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RESEARCH ARTICLE

EFFECT OF INCORPORATING EUPHORBIA HETEROPHYLLA INTO A DIET BASED ON PANICUM MAXIMUM AND PELLETED FEED ON THE ZOOTECHNICAL PARAMETERS OF THE DOE RABBIT (ORYCTOLAGUS CUNICULUS) REARED IN CÔTE D'IVOIRE

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Abstract

Background and problem statement: Ivorian rabbit farming, still modest (≈35,000 rabbits/year), is constrained by the cost of industrial pellets. Panicum maximum, an abundant local forage, remains low in protein, hence the interest of combining it with Euphorbia heterophylla, which is rich in protein and alpha-linolenic acid and whose overall effect on the zootechnical parameters of the doe rabbit remains poorly documented.
Objective: To evaluate the effect of incorporating E. heterophylla into a Panicum + pellet diet on the performance of the reproducing doe rabbit and her offspring.
Materials and methods: The trial was conducted at LZPA/INP-HB (Yamoussoukro) on 20 hybrid does divided into two diets, PanGran (PG) and PanGranEuph (PGE), followed over three kindlings. Bromatological composition was determined using AOAC/ISO methods; the data collected were analysed using Python 3.
Results: Despite reduced intake during gestation (169.2 vs 175.4 g/d) and lactation (254.1 vs 269.3 g/d; $p < 0.001$), PGE does showed a higher weight at kindling (2.99 vs 2.80 kg; $p < 0.001$) and markedly higher prolificacy (7.23 vs 4.97 kits/litter; $p < 0.001$), with kits that were heavier at birth (52.45 vs 49.83 g) and at weaning (584.8 vs 558.1 g). In the post-weaning phase, PGE showed a better weight at 60 d (1.26 vs 1.11 kg), average daily gain-ADG (22.57 vs 18.24 g/d) and feed conversion ratio-FCR (3.39 vs 4.44), with no excess mortality (6.11 vs 6.17%).

During fattening, PGE retained its advantage (weight at 90 d: 2.23 vs 1.81 kg; ADG: 32.28 vs 23.62 g/d; FCR: 3.33 vs 4.65; $p < 0.001$ for all), with lower intake. Prolificacy showed the strongest cross-sectional correlations with

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subsequent performance (r = 0.71 to 0.85); these associations are phenotypic and do not establish a causal or predictive relationship.
Conclusion: Incorporating E. heterophylla significantly improves reproductive, growth and fattening performance, confirming its value as a low-cost local forage resource.

Introduction:-

Rabbit farming occupies a growing place in animal production systems in Côte d'Ivoire, where it constitutes an accessible source of animal protein and an income-generating activity for many households. According to available data, Ivorian rabbit production has very little data on its production system, with only a few recent studies providing results on the farming systems in certain localities of the country and on the growth performance of rabbits (Sangare et al., 2022). National annual production is estimated at approximately 35,000 rabbits with a carcass weight of 1.5 kg, i.e. about 50 tonnes (SORO et al., 2024), a volume that remains modest relative to national animal protein needs, with Côte d'Ivoire remaining largely dependent on imports to cover its meat consumption.

One of the main obstacles to the development of rabbit farming lies in the high cost of industrial pelleted feed. According to work carried out on rabbit farmers in the Abidjan District, many farmers start their operations with an exclusively forage-based or mixed diet, combining forage and industrial pellets, a system that greatly reduces the cost of rabbit production (Sangaré et al., 2022). In Côte d'Ivoire, rabbit farming is thus carried out intensively with a diet based exclusively on pellets, semi-intensively with a mixed diet combining pellets and green forage, or extensively using only green forage (Kouakou et al., 2019).

Among the forage resources available locally, Panicum maximum (Guinea grass) is widely used owing to its abundance and year-round availability, but its nutritional value, in particular its protein content, remains limited for meeting the growth requirements of rabbits. Combining it with plants richer in nitrogen and lipids is therefore an avenue explored by several authors to improve the zootechnical performance of animals fed at lower cost. Euphorbia heterophylla (milkweed), a weed widespread in Ivorian crops, is of particular interest in this respect. According to Kouakou et al. (2019), this plant is well appreciated by rabbits, in which it can constitute 70% of dry-matter feed intake, and is distinguished by an alpha-linolenic acid (ALA, C18:3 n-3) content representing, according to the same authors, about 56% of total fatty acids, a proportion close to that of flax (Linum usitatissimum).

Several studies conducted in Côte d'Ivoire have already explored the use of this plant in rabbit feeding. Kouakou et al. (2015), in a study on the effect of Guinea grass combined with milkweed or sweet potato leaves, showed that improvements in the milk production of local does reached +15.51%, +27.74% and +19.98%, respectively, compared with the diet based on Panicum maximum alone, suggesting that these green forages could be used as supplements for the reproducing doe. Regarding meat quality, Kouakou et al. (2019) studied the effect of the duration of supplementing a pellet-based diet with milkweed leaves and stems on the omega-3 enrichment of rabbit meat, confirming the nutritional interest of this plant beyond its zootechnical properties alone. Furthermore, Kimsé et al. (2013), in a trial on Centrosema pubescens supplied as a supplement to pellets, showed that nutrient digestibility (dry matter, organic matter, total nitrogenous matter, ADF, NDF) was significantly higher in the diet containing the forage, with a positive effect on the digestive health of meat rabbits, while Akoutey and Kpodekon (2012) studied the incorporation of Pueraria phaseoloides into pelleted feed intended for young rabbits, confirming the general interest of tropical forage legumes and weeds in the Ivorian rabbit diet.

Despite these advances, the studies conducted at the Institut National Polytechnique Félix Houphouët-Boigny of Yamoussoukro by Kouakou et al. (2015, 2016) on the valorisation of the leaves and stems of Euphorbia heterophylla did not systematically address the full range of zootechnical parameters of the doe rabbit under real farming conditions, particularly when this plant is combined simultaneously with Panicum maximum and a pelleted feed, under the practical conditions encountered by small- and medium-scale Ivorian rabbit farmers. Yet, a better understanding of the effect of this type of mixed diet on parameters such as live weight, average daily gain, feed intake, feed conversion ratio, or the reproductive performance of the doe appears essential for proposing economically viable feeding strategies adapted to the local context.It is within this framework that the present study was conducted, aiming to evaluate the effect of incorporating Euphorbia heterophylla into a diet based on Panicum maximum and pellets on the zootechnical parameters of the doe rabbit (Oryctolagus cuniculus) reared in Côte d'Ivoire. The expected results should contribute to optimisingfeeding strategies in rabbit farming, reducing production costs and, more broadly, to the sustainable development of the Ivorian rabbit farming sector.

Materials and Methods:-

Study site:-

The animal experiment was conducted at the large experimental farm of the Laboratory of Animal Husbandry and Production (LZPA), Department of Agriculture and Animal Resources (ARA) of the Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), in Yamoussoukro, Côte d'Ivoire (6.88822° N; −5.22020° W). The study area has a tropical savanna climate of the Aw type (Köppen-Geiger classification), with an average annual temperature of about 26°C and average annual rainfall of 1,100 mm.

Rearing facilities and experimental animals:-

The trial was carried out in the rabbit house (54 m²) of the experimental farm of the Laboratory of Animal Husbandry of the DFR-ARA of INP-HB in Yamoussoukro. It involved twenty hybrid does (Oryctolagus cuniculus), aged 19 months, with an average live weight of 2.7 ± 0.4 kg, allocated equally to the two diets (n = 10 per group) and followed individually over three successive kindlings so that each doe served as her own reference across parities, a repeated-measures design that increases statistical power for a given number of animals and is consistent with the sample sizes used in comparable tropical rabbit-feeding trials (e.g. Kouakou et al., 2015, 2016, 2019; Kimsé et al., 2013). The number of does was further constrained by the individual breeding-cage capacity of the experimental facility. Each female was housed individually in a breeding cage (60 × 40 × 30 cm) resting on wire mesh allowing feed refusals and faeces to be collected separately. During gestation, each cage was converted into a maternity cage by adding a nest box (40 × 25 × 30 cm). The facility also included fifteen growth and fattening cages (90 × 40 × 30 cm) intended to house the kits from the litters, each equipped with a metal feeder and a drinker.

Feed and experimental diets:-

The animals received Panicum maximum (Poaceae, G23 variety), Euphorbia heterophylla (Euphorbiaceae), and a commercial breeding-and-growth pelleted rabbit feed (IVOGRAIN®). Two experimental diets were established: PanGran, combining Panicum maximum and pelleted feed, and PanGranEuph, combining Panicum maximum, pelleted feed and Euphorbia heterophylla. The amounts of feed distributed were adapted to the physiological stage of the animals, namely lactation, growth and fattening. Each physiological stage comprised three successive 10-day feeding phases. Feed was distributed daily in the morning. Before the start of the experiment, each doe received 300 g of Panicum maximum and 200 g of pelleted feed daily. Does in the PanGranEuph group additionally received 400 g of Euphorbia heterophylla. The quantities of feed distributed during the different experimental phases are presented in Table 1. On a fresh-matter basis, E. heterophylla represented between 40% (lactation, phase 1) and 67% (fattening, phase 3) of the total daily feed offered to PGE animals, a range consistent with the up to 70% of dry-matter intake reported for this forage in the rabbit by Kouakou et al. (2019); pelleted feed was distributed at the same rate in both groups, so that the PGE ration corresponds to the PG ration with E. heterophylla added rather than substituted.

Table 1:- Quantities of feed distributed (g) for the experimental diets according to physiological stage and feeding phase. Pan Gran (PG)

Phases	Lactation			Growth			Fattening		
	Pan	Gran	Euph	Pan	Gran	Euph	Pan	Gran	Euph
Phase 1 (d1-10)	400	200	-	50	80	-	100	130	-
Phase 2 (d10-20)	500	250	-	75	100	-	100	140	-
Phase 3 (d20-30)	600	300	-	100	120	-	100	150	-

Pan Gran Euph (PGE)

Phases	Lactation			Growth			Fattening		
	Pan	Gran	Euph	Pan	Gran	Euph	Pan	Gran	Euph
Phase 1 (d1-10)	400	200	400	50	80	200	100	130	400
Phase 2 (d10-20)	500	250	800	75	100	300	100	140	450
Phase 3 (d20-30)	600	300	1200	100	120	400	100	150	500

Pan: Panicum maximum; Gran: pelleted feed; Euph: Euphorbia heterophylla; d: day.

Bromatological analysis equipment:-

The bromatological composition of the experimental feeds was determined as follows: dry matter by oven desiccation (AOAC method 934.01); mineral matter (total ash) by incineration in a muffle furnace at 550°C (AOAC method 942.05); total nitrogenous matter by the Kjeldahl method (mineralisation, distillation, titration; AOAC method 954.01, conversion factor N × 6.25); crude fat by petroleum-ether extraction (AOAC method 920.39); crude fibre by the Weende method (AOAC 978.10); starch by the Ewers polarimetric method (ISO standard 10520); total polyphenols by the Folin-Ciocalteu colorimetric method, expressed as gallic acid equivalents (reading at 750–760 nm); total flavonoids by the aluminium chloride ($AlCl_3$) colorimetric method, expressed as quercetin equivalents; and hydrocyanic acid by the picrate paper method.

The analyses were performed using the following equipment: desiccators (GLASWERK, 250 SAPAIC, Wertheim, Germany), ball mill (RETSCH S1, Haan, Germany), precision electronic balances (d = 0.001 mg, maximum capacity 200 g, model A220S, Sartorius, Germany; d = 0.01 mg, maximum capacity 4 kg, model U4100, Sartorius, Germany), rotary evaporator (Rotavapor Büchi R120, Flawil, Switzerland), oven (Memmert UL80, Schwabach, Germany), muffle furnace (Nabertherm L5/11, Lilienthal, Germany), mineralisation racks (FOSS Tecator 1000-1217, Nanterre, France) and Kjeldahl distiller (Büchi 321, Flawil, Switzerland).

Growth and reproduction parameters:-

- Useful prolificacy rate: PR = Average number of kits born alive / Number of kindlings
- Daily intake: Int (g) = Amount of feed distributed (g) − Amount of feed refused (g)
- Average daily gain: ADG (g/d) = (Final average weight − Initial average weight) / Number of days of the period considered
- Specific growth rate: SGR (%/d) = 100 × [ln (Final average weight) − ln (Initial average weight)] / Number of days of the period considered
- Feed conversion ratio: FCR = Quantity of feed ingested (g DM) / Corresponding weight gain (g)
- Mortality rate: MR = (Number of deaths / Number of animals placed) × 100

Statistical analysis:-

Analysis was performed using Python 3 (SciPy 1.x, statsmodels and Pingouin 0.6 libraries), a statistical environment equivalent to R or SPSS for this type of design. This choice is justified by the need to handle a mixed model (repeated-measures ANOVA, between-subjects group factor and within-subjects parity factor), which these libraries implement identically to the corresponding functions in SPSS (GLM Repeated Measures) or R (afex/ez packages).

Statistical approach applied to each variable:-

- Descriptive statistics (mean ± standard deviation) by group and by parity;
- Shapiro-Wilk normality test and Levene's test of homogeneity of variances;
- Two-way mixed ANOVA (Group × Parity) with post-hoc test where relevant;
- Group-comparison tests for confirmation: Student's t-test for independent samples and the non-parametric Mann-Whitney test (used when normality was not verified);
- Pearson correlations between quantitative variables.

The significance threshold was set at $\alpha = 0.05$. For litter-level traits (number and weight of kits at birth and at weaning, post-weaning and fattening growth parameters), the doe/litter, not the individual kit, was treated as the statistical unit, in order to avoid pseudoreplication arising from the non-independence of kits reared in the same litter. For the mortality data, whose distribution deviates markedly from normality (Table 7), the parametric ANOVA results are reported for consistency with the other traits but should be interpreted with caution; a generalised linear model with a binomial or Poisson error structure would be a more appropriate approach for these count/proportion data and is recommended for future analyses of this dataset.

Ethical statement:-

This study used animals according to the standards established by the guide of good practices in animal husbandry of the OIE (2009).

Results:-

Bromatological composition of the experimental feeds:-

Table 2:- Bromatological composition of the feeds administered (g/kg DM, unless otherwise stated).

Parameters	Panicum maximum	Euphorbia heterophylla	Pelleted feed
Dry matter (DM) %	21.8 ± 1.5	15.8 ± 1.2	88.7
Total nitrogenous matter (TNM)	107.2 ± 8.4	185.6 ± 22.3	163.4
Crude fat (CF)	34.8 ± 5.2	48.7 ± 7.1	42.3
Crude fibre (CFi)	312.5 ± 18.6	198.4 ± 25.3	—
Starch	48.3 ± 9.2	82.6 ± 12.4	278.5
Total polyphenols (mg GAE/g)	12.4	28.6 ± 3.7	—
Total flavonoids (mg QE/g)	4.2	9.8 ± 1.4	—
Hydrocyanic acid (mg/kg)	< 10	< 10	—

Performance of the reproducing does:-

Table 3 presents the performance of the reproducing does recorded during the trial series, namely the initial weight of the does, their weight at kindling, and the amount of feed ingested by the does during gestation and lactation.

After analysis of the data, the average weights of the does in the two groups (PG: Panicum maximum + Pellet, and PGE: Panicum maximum + Pellet + Euphorbia heterophylla) were statistically homogeneous at the outset (PG 2.45 ± 0.19 kg vs PGE 2.51 ± 0.23 kg; Group effect ns, $p = 0.127$), with a significant Parity effect and a significant Group × Parity interaction ($p < 0.001$ and $p < 0.05$, respectively). At kindling, doe weight showed a significant Group effect (PG 2.80 ± 0.18 kg vs PGE 2.99 ± 0.20 kg; $p < 0.001$) and no interaction ($p = 0.853$).

Regarding feed intake, PG does consumed significantly more (175.4 ± 3.5 g/d) than PGE does (169.2 ± 4.4 g/d; $p < 0.001$) during gestation, with high significance ($p < 0.001$) for all three effects (Group, Parity, Interaction). During lactation, the same trend was observed with an even more pronounced effect: PG 269.3 ± 5.3 g/d vs PGE 254.1 ± 3.2 g/d ($p < 0.001$). The Group × Parity interaction was also significant ($p = 0.003$).

Table 3:- Performance of the reproducing does.

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Initial weight (kg)	2.45 ± 0.19	2.51 ± 0.23	Group	2.56	0.127 ns
			Parity	284.94	< 0.001
			Group × Parity	5.43	0.009
Weight at kindling (kg)	2.80 ± 0.18	2.99 ± 0.20	Group	27.21	< 0.001
			Parity	114.91	< 0.001
			Group × Parity	0.16	0.853 ns
Feed intake/day in gestation (g/d)	175.4 ± 3.5	169.2 ± 4.4	Group	39.14	< 0.001
			Parity	22.58	< 0.001
			Group × Parity	12.38	< 0.001
Feed intake/day in lactation (g/d)	269.3 ± 5.3	254.1 ± 3.2	Group	212.11	< 0.001
			Parity	27.11	< 0.001
			Group × Parity	6.89	0.003

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Prolificacy and litter characteristics at birth:-

Prolificacy and litter characteristics at birth are presented in Tables 4a and 4b. Regarding the number of kits born per litter and their average weight (Table 4a), statistical analysis indicates a major difference in the number of kits born per litter, in favour of PGE (7.23 ± 1.04 vs 4.97 ± 0.81; $p < 0.001$), with no Parity effect ($p = 0.214$) nor interaction ($p = 0.719$). Kits in this group were also the heaviest at birth (52.45 ± 2.29 g vs 49.83 ± 1.89 g; $p = 0.005$). Analysis of Table 4b shows that the prolificacy rate of the does in the PGE group was markedly higher than that obtained with PG females ($t(18) = -7.55$, $p < 0.001$; $U = 0.5$, $p < 0.001$).

Table 4a:- Number of kits born per litter and their average weight.

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Number of kits born/litter	4.97 ± 0.81	7.23 ± 1.04	Group	57.01	< 0.001
			Parity	1.61	0.214 ns
			Group × Parity	0.33	0.719 ns
Average weight of kits born (g)	49.83 ± 1.89	52.45 ± 2.29	Group	10.25	0.005
			Parity	0.87	0.429 ns
			Group × Parity	0.23	0.792 ns

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Table 4b:- Prolificacy rate (average number born per litter over 3 kindlings).

Statistic	PG	PGE	Test	Value	P
Mean ± SD	4.97 ± 0.55	7.23 ± 0.77	Student's t	t(18) = -7.55	p < 0.001
Min – Max	4.33 – 6.00	6.00 – 8.67	Mann-Whitney	U = 0.5	p < 0.001

Growth of kits until weaning:-

Analysis of the data in Table 5 indicates that PGE kits retained their weight advantage at weaning (584.8 ± 28.5 g vs 558.1 ± 31.7 g; $p = 0.017$), although with a more moderate effect ($p = 0.017$) than at birth, and a significant Group × Parity interaction ($p = 0.008$). At weaning, the number of kits remained the same as at birth. The same major difference in the number of kits born per litter, in favour of PGE (7.23 ± 1.04 vs 4.97 ± 0.81; $p < 0.001$), with no Parity effect ($p = 0.214$) nor interaction ($p = 0.719$), was also observed at this stage.

Table 5:- Number of weaned kits and their average weight.

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Average weight of kits at weaning (g)	558.1 ± 31.7	584.8 ± 28.5	Group	6.95	0.017
			Parity	0.04	0.957 ns
			Group × Parity	5.50	0.008
Number of kits at weaning	4.97 ± 0.81	7.23 ± 1.04	Group	57.01	< 0.001
			Parity	1.61	0.214 ns
			Group × Parity	0.33	0.719 ns

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Post-weaning growth (weaning – 60 days of age):-

Post-weaning growth took place over 30 days. Table 6 presents the post-weaning growth parameters of kits up to 60 days of age. Analysis of the data in this table shows a clear and increasing weight gap ($p < 0.001$) between the two groups (PGE 1.26 ± 0.05 kg vs PG 1.11 ± 0.06 kg), with a significant interaction ($p = 0.038$). Average daily gain (PGE 22.57 ± 1.41 g/d vs PG 18.24 ± 1.61 g/d) varied significantly ($p < 0.001$). For this parameter, neither Parity ($p = 0.103$) nor the interaction ($p = 0.346$) were significant. As during gestation/lactation, PGE kits ingested less (76.36 ± 4.51 g DM/d) than PG kits (80.45 ± 3.70 g DM/d; $p < 0.001$), with a significant interaction ($p = 0.007$). The feed conversion ratio decreased from 4.44 ± 0.38 for PG to 3.39 ± 0.27 for PGE ($p < 0.001$). The Parity effect was significant here but weak ($p = 0.038$), with no interaction ($p = 0.190$). The specific growth rate recorded for PGE (2.56 ± 0.14 %/d) was significantly higher ($p < 0.001$) than that of the PG group (2.28 ± 0.16 %/d), with no Parity effect or interaction.

Table 6:- Post-weaning growth parameters of kits up to 60 days of age.

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Live weight of kits at 60 days (kg)	1.11 ± 0.06	1.26 ± 0.05	Group	125.13	< 0.001
			Parity	1.63	0.211 ns
			Group × Parity	3.59	0.038
Average daily gain (g/d)	18.24 ± 1.61	22.57 ± 1.41	Group	190.95	< 0.001
			Parity	2.42	0.103 ns
			Group × Parity	1.09	0.346 ns
Average feed intake (g DM/d)	80.45 ± 3.70	76.36 ± 4.51	Group	24.39	< 0.001
			Parity	2.00	0.150 ns
			Group × Parity	5.65	0.007
Feed conversion ratio	4.44 ± 0.38	3.39 ± 0.27	Group	228.27	< 0.001
			Parity	3.59	0.038
			Group × Parity	1.74	0.190 ns
Specific growth rate	2.28 ± 0.16	2.56 ± 0.14	Group	51.50	< 0.001
			Parity	2.58	0.090 ns
			Group × Parity	0.05	0.948 ns

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Post-weaning mortality:-

The number of dead kits and the mortality rate in each group are presented in Table 7. Statistical analysis of this table revealed no significant difference between groups (PG 0.30 ± 0.47 vs PGE 0.47 ± 0.57; $p = 0.175$), nor for Parity or the interaction. Mortality rate results were nearly identical between groups (PG 6.17 ± 9.77% vs PGE 6.11 ± 7.31%; all effects non-significant, $p > 0.95$). Statistical note: the standard deviations in Table 7 exceed the means (9.77 for a mean of 6.17), indicating a strongly asymmetric/non-normal distribution, typical of mortality-rate data with many zero values.

Table 7:- Number of dead kits and mortality rate (weaning–60 d).

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Number of dead kits (weaning–60d)	0.30 ± 0.47	0.47 ± 0.57	Group	1.99	0.175 ns
			Parity	0.05	0.951 ns

			Group × Parity	0.05	0.951 ns
Mortality rate (%)	6.17 ± 9.77	6.11 ± 7.31	Group	0.00	0.977 ns
			Parity	0.01	0.993 ns
			Group × Parity	0.01	0.993 ns

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Fattening after growth (60–90 days of age):-

Fattening lasted 30 days following post-weaning growth. Data collected during this phase are presented in Table 8. Statistical analysis of these data shows, for live weight (2.23 kg for PGE vs 1.81 kg for PG) and feed conversion ratio (3.33 for PGE vs 4.65 for PG), a significant difference between the two groups ($p < 0.001$), with a Parity effect ($p = 0.003$ and $p = 0.036$, respectively) and an interaction ($p = 0.013$ and $p = 0.010$, respectively). For average daily gain (32.28 ± 2.36 g/d for PGE vs 23.62 ± 1.90 g/d for PG) and feed intake (106.99 ± 2.55 g DM for PGE vs 109.24 ± 5.58 g DM for PG), a significant difference was observed between the two groups ($p < 0.001$) with a Parity effect ($p = 0.004$ and $p < 0.001$, respectively) and no interaction ($p = 0.076$ and $p = 0.324$, respectively). For the specific growth rate, only a Group effect was found ($p < 0.001$), with no Parity effect ($p = 0.149$) or interaction ($p = 0.401$).

Table 8:- Post-growth fattening parameters.

Parameters	Mean ± SD		Source of variation	F	P
	PG	PGE			
Live weight of rabbits at 90 d (kg)	1.81 ± 0.09	2.23 ± 0.09	Group (diet)	557.92	< 0.001
			Parity	6.97	0.003
			Group × Parity	4.87	0.013
Average daily gain (g/d)	23.62 ± 1.90	32.28 ± 2.36	Group (diet)	270.52	< 0.001
			Parity	6.56	0.004
			Group × Parity	2.77	0.076 ns
Average feed intake (g DM)	109.24 ± 5.58	106.99 ± 2.55	Group (diet)	5.27	0.034
			Parity	11.94	< 0.001
			Group × Parity	1.16	0.324 ns
Feed conversion ratio (FCR)	4.65 ± 0.37	3.33 ± 0.22	Group (diet)	362.49	< 0.001
			Parity	3.67	0.036
			Group × Parity	5.27	0.010
Specific growth rate (SGR)	1.65 ± 0.12	1.90 ± 0.11	Group (diet)	47.69	< 0.001
			Parity	2.01	0.149 ns
			Group × Parity	0.94	0.401 ns

df Group = 1,18; df Parity and Interaction = 2,36. ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. PG: Panicum maximum + Pellet diet; PGE: PG + Euphorbia heterophylla diet.

Correlation between parameters:-

The various correlations between parameters are presented in the Pearson correlation matrix (lower triangle, Table 9). Analysis of correlations among the studied parameters highlights the prolificacy rate (var. 8) as the variable most strongly correlated, cross-sectionally, with the entire production cycle, this reproduction-phase variable being the most strongly connected to the subsequent growth and fattening phases (weight at 60 d: $r = 0.71$; growth ADG: $r = 0.76$; growth FCR: $r = -0.80$; number of rabbits entering fattening: $r = 0.85$; weight at 90 d: $r = 0.82$; fattening ADG: $r = 0.81$; fattening FCR: $r = -0.80$; $p < 0.001$ for all), thereby far exceeding, in strength and consistency, the other reproductive variables. The number of kits born per litter (var. 3) extends this effect with near-mechanical continuity toward the number of rabbits entering fattening ($r = 0.93$***), and remains strongly associated with

weight at 90 d (r = 0.76***), fattening ADG (r = 0.76***), as well as growth FCR (r = −0.76***) and fattening FCR (r = −0.72***).
Conversely, feed intake by the lactating doe (var. 7) is negatively related to the subsequent performance of the kits, with higher intake during lactation associated with poorer downstream performance (growth ADG: r = −0.70***; growth FCR: r = 0.75***; weight at 90 d: r = −0.76***; fattening ADG: r = −0.74***; fattening FCR: r = 0.78***), an inverse relationship notably different from that observed for prolificacy. Furthermore, weight at 60 d and growth ADG (var. 9 and 10) appear as the bridging variables between the growth and fattening phases, with high correlations with weight at 90 d (r = 0.91*** and r = 0.89***, respectively) and fattening FCR (r = −0.75*** and r = −0.76***, respectively), while growth FCR (var. 12) is strongly correlated with overall fattening performance (weight at 90 d: r = −0.90***; fattening ADG: r = −0.80***; fattening FCR: r = 0.78***).

Finally, it is worth noting that the doe's initial weight and weight at kindling (var. 1 and 2) show markedly weaker inter-phase correlations than prolificacy, with initial weight not significantly correlated with any growth or fattening variable (r < 0.25), while weight at kindling shows only moderate correlations with the number of rabbits entering fattening (r = 0.54*) and weight at 90 d (r = 0.47*), far below the associations observed for prolificacy. These are Pearson phenotypic correlations computed on a sample of 60 observations across two diet groups; they describe the strength and direction of association between variables and do not, on their own, establish a causal or predictive relationship, since diet, parity and the doe's body format co-vary within this design.
Row and column header numbers refer to the legend below.

Table 9:- Pearson correlation matrix between the studied parameters (lower triangle).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	,89*																			
3	,24	,56*																		
4	,16	,41*	,53*																	
5	-,05	,08	,21	,18																
6	,33*	,07	-,42*	-,32*	-,23															
7	,07	-,20	-,66*	-,40*	-,30*	,60*														
8	,15	,45*	,89*	,56*	,27*	-,53*	-,80*													
9	,17	,40*	,66*	,41*	,66*	-,43*	-,67*	,71*												
10	,23	,46*	,72*	,43*	,40*	-,43*	-,70*	,76*	,95*											
11	-,28*	-,38*	-,42*	-,33*	-,19	,07	,44*	-,46*	-,27*	-,25										
12	-,29*	-,53*	-,76*	-,47*	-,41*	,39*	,75*	-,80*	-,90*	-,93*	,56*									
1	,27	,46	,68	,38	-,04	-	-	,69	,72	,90	-,18	-								

3	*	*	*	*		,35 *	,61 *	*	*	*		,82 *								
14	-,00	,13	,32 *	,21	-,03	-,13	-,12	,22	,06	,09	,02	-,06	,11							
15	-,07	-,02	,07	,12	-,08	-,08	,02	,01	-,09	-,07	,13	,12	-,05	,93 *						
16	,25 *	,54 *	,93 *	,48 *	,24	-,40 *	-,65 *	,85 *	,67 *	,72 *	-,45 *	-,78 *	,67 *	-,03	-,28 *					
17	,18	,47 *	,76 *	,50 *	,53 *	-,51 *	-,76 *	,82 *	,91 *	,89 *	-,40 *	-,90 *	,72 *	,16	-,01	,75 *				
18	,17	,47 *	,76 *	,51 *	,38 *	-,52 *	-,74 *	,81 *	,76 *	,77 *	-,45 *	-,80 *	,65 *	,20	,04	,72 *	,96 *			
19	,37 *	,28 *	-,06	-,19	-,10	,35 *	,34 *	-,19	-,17	-,17	-,10	,09	-,13	-,04	-,01	-,05	-,12	-,07		
20	-,04	-,35 *	-,72 *	-,53 *	-,40 *	,59 *	,78 *	-,80 *	-,75 *	-,76 *	,41 *	,78 *	-,63 *	-,19	-,03	-,69 *	-,94 *	-,96 *	,30 *	
21	,11	,39 *	,62 *	,45 *	,10	-,45 *	-,59 *	,66 *	,40 *	,44 *	-,46 *	-,53 *	,43 *	,23	,10	,57 *	,74 *	,90 *	,02	-,86 *

*** correlation significant at p < 0.05 threshold.**

Legend of variables:-

No.	Variable	No.	Variable	No.	Variable
1	Initial doe weight (kg)	8	Prolificacy rate	15	Growth-phase mortality (%)
2	Doe weight at kindling (kg)	9	Weight at 60 d (kg)	16	No. of rabbits entering fattening
3	No. of kits born/litter	10	Growth ADG (g/d)	17	Weight at 90 d (kg)
4	Average weight of kits born (g)	11	Growth-phase feed (g DM)	18	Fattening ADG (g/d)
5	Weight of kits at weaning (g)	12	Growth FCR	19	Fattening-phase feed (g DM)
6	Feed intake, gestating doe (g)	13	Growth SGR	20	Fattening FCR
7	Feed intake, lactating doe (g)	14	Growth-phase mortality (no.)	21	Fattening SGR

Discussion:-

Beyond the expected correlations between indicators within the same physiological phase (for example, ADG and feed conversion ratio within the fattening phase, which are largely related by mathematical construction), the matrix reveals several inter-phase associations that provide new biological information on how the effects of the PGE diet propagate throughout the production cycle, from reproduction to fattening.

The prolificacy rate of the does was found to be positively correlated with several fattening parameters of the kits (weight at 90 days, ADG, number of rabbits entering fattening), suggesting that the largest litters (typically observed in the PGE group) are also those whose offspring show the best subsequent growth performance. This result is consistent with work conducted in Côte d'Ivoire on the incorporation of Euphorbia heterophylla into doe rabbit feeding, where adding this forage plant to a Panicum maximum-based diet was associated with a simultaneous improvement in milk production, the number of kits per litter, and their growth up to weaning (Konan et al., 2021). The same authors, in a complementary trial on supplementation with local forages (Desmodium or Panicum), confirmed that does receiving an enriched diet show a larger litter size, better kit survival, and superior post-weaning growth compared with control groups (Koné et al., 2022).

The foundational trials by Kouakou et al. (2015, 2016) on the Panicum maximum – Euphorbia heterophylla combination had already shown that this plant, being particularly well ingested by rabbits, improved daily weight gain while reducing the feed cost per kilogram of carcass produced. The correlation observed between prolificacy and fattening performance can be interpreted in light of the concept of fetal and perinatal programming: the mother's nutritional availability during gestation and lactation conditions not only the number of weaned young but also their subsequent growth potential, via effects on placental development, milk quality, and the early metabolic status of the kit (López-Tello et al., 2019). In rabbits, it has also been shown that inadequate maternal nutrition during gestation can durably alter the post-weaning growth trajectory of the offspring, even in the absence of any subsequent feed restriction (Simitzis et al., 2019). From this perspective, the better prolificacy and better growth of kits from the PGE group would not be two independent results, but two complementary expressions of a single effect of the maternal diet on the productive capacity of the litter.

This interpretation is also consistent with the quantitative genetics data reported by Ayyat et al. (2024) in three Egyptian rabbit breeds (New Zealand White, Californian, Gabali), which revealed positive and moderate genetic correlations between litter size at birth and litter weight at birth, themselves favourable to higher body weight at the end of growth. While genetic determinism and nutritional determinism differ, both converge toward the same operational conclusion: a larger, better-fed litter from gestation onward constitutes a favourable ground for the subsequent performance of kits, rather than a factor diluting their individual performance.

The strong positive correlation between the doe's initial weight and her weight at kindling ($r = 0.89$) confirms that the reproducer's body format, already established before entering reproduction, strongly conditions her subsequent weight trajectory. This result is in line with the findings of Obugo et al. (2024), who studied the effect of New Zealand White doe weight at first mating on their subsequent reproductive performance: does bred at a higher body weight showed better management of gestation and lower pre-weaning mortality than those bred at an insufficient weight, underscoring the importance of initial body format as a prognostic factor for reproductive career.

This relationship between initial weight and weight during reproduction is also consistent with the work of Ludwiczak et al. (2021) on Hycole does followed over nine consecutive kindlings, who reported that the doe's body weight at insemination remains a structuring factor for litter performance throughout the reproductive career, before declining at advanced parities. Applied to the present trial, this observation suggests that the weight advantage already present in PGE does before entering reproduction may have contributed, in addition to the direct effect of the diet, to their better performance at kindling and, by extension, to that of their litter.

Taken together, these results call for not restricting the evaluation of the PGE diet to its direct effects on the fattening phase alone, but for considering the production cycle in its continuity. The improvement in initial weight and weight at kindling, together with higher prolificacy, appears to cascade through to the growth and fattening performance of the kits, rather than constituting effects confined to each phase. This integrated reading is consistent with the literature on Euphorbia heterophylla, which repeatedly emphasises that the zootechnical value of this plant is not limited to a one-off effect on intake or growth, but translates into measurable productivity gains at several stages of the reproductive cycle (Konan et al., 2021; Koné et al., 2022).

These results support the value of E. heterophylla as a low-cost local forage resource for reducing Ivorian farmers' dependence on industrial pellets, without compromising doe fertility. Additional trials on optimising the level of pellet supplementation during gestation and lactation would help limit the loss of prolificacy observed under the PGE diet. The correlations reported here are phenotypic and were calculated on a sample of 60 observations distributed between two diets; on their own, they do not allow a direct causal effect of the maternal diet to be distinguished from a simple effect of selection or body format of the does. Further analyses (mediation models, adjustment for initial weight as a covariate) would help clarify the respective contribution of these mechanisms in future generations of trials on this forage combination.

Species of the genus Euphorbia typically produce an irritant latex rich in diterpene esters, and toxic effects have been documented in livestock browsing certain Euphorbia species. The case of E. heterophylla nonetheless appears distinct: hydrocyanic acid content remained below 10 mg/kg DM in both Panicum maximum and E. heterophylla in the present study (Table 2), well under levels of concern for cyanogenic forages, and this plant has already been used as a rabbit-feed ingredient in several independent Ivorian trials (Kouakou et al., 2015, 2016, 2019; Konan et al., 2021; Koné et al., 2022) without reports of clinical toxicity or digestive disorders; the present trial likewise recorded no excess mortality in the PGE group relative to PG (6.11 vs 6.17%; Table 7). These convergent observations support the practical safety of E. heterophylla as fed here, but they do not constitute a formal toxicological evaluation: the latex and antinutritional fractions of the plant were not characterised, and liver or kidney function markers were not monitored. Such analyses, together with trials at higher inclusion levels and over a longer duration, would be needed to rule out sub-clinical effects and should be included in future work on this forage.

For Ivorian rabbit farmers, the main practical implication of these results is that E. heterophylla, a weed that is locally abundant and free to harvest, can be added to a Panicum maximum + pelleted-feed ration without reducing the amount of pelleted feed distributed, while improving prolificacy, growth and feed conversion ratio, and lowering intake at every physiological stage (Tables 3, 6 and 8). Since pelleted feed was distributed at the same rate in both groups, the reduction in feed cost associated with the PGE diet stems from the improved feed conversion ratio and from E. heterophylla being harvested rather than purchased, consistent with the feed-cost reductions already reported for this same forage combination by Kouakou et al. (2016). A full monetary cost-benefit analysis was beyond the scope of the present trial, since local market prices for pelleted feed and the labour cost of harvesting E. heterophylla were not recorded here; converting the feed conversion ratio and intake differences reported in Tables 3, 6 and 8 into a cost per kilogram of live-weight gain, using current local input prices, is a direct next step that we recommend for a follow-up study specifically addressing the economics of this diet for Ivorian smallholder rabbit farmers.

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Declaration of Conflicts of Interest:-
The authors declare that they have no conflicts of interest.

Data Availability:-
The raw data supporting the conclusions of this article will be made available by the authors upon request.

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