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Effect of Season, Parity and Lactation on Reproductive Performance of Sows in a Tropical Humid Climate

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ABSTRACT : The aim of this study was to analyze post-weaning reproductive performance of Large White sows in relation to season, parity and their lactation performance under tropical conditions in Guadeloupe (French West Indies, 16° Lat. N, 61° Long. W.). This work was based on data recorded in the experimental unit of INRA from January 1993 to December 2003. Two seasons were determined *a posteriori* from climatic parameters recorded continuously in a station close to the experimental unit. Mean ambient temperature was higher during the hot season than the warm season (26°C vs. 24°C) but relative humidity was comparable for both seasons (i.e. 87% on average). Season had a significant effect on all reproductive parameters analyzed. Primiparous sows weaned in the hot season had a higher probability of a prolonged weaning to estrus interval, WEI (odds ratio was 4.1; $p<0.01$) but multiparous sows were not affected. A higher probability of a prolonged weaning to conception interval, WCI (odds ratio >2.5, $p<0.01$) and a lower subsequent farrowing rate (-10%, $p<0.01$) were found for sows weaned in the hot season. A higher daily feed intake during lactation reduced the probability of a prolonged WEI ($p<0.05$). Body weight and average back-fat thickness at farrowing affected WEI and WCI ($p<0.05$), whereas body weight and average backfat thickness change in lactation did not. This study confirms the negative effects of the hot season on primiparous reproductive performance. It also indicates that lactation performance influences sow non-productive period.
(**Key Words :** Reproductive Performance, Sow, Parity, Tropical Climate)

INTRODUCTION

In commercial farms, nowadays, sows generally exhibit a fertile estrus within 7 d after weaning (Soede et al., 2000). However, estrus is delayed in a variable proportion of sows. Nutritional deficit during lactation is well known to increase the weaning to estrus interval, especially in primiparous sows (Vesseur et al., 1994; Whittemore, 1996). Lower feed intake in lactation and higher body weight loss have been found to be associated also with a lower conception rate (Kirkwood et al., 1987) and a reduced litter size (Hughes, 1993). As reviewed by Quesnel and Prunier (1995), reproductive performance is also affected by sow management (lactation length, feed characteristics), animal related factors (milk production, genotype) and seasonal factors (temperature, photoperiod, humidity). In seasonal breeders, such as the European wild sow, changing photoperiod regulates the reproduction mechanism, through variations in melatonin secretion by the pineal gland. The melatonin profile of domestic sow is also influencing by season and Peltoniemi et al. (1999) concluded photoperiod as the primary environmental factor influencing the lower reproductive performance in summer. In other temperate climates and in climatic chambers, the combined negative effects of the ambient temperature and photoperiod contribute to affect the reproductive performance of sow (review by Prunier et al., 1996). Characteristics of tropical humid climate differ from temperate climates, particularly low changes in photoperiod and high variations in ambient temperature and relative humidity among seasons (Berbigier, 1988). Limited information is available on the effect of season on the reproductive performance of sows rearing in a tropical humid area. In Thailand, Tantasuparuk et al. (2000a) showed that the combined effects of high temperature and humidity play an important role in seasonal changes of sow reproductive efficiency. The aim of this

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study is to investigate some factors affecting sow reproductive performance, including season and parity influences, as well as the effect of lactation performance. Analyzes were performed from data recorded over an eleven-year period in the tropical humid context of the experimental herd of INRA in Guadeloupe F.W.I (16° Lat. N., 61° Long. W.).

MATERIALS AND METHODS

Data collection and animal management

The data were collected in an INRA experimental herd located in the humid tropical area (Guadeloupe, French West Indies, 16° Lat. N., 61° Long. W.) from January 1993 to December 2003. A total of 1,181 mating and 888 farrowing records (255 Large White sows) were available over the whole period considered. During the gestation period, sows were restrictively fed with a conventional diet based on corn, soybean, wheat middling, and wheat bran and containing 13 MJ/kg of digestible energy, 14% crude protein and 0.55% lysine. Between d 30 post-weaning and farrowing, sows were housed in groups of four animals and were daily given 3 kg of the gestation diet. Ten days before farrowing, the animals were moved to a semi open farrowing unit. The lactation diet contained 14 MJ/kg of digestible energy, 17.3% crude protein and 0.83% lysine and was formulated using corn, wheat middling, and soybean to meet or exceed amino acids requirements (National Research Council, 1998). On the farrowing day (d 0), sows received 1 kg of the gestation diet. Feed allowance was progressively increased by 1 kg each day until d 5. Over these first 4 d *post-partum*, the proportion of gestation diet decreased regularly (100, 75, 50, 25 and 0%, on d 0, d 1, d 2, d 3 and d 4, respectively) with the increase in the lactation diet. Sows were offered feed *ad libitum* from d 5. Sows were fed once daily at 07:00 and had free access to water from a low-pressure nipple drinker. Feed refusals were daily weighed. Cross fostering was practiced within the first 48 h after birth in order to standardize litter size to 10 or 11 piglets. Creep feed (15.3 MJ/kg of digestible energy, 20% crude protein and 1.47% lysine) was provided for piglets from 21 d of age. Lactation length was approximately 4 weeks (27.9±3.1 d). At weaning, sows were moved into individual stalls located in front of the boars' pens. During the first 14 d after weaning, sows were observed twice daily in presence of a mature boar for the onset of standing estrus. Other signs of estrus such as vulva swelling, reddening or reaction to back-pressure were also checked. Once sows stood to be mounted by a boar, they were inseminated twice with a maximum 24-h interval, using either supervised natural mating (NM) or artificial insemination (AI). A large part of seminal doses came from the experimental unit (i.e. 88%) and the remaining came from selected purebred boars herd. The two repeated inseminations during the estrus were considered as the same insemination event. Sows not detected in estrus within 14 d after weaning were checked for signs of estrus once daily. Pregnancy diagnosis was performed using boar passage and confirmed by ultrasonography 3 weeks after insemination. Puberty was checked each day by observation of vulva reddening, swelling and response to back pressure and gilts were mated at the second or third post-pubertal estrus after a synthetic progestin treatment. Whatever the parity number, reasons for sow culling were conception failure after second remating (8.4%), small litter size (11.2%) and health problem (80.4%).

Measurements

Ambient temperature and relative humidity were continuously recorded (one measure every 30 s) from a meteorological station (Campbell Scientific Ltd., Shepshed, UK) close to the experimental unit. Sows were weighed and backfat thickness was measured ultrasonically (Agroscan, E.C.M., Angoulême, France) 10 d before and 1 d after farrowing, and at weaning. Backfat thickness measurements were carried out at 65 mm from the midline of the point beside the shoulder and the last rib on each flank. Average backfat thickness was calculated as the average of measurements on the two sites. Piglets were individually weighed at birth and every week until weaning.

Traits and statistical analyzes

The 24 h maximum, minimum and mean of ambient temperatures and relative humidities were averaged per month. A principal component analyze and a hierarchical classification (SPAD-TM®, 1993) were used to discriminate seasons over year with 24 h mean temperature and relative humidity, diurnal changes in temperature and in relative humidity.

During the lactation period, sow's daily feed intake was determined as the difference between feed allowance and refusals. The studied variables for reproductive performance were the interval from weaning to estrus (WEI), the interval from weaning to conception (WCI), which was defined as the number of days between weaning and successful insemination; the farrowing rate (FR), which is defined as the proportion of inseminated sows that farrowed related to the total number of inseminated sows (including gilts and sows that were culled before successful farrowing) and the subsequent farrowing rate, SFR, which represents the occurrence of successful inseminations at the first estrus after weaning and then it excludes data from gilts that have experienced their first insemination. A total of ten sows (3 multiparous and 7 primiparous sows) with a

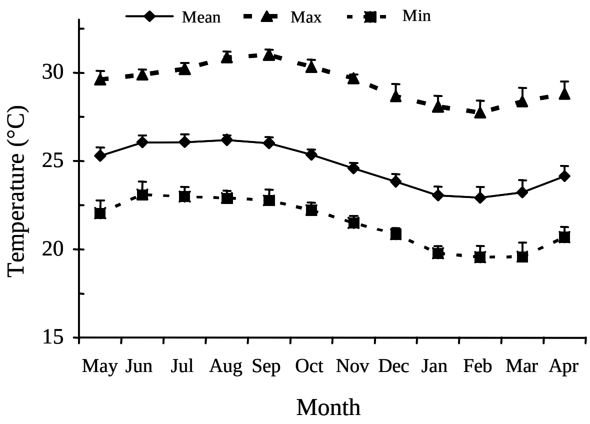

Figure 1. Seasonal variation (+s.d.) in ambient temperature between January 1994 and December 2003; warm season: November to April; hot season: May to October.

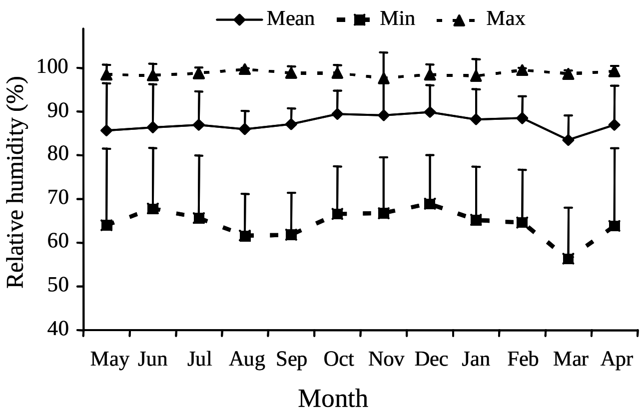

Figure 2. Seasonal variation (+s.d.) in relative humidity between January 1994 and December 2003; warm season: November to April; hot season: May to October.

WEI higher than 22-d was excluded from the analyze because they are likely to include sows having a silent ovulation after weaning. For SFR, primiparous sows represented sows inseminated after their first lactation, rather than sows that have experienced two gestations. Discrete traits, i.e. DWEI and DWCI were defined from WEI and WCI measurements. Two categories were defined for DWEI, i.e. "normal" when the interval was up to 5 d and as "prolonged" when it exceeded 5 d. Similarly, DWCI was assigned a value of "0" when WCI was lower than 7 d and a value of "1" otherwise. Length of normal or prolonged interval was chosen according to the distribution of WEI and WCI. FR and SFR were defined as dichotomous traits, which were assigned a value of '1' when sows was successful mated and '0' otherwise. All discrete variables were assumed to follow a binomial distribution (DWEI, DWCI, FR, SFR) or a Poisson distribution (WEI, WCI). Descriptive statistics were obtained using MEANS and FREQ procedures (SAS, 1997). Logistic and log-linear models were applied to discrete variables. A sow effect was included as a random effect using the GLIMMIX macro (Littel et al., 1996) to account for repeated observations for many of the sows. Odds ratios were estimated from logistic linear models to get information about their relative risk pattern. From log-linear models, the results have been both presented as least square means before (in log linear scale) and after back transformation (in the original scale) and an approximate standard error in the original scale was calculated using the delta-method (Littel et al., 1996). The number of records including all measurements, especially weight and backfat thickness measurements, was limited (n = 410). For this reason, two sets of analyzes were performed. In the first set, all sows were considered and only the effects of sow, season (warm vs. hot), parity (primiparous vs. multiparous), type of mating (NM vs. AI) and two-way interactions between these factors could be analyzed. The most appropriate definition of seasonal effects was used for each dependant variable, i.e. season of weaning for WEI, WCI, DWEI, DWCI, SFR, and season of mating for FR. Additional analyzes were performed using the effect of season of weaning for WEI, WCI, DWEI, DWCI and SFR and adding the effect of DWEI or WEI as fixed effect or covariable when analyzing SFR. In the second set of analyzes, only data with complementary information on sow lactation performance were used. Mean values of available variables were compared between the sub sample and the excluded data in order to check the representativity of the sub sample analyzed. The effects of lactation performance corrected by parity, i.e. average daily feed intake (ADFI), sow body weight and average back-fat thickness at farrowing, body weight and average back-fat thickness loss during lactation, litter body weight at weaning were investigated on DWEI and DWCI. Taking into account of significant correlation between lactation performance parameters, each explanatory variable was considered separately. Finally, Spearman correlations analyze was used to determine the relationships between residual values of performance in lactation and reproductive performance (CORR procedure, SAS Institute, 1997).

RESULTS

Characterization of the two seasons

Figure 1 and 2 show the seasonal changes and yearly variation in ambient temperature and relative humidity, respectively. The lowest and the highest mean 24 h temperatures were measured in February (i.e. 22.9±0.6°C) and in August (i.e. 26.2±0.3°C), respectively. Mean relative humidity was the lowest in March (i.e. 83.5±5.6%) and the highest in December (i.e. 89.9±6.2%). Two seasons were discriminated from a principal component analyze: a warm season between November and April and a hot season

Table 1. Main characteristics of seasons (means±standard deviations)*

Item	Season	
	Warm	Hot
Temperature (°C)		
Minimal	20.3±0.9	22.7±0.5
Maximal	28.6±0.8	30.3±0.7
Mean	23.6±0.8	25.8±0.5
Relative humidity (%)		
Minimal	64.2±13.1	64.6±12.8
Maximal	98.6±2.9	98.8±1.8
Mean	87.7±6.8	86.9±7.5
Duration of diurnal period (hh:min)[c]	11:40	12:20

* Correspond to the mean daily ambient temperature and relative humidity between January 1994 and December 2003; Season: Warm season: November to April. Hot season: May to October; Diurnal period: 06:20 h to 18:00 h and 05:50 h to 18:10 h, for warm and hot seasons, respectively (according to Météo France).

between May and October. The average ambient temperature was lower in the warm season than in the hot season (23.6±0.8 vs. 25.8±0.5°C; Table 1). Relative humidity was comparable and averaged 87.0%, so that seasonal difference was more attributable to difference in ambient temperature than in humidity. According to data from the French national meteorological institute (Meteo France), day length was slightly lower during the warm than during the hot season (11 h 40 min vs. 12 h 20 min, respectively).

Table 2. Descriptive statistics of the data*

	n	Mean	s.d.	Median
Dependant variables*				
FR (%)	1,181	75.2	-	-
SFR (%)	639	77.2	-	-
WEI (days)	761	4.7	2.4	4.0
WCI (days)	639	10.2	15.9	4.0
Independent variables				
Parity	1,181	3.3	2.2	3.0
Lactation length (days)	859	27.9	3.1	28.0
ADFI in lactation (kg)	410	4.21	0.88	4.22
Sow BW at farrowing (kg)	410	239.4	40.4	242.7
Sow BW at weaning (kg)	410	222.5	40.6	222.9
Sow BW change (kg)	410	16.8	13.8	17.0
BFT at farrowing (mm)	410	20.8	4.8	20.1
BFT at weaning (mm)	410	17.4	4.2	16.7
BFT change (mm)	410	3.4	2.9	3.2
Litter size at birth	888	10.5	3.9	12.0
Litter size at weaning	859	8.7	2.0	9.0
Litter weight at birth (kg)	410	14.0	3.7	14.1
Litter weight at weaning (kg)	410	62.8	17.1	64.3

* s.d. = Standard deviation, n = Number of samples; FR = Farrowing rate; SFR = Subsequent farrowing rate after weaning; WEI = Weaning-to-estrus interval; WCI = Weaning-to-conception interval; ADFI = Average daily feed intake; BW = Body weight; BFT = Back-fat thickness.

Reproductive performance

Descriptive statistics for both reproduction and production traits of sows are presented in Table 2. From a total of 1,181 mating, AI was used more frequently (i.e. 66%) than NM. The yearly farrowing rate and the yearly

Table 3. Structure of the analyzed data and levels of significance*

Dependant variables[b]	First analyze					
	FR	SFR	WEI	WCI	DWEI	DWCI
First analyze						
No of observations	1,181	639	639	639	639	639
Explanatory variables						
Season[c]	0.01	0.01	n.s	0.01	0.01	0.01
Parity[c]	n.s	n.s	0.01	0.01	0.01	0.05
Season×parity	0.05	n.s	0.01	n.s	0.01	n.s
Type of mating	0.01	-	-	-	-	-
WEI	-	n.s	-	-	-	-
DWEI	-	0.01	-	-	-	-
Second analyze					DWEI	DWCI
No of observations	-	-	-	-	410	335
ADFI	-	-	-	-	0.05	n.s
Sow BW at farrowing	-	-	-	-	0.01	0.01
Sow BFT at farrowing	-	-	-	-	0.01	0.01
Sow BW at weaning	-	-	-	-	0.01	0.01
Sow BFT at weaning	-	-	-	-	0.01	0.01
Sow BW change	-	-	-	-	n.s	n.s
Sow BFT change	-	-	-	-	n.s	n.s
Litter size at weaning	-	-	-	-	0.05	n.s
Litter weight at weaning	-	-	-	-	0.05	0.05

* n.s: Non-significant (p>0.05); FR = Farrowing rate; SFR = Subsequent farrowing rate after weaning; WEI = Weaning-to-estrus interval; WCI = Weaning-to-conception interval; DWEI = Percentage of prolonged weaning-to-estrus interval (>5 d); DWCI = Percentage of weaning-to-conception interval (>7 d); ADFI = Average daily feed intake; BW = Body weight; BFT = Back-fat thickness; Season: Warm season: November to April. Hot season: May to October; season of mating (FR) or of weaning (WEI, DWEI, WCI, DWCI, SFR); Parity: primiparous vs. multiparous.

Table 4. Effect of season and parity on the interval from weaning to estrus (WEI), the interval from weaning to conception (WCI), the percentage of prolonged WEI (DWEI), the percentage of prolonged WCI (DWCI) and the subsequent farrowing rate after weaning (SFR) (n = 639 except for FR n = 1,181; least square means±standard errors)*

	Season[b]				Significance		
	Warm		Hot				
	Primiparous	Multiparous	Primiparous	Multiparous	S	P	S×P
FR (%)	70.3±13.0[a]	79.2±7.9[a]	66.5±16.5[a]	56.3±15.6[b]	0.01	n.s	0.05
WEI (days)	4.76±1.05[a]	4.71±0.85[a]	5.64±1.15[b]	4.52±0.83[a]	n.s	0.01	0.01
DWEI (%)	10.6±5.9[a]	6.0±2.9[a]	43.9±20.7[b]	5.4±2.7[a]	0.01	0.01	0.01
SFR (%)[c]	97.0±2.0 [a]	97.5±1.3[a]	82.2±9.1[b]	87.6±5.9[b]	0.01	n.s	n.s
WCI (days)	6.78±2.62[a]	6.13±1.92[a]	16.42±5.07[b]	10.54±3.12[c]	0.01	0.01	n.s
DWCI (%)	10.4±6.1[a]	8.0±3.9[a]	38.0±18.4[b]	20.5±9.2[c]	0.01	0.05	n.s

* From mixed linear model analyze including the effect of season of weaning (S), parity (P), season-parity interaction as fixed effects and sow as random effect; standard errors were approximated using the Delta method; means values, within the same row, with different superscript letters differ at p<0.05;. n.s: Non-significant (p>0.05).

Warm season: November to April. Hot season: May to October.

Significant effect (p<0.01) of DWEI on SFR: 95% for sows with WEI<5 d and 87% for sows with WEI>5 d.

Table 5. Residual correlation coefficients between performance during lactation and postweaning reproductive performance (n = 324)*

	WCI	BW at farrowing	BW at weaning	BW change	BFT at farrowing	BFT at weaning	BFT change	ADFI	Litter size at weaning	Litter weight at weaning
WEI	0.34**	-0.02	-0.07	-0.07	-0.04	-0.06	0.03	-0.13*	-0.13*	-0.09
WCI		-0.08	-0.05	-0.06	-0.11*	-0.10	-0.02	-0.09	0.05	0.02
BW at farrowing			0.89**	0.14*	0.32**	0.37**	0.00	0.07	-0.05	-0.10
BW at weaning				0.26**	0.27**	0.39**	-0.12*	0.14*	-0.19**	-0.29*
BW change					-0.09	0.09	-0.31**	0.16**	-0.37**	-0.50**
BFT at farrowing						0.73**	0.52**	-0.24**	0.07	0.01
BFT at weaning							-0.10	-0.16**	-0.04	-0.12*
BFT change								-0.14*	0.15**	0.22**
ADFI									0.06	0.31**
Litter size at weaning										0.65**

* For abbreviations see Table 3; Correlation with absolute value of 0.11 and above are significant at 5% level and of 0.15 or above are significant at 1% level of significance; residual values of each variable were obtained with a linear model included the effect of season, parity and their interaction.

culling percentage for the 11-year period were 75.7±9.1% and 32.5±15.2%, respectively. Culling during the warm season accounted for 46.4% of the total culls (53.6% during the hot season). WEI and WCI averaged 4.7, and 10.2 d, respectively. The median value for these data was comparable (i.e. 4.0 d). During lactation, ADFI, body weight loss and back-fat thickness loss averaged 4.21 kg/d, 16.8 kg, and 3.4 mm, respectively. At weaning, litter size and litter weight averaged 8.7 and 62.8 kg, respectively.

Influence of season, parity, type of mating on reproductive performance

Table 3 summarizes the structure of the data analyzed and the levels of significance for the factors of variation (or exploratory variables) considered. FR was greater (p<0.01) when sows were mated naturally. FR obtained through NM compared with AI was 75.9 vs. 58.8% for primiparous sows and 76.2 vs. 61.9% for multiparous sows. There was a parity x season interaction for FR, WEI and DWEI (Table 3). Season influenced (p<0.05) the FR of multiparous sows, whereas primiparous sows were not affected (Table 4). In contrast, WEI and the percentage of sows with a prolonged WEI increased during the hot season for first parity sows (but not for multiparous sows, +0.9 d and +33%, respectively, Table 4). The effect of WEI on SFR was not significant (p<0.09), but DWEI was associated with SFR (p<0.01); SFR for sows with WEI ≤5 d averaged 95% vs. 87% for sows with a prolonged WEI. A highly significant seasonal influence (p<0.01) was observed for SFR (Table 4). The highest proportion of successful insemination after weaning was observed for sows weaned in the warm season (97 vs. 85%). WCI and DWCI were also influenced by the season (p<0.01); the probability for a primiparous sow to have a prolonged WCI was almost 4 times higher when weaning occurred during the hot than during the warm season; the effect was more than 2.5 times higher in multiparous sows.

Influence of lactation performance on WEI and WCI

The residual correlations between lactation performance, WEI and WCI are presented in Table 5. Significant correlations between WEI, WCI and lactation performance

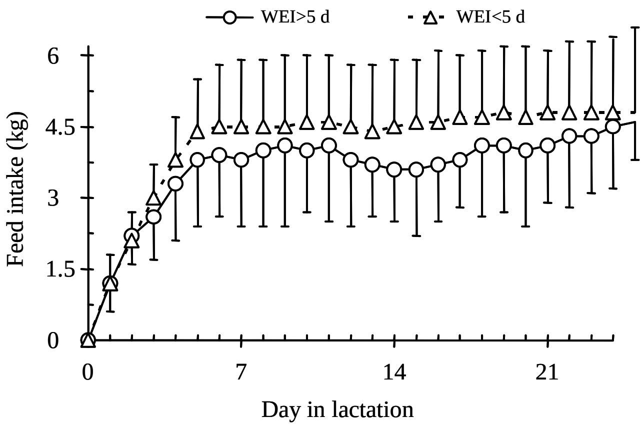

Figure 3. Daily feed intake during lactation according to the subsequent WEI (WEI>5 d: n = 39; WEI<5 d: n = 371). Coefficient of correlation between WEI and average daily feed intake average -0.19 in week 1 (** p<0.01), -0.17 in week 2 (p< 0.01), -0.18 in week 3 (p<0.01) and 0.10 in week 4 (p>0.05).

are low (i.e. less than 0.40): WEI was negatively correlated with ADFI and litter size at weaning (i.e. r = -0.13, p<0.05) and WCI was poorly associated with back-fat thickness at farrowing (i.e. r = -0.11, p<0.05).

Whatever the considered week in lactation, sow feed intake pattern was significantly different between sows showing estrus symptoms within 5 d after weaning and sows with prolonged WEI (Figure 3). The correlation between WEI and the average weekly feed intake was greater than 0.17 during the first three weeks of lactation, but it was not significant during the last week of lactation. The difference between the two patterns was highest in mid-lactation (10-19 d after farrowing) and averaged 1 kg. Logistic regression analyze revealed that an increase in sow body weight or back-fat thickness at farrowing or at weaning reduced the probability of a prolonged WEI (Table 6). A sow was 1.12 times and 1.02 times as likely to have a prolonged WEI when average back-fat thickness and body weight at farrowing were 1 mm less (p<0.01) and 1 kilogram less (p<0.05), respectively. For instance, the probability for a sow with 15 mm back-fat thickness at farrowing, to have an extended WEI was 1.40 times (= 1.12^3) higher than for a sow with 18 mm average back-fat thickness at farrowing. The probability for a sow with 200 kg body weight at farrowing, to have a prolonged WEI, was 2.3 times higher than a sow with 240 kg body weight at farrowing. A greater sow body weight at farrowing or a greater back-fat thickness at farrowing reduced the probability of a prolonged WCI (odds ratios larger than 0.90, p<0.05).

DISCUSSION

In our study, the proportion of sows expressing estrus between 3 and 8 d after weaning was approximately 95%. This is consistent with performance reported in analyzes of production database (in France: Le Colzer et al., 1997; in the USA: Koketsu et al., 1997a; in Thailand: Tantasuparuk et al., 2000a). It is now well established that WEI is extended in first parity sows as compared to higher parities (Martinat-Botte et al., 1984; Tummaruk et al., 2000a). In the present study, this is true only during the hot season. Indeed, during the warm season WEI is similar in primiparous and in multiparous sows. Moreover, the WEI of first parity sows was affected by season, which is in agreement with some results obtained in tropical (Omeke, 1989; Tantasuparuk et al., 2000a) and temperate areas (Clark et al., 1986 ; Xue et al., 1994; Tummaruk et al., 2000b). When testing the effect of ambient temperature (20

Table 6. Estimated odds ratios of performance in lactation on prolonged weaning-to-estrus interval (DWEI) and prolonged weaning-to-conception interval (DWCI)

Item	DWEI (n = 410)				DWCI (n = 325)			
	Odds ratio	95% confidence Lower	95% confidence Upper	Significance	Odds ratio	95% confidence Lower	95% confidence Upper	Significance
Sow BW								
At farrowing	0.98	0.97	1.00	0.05	0.98	0.97	1.00	0.05
At weaning	0.99	0.97	1.00	0.05	0.99	0.98	1.01	n.s
Variation	1.00	0.97	1.02	n.s	0.99	0.96	1.01	n.s
Sow BFT								
At farrowing	0.89	0.81	0.97	0.01	0.90	0.82	0.98	0.05
At weaning	0.87	0.78	0.97	0.01	0.87	0.79	0.97	0.01
Variation	0.98	0.86	1.11	n.s	0.99	0.88	1.11	n.s
Feed intake in lactation								
ADFI	0.98	0.99	1.00	0.05	1.00	0.99	1.01	n.s
Total	0.99	0.99	1.00	n.s	1.00	0.99	1.01	n.s
Litter performance								
No. piglets at weaning	0.81	0.68	0.96	0.05	0.87	0.73	1.03	n.s
Weight at weaning	0.98	0.97	1.01	n.s.	0.98	0.96	1.01	n.s

n.s.: Non-significant: p>0.05; the effect of parity was included in the model.

vs. 26°C) on post-weaning reproductive performance in lactating sows over three consecutive lactations, Quiniou et al. (2001) did not find a significant effect of temperature on WEI, but the proportion of animals with delayed estrus at 26°C was higher in primiparous sows than in higher parities. From French commercial data collection, Martinat-Botte et al. (1984) showed that the effect of seasonal changes of WEI was accentuated in primiparous sows than in multiparous sows.

Recent findings in the pig suggested that photoperiod is the primary cue to seasonal infertility (Peltoniemi et al., 2000). In our experimental conditions, the length of the diurnal period was rather comparable in both seasons. Hence, the effect of season in the present study is more likely related to climatic parameters (ambient temperature and relative humidity) than to photoperiod. The mechanisms by which season affects reproductive performance are not fully understood (Prunier et al., 1996; Tummaruk et al., 2001). The delayed estrus after weaning in the hot season could be attributed to a heat stress-induced decrease in ADFI and the subsequently accentuated nutritional deficit during lactation (reviewed by Black et al., 1993 and more recently by Prunier et al., 2003). Indeed, in the present study, first parity sows consumed 12% less feed and they lost 7 kg body weight more than multiparous sows, in the hot season than in the warm season. The effect of feed level during lactation on occurrence of estrus after weaning has been extensively described, especially for primiparous sows (Dourmad et al., 1994). From our results, sows with prolonged WEI consumed less than others, and the reduction in ADFI was accentuated in early and mid-lactation (i.e. between d 1 and d 21). Investigating the influence of weekly feed intake during a 3-wk lactation period on WEI, Koketsu et al. (1996a and 1996b; 1997b) reported that increased sow feed intake during the first and/or the second week improves return to estrus after weaning. The WEI is mainly related to mean or episodic secretion of luteinizing hormone (LH) during mid-lactation or before weaning (Shaw and Foxcroft, 1985; Tokach et al., 1992). The secretion of LH as early as d 14 after farrowing has been demonstrated to be influenced by inadequate nutrient intake and sow catabolic state in early lactation (Tokach et al., 1992; Koketsu et al., 1996b). As a consequence, the ovaries may not be able to respond properly to the gonadotropic stimuli associated with weaning, which normally allow the sow to ovulate within a week. Besides nutrient intake influence, sow body reserves have also been reported to affect WEI (King and Williams, 1984a, b; Whittemore and Morgan, 1990) . In the present study, higher body weight and back-fat thickness at farrowing decreased the risk of having prolonged WEI. This supports previous assumptions, that a critical amount of adipose and/or muscle tissues at farrowing is necessary for a normal ovarian activity after weaning (for review, see Dourmad et al., 1994). Therefore, the reduced post-weaning reproductive performance of first parity sows during the hot season may be related to their lower body reserves at farrowing as compared to multiparous sows (188±20 vs. 253±32 kg of body weight and 18±4 vs. 21±5 mm of average back-fat thickness at farrowing). Supporting this, in a meta-analyze on 25 publications, Charette et al. (1995) showed that WEI and DWEI were similar for sows of various parities with similar body weight at farrowing. In first parity sows, Mullan and Williams (1989) pointed out that the mobilization of body reserves during lactation was partly determined by the amount of reserves present at the beginning of lactation. However, no negative association between body weight or back-fat thickness losses and WEI was found in our study. Charette et al. (1995) suggested that the WEI is not related with protein or lipid loss in lactation but rather with the absolute body mass or protein mass at farrowing. Finally, independently of its effects on voluntary feed intake, an elevated ambient temperature has a direct effect on reproductive performance. Messias de Bragança et al. (1998) reported in pair fed primiparous sows that the first estrus after weaning was delayed in sows exposed to 30°C during lactation compared to sows maintained at 20°C. However, the conclusions drawn in their study need to be confirmed on a larger number of animals.

According to Robinson and van Niekerk (1978), Singh et al. (1989), and Peltoniemi et al. (1999), the farrowing rate is reduced during the hottest season. Recent studies (Tast et al., 2002; Singh and Singh, 2003) which reported a seasonal effect on FR have suggested that the major biological parameters leading to the FR reduction are failures in fertilization and/or sow inability to maintain pregnancy. In addition, a reduced reproductive performance of boars could also be involved in the decrease of FR in elevated temperature (Wettmann et al., 1976; Hughes, 1998; Chiang and Hsia, 2005). Unfortunately, no semen evaluation was performed in our work, but according to previous studies, heat stress has been demonstrated to decrease semen quality in boars (Kennedy and Wilkins, 1984; Suriyasomboon et al., 2004). Present findings, as previous ones (Xue et al., 1994), show that the effect of month of insemination affects farrowing rate only in multiparous sows. This suggests that season has more impact on insemination or gestation success in sows that have experienced lactation than in gilts at first breeding. Consistently, farrowing rate of sows that were inseminated after weaning (SFR) was reduced during the hot season.

Part of the seasonal farrowing rate impairment is likely to be related to the seasonal impact on WEI. In the present study, sows with shorter WEI had the highest SFR. Better reproductive results were previously reported in sows with short interval (Steverink et al., 1999; Tummaruk et al., 2000b). Bracken et al. (2003) have found a 27% decrease in conception rate when the weaning-to-ovulation interval increases beyond 6.5 d. Under tropical humid conditions, Tantasuparuk et al. (2000b) have observed lower SFR for sows showing estrus between 7 and 10 d after weaning than for sows showing estrus within 6 d. As reviewed by Prunier et al. (2003), the relationship between WEI and subsequent reproductive performance is likely to be the consequence of lactation impact on post-weaning ovulation rate, fertilization and embryo survival.

In relation with the increased WEI and the reduced SFR, the occurrence of extended WCI was significantly higher during the hot season than during the warm season. Moreover, the proportion of sows with a prolonged WCI after weaning in the hot season was affected by parity with longer WCI in primiparous than in multiparous sows. Similarly to WEI, primiparous sows had higher WCI than multiparous sows only during the hot season. The latest results contrast with those obtained by Tantasuparuk et al. (2000a) who reported a decrease in WCI with parity whatever the season, in a study conducted in Thailand over a 3-yr period and involving about 4,600 sows. To explain these effects, the latter authors suggested a climatic acclimatization of sows with age.

CONCLUSION

Present results confirm the effects of season and parity on reproductive performance in sows raised in tropical humid area. They showed that small annual variations (only 2°) in the ambient temperature could be significant for reproductive performance of sows. In the warm season, return to estrus is similar in multiparous and primiparous sows, but first parity sows are more prone to reproductive problems during the hot season. Moreover, sow non-productive period is also influenced by lactation performance which emphasizes that some attention should be directed toward the influence of lactation performance combined with seasonal change on young sows.

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