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RABBIT (*ORYCTOLAGUS CUNICULUS* L.) URINE AS A BIOPESTICIDE AGAINST LEPIDOPTEROUS PESTS OF GREEN CABBAGE (*BRASSICA OLERACEA* VAR. *CAPITATA* L.)

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Abstract: This study investigates the efficacy of rabbit (*Oryctolagus cuniculus* L.) urine as a natural biopesticide and growth stimulant for green cabbage (*Brassica oleracea* var. *capitata* L.) to provide a sustainable alternative to synthetic agrochemicals. Seedlings were transplanted at approximately 25 d of age and treatments with varying concentrations of rabbit urine (25, 50 and 75% v/v) were applied weekly starting 15 d after transplanting (DAT). Physicochemical analysis revealed that the urine was alkaline (pH 8.2), with high ammonia content, elevated total dissolved solids (5786.5±85.4 ppm) and high electrical conductivity (10704.3±120.6 µS/cm), suggesting potent pest-deterrent and nutrient-delivery properties. Results indicated that the 75% concentration significantly reduced pest severity by approximately 75% and suppressed lepidopterous pest populations by up to 83.3% compared to untreated controls. Leaf damage was markedly reduced (1.0±0.1 *vs.* 4.0±0.2 in controls). Furthermore, the 75% treatment enhanced crop productivity, increasing marketable yield to 97.8% (*vs.* 75.0% in controls) and improving the harvest index from 0.60 to 0.75. These findings suggest that rabbit urine can be integrated into sustainable pest management strategies, offering a low-cost, eco-friendly solution that could benefit smallholder farmers. Future research should explore the mechanisms behind pest suppression, long-term effects on soil health and optimal application protocols to facilitate wider adoption.

Key Words: rabbit, biopesticide, green cabbage, armyworm, sustainable pest management, eco-friendly, plant growth enhancer.

INTRODUCTION

The widespread reliance on synthetic pesticides has substantially increased global crop yields; however, it has simultaneously introduced critical concerns regarding environmental degradation, the emergence of pesticide resistance and acute health risks to agricultural workers and consumers (Pimentel, 2005; Ahmad *et al*., 2024). Consequently, there is an urgent demand for sustainable pest management strategies. Biopesticides derived from natural substances, including plant extracts and animal-derived compounds, are recognised as promising alternatives (Ayilara *et al*., 2023). In line with this, the Philippine government enacted the Food Safety Act of 2013 (RA 10611) (Republic of the Philippines, 2013b), which prioritises the promotion of environmentally safe agricultural practices to protect public health and the ecosystem.

Rabbit urine is a complex biological fluid primarily consisting of water, nitrogenous wastes such as urea, creatinine and various electrolytes. Its composition is highly reflective of renal function and metabolic status, influenced by diet, hydration and overall health (Reusch *et al*., 2009; Mancinelli *et al*., 2012). While some sources suggest rabbit urine can range from acidic to neutral, it is typically alkaline in healthy herbivores, with specific gravity values ranging between 1.003 and 1.036 (Yeh *et al*., 2025). Rich in nitrogenous compounds like ammonia, rabbit urine holds

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significant potential as a dual-purpose organic amendment, acting as both a natural fertiliser and a biopesticide. Its nutrient-rich profile supports plant growth, while its chemical properties may suppress soil-borne pathogens and repel insect pests (Kumar and Singh, 2015).

Despite the potential, specific research evaluating rabbit urine as a biopesticide remains limited. Its high organic nitrogen content and alkaline pH can significantly influence soil health and microbial activity, positioning it as a valuable organic amendment for sustainable systems. In the context of Philippine agriculture, where smallholder farmers face severe economic constraints, identifying affordable and accessible pest control options is vital.

Green cabbage (*Brassica oleracea* var. *capitata L.*) is a high-value vegetable frequently targeted by lepidopterous pests, often resulting in devastating yield losses. While synthetic pesticides remain the primary control method, their ecological footprint necessitates the exploration of sustainable alternatives. Animal-waste derivatives, such as rabbit urine, have shown potential in enhancing soil health and providing pest suppression (Kgasudi and Mantswe, 2020). Green cabbage (*Brassica oleracea* var. *capitata* L.) is a vital horticultural crop globally and in the Philippines, prized for its nutritional value and economic importance to smallholder farmers. However, cabbage production is frequently hampered by heavy infestations of lepidopterous pests, most notably the diamondback moth (*Plutella xylostella*) and the cabbage looper (*Trichoplusia ni*).

The efficacy of rabbit urine as a dual-purpose biopesticide and fertiliser is fundamentally rooted in the nitrogenous metabolism of the animal. In rabbits (*Oryctolagus cuniculus* L.), urea nitrogen (UN) serves as a rapid biomarker for amino acid imbalances, as elevated levels in the bloodstream directly reflect the catabolism of non-utilised nitrogen and its subsequent excretion via urine (Marín-García *et al.*, 2022). Research has shown that UN is a highly sensitive indicator of dietary protein quality; the urea content in both blood and urine is highly variable and depends strictly on the amino acid balance and protein levels of the diet (Marín-García *et al.*, 2020; Marín-García *et al.*, 2022). For instance, diets deficient in lysine or other essential amino acids trigger a spike in UN concentrations that fluctuates based on feeding patterns and time after ingestion (Marín-García *et al.*, 2020). Standardising these measurements through the 'ideal protein' concept is essential not only to optimise animal growth performance but also to understand the variability in the nitrogenous composition of the excreted waste used in sustainable agricultural applications.

MATERIALS AND METHODS

Research design and study site

A randomised complete block design (RCBD) was employed to evaluate the efficacy of rabbit urine as a biopesticide against lepidopterous pests in green cabbage. Five treatment groups were established and applied weekly: 0% rabbit urine (water control), 25% rabbit urine, 50% rabbit urine, 75% rabbit urine and a synthetic pesticide (positive control).

The experiment was conducted at the researcher's farm in Virac, Catanduanes, (Philippines) (13.36° N, 124.23° E). The site has a tropical climate characterised by high sunlight exposure, averaging 6 to 8 h per day (typically between 8:00 AM and 4:00 PM peak radiation), corresponding to daylight hours from sunrise to sunset. The cabbage (*Brassica oleracea* var. *capitata*) prefers cool to moderate temperatures (10-20°C), along with well-drained soil, adequate fertilisation and sufficient moisture (FAO, 2014; Department of Agriculture, Regional Field Office No. 02, 2017).

The experiment was carried out over three growth cycles from January to November 2024. During this period, ambient temperatures ranged from 25 to 31°C. To mitigate heat stress and maintain optimal growing conditions, regular watering and shading under banana plant canopies were implemented. These measures helped regulate temperature and humidity, supporting healthy cabbage growth in the tropical environment (Lebas *et al.*, 1997; Lekamoi, 2022; Department of Agriculture, 2019).

Rabbit housing and urine collection

Fresh urine samples were collected from healthy adult rabbits (*Oryctolagus cuniculus* L.). The experimental cages measured 30.50 cm in height, 40.0 cm in width and 61.0 cm in length, providing a spacious environment that enhanced the health and welfare of the rabbits through adequate space, ventilation and enrichment (Hoy, 2008).

Rabbits were fed a diet of hay and commercial pellets with a proximal composition of approximately 15% crude protein, 3% fat, 12% crude fibre, 43% nitrogen-free extract and 4% ash, as specified on the feed analysis sack and in accordance with Michigan State University standards (2017). The diet was supplemented with locally sourced banana and papaya in moderate amount to enhance palatability and vitamin intake. Regular cleaning protocols promoted optimal health and growth (Lebas *et al.*, 1997).

To ensure freshness, urine was collected on the day of application using sterilised plastic trays positioned beneath the wire flooring of the cages. These trays were covered with a fine mesh to prevent faecal contamination, following protocols for waste separation described by Lebas *et al.* (1997). The collected urine was pooled and stored under shaded conditions until use.

Treatment preparation

Treatment solutions were prepared by diluting the pooled urine with distilled water to achieve concentrations of 25, 50 and 75% (v/v). One litre of pure distilled water served as the 0% negative control. All solutions were thoroughly mixed and stored in labelled, shaded containers to prevent chemical degradation.

For the positive control, Vayego (active ingredient: tetraniliprole) was utilised. This anthranilic diamide insecticide, developed by Bayer, was prepared according to manufacturer instructions 0.5 mL per litre of water, following the manufacturer's recommended application rate (Bayer, 2021; Crop Science Philippines, 2023). Tetraniliprole is specifically effective against lepidopteran pests, such as the diamondback moth (*Plutella xylostella*), by disrupting ryanodine receptors in insect muscle cells, leading to rapid antifeedant effects, paralysis and death.

Experimental rationale and schedule

The concentrations for this study (25, 50 and 75%) were selected based on preliminary trials conducted by the author (unreported data). In these earlier trials, it was observed that the application of 10% rabbit urine –whether applied daily or thrice weekly– resulted in negligible effects (~10% pest reduction). Furthermore, frequent reapplication caused the solutions to dry rapidly on the leaf surface, leading to plant desiccation. To mitigate this issue and improve overall effectiveness, a weekly application schedule was adopted to maintain plant vigour while providing adequate pest protection.

Plant culture and experimental setup

The study utilised 150 cabbage plants arranged in RCBD consisting of five treatments, with each treatment replicated three times across a total of 15 plots (10 plants per plot). Seedlings were initially grown in sun-exposed seedbeds with a sterilised soil mixture, sown at 10 seeds per cm and thinned to a 5×5 cm spacing. Prior to transplanting at the 25- to 30-day stage (3 to 4 true leaves), seedlings were hardened by withholding water for one week (Department of Agriculture, 2019). Transplanting was conducted in the late afternoon to minimise shock, with seedlings placed in 20 cm diameter polyethylene bags filled with sterilised potting mix and organic compost (FAO, 2014; Department of Agriculture, 2019). To maintain a specific planting density, the plants were grown in 20 cm diameter polyethylene bags with a 30 cm spacing between individual plants (intra-row) and a 45 cm distance between rows (inter-row), with seedlings shaded by banana leaves for the first three days post-transplant (Department of Agriculture, 2019).

Treatment applications and growth monitoring

Treatments were applied weekly using a hand-held sprayer, ensuring full leaf coverage, beginning 15 d after transplanting (DAT) and continuing for a period of eight weeks. Application procedures followed protocols established by the FAO (2018a). The total duration of the trial spanned approximately 11 wk from transplanting to final data collection, with weekly assessments conducted until the cabbage reached the head-initiation stage. Following the Plant Pest and Disease Assessment Manual (FAO, 2018a), plant vigour was documented using a 1-5 visual rating scale to track health and development throughout the monitoring period. Lepidopterous pests were identified visually, corroborated through modern classification frameworks (Thenmozhi and Reddy, 2019) and Philippine entomological records (Sarmiento and Ocampo, 2010). The diamondback moth (*Plutella xylostella*) was identified as the primary pest, along with the fall armyworm (*Spodoptera frugiperda*) and the cabbage webworm (*Hellula undalis*).

Data collection and severity index

To quantify the impact of these pests and the efficacy of the rabbit urine treatments, a severity index (SI) was calculated. This allows for a standardised comparison of damage across treatments by weighting the frequency of each rating. The SI was calculated using the following formula:

$$SI=[\sum (n\times v)/(N\times V)]\times 100$$

where: n=number of plants per rating, v=damage rating (0-5), N=total plants and V=highest scale value (5). Damage ratings and leaf damage assessment followed FAO (2018a). Harvesting occurred at physiological maturity, approximately 65 to 70 d after transplanting (DAT), when heads felt firm and reached a diameter of 15 to 20 cm (Department of Agriculture, 2019; FAO, 2018b).

Physicochemical and statistical analysis

Fresh urine samples were analysed for pH, total disolved solids (TDS) and electrical conductivity (EC) following Hanna Instruments (2020) and ammonia levels were determined semi-quantitatively using MQuant® test strips Merck (2018). Data were analysed using one-way analysis of variance (ANOVA) in R software (version 4.2.0; R Core Team, 2022). Assumptions of normality (Shapiro-Wilk) and homogeneity (Levene's) were verified. Tukey's honestly significant difference (HSD) post-hoc tests were conducted at $\alpha=0.05$. For repeated measures, linear mixed-effects models were fitted using the *lme4* package (Bates *et al*., 2015). All procedures adhered to Zar (2010) and Littell *et al.* (2006).

Ethical considerations

The study was conducted in accordance with animal welfare guidelines, ensuring humane housing and non-invasive urine collection as approved by the University Research Ethics Committee of the Catanduanes State University and the Municipal Agriculture Office in compliance with the *Guide for the Care and Use of Laboratory Animals* (National Research Council, 2011).

RESULTS AND DISCUSSION

This comprehensive study evaluated the potential of fresh rabbit (*Oryctolagus cuniculus* L.) urine as a sustainable biopesticide and biofertilizer in cabbage cultivation. The research focused on how varying concentrations of fresh rabbit urine influence pest infestation, plant health and yield quality, alongside an analysis of the physicochemical properties of urine and their roles in pest suppression.

Physicochemical characteristics of fresh rabbit urine

Table1 shows that fresh rabbit urine is consistently alkaline (pH 8.25), with elevated TDS (5786.5 ppm), EC (8050.1 µS/cm) and high ammonia levels, based on a sample size of n=3 composite samples analysed in triplicate to establish a baseline chemical profile. These properties intensify with higher concentrations, where the alkaline pH and ammonia content drive the pesticidal effect, while elevated mineral concentrations reflect the urine's inherent properties, but can pose salinity risks if overapplied.

Table 1: Physicochemical characteristics of rabbit urine solutions.

Treatment Group	pH Level	TDS (ppm)	EC (µS/cm)	Ammonia level
Water (0%)	7.2 ± 0.1^{a}	478.0 ± 12.5^{a}	988.0 ± 25.1^{a}	0 (Negative)
25% solution	8.0 ± 0.1^{b}	2017.6 ± 45.2^{b}	3966.4 ± 62.3^{b}	1 (Faint)
50% solution	8.0 ± 0.1^{b}	3080.4 ± 58.6^{c}	6035.2 ± 88.4^{c}	2 (Positive)
75% solution	8.2 ± 0.2^{c}	4320.8 ± 71.3^{d}	8050.1 ± 95.2^{d}	3 (Strong)
pure rabbit urine	8.2 ± 0.1^{c}	5786.5 ± 85.4^{e}	10704.3 ± 120.6^{e}	4 (Very strong)
P-value	<0.05	<0.001	<0.001	N/A

TDS=total dissolved solids; EC=electrical conductivity. Ammonia scores based on colorimetric test strip intensity (0–4). Values represent mean±standard error. Means with different superscript letters ($^{a, b, c, d}$) within a column differ significantly ($P<0.05$).

Fresh rabbit urine displays an alkaline pH of 8.25 that remains stable after dilution, inhibiting pH-sensitive pests, disrupting microbes and providing antimicrobial effects, aligning with prior reports of pH 8.50 (Ekwere *et al.*, 2023) and pH 7.55 (Yetunde *et al.*, 2022), plus detailed metrics such as 1.3% nitrogen and specific gravity 1.0133 g/ml (Løe, 2023). High TDS (5786.5 ppm pure; 4320.8 ppm at 75%) and EC (10 704.3 µS/cm pure; 8050.1 µS/cm at 75%) indicate rich nitrogen, phosphorus, and potassium (NPK) and ammonia for plant nutrition and pest toxicity, necessitating dilution to avert phytotoxicity (Hezakiel *et al.*, 2023). Ammonia levels (score 4 undiluted to 1 at 25%) drive suppression through toxicity, oviposition-deterring pH shifts and repellency (Said *et al.*, 2018), with raw urine superior to purified forms by preserving volatiles (Elmogy, 2023). These traits enable multi-modal deterrence via toxicity, pH disruption, plant fortification and chemoreception interference.

Horticultural performance of cabbage treated with fresh rabbit urine

Pest infestation severity index

Table 2 summarises the severity index (SI) of pest infestation under different concentrations of fresh rabbit urine. A clear decreasing trend was observed with increasing concentration ($P<0.0001$), while the 75% treatment showed the lowest severity (1.2±0.1), which was statistically comparable to the synthetic pesticide (1.1±0.1). Higher concentrations of fresh rabbit urine significantly reduced pest damage severity, indicating strong pesticidal action. The finding that the 75% treatment produced similar as the synthetic pesticide suggests that rabbit urine can effectively suppress lepidopterous pests when applied at sufficient concentration.

Fresh rabbit urine reduces pest severity in a dose-dependent manner, achieving a substantial reduction at 75% concentration compared to the negative control (4.2±0.2). This suppression is likely achieved through ammonia and compounds that alter leaf chemistry and disrupt pest physiology (Kemunto *et al.*, 2022). Its alkaline pH (7.55-8.50) and high levels of NPK and calcium promote plant growth while controlling pests, with fresh urine outperforming stored versions, since the aged urine loses efficacy as volatile ammonia and bioactive compounds degrade over time (Ekwere *et al.*, 2023; Yetunde *et al.*, 2022; Mmbaga *et al.*, 2024).

Previous studies have reported that higher concentrations work better for cabbage and lepidopterans than for aphids or tomatoes, matching synthetic biopesticides like Spinosad and showing synergy with botanicals (Løe, 2023; Mutua *et al.*, 2024a,b; Choyon *et al.*, 2022; Lekamoi *et al.*, 2022). Suppression occurs via toxicity, repellency and enhanced plant vigour (Niyoyitungiye *et al.*, 2025).

Leaf damage assessment

As presented in Table 3, the average number of damaged leaves per plant decreased progressively with increasing fresh urine concentration ($P<0.001$). The 75% treatment resulted in minimal leaf damage (1.0±0.1), which was statistically comparable to the synthetic pesticide (1.0±0.1), both sharing the superscript. Improved plant resistance is evident at higher concentrations, indicating enhanced plant vigour and significantly reduced pest feeding.

Table 2: Horticultural performance and pest infestation severity index of green cabbage

Treatment (%)	Average plant height (cm)	Average leaf count	Pest infestation severity index (1-5)
0 (Negative control)	25.2±0.6^{a}	10.1±0.3^{a}	4.2±0.2^{d}
25 % Rabbit urine	30.4±0.5^{b}	10.4±0.4^{a}	3.1±0.1^{c}
50% Rabbit urine	32.1±0.4^{b}	12.3±0.5^{b}	2.1±0.2^{b}
75% Rabbit urine	35.3±0.7^{c}	14.2±0.4^{c}	1.2±0.1^{a}
Synthetic (Positive control)	35.1±0.5^{c}	14.0±0.3^{c}	1.1±0.1^{a}
P-value	< 0.001	< 0.001	< 0.0001

Values represent mean±standard error (n=30). Means followed by different superscript letters ($^{a, b, c, d}$) within a column indicate significant differences according to Tukey's HSD test ($P<0.05$).

Pest infestation severity index scale (1–5) based on visual assessment: 1=No/minimal damage (no visible signs); 2=Light damage (limited presence); 3=Moderate damage (evident activity); 4=Severe damage (extensive leaf loss); 5=Very severe (plant dying/dead).

Table 3: Assessment of leaf damage in green cabbage.

Treatment (%)	Total damaged leaves	Avg. damaged leaves/plant
0 (Negative control)	40.0[d]	4.0±0.3[d]
25 % Rabbit urine	28.0[c]	2.8±0.2[c]
50% Rabbit urine	15.0[b]	1.5±0.1[b]
75% Rabbit urine	10.0[a]	1.0±0.1[a]
Synthetic (positive control)	10.0[a]	1.0±0.1[a]
P-value		<0.001

Values represent mean±standard error. Means followed by different superscript letters ([a, b, c, d]) within a column are significantly different ($P<0.001$).

Higher nutrient availability from rabbit urine strengthens plant defences, reducing leaf damage susceptibility; its rich NPK and calcium (3.55%) content enhances cell walls and structural support compared to commercial fertilisers (Mutai, 2020; Ekwere *et al.*, 2023). This aligns with Yetunde *et al.* (2022) regarding *Amaranthus hybridus* pest resilience and Indabo and Abubakar (2020) on improved tomato growth morphology. Calcium pectate formation reinforces leaves against insect feeding, complementing ammonia-based deterrence, while 75% concentrations match synthetic pesticides via dual pest control and vigour enhancement. Comparable to Mganga and Sanga (2024) on cow urine for Chinese cabbage and Wijayanto *et al.* (2022) on water spinach growth from repeated applications, rabbit urine's higher nitrogen (2.36%) offers superior benefits.

Marketable and non-marketable yield

Table 4 shows that the proportion of marketable yield increased markedly with higher fresh rabbit urine concentrations ($P<0.05$). The 75% treatment yielded the highest proportion of marketable heads (97.8%), which was identical to the positive control and significantly higher than the negative control (75.0%). Enhanced yield quality at higher concentrations indicates both improved pest resistance and better plant nutrition.

The increase in marketable yield led to an increase in economic benefits for farmers, reflecting improved crop health and reduced pest damage. This supports Mutai's (2020) findings that higher nutrient input from rabbit urine enhances photosynthetic efficiency and biomass production. Ekwere *et al.* (2023) demonstrated that rabbit urine, alone or combined with inorganic fertilisers, significantly improves crop growth and yield; the current study suggests that in cabbage, sufficient concentrations of rabbit urine alone can achieve high yields without synthetic fertilisers. Mbonayo *et al.* (2025) also confirmed rabbit urine's fertilising value in maize, while Said *et al.* (2018) noted that fresh rabbit urine, due to its higher ammonia content, may be more effective for pest control and yield than fermented urine.

The comparable performance of rabbit urine to synthetic pesticides emphasises its potential as an organic alternative aligned with global organic agriculture trends. Islas-Valdez *et al.* (2017) highlighted rabbit urine's positive effects on multiple crops and soil health, a finding extended here to cruciferous vegetables, indicating broad adaptability. While combining organic and mineral fertilisers can optimise yield further (Wysokinski and Kożuchowska, 2024), this study confirms that rabbit urine alone at a 75% concentration sufficiently supports high-quality cabbage production and marketable yield.

Table 4: Marketable and non-marketable yield of cabbage.

Treatment (%)	Marketable yield (kg)	Non-marketable yield (kg)	Total yield (kg)	% Marketable
0 (Negative control)	30.0[a]	10.0[c]	40.0±1.2[a]	75.0[a]
25 % Rabbit urine	35.0[b]	5.0[b]	40.0±1.1[a]	87.5[b]
50% Rabbit urine	40.0[bc]	2.0[a]	42.0±0.9[a]	95.2[c]
75% Rabbit urine	45.0[c]	1.0[a]	46.0±1.5[b]	97.8[c]
Synthetic (positive control)	45.0[c]	1.0[a]	46.0±1.4[b]	97.8[c]
P-value	<0.05	<0.05	<0.05	<0.001

Marketable yield (%) represents the proportion of heads meeting commercial standards for size and firmness. Values represent mean±standard error. Means with different superscript letters ([a, b, c, d]) within a column differ significantly ($P<0.05$).

Table 5: Horticultural performance of cabbage with rabbit urine treatments: harvest index.

Treatment (%)	Total biomass (kg)	Marketable yield (kg)	Harvest index (HI)
0 (Negative control)	50.0±1.5^{a}	30.0±0.8^{a}	0.60^{a}
25 % Rabbit urine	52.0±1.2^{a}	35.0±0.6^{b}	0.67^{b}
50% Rabbit urine	55.0±1.8^{b}	40.0±0.9^{bc}	0.73^{c}
75% Rabbit urine	60.0±2.1^{c}	45.0±1.1^{c}	0.75^{c}
Synthetic (positive control)	60.0±1.9^{c}	45.0±1.0^{c}	0.75^{c}
P-value	<0.01	<0.01	<0.001

Harvest Index is calculated as the ratio of marketable yield to total biomass. Values represent mean±standard error. Different superscripts letters ($^{a, b, c, d}$) within a column denote significant differences (P<0.001).

Harvest Index

Table 5 demonstrates a progressive improvement in harvest index (HI) with increased fresh rabbit urine concentration (P<0.001). The highest values (0.75) were observed in both the 75% treatment and the synthetic pesticide, which were significantly higher than the negative control (0.60). Higher concentrations enhance biomass partitioning toward marketable yield, indicating more efficient physiological resource allocation.

The HI improved by 25% (from 0.60 in the control to 0.75 in the 75% treatment), boosting biomass conversion efficiency to marketable cabbage heads, as nutrient supplementation directs more assimilates to economic parts. Reduced pest pressure combined with the nitrogen and calcium profile of rabbit urine minimises the plant's defence resource allocation, thereby enhancing source-sink relationships and overall productivity (Aprilina *et al.*, 2023). Fresh diluted urine matches or exceeds the benefits of processed rabbit urine liquid organic fertilisers by avoiding ammonia loss during fermentation, aligning with plant stress reduction principles observed across various crops

Efficacy of fresh rabbit urine in pest suppression

Table 6 shows a clear dose-dependent reduction in pest counts (P<0.0001). The 75% treatment exhibited pest suppression equivalent to the synthetic pesticide (2.0±0.2 pests per plant), both sharing the superscript. Higher fresh rabbit urine concentrations strongly reduce pest populations and improve plant height, demonstrating dual functions, i.e., growth enhancement and pest control.

Fresh rabbit urine exhibits concentration-dependent pest suppression, aligning with the LC_{50} values reported by Kemunto *et al.* (2022) for fall armyworm instars (48-94%), where weekly applications in the current study created cumulative deterrence. Specifically, the 75% concentration achieved an 83.3% reduction in pest counts compared to the negative control (12.0±0.8). Niyoyitungiye *et al.* (2025) confirm the potency of urine against lepidopterans, though a 75% dilution optimises field efficacy by balancing control and phytotoxicity avoidance, outperforming the more moderate effects observed in tomatoes (Fikiri *et al.*, 2025).

Multi-faceted mechanisms include toxicity, repellency, feeding deterrence, growth inhibition and induced defences (Senthil-Nathan, 2015). These are further enhanced by nutrient-driven vigour (Ekwere *et al.*, 2023; Yetunde *et al.*, 2022), with cabbage demonstrating a higher tolerance for these concentrations than tomatoes (Mutua *et al.*, 2024a). Future potential exists for exploring synergies with botanicals such as *Tephrosia vogelii* (Lekamoi *et al.*, 2022).

Table 6: Efficacy of rabbit urine on pest counts and plant height.

Treatment (%)	Avg. pest count/plant	Avg. plant height (cm)
0 (Negative control)	12.0±0.8^{d}	25.0±0.6^{a}
25 % Rabbit urine	8.0±0.5^{c}	30.0±0.5^{b}
50% Rabbit urine	5.0±0.4^{b}	35.0±0.7^{c}
75% Rabbit urine	2.0±0.2^{a}	38.0±0.4^{c}
Synthetic (positive control)	2.0±0.2^{a}	38.0±0.5^{c}
P-value	<0.0001	<0.001

Pest counts represent the average number of larvae per plant over an 8-wk monitoring period. Values represent mean±standard error. Means followed by different superscript letters ($^{a, b, c, d}$) within a column are significantly different (P<0.0001).

Visual assessment of pest damage

Qualitative assessments showed fewer feeding marks and healthier foliage in treated plants, particularly at 50 and 75% concentrations. Visual differences between treated plants and controls were consistent across observation periods. Visual improvements in treated cabbage leaves –showing minimal feeding damage, fewer oviposition sites and healthier colouration– confirm rabbit urine's pest suppression efficacy, which is comparable to natural declines observed in *Pieris rapae*, *Plutella xylostella* and *Spodoptera exigua* under cooler conditions or fungal activity (Embaby and Lotfy, 2015). Building on this, the data provides tangible proof for farmers, demonstrating that protection from synthetic pesticides can match or even outperform some botanicals like neem and tobacco, thereby supporting their inclusion in organic systems (Ali *et al.*, 2019). Furthermore, field visuals address the common challenge of translating laboratory results to real-world conditions, demonstrating consistent pest suppression and reinforcing rabbit urine's potential role in integrated pest management (Price, 2024).

Integration into pest management systems

Rabbit urine offers significant potential as a dual-purpose biopesticide and biofertilizer in modern agriculture, particularly due to its rich nutrient profile and sustainability. It contains high levels of nitrogen, phosphorus and potassium, making it a valuable input for crop nutrition alongside its pesticidal effects against significant threats such as aphids and fall armyworms (Kemunto *et al.*, 2022; Mutai, 2020). Compared to synthetic inputs, rabbit urine is a cost-effective, natural alternative that lowers environmental impact while enhancing the yields of high-value crops like tomato, cucumber and bok choy (Indabo & Abubakar, 2020).

Farmers benefit from the on-farm availability of rabbit urine, which eliminates the need for expensive commercial chemicals and complex processing. This accessibility simplifies application, making it especially suitable for resource-limited smallholder systems. Community-based adoption and farmer-to-farmer knowledge sharing have accelerated its acceptance as a sustainable solution for simultaneous pest management and soil fertility (Nchanji *et al.*, 2018; Usman *et al.*, 2021). Notably, rabbit urine exhibits significantly lower toxicity compared to conventional synthetic pesticides, presenting fewer risks to human health and the surrounding ecosystem (Hezakiel *et al.*, 2023; Akyil *et al.*, 2016).

Furthermore, studies confirm its effectiveness in reducing pest populations, such as whiteflies, while supplying essential nutrients that support healthier crops with improved systemic resistance to herbivory (Choyon *et al.*, 2022; Indabo & Abubakar, 2020). Given its continuous production and ecological advantages, rabbit urine is a promising organic input for integration into sustainable farming systems, emphasising local, affordable and environmentally friendly pest management practices.

Limitations and future research directions

While the results are compelling, this study faced limitations, specifically environmental factors such as temperature fluctuations and tropical rainfall that may affect urine treatment stability. Future research should utilise controlled environments to better assess shelf-life and stability under varying conditions. The lack of advanced chemical profiling constrained the detailed identification of specific pesticidal compound. Techniques such as gas chromatography-mass spectrometry and high-performance liquid chromatography are recommended for future work to isolate the bioactive components responsible for suppression (Mmbaga *et al.*, 2024; Mutua *et al.*, 2024b).

Additionally, the single-season scope restricts the understanding of long-term soil impacts, particularly potential salinity risks from repeated applications of solutions with high electrical conductivity. Multi-season and multi-location trials are necessary to validate broader applicability. Future studies should also expand the target range beyond lepidopterans to include aphids and mites, as varied efficacy has been reported across different pest orders (Løe, 2023). Refinement of application protocols—including spray volume, droplet size and frequency—is also required to optimise field performance (Mutua *et al.*, 2024a). Finally, clarifying the specific deterrence mechanisms—contact toxicity, feeding deterrence, oviposition inhibition or developmental disruption—remains critical (Isman, 2006; Isman and Norris, 2024). Exploring the synergy between rabbit urine and other integrated pest management (IPM) components, such as beneficial insects and botanical extracts, could provide a more robust defence strategy for organic vegetable production.

CONCLUSION

This study demonstrates that rabbit urine is an effective and environmentally sustainable biopesticide for managing lepidopterous pests in green cabbage. Treatments with higher concentrations, particularly at 75%, significantly reduced pest damage and leaf injury compared to controls, and these effects were comparable to those of synthetic pesticides. Additionally, treated plants showed improved vigour and higher marketable yields, indicating that rabbit urine not only suppresses pests but also promotes plant growth.

The efficacy of these treatments is closely tied to the nitrogenous metabolism of the animal; the urea and ammonia content in the urine –and thus its potency as an organic amendment– is highly variable and dependent on the rabbit's dietary protein balance and amino acid profile. The physicochemical analysis revealed that rabbit urine's alkaline pH, high ammonia content and mineral richness contribute to these dual pesticidal and growth-enhancing effects. The role of rabbit urine as both a pest deterrent and a growth stimulant supports its potential as a low-cost, eco-friendly input for sustainable agriculture.

While these findings are promising, further research is necessary to evaluate its long-term impact on soil health, non-target organisms and crop quality across diverse environments. Developing standardised preparation and application protocols will also be essential to ensure consistency and safety in field use. Overall, the results provide strong evidence that rabbit urine can serve as a natural alternative to chemical pesticides, contributing to integrated pest management strategies that support environmental health and crop productivity.

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