Review Article

Cow Urine's Agricultural Renaissance: Enhancing Crop Yield and Environmental Sustainability

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Abstract

In recent decades, global awareness of the need to conserve the natural environment and safeguard food integrity has increased markedly, leading to renewed interest in organic and low-input farming systems. Cow urine is a distinctive organic resource that is easily accessible on dairy farms and has been used as a fertilizer, plant growth booster, and natural pesticide in agriculture. It is mostly water (≈95%) and contains urea, mineral salts, hormones, and enzymes that can supply nutrients and bioactive compounds to crops. Experimental studies indicate that cow urine and cow urine-based formulations may improve certain growth parameters, enhance yield components, and suppress selected pests and pathogens under specific conditions. However, the evidence base remains fragmented and context-dependent, as many reports are small scale, short term, or combine cow urine with other inputs, making it difficult to isolate its independent effects or generalize across crops and environments. In addition, variability in cow urine composition, limited standardization of formulations, and the scarcity of large, replicated field trials constrain robust conclusions about its agronomic efficiency relative to conventional fertilizers and pesticides. This review summarizes reported uses of cow urine and cow urine-based formulations in agricultural practices, critically evaluates their benefits and limitations.

Categories: Organic agriculture, Disease & pests of crops, Use of biostimulants, biofertilizers, bioinoculants in sustainable agriculture

Keywords: organic farming, cow urine, biopesticide, plant growth stimulant, fertilizer

Introduction And Background

Most Indians depend on agriculture for their livelihood, which is currently facing numerous challenges, such as soil degradation, high cost of chemical pesticides, pesticide resistance, low crop yield, and high production costs. According to the UNFPA World Population Dashboard, in 2025, India's population was approximately 1.464 billion, due to this growing population, the demand for food is rising rapidly compared to its production [1]. To meet the food demand of the growing population, agricultural practices must be modified accordingly. In Indian agriculture, synthetic pesticides are widely used for pest management to enhance crop yield because of their immediate knockdown effect. However, the excessive use of this pesticide has led to environmental pollution, the development of pesticide-resistant pests, and health hazards [2].

The widespread use of synthetic agrochemicals has negatively affected the environment, human health, and biodiversity. Although these synthetic agrochemicals effectively control pests, they cause environmental damage, soil degradation, water pollution, and resistance development in pests, posing significant challenges to sustainable agriculture [3,4]. Therefore, there is increasing interest in safer and eco-friendly solutions that can overcome the negative impact of synthetic agrochemicals while maintaining productivity. In this case, organic farming may become a promising alternative to synthetic agrochemicals because of its natural inputs, which maintain ecological balance. Among the various options, cow urine has been proposed as a promising organic input component in some studies because of its nutritional and bioactive components, which enhance crop yield and protect against pests and diseases [5]. Therefore, interest in organic agrochemicals is rapidly increasing. Organic farming plays an important role in enhancing crop growth and yield while maintaining the biological and physical health of the soil. In India, cows are collaborators with humans in agriculture. Farm produces large quantities of cow urine and dung. Although cow urine can be used as a fertilizer and biopesticide, most farmers neglect its use [6].

Cow urine is rich in nutrients, such as nitrogen, phosphate, potassium, calcium, magnesium, chlorite, and sulfate. It is mostly water (95%) and contains a small amount of urea and other compounds (5%), providing several essential nutrients and bioactive compounds that can contribute to plant growth and development. Since ancient times, cow urine has been known to have significant effects on both human health and agriculture. It has been conventionally used as a biopesticide and biofertilizer, and its antifungal, antibacterial, and nutritional properties enhance crop growth and improve soil productivity. At different stages of plant growth, cow urine application manages nutrient deficiency and boosts crop development. These benefits of cow urine can effectively manage nutritional deficiencies, provide protection against diseases and pests, and emerge as an alternative eco-friendly solution to chemical pesticides. Additionally, cow urine is used as a bioinsecticide and biofungicide, which controls pest and disease attacks on plants and enhances crop development. The reduced usage of cow urine and cow urine-based products in the Indian crop protection sector and the increased demand for synthetic pesticides are significant concerns. Researchers must recognize the role of cow urine-based products in sustainable agriculture and reestablish their historical value. However, a rigorous, evidence-based evaluation of cow urine's efficacy, mechanisms, and limitations is needed to determine its role in sustainable agriculture and to guide future research and policy [7,8]. Most of the available literature on cow urine in agriculture appears to originate from India and a few other countries in South Asia and Africa. Because high-impact, peer-reviewed studies from broader international settings remain limited, the current evidence base may not fully support the global generalization of the findings.

Review

Historical use of cow urine in agriculture

Cow urine (gomutra) is traditionally used for therapeutic purposes in Ayurvedic and folk medicine. It is also referred to as Amritha and Sanjivani in ancient Vedic literature [9]. Cow urine contains approximately 23 micro and macronutrients and possesses numerous preventive and bactericidal qualities that are advantageous for agricultural development. In ancient Indian farming, cow urine was used as a natural fertilizer and insect repellant. In conventional agriculture, cow urine is used as farmyard manure after being mixed with cow dung. Cow urine is rich in nutrients such as nitrogen, phosphate, and potassium, which promote the growth of plants. It can be applied as a foliar spray or mixed with soil. Nitrogen, phosphorus, and potassium are the three key elements necessary for optimal plant growth and development. Cow urine is particularly rich in nitrogen and potassium [10,11].

The application of cow urine along with organic amendments markedly improved arugula growth and quality compared to the untreated control, increasing fresh and dry leaf biomass, plant height, chlorophyll content, total polyphenols, and antioxidant activity. Treatments using bokashi plus 1% diluted cow urine increased fresh leaf biomass by up to 87% and 76% at 30 and 20 g doses, respectively, and also enhanced the chlorophyll index at the highest doses. This approach proved effective in terms of yield, cost, and environmental sustainability, supporting cow urine-based organic amendments as a viable, eco-friendly alternative to conventional fertilizers [12]. The increasing food demand of the growing population requires a shift towards modern agricultural practices to enhance pesticide efficiency, such as the collaborative application of bio-based materials and chemicals to achieve synergistic results by boosting plant development and pest management. This approach ultimately safeguards the food supply for the growing population in an eco-friendly and cost-effective way. These findings indicate the need to use organic fertilizer sources, such as cow urine and dung, to optimize production sustainably while improving soil health. It is an excellent source for enhancing the physicochemical and biological features of soil, resulting in increased plant yields on a sustainable basis without depleting soil fertility [13,14].

Nutrient composition of cow urine

Cow urine contains multiple nutrients, such as nitrates, phosphates, sodium, manganese, iron, silicon, chloride, magnesium, citrate, tartrate, and sulfate among its constituents. It also contains minerals, lactose, enzymes, creatine, hormones, and vitamins A, B, C, D, and E. Cow urine contains important nutrients (Table *1*). Using cow urine in organic farming is an effective method for controlling various plant diseases and enhancing crop yield by providing essential nutrients to plants. The specific gravity of cow urine varies from 1.025 to 1.045, and the volume of cow urine varies from 17 to 45 ml/kg/day. The pH of cow urine may vary from 7.4 to 8.4, depending on the season. Additionally, it generally comprises 40-45 ml of total nitrogen per kg of body weight per day, with urea nitrogen constituting 23-28 ml/kg of total nitrogen per day [15,16].

The following is a rundown of the remaining important components

Chemical constituents	Fresh cow urine	Fermented cow urine	Unit	Reference
Chloride (Cl^-)	1,556	4,514	mg/L	[17]
Sulphate (SO_4^{2-})	364	252	mg/L	
Nitrite (NO_2)	2.0	22.4	mg/L	
Phosphorus pentaoxide (P_2O_5)	26.8	7.49	mg/L	
Potassium (K)	3230.193	-	mg/L	[18]
Magnesium (Mg)	24.837	-	mg/L	
Sodium (Na)	7.606	-	mg/L	
Calcium (Ca)	1.312	-	mg/L	
Zinc (Zn)	0.081	-	mg/L	
Gold (Au)	0.085	-	mg/L	
Iron (Fe)	0.01955	-	mg/L	
Chromium (Cr)	0.000187	-	mg/L	
Aluminum (Al)	0.00756	-	mg/L	

TABLE 1: Chemical constituents of healthy cow urine.

Note: Concentrations originally reported in parts per billion (ppb) were converted to milligrams per liter (mg/L) using the conversion factor of 1 ppb = 0.001 (mg/L). The values for potassium, magnesium, sodium, calcium, zinc, gold, iron, chromium, and aluminum in fresh cow urine were converted accordingly. Data on these elements in fermented cow urine are currently unavailable.

Protein breakdown produces urea, which is a key nitrogen source for plants when applied to soil. In cow urine, urea and other ingredients help create a condition that controls some pathogenic microorganisms; however, urea itself is not widely recognized as a potent antibacterial agent in agriculture. The antimicrobial activity reported for urine samples likely reflects the combined effects of uric acid, ammonia, salts, other metabolites, and microbial constituents, rather than urea alone [19].

Cow urine is an effective resource for boosting soil fertility, crop yield, and crop quality. This may be used in fertigation, which is increasingly used in several crops to prevent fertilizer loss. Vegetative growth increased following the application of urine at 125 kg N/ha; however, the greatest improvements in yield and quality were observed at an application rate of 100 kg N/ha. Fifty percent substitution of urea with urine resulted in better morphological, yield, and quality traits than the other urine-urea combinations [20,21].

The application of a high dosage of cow urine increases the dissolved organic carbon in soil and enhances microbial activity and nutrient availability. The mixture of farmyard manure (FYM) at a rate of 12.5 t/ha with cow urine at 34,300 L/ha significantly improved soil organic carbon (0.58%), available nitrogen (272.4 kg/ha), phosphorus (23.5 kg/ha), and potassium (199.9 kg/ha) levels. Higher levels of nitrogen (N), phosphorous (P), and potassium (K) were detected in the soil with various urine application sources than in the control group [22,23].

Integrated mechanism of cow urine: antifungal, insecticidal, and fertilizer activities

The reported agronomic effects of cow urine are likely mediated through several, partly overlapping mechanisms rather than a single pathway. Its antifungal efficacy is derived from its complement of small molecular weight cationic antimicrobial peptides (1.7-1.8 kDa) that disrupt fungal cell membranes by interacting with anionic phospholipids, combined with over 46 plant-origin metabolites, including baicalin and phlorizin chalcone, which provide additional antimicrobial and antioxidant activities [24]. Major chemical constituents such as carbolic acid, urea, and uric acid function as disinfectant agents against phytopathogenic fungi that generate oxidative stress, achieving mycelial growth inhibition of 12.50% to 90% against *Colletotrichum capsici* and 0.0% to 47.61% against *Fusarium oxysporum*. This is supplemented by enzymatic pathways involving chitinases, glucanases, cellulases, and proteases that degrade fungal structural components [25,26]. Cow urine functions as a bio-enhancer for insecticidal action when formulated with botanicals such as neem, ginger, and ocimum. It inhibits pest detoxification enzymes and enabling higher *in vivo* concentrations of plant-derived toxins while permitting synergistic targeting of multiple physiological sites. Biopesticide formulations achieving 70% control of tomato fruit borers and increased yield from 15 to 35 t/ha [27]. For plant growth and fertilizer activity, cow urine enriches soil microbiome diversity through its role as a key component in jeevamrit microbial formulations, introducing beneficial bacteria, including *Azospirillum*, *Pseudomonas*, and *Actinomycetes*, which produce plant hormones, such as Indole Acetic Acid (IAA), to enhance seedling survival, shoot development, and root health, while exhibiting synergistic effects when combined with gibberellic acid to significantly improve plant emergence, height, leaf growth, spike initiation, and corm production [26,28]. At present, these mechanistic explanations remain hypothetical for some studies and are not uniformly supported across crops, environments, or formulations, underscoring the need for controlled studies linking specific chemical constituents to defined plant physiological responses.

Applications of cow urine in agriculture

From ancient times, cow urine and cow urine-based products have been known for their agricultural benefits, such as biofertilizers, biofungicides, and bioinsecticides. The organic and inorganic components of cow urine may boost the activity of beneficial microbes that address nutrient deficiency [29].

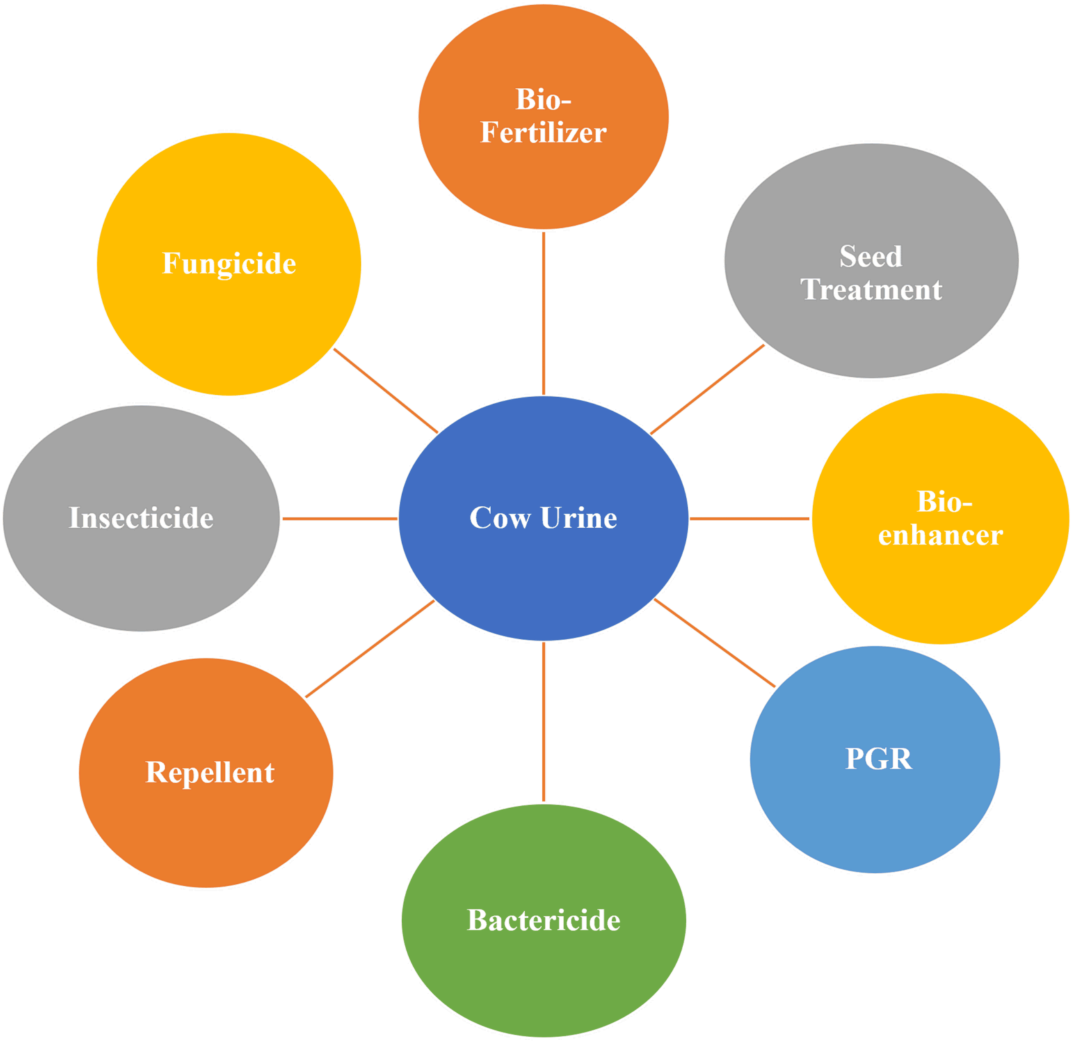

FIGURE 1: Applications of cow urine.

Furthermore, cow urine has been shown to have bactericidal activity in some studies, inhibiting the growth of harmful bacteria and protecting crops [30]. It acts as a bio-enhancer by supplying essential nutrients and promoting soil microbial activity, thereby improving plant growth and yields. Additionally, cow urine serves as a plant growth regulator (PGR), repellent, and effective seed treatment, enhancing germination and providing protection against diseases and pests (Figure *1*). These products are intended to enhance soil fertility, expedite the breakdown of organic waste, and protect crops from pests and diseases. To enhance soil fertility, boost crop yield and quality, and manage pests and diseases, organic solutions such as cow urine, neem extract, vermiwash, and fish wash have been used [31].

Cow urine as a plant growth stimulant

Cows are considered an important part of the rural economy and have considerable social and cultural importance. Cow urine is recognized as the most influential animal-based product with several agricultural applications. Its uses include vermicomposting, biofertilizers, and biopesticides, which enhance vegetable output and aid in plant disease prevention. Although research on cow urine has shown encouraging findings, further meticulously designed investigations are required to confirm its advantageous characteristics for agriculture and to enhance awareness of its prospective applications [32]. In Hinduism, the cow is considered sacred. Their milk, dung, and urine are useful, especially the milk. Ancient Hindu texts, such as the Vedas, mention the benefits of cow urine and dung. The researchers found that cow urine can help plants growth and fight bacterial infections. They studied the effects of different amounts (0%, 5%, 15%, and 25%) of cow urine on maize, wheat, grass, tukmaria, and fennel plants for 30 days. They measured the plant height, shoot and root lengths, number of leaves, and root weight. Researchers have studied the effects of cow urine on bacteria and fungi, such as *Escherichia coli* and *Aspergillus* sp. They used a method called Gas Chromatography-Mass Spectrometry (GC-MS) to check the chemicals in cow urine. The study found that 5% cow urine concentration provided an optimal balance of growth-promoting compounds that enhanced plant development, while higher concentrations (25%) demonstrated stronger antimicrobial efficacy against *Escherichia coli* and *Aspergillus* sp., suggesting a concentration-dependent trade-off between plant growth promotion and antimicrobial activity. They identified 16 compounds in cow urine using GC-MS. Six of these fight against fungi, three kill bacteria, and two compounds help plants growth. This study showed that cow urine can stop the growth of bacteria and fungi and improve plant growth [33].

The researchers conducted a study to evaluate the efficacy of cow urine as an antifungal agent against three fungal pathogens, *Fusarium oxysporum*, *Rhizoctonia solani*, and *Sclerotium rolfsii*, which cause damping-off and wilting diseases in *Trigonella foenum-graecum* (Methi) and *Abelmoschus esculentus* (Bhindi). The study was conducted under controlled laboratory conditions. Cow urine at concentrations of 5%, 10%, and 15%, was incorporated into potato dextrose agar with distilled water plates serving as controls. A 5 mm disc of all three fungal strains were incubated at 28±2°C for 7 days, and the percentage mycelial inhibition was calculated. The findings indicated that the growth of the test fungi was inhibited on plates treated with cow urine compared to that on the control plates. The 15% cow urine solution exhibited the best antifungal activity against the test fungi. It inhibited *F. oxysporum* the most at 78.57%, followed by *R. solani* at 78.37%, and *S. rolfsii* at 73.84%. They also studied pot culture, in which seeds were sown in autoclaved garden soil (pH 7) irrigated daily with 1-5% (v/v) cow urine, and tap water irrigated pots were considered as control. After 25 days, phenotypic parameters such as plant height, root and shoot lengths, and leaf and branch counts were measured. The effects of cow urine on protein and chlorophyll levels were also investigated. Growth promotion was observed across the tested doses, with an optimum at approximately 5%. For example, the height of *T. foenum-graecum* (Methi) plants increased to 14.30 ± 0.40 cm compared to 9.00 ± 0.46 cm in the control group. Additionally, protein and chlorophyll content rose markedly to 174.97 ± 0.50 mg/mL and 1.869 ± 21 mg/g, respectively, whereas in untreated plants, these values were 36.50 ± 0.46 mg/mL and 0.437 ± 71, respectively. Similarly, the maximum plant height of *A. esculentus* (Bhindi) was 13.97 ± 0.50 cm, compared to 6.5 ± 0.46 cm in the control. Furthermore, the protein and chlorophyll levels increased to 164.40 ± 0.32 mg/mL and 2.246 ± 28 mg/g, respectively, whereas in untreated plants, these values were 38.80 ± 0.46 mg/mL and 0.171 ± 91 mg/g, respectively. All experiments were performed in triplicate, and the critical differences were analyzed at $P \leq 0.05$. Overall, the data indicate that cow urine at higher concentrations can both inhibit key fungal pathogens and significantly enhance the vegetative growth of *T. foenum-graecum* (Methi) and *A. esculentus* (Bhindi) [7].

Impact of cow urine on crop yield

Cow urine significantly improves soil health, crop quality, and yield. In chickpeas, a field experiment was carried out during season 2020-2021, a randomized block design (RBD) with 10 treatments and three replications. The foliar application of cow urine plus vermiwash at 10 ml/L during flowering and pod formation produced a grain yield of 29.98 q/ha and net economic returns of INR 99,850/ha [34]. Similarly, mustard (*Brassica rapa L.*) was cultivated in inceptisol soil in Central Sulawesi using a randomized complete block design (RCBD) with five cow urine concentrations (0, 20, 40, 60, and 80%) replicated three times. The 80% soil-applied cow urine produced the highest yield of 50.666 t/ha. The study noted that even this high rate may not be optimal and recommended testing concentrations above 80% for inceptisol conditions, while also reporting improved physiological parameters, such as leaf area and nutrient uptake [35]. In wheat production, a split-plot design with three fertility levels 60%, 80%, and 100% recommended dose of fertilizer (RDF) and four foliar sprays of cow urine at 30, 50, 70, and 90 days after sowing were applied at concentrations of 50%, 75%, and 100% (undiluted), with water as the control, produced statistically significant dose-dependent responses, with 100% (undiluted) cow urine spray recording 27.21% higher grain yield than the control [36]. In boro rice trials in Bangladesh, a completely randomized design (CRD) was used to compare three treatment groups: untreated control (T_0), chemical fertilizer and pesticide (T_1), and cow urine biofertilizer with biopesticide (T_2). Treatment T_2 achieved the highest grain yield of 5.85 t/ha compared to T_1 (5.42 t/ha) and T_0 (1.1 t/ha), with a mean grain per panicle of 253 [37]. In paddy rice, an RBD examined five nitrogen-cow urine combinations: treatment T_4 (90 kg N/ha + 60 kg K/P/ha + cow urine) registered the maximum grain yield and nitrogen uptake of 85.66 kg/ha [29]. In Indian mustard, factorial experiments combining three fertility levels (50%, 75%, and 100% RDF) with four cow urine application rates (0, 300, 600, and 900 L/ha) demonstrated that 100% RDF + 900 L/ha cow urine significantly enhanced dry matter accumulation and NPK uptake [38].

The selected studies collectively demonstrate the positive impact of cow urine as a biofertilizer across diverse crops and agroecological settings, highlighting its potential to enhance soil health, nutrient uptake, physiological growth parameters, and ultimately crop yield and economic returns. However, the variability in experimental designs, application methods (foliar spray versus soil application), concentrations, and fertility levels underscores the complexity of optimizing cow urine use in agriculture. While high concentrations, such as 80% soil application in mustard and undiluted foliar sprays in wheat, yielded significant improvements, some studies suggest that even these levels may not represent the upper threshold for efficacy, indicating the need for further dose-response investigations. Additionally, the integration of cow urine with other inputs, such as chemical fertilizers and vermiwash, appears to produce synergistic effects; however, the mechanisms underlying these interactions remain insufficiently elucidated. This heterogeneity in experimental parameters and outcomes highlights the necessity for standardized protocols and long-term field evaluations to establish optimal application rates, timing, and combinations tailored to specific crops and soil types, thereby ensuring the reproducibility and scalability of the results.

Biopesticide activity of cow urine

Effect on Insects

The scientists conducted research to evaluate the effectiveness of neem kernel extract (NKE in cow urine), neem leaf extract (NLE), neem oil, and chemical insecticides (Phosphamidon and Dimethoate) against mustard aphids (*Lipaphis erysimi*) and additionally tested their effect on beneficial coccinellid beetles. All treatments significantly reduced aphid infestation and increased the mustard grain yield. The most effective treatments were dimethoate (0.03%) combined with either NKE 3% or NLE 3%, followed by higher concentrations of Dimethoate and Phosphamidon. Phosphamidon 0.04% provided the highest grain yield and net profit (INR 9246/ha), whereas NKE 3% also provided a high profit (INR 5938/ha) and the best cost-benefit ratios (NKE 2% and 3%). The study concluded that applying 3-4 foliar sprays of NKE 3% (in cow urine), either alone or combined with a reduced 0.03% of dimethoate, can safely and effectively manage mustard aphids [39]. Cow urine, either alone or in combination with various plant leaf extracts has demonstrated significant potential as a cost-effective and environmentally sustainable approach for managing diverse insect pests in multiple agricultural systems. Field studies on pigeonpea revealed that treatments combining Madar and cow urine at 5% (w/v), followed by Lantana and cow urine at 5% (w/v), proved highly effective in reducing damage from the pod borer complex, including pod bug (*Clavigralla gibbosa*), green stink bug (*Nezara viridula*), gram pod borer (*Helicoverpa armigera*), and tur plume moth (*Exelastis atomosa*) [40]. The researchers tested cow urine as a low-cost biofertilizer for 'Regina 2000' lettuce using both soil and foliar applications from 0 to 1.25% concentration. The best foliar rate, 1.25%, gave the highest yield (17.00 t/ha), a 28.1% increase over the control, with fresh and dry leaf mass increasing as the concentration increased. Soil application showed a quadratic response, with maximum yield (14.92 t/ha) at approximately 1.0%, which was a 47.3% increase over untreated plants. Superior foliar performance is linked to easier urea diffusion through the leaf cuticle, improving nutrient absorption and growth stimulation beyond simple nutrition. Thus, cow urine at 1.25% as a foliar spray or approximately 1.0% in soil is a sustainable, low-cost fertilization option for lettuce [41]. Research evaluated cow urine, cow dung, and lambda-cyhalothrin solutions for controlling sucking bugs on *Amaranthus cruentus*. A 1:1 urine-to-water mixture proved to be the most effective among the natural treatments; however, lambda-cyhalothrin demonstrated superior performance, achieving lower insect populations (0.03 insects per plant) within 24 hours compared to the biopesticide alternative. Although cow urine treatments eventually matched synthetic pesticide efficacy by day 5, the chemical insecticide provided faster and more pronounced initial pest control, establishing its advantage for rapid suppression [42]. The use of a combination of cow urine, neem oil, and neem seed kernel extracts (NSKE) led to improved yields and increased effectiveness against sucking insect pests, such as aphids, jassids and thrips, in BT cotton. These treatments are potentially recommended for organic farming because of their efficacy, cost efficiency, and minimal influence on the natural predators of sucking insect pests [43]. *Chilo partellus* (stem borer) is major pest in Africa which presents a considerable danger to sorghum, causing substantial damage to crop. The researcher studied the effectiveness of using *Milletia ferruginea* seed powder in combination with cow urine and *Phytolacca dodecandra L*. seed powder mixed with cow urine for controlling stem borers. A mixture of *Milletia ferruginea* seed powder and cow urine demonstrated significant lethality at a concentration of 3 ml, resulting in 100% mortality within three days [44]. The papaya mealybug (*Paracoccus marginatus*) poses a considerable risk to papaya cultivation in Sri Lanka, leading to economic losses. The investigators performed a study to evaluate the efficacy of various chemicals and biopesticides (Imidacloprid, Acetamiprid, Acephate, Thiamethoxam, Chlorantraniliprole, Profenofos, Abamectin, Diazinon, and Thiocyclam Hydrogen Oxalate) and six biopesticides, Including Neem leaves fermented solution (1 g/ml), neem leaf extract (20 g/ml), *Pavetta indica* leaf extract (20 g/ml), garlic extract (20 g/ml), vermiwash, and fermented cow urine (100% v/v), against this pest. Among these biopesticides, fermented cow urine (100% v/v), *Pavetta indica* leaf extract (20 g/ml), and garlic bulb extract (20 g/ml) demonstrated the strongest pest control effects, leading to higher mortality rates. After 48 h of exposure, the mortality rates of *Paracoccus marginatus* were 87.9%, 83.3%, and 75.8% when treated with garlic extract, *Pavetta indica* leaf extract, and fermented cow urine, respectively [45].

Effect on Nematodes

The scientists conducted greenhouse experiments in Nigeria to assess the impact of cow dung and cow urine, both separately and in combination, on controlling root-knot nematodes in tomato plants. Their findings indicated that cow dung, cow urine, and their combination significantly surpassed the untreated control group, with the mixture of urine and dung being particularly effective [46]. Complementary *in vitro* studies employed cavity blocks and Petri plates to test seed kernel extracts, cow urine, and Agni Astra at multiple concentrations (2%, 5%, and 10%), with observations recorded at 12, 24, 36, and 72 hours of exposure on percent mortality of juveniles and egg hatching inhibition. Cow urine at 10% concentration demonstrated the highest mean percent juvenile mortality of 93.76%, followed by Agni Astra at 2% with a mean percent juvenile mortality of 91.81%, while the lowest mean percent juvenile mortality was achieved by Dharek seed kernel extract at 2% concentration. Additionally, cow urine at 10% concentration achieved the highest mean percent inhibition of egg hatching at 75%, followed by Agni Astra at 2% and neem seed kernel extract at 10% concentration, both achieving 66.67% inhibition [47].

Effect on Insect Larvae

Cow urine adversely affects insect larvae, functioning as a natural larvicide that induces substantial mortality at specific concentrations, primarily because of the presence of substances such as urea and other bioactive compounds that disrupt larval growth and physiological development. Studies have indicated its potential as a biopesticide for pest management when it is used correctly. Mosquitoes pose a considerable public health risk because they are disease vectors. This study evaluated the larvicidal properties of various concentrations of cow urine and its distillate (5%, 10%, and 15%) on *Culex quinquefasciatus* larvae over a three-day period. The study revealed a dose-dependent increase in larval mortality, with the highest mortality observed at 15% concentration. This study underscores the effectiveness of cow urine and its distillates in controlling mosquito larvae in a safe and cost-effective manner [48].

Fungicide and biofungicide

Early blight, caused by *A. solani*, threatens tomato production. *In vitro*, propiconazole 250 EC resulted in the highest growth inhibition (96.67% at 250 ppm), followed by mancozeb 50% WP (84.44%), cow urine 20% concentration showed (78.49%). Under field conditions, the gap widened: Propiconazole 25% EC (0.2% foliar) achieved 6.50% disease intensity and 17.77 t/ha yield, while combined seed treatment + foliar cow urine (10%) resulted in 28.7% disease intensity and 14.72 t/ha. While Propiconazole's superior efficacy delivers 89.28% disease control relative to untreated fields, cow urine offers a sustainable alternative free from hazardous chemical residues, making it valuable for organic farmers and resource-constrained smallholders despite the 17% yield penalty. The choice depends on the farming context: commercial growers prioritizing maximum yield favor propiconazole, while organic or premium-market producers may justify cow urine's reduced efficacy for environmental and health benefits. An integrated approach using cow urine for early season suppression and propiconazole during high-pressure disease periods optimizes both disease management and sustainability objectives [49]. The researchers investigated the inhibitory effects of fresh and aged cow urine (3 months) at 5-40% concentrations on the development of *Pythium apahidermatum* and *F. oxysporum* f. sp. *Zingiberi*, a fungus that impact ginger plants, using the "poison food" methodology. These findings indicate that cow urine may significantly suppress this fungus, especially at concentrations of 20% or higher. Aged cow urine was more efficient as an inhibitor than fresh cow urine, indicating strong in vitro potential against rhizome rot; however, field validation is required [50]. Seed-borne fungal diseases are a major obstacle to wheat production, necessitating effective and sustainable management strategies. A novel cow urine-based mancozeb suspension concentrate formulation demonstrated antifungal efficacy comparable to standard mancozeb at half the dosage (1 g/kg versus 2.5 g/kg), while simultaneously reducing environmental pollution and enhancing seed germination [51]. The scientist evaluated aqueous and cow urine-based extracts from six native plants against *Alternaria brassicicola*, demonstrating that *Phyllanthus emblica* achieved 65.47% mycelial inhibition in aqueous form, while cow urine alone resulted in 100% mycelial growth inhibition at 10-20% concentrations. These findings suggest that cow urine is a promising eco-friendly alternative for managing crop diseases [52].

Composition variability of cow urine

The composition of cow urine exhibits substantial variability, which is influenced by multiple interconnected factors. The composition of cow urine depends on the breed and diet of the cows [53,54]. Breed-related variability is a major source of compositional difference. Studies comparing indigenous and exotic cow breeds have demonstrated distinct nutrient profiles, with indigenous breeds (Gir, Sahiwal, Rathi, and Deoni) consistently exhibiting higher nitrogen and potassium contents than exotic breeds (Holstein-Friesian). The nitrogen content of indigenous cow urine ranged from 0.38 to 0.46%, whereas that of exotic breeds was 0.37 to 0.40%. Similarly, the potassium levels in urine varied significantly between breeds, with Gir cow recording 0.91%, Sahiwal 0.82%, and Deoni 0.80%, compared to lower values in the exotic breeds. In addition to the major nutrients, the micronutrient content also varies substantially among breeds. The average iron content in the urine of indigenous cow was 19.82 mg/kg, whereas that of exotic cow was 14.67 mg/kg. The manganese content ranged from 4.80 to 19.20 mg/kg, copper from 1.44 to 2.40 mg/kg, and zinc from 2.96 to 2.37 mg/kg across different breeds [55,56]. Additionally, breed-specific differences were observed in mineral composition through elemental analysis, with potassium, chloride, aluminum, and silicate showing higher concentrations in Kasargod Dwarf than in Deoni [53]. Beyond breed differences, dietary protein intake directly influences nitrogen excretion patterns, with dietary intake and composition significantly affecting total nitrogen excretion and the composition of excreta [56]. Post-collection processes introduce dramatic changes: fresh urine pH ranges from 6.04 to 8.16 but becomes alkaline (8.43-9.15) within 30-60 days of storage, and ammonia nitrogen escalates from fresh levels to significantly higher concentrations during fermentation [57]. These multifactorial variations necessitate careful standardization of research protocols and agricultural applications.

Comparison of cow urine with conventional fertilizers and pesticides

Cow urine-based formulations prioritize sustainability, safety, and farmer accessibility through biodegradability and cost-effectiveness, whereas conventional synthetic pesticides deliver superior efficacy, consistency, and long-term pest control backed by regulatory approval. The core trade-off is between environmental and social benefits and immediate effectiveness of pest control. Integrated Pest Management (IPM) strategies can leverage both approaches strategically, deploying natural formulations in organic systems and conventional options for emergency outbreak scenarios. The detailed comparison tables below provide specific data on efficacy, safety, economics, and environmental impacts to inform the selection of context-specific agricultural practices (Table *2*).

Parameter	Cow urine & its formulations	Conventional pesticides
Composition & chemistry		
Chemical composition	It consists of 95% water, 2.5% urea, and 2.5% minerals, salts, hormones, and enzymes, including N, Ca, P, K, uric acid, hippuric acid, and creatinine [58].	Synthetic organic compounds, often containing organophosphates, pyrethroids, neonicotinoids with specific molecular targets
Active compounds	Bioactive plant extracts combined with cow urine, such as neem, nochi, and adhatoda [59].	Single or multiple synthetic chemical active ingredients
Efficacy & performance		
Pest control efficacy	NNA 15% achieved 70.23% BPH and 72.48% GLH reduction [59].	High initial efficacy (often 80-95%+) with rapid knockdown effect
Residual activity	10-15 days post-application, requiring multiple seasonal applications [59].	Extended residual activity (14-30+ days depending on type)
Concentration dependency	It was highly concentration-dependent, with 100% Panchagavya showing phytotoxicity [60].	Consistent efficacy across standard concentrations; dose-response curves well-established
Synergistic effects	Combined botanical extracts *(L. camara* + *C. odorata* + cow urine) were more effective than individual components [61].	Single compound efficacy; synergy dependent on formulation design
Crop specificity	Variable efficacy across different crops and pest species [61].	Broad-spectrum activity; registered for multiple crops
Environmental impact		
Biodegradability	Rapidly biodegradable into harmless, nontoxic elements [61].	Persistent in the environment; bioaccumulation in soil and water [60].
Soil health	It enhances soil microorganisms, increases organic matter, and improves microbial activity [58].	It detrimentally affects the soil structure and reduces the number of beneficial microorganisms [60].
Water pollution	Minimal water contamination risk	Significant groundwater contamination potential
Ecosystem impact	Moderate impact on non-target beneficial arthropods; 15% NNA extract showed 27.70% impact on spiders and 32.99% on coccinellids [59].	Severe impact on non-target organisms; kills beneficial predators and parasitoids

Cost economics		
Production cost	They are available in local dairy farm at low cost and made from farm waste materials [58].	High cost of synthetic chemicals; patented formulations
Application cost	Lower application frequency with labor; cost-effective [61].	Higher cost with frequency dependence on crop requirements
Storage requirements	Simple storage; fermented stock is preferred over fresh stock [58].	Requires specialized storage conditions; shelf-life dependent
Nutrient management		
Nutrient supply capacity	Cannot provide all nutrients required by crops; serves as a supplement [60].	Synthetic fertilizers provide targeted nutrient content
Plant growth promotion	Plant growth promoters through; IAA production, N fixation, and P solubilization [62].	Nutrient supply only; no inherent growth promotion
Soil fertility enhancement	Long-term fertility improvement through organic matter accumulation	Short-term nutrient availability; declining long-term fertility
Biofertilizer properties	It acts as a biofertilizer in formulations such as Panchagavya [58].	Not biofertilizer; chemical fertility input only
Standardization & quality control		
Standardization	Lacks standardized protocols; formulation varies by source and preparation [63].	Highly standardized; regulated by authorities; consistent quality
Quality parameters	Dependent on cow breed, ingredients, fermentation conditions [62].	Fixed chemical composition; batch testing mandatory
Regulatory approval	Limited regulatory framework and challenges in commercialization [63].	Regulated; registered pesticides with established approval process
Variability	There is a high variability between formulations and sources [62].	Minimal batch-to-batch variability
Formulation types		
Traditional formulations	Panchagavya, Jeevamrit, Beejamrit, Matka-khad [58].	Single active ingredient or multi-component synthetic blends
Advanced formulations	Nanoformulation with improved bioavailability [63].	Nano-pesticides; encapsulated formulations

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TABLE 2: Comparative analysis of cow urine-based formulations and conventional pesticides.

NNA, Neem + Nochi + Adhathoda; BPH, Brown Plant Hopper; GLH, Green Leaf Hopper; IAA, Indole Acetic Acid.

Nevertheless, cow urine-based products have advantages in terms of biodegradability, low residue risk, and reduced potential for resistance development, suggesting that, based on current evidence, cow urine is best regarded as a complementary component within integrated nutrient and pest management strategies, especially in organic and low-input- systems [64].

Challenges and limitations of cow urine

Despite its considerable potential in agricultural applications, cow urine faces significant barriers to widespread adoption. Key limitations include the lack of quality control and standardization, as the physicochemical composition varies considerably across sources, making it difficult to ensure consistent results in commercial products. Practical challenges in collecting, storing, and preventing microbial contamination during handling remain inadequately addressed in the literature. Additionally, nitrogen leaching is a concern when applied to soils, as it potentially reduces effectiveness and contributes to environmental pollution [31]. A mechanistic understanding of the bioactive compounds in cow urine requires further research to isolate and characterize the compounds responsible for their antimicrobial and therapeutic effects. Practical barriers also include difficulties in accessing cow urine and feedstock, with some farmers reporting challenges in securing a regular supply and convincing neighbors of their need for cow urine. Finally, social acceptance remains variable, with preferences for cow urine over alternative sources in some regions due to cultural perceptions. The regulatory approval of cow urine-based products remains inconsistent across different regions and countries, limiting the market development and commercial viability of cow urine-based products [65].

Regulatory aspects and acceptance in modern agriculture

1. Lack of Standardization: There are no specific rules and regulations for cow urine collection, treatment, and utilization in agriculture in India or globally, complicating the assurance of its safe and effective use.

2. Scientific Acceptance: The scientific community finds it difficult to understand and prove the benefits of cow urine. This leads to doubt and resistance among modern farmers in adopting these practices [66].

3. Inadequate Regulations: Globally, farming rules do not adequately cover animal by-products such as cow urine, leaving gaps in supervision. This lack of understanding may slow its official use in farming [67].

4. Ammonia Volatilization: When cow urine is applied directly to the soil, a significant amount of its nitrogen can be converted into ammonia gas and escape, reducing its effectiveness.

5. Lack of Research: More comprehensive studies are required to ascertain the appropriate application rates and techniques for various crops and soil types to maximize the advantages of cow urine [50].

Social and cultural challenges

1. Societal Acceptance: The use of cow urine lacks widespread acceptance in several societies, where it is often linked to traditional or rural customs.

2. Public Perception: The stigma associated with animal waste and its use may establish social and cultural impediments to the adoption of cow urine-based techniques.

3. Community Engagement: Communities need to be involved and educated to use cow urine systems effectively. This is difficult in areas with limited resources [66].

4. Cultural Perceptions: In many cultures, cow urine is considered a part of rural or traditional customs. This can cause conflicts with modern farming supporters [68].

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5. Limited scientific data: Although cow urine has been historically used in some areas, extensive studies on its effectiveness of cow urine as a fertilizer for various crops and soil types remain inadequate [49].

Future perspective

According to reported studies, cow urine is a potentially useful animal by-product for improving certain aspects of crop growth, yield components, and soil fertility, and for contributing insecticidal and antifungal activity when used in appropriate formulations. However, nutrient management in modern farming systems cannot yet rely solely on cow urine, as its nutrient content is lower and more variable than that of synthetic fertilizers, and evidence for complete substitution under high-yield conditions is limited. To reduce the environmental damage associated with synthetic agrochemicals, future research should prioritize integrated strategies that combine cow urine with other organic amendments and, where necessary, reduced doses of synthetic fertilizers or chemical pesticides [69,70]. Well-designed, replicated field experiments across multiple seasons and locations, including economic analyses, are required to define agronomically and financially viable application rates, timings, and combinations [71].

Conclusions

Integrating cow urine into organic agriculture has the potential to reduce reliance on synthetic pesticides and contribute multiple benefits, such as biofertilization, disease suppression, and pest deterrence, which may improve crop quality and yields. However, the existing evidence is limited, variable, and context-dependent; the reported efficacy depends on factors such as concentration, formulation, application timing and method, crop species, pathogen or pest species, and local soil and climate conditions. Owing to these uncertainties, widespread adoption is not recommended without further validation. Future research should investigate how cow urine interacts with other approved organic farming inputs to better integrate them for enhanced crop production and profitability in the long run. To ensure the enduring viability of agriculture, organic agricultural techniques must be used. Research on the interactions between cow urine and other approved organic inputs, such as compost, manure, biofertilizers, and permitted biopesticides, will help develop integrated, evidence-based application protocols. This resource has gained prominence in the agricultural industry, providing solutions from seed planting to pest management. This may efficiently reduce insect populations, and suppress mold proliferation, which is especially crucial in organic agriculture, where synthetic pesticides are prohibited. The dependence on synthetic agrochemicals, influenced by the present conditions, poses long-term threats to the environment and ecology. Consequently, adopting sustainable farming techniques is essential to ensure food security.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Umesh S. Bhoi, Jamatsing D. Rajput, Rohit H. Patil, Sunil H. Koli

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Data Availability Statements

Data sharing is not applicable. This work is theoretical; no datasets were generated or analyzed.

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