	222	2.38	2	1.85	0 - 8
	Pregnant	607	2.29	2	2.06	0 - 12
	Total	829	2.31	2	2.01	0 - 12

Table 1B. Descriptive statistics of categorical variables that affect pregnancy efficiency.
Tabla 1B. Estadística descriptiva de variables categóricas que afectan la eficiencia en la preñez.

Variable	Level	n	%	Nonpregnant	Pregnant	% Pregnant (pregnant/total)
Owner´s sex	Female	278	33%	65	213	77%
	Male	575	67%	161	414	72%
Owner´s province	Cachapoal	314	37%	88	226	72%
	Cardenal Caro	83	10%	13	70	84%
	Colchagua	456	53%	125	331	73%
Herd size	1 - 5	158	18%	36	122	77%
	6 - 10	111	13%	33	78	70%
	11 - 20	184	22%	47	137	74%
	21 - 30	186	22%	39	147	79%
	Over 30	214	25%	71	143	67%
Type of AI	Detected estrus	706	83%	188	518	73%
	Fixed-time	147	17%	38	109	74%
Cow´s biotype	Beef	223	26%	56	167	75%
	Dairy	630	74%	170	460	73%
Bull´s biotype	Beef	300	35%	76	224	75%
	Dairy	553	65%	150	403	73%

Table 2. Multivariable model for explanatory variables in the pregnancy probability model of inseminated cows in the BPGP.

Tabla 2. Modelo Multivariable para variables explicativas en el modelo de probabilidad de preñez de vacas inseminadas en el BPGP.

Variable	Odds Ratio	Std. Err.	p-value	[95% Conf. Interval]	
Baseline odds	7.838	5.090	0.002	2.194	27.989
Province (Cachapoal as reference)					
Cardenal Caro	2.685	1.101	0.016	1.201	6.001
Colchagua	1.144	0.222	0.486	0.782	1.674
Herd size (1-5 as reference)					
6-10	0.733	0.212	0.284	0.416	1.292
11-20	0.881	0.237	0.640	0.519	1.495
21-30	1.039	0.300	0.894	0.589	1.831
30 or more	0.502	0.139	0.013	0.291	0.867
Inseminator´s experience (1-4 years as reference)					
5-9	1.144	0.287	0.590	0.700	1.871
10 or more	2.011	0.542	0.010	1.185	3.411
Type of AI (detected estrus as reference)					
Fixed-time	0.458	0.131	0.007	0.261	0.806
Body condition	0.702	0.140	0.077	0.475	1.038

Std. Err.: standard error, Conf. Interval: confidence interval.

Std. Err.: error estándar, Conf. Interval: intervalo de confianza.

Results

Although the statistical analysis was performed only on cows that had a pregnancy diagnosis by ultrasound, the general results of the BPGP are described below for an overview of the program.

The BPGP general output

The BPGP was implemented between May 2015 and January 2018 among small farmers of the O'Higgins region. AI was performed in 29 of 33 municipalities belonging to the three provinces of the region and benefiting 295 farmers (each owning a separate farm). In total, 168 farmers were in Cachapoal Province, 114 farmers were in Colchagua Province, and 13 farmers were in Cardenal Caro Province. Most of the farmers were male (77%). Fifty-six percent of them had between 1 and 5 cows, 19% had 6 to 10 cows, 13% had 11 to 20 cows, 7% had 21 to 30 cows, and only 5% had more than 30 cows. The BPGP included 22 inseminators whose ages ranged between 21 and 69, with an average of 43.6 years. The experience of the inseminator ranged between 0 and 48 years, with an average of 11.4 years. The type of AI performed was 91% by detected estrus and 9% at a fixed time. In total, 2,900 AIs were performed on 1,773 cows, and 1,127 had a second AI through the program. AIs were performed mainly between October and December according to the timing of the pastures to ensure that both mothers and offspring had sufficient food (figure 1, page 383).

Of the total number of cows inseminated, 508 corresponded to heifers, with an average age of 17 months. The average age, body condition, and number of births of the cows inseminated were 4.3 years old, 3.5, and 2.2 births, respectively. The highest number of inseminations was performed using semen from dairy bulls (56.4%), mostly Jersey followed by Holstein Friesian with contributions of 37.3% and 19.1%, respectively. In the case of beef cattle (43.5%), the main breed used was Red angus (24.7%) followed by Aberdeen angus (18.8%).

Pregnancy diagnosis

According to the ultrasound technique performed in 853 inseminated cows, 72% of the cows were pregnant, 26% were nonpregnant, and 2% yielded a doubtful pregnancy diagnosis. Of the 853 pregnancy diagnoses made, 694 cows were inseminated once; among them, 525 were diagnosed as pregnant, and 169 were diagnosed as nonpregnant. Of the 159 cows inseminated twice, 109 cows were diagnosed as pregnant, and 50 were diagnosed as nonpregnant.

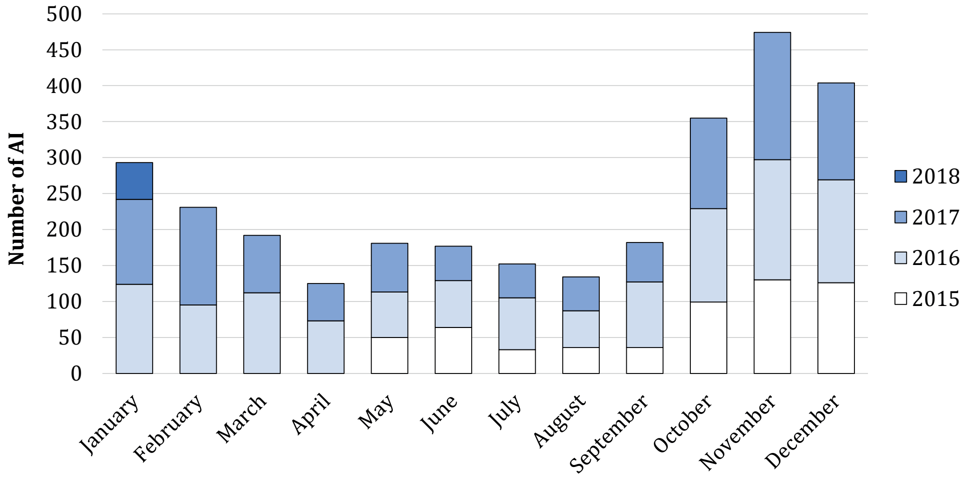

Figure 1. Number of AIs by month and year.

Figura 1. Número de IA por mes y año.

From the information obtained, 38.7%, 27.2%, 20.2% and 13.8% of the offspring were Jersey, Red angus, Aberdeen angus and Holstein Friesian, respectively. Notably, 50% of the offspring were female, and the other half were male.

Descriptive statistics

When continuous variables were averaged over the pregnant and nonpregnant cow groups as diagnosed by ultrasonography, distinct patterns were observed (table 1A, page 381). Inseminator age and experience were higher in the group of pregnant cows than in the group of nonpregnant cows. In contrast, the cow's age, body condition, and number of births were similar in the two groups. For categorical variables, the herd size and the province showed a higher percentage of pregnancy and were correlated with a higher potential for insemination success (table 1B, page 381).

Statistical modeling

The variables unconditionally associated with the gestational status of the cows were body condition, inseminator experience, cow and bull biotype, type of AI, herd size, and province. No correlations that were large enough to suggest a potential for collinearity problems in the model were found among these variables. The final model was built with the following variables: province, herd size, inseminator's years of experience, type of AI, and body condition. Body condition was maintained in the final model, but it was not significant as its removal caused a substantial change in the coefficient of the 10+ category of the inseminator's years of experience, suggesting a possible confounding effect among these variables. The two interactions we tested (body condition*inseminator's years of experience and body condition*type of AI) were not significant; therefore, they were removed from the final model. The final model is shown in table 2 (page 382). This model suggests that the pregnancy log odds in Cardenal Caro Province were approximately 2.7 times higher than those in Cachapoal Province, but no significant differences were observed between Colchagua and Cachapoal Provinces. The pregnancy log odds of inseminators with 10 or more years of experience were two times greater than those of inseminators with between 1 and 4 years of experience. The log odds of pregnancy decreased by 0.5 in farms with 30 or more cows compared with farms with 1 to 5 cows. For the type of AI, the pregnancy log odds decreased by 0.46 when AI was conducted at a fixed time with hormone synchronization compared with heat detection. Finally, the model suggests that cows with greater body condition had lower log odds of becoming pregnant after AI, but this trend was not significant.

Discussion

In the O´Higgins region, 35% of family farmers are INDAP users, and 92% of them are male while only 8% are female. Of these farms, 82% are managed by farmers older than 50 years, 37% of farmers have incomplete basic education (*i.e.*, preparatory school), and only 6% have a university education (19). As the majority of farmers are older men with limited learning, the implementation of technological tools, such as AI, demands education. This can be achieved through seminars and field visits so that the family farmers can see the productivity improvements and the advantages of this type of technology. Explaining to farmers that small modifications with these tools can significantly contribute to their reproductive performance and that these technological tools are not difficult to implement is important. Education to farmers has been implemented since 2010 by INDAP and ProAgro, and it involves farmers going to southern Chile to learn the insemination technique; many of these farmers are inseminators and promoters of this type of program, and they bring awareness of this technology to other farmers and encourage them to take advantage of it. The offspring born as a result of AI have better genetic characteristics than their mothers, can rapidly improve the quality of the herds (whether for beef or milk), achieve greater weight gain, and subsequently result in higher meat productivity or milk quality. These consequences can raise the productivity of the herd and improve small farmer´s quality of life (3, 4, 23, 25). To determine which variables are most important in the probability of pregnancy of cows in this region, a statistical study was conducted with different variables related to the reproductive outcome.

The results show that beef cattle are concentrated in the coastal dry zone (Cardenal Caro Province) and dairy cattle in the central area near the Andes mountain range (Cachapoal and Colchagua provinces). A significant difference between the AIs performed in the 3 provinces was found, with Cardenal Caro Province achieving the highest pregnancy rates. The cattle of this province showed a significantly higher probability of pregnancy despite the majority of AIs performed in this province being at a fixed time with a hormonal protocol, which is known for having pregnancy rates below detected estrus AI (21). This could have been achieved because a correct AI technique was performed. The veterinary doctor that performed 88% of these AIs has nine years of expertise and considered all of the factors that influence AI, such as cow age, postpartum days, body condition, and alimentation. He evaluated all of the cows and excluded for AI those that had a low reproductive yield. Another factor that can contribute to these results is the efficient cow handling of the farmers. As they live in a more remote area and have less access to water and supplies, they take good care of their animals, raising only cows that they can feed and keep in good condition with a balanced diet and good access to water. This would demonstrate that with adequate basic management, such as feeding and a good AI technique, increasing reproductive efficiency is possible even with methods such as AI at a fixed time.

The experience of the inseminators showed a significant association with pregnancy rate, a fact that shows that practice in AI is fundamental to generating a reproductive advancement in the herd. In addition to developing the necessary skill and ability to perform a good AI technique, determining which cows can or cannot be inseminated given the characteristics of the cow and the production system is also important in AI. Classifying and excluding cows that are too young or too old or that do not have an adequate body condition are essential for this technology to be effective. Although the inseminators in the BPGP are of different ages and have different years of experiences, all are interested in continuous learning; thus, continuing training for inseminators is essential in this practice. INDAP and ProAgro are continuously conducting talks and workshops on this topic, as a fundamental part of the program is that farmers and inseminators train and update their knowledge regarding this technology. The government and universities must continue promoting education and the incorporation of new tools to improve the efficiency of the work on farms.

The number of cows the owner had is another variable that affects pregnancy rates, with small herds having a greater probability of generating offspring. With fewer animals, the detection of estrus is better, and therefore the probability for pregnancy is higher. This can be observed in small herds of dairy cows, where the owner milks them every day and can see if any cow goes into heat and subsequently perform the AI. However, in large herds and especially for cows destined for meat production, the observation becomes more difficult as most of the time, the cows are on a large field grazing. Family farming is mainly for subsistence; thus, very large herds are more difficult to manage if farmers do not have the necessary tools and help. This is an important aspect to consider as most farmers are older, and their children and grandchildren migrate to the cities rather than stay in the countryside (7). During the last two decades, the number of family farms has decreased, and an out-migration of farm and nonfarm residents has occurred. This can be explained by the fact that young people today have better education and more tools than their parents and obtain better-paying jobs in cities than in the countryside. Policymakers have developed long-term strategies to mitigate the negative consequences of the exit from agriculture and to sustain or rejuvenate the rural population; however, positive results have not been seen, and the incentives are not encouraging. One way to maintain the young population or, better yet, to encourage the return of these qualified young people, is to show them that improvements can be made in the productive systems through technologies such as AI. Such young people are the best candidates to improve and implement these new technologies because of their access to, ease of use of and reliance on technologies that older people often do not understand well (7).

The type of insemination is also associated with the success of pregnancy, confirming that AIs performed with detected estrus are more effective than those with hormone synchronization. When a hormonal protocol synchronizes the estrus of cows, the pregnancy rate and the productive performance of the herd decrease (21, 36). In this program, AI at a fixed time was performed mainly in cows from farmers that did not have access to an inseminator because they were far apart. When AI at a fixed time is performed, the inseminator diagnoses, registers, and inseminates; thus, when the program is not in place, the farmers stop inseminating as they are not in the habit of checking for estrus and recording. AI at detected estrus is always preferred, not only for the higher pregnancy success but also for farmers to establish a habit of examining and keeping records of their cows. Notably, the best pregnancy rate is obtained when the bull mounts a cow in estrus; however, the cost of having a bull in the herd is greater than the total productive gain. This reinforces the idea that in small herds, AI is a good technique to use, especially in places of difficult access where the most viable alternative is AI at a fixed time with a hormonal protocol, such as the one included in the BPGP.

Finally, body condition may affect pregnancy, especially for cows with greater body condition, which were less likely to become pregnant. The scale used in this study shows that extremes in body condition are ineffective in generating a pregnancy, as mentioned by other authors (11). A cow should be inseminated under a condition of at least 2.5 considering the postpartum days for better maintenance and development of pregnancy (5, 37). If a cow is inseminated with a low body condition, the fetus is most likely to be reabsorbed due to the high energy outflow it needs. In contrast, if a cow is inseminated with a very high body condition, it can become pregnant, but problems at the end of gestation and delivery can lead to the death of the calf and the cow.

According to the Food and Agriculture Organization (FAO) (2015a), livestock production is growing faster than any other sector, and by 2050 livestock is predicted to become the most important agricultural sector in terms of added value. Its value is rising quickly because of rapid increases in livestock production resulting from population growth, urbanization, changes in lifestyles and dietary habits, and increasing disposable incomes. In this regard, Latin America is viewed as a valuable resource for the genetic improvement of livestock on a global scale (22, 33). Taking advantage of the animals in our production systems is imperative because many of them are resistant to stress such as droughts, are free from particular diseases, and can survive on high-roughage feeds. Fundamentally, improving the production systems can enable opting for fair prices and competing with other farmers in global trade. As consumers are increasingly demanding more food, which should be produced in sustainable agricultural systems, accelerating the favorable selection of genes with a better feed conversion rate by using natural resources as efficiently as possible to achieve the direct conservation of the environment is necessary (28, 38). AI is a technology that not only improves the productivity of the herd but also helps the farmer and other animals to introduce genes with better reproductive characteristics and consequently helps the local community, as it involves a better use of available natural resources (8, 12). Although this is a small study in one region of the country, it shows the factors that affect the pregnancy rates of artificially inseminated cows in the hope of generating more interest from governments in continuing to supply these types of technologies to those most in need, emphasizing the overriding variables to obtain better production yields.

Conclusion

In this study, we determined the success of AI modeled as a function of different biological, environmental, and social factors recorded by the BPGP using logistic regression. We observed that the province, the number of cows the owner had, the experience of the inseminator, the type of AI, and the body condition of the cow showed a direct effect over pregnancy probability. The final endpoint is the birth of offspring with better productive characteristics through the introduction of a genetic breeding program that is relatively simple, cheap, and, above all, low risk. Although more studies are necessary to analyze the possible causes associated with some results and the cost-benefit ratio, the result evidenced in this study demonstrated the importance of some variables to generate offspring through the implementation of BPGP. This type of program can contribute to the improved livelihood of people who depend on low-input systems. These breeding programs must have outputs consistent with the producer's objectives and be driven by incentives from the market to justify the producer's investment. Therefore, when adopting this biotechnology, the results should have a distinct benefit in terms of animal improvement and economic returns to small farmers, helping decrease hunger and enhance food security.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Acknowledgments

The authors would like to thank all of the small farmers who made the BPGP possible and Christian Hidalgo and Martín Sepúlveda for the English revision of this manuscript.

This work was supported by the National Institute of Agricultural Development (INDAP).