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A Systematic Evaluation of the Physicochemical Attributes and Agronomic Potential of Cow Urine

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Abstract

The intensive use of synthetic chemicals in the agro-sector these days has called for an urgency to practice natural farming, and it is necessary to regain the capacity to produce natural food. Adoption of exhaustive and modern cropping practices with high-yielding crop cultivars and unbalanced fertiliser application resulted in the emergence of widespread micronutrient deficiency in soils and crops in India, leading to reduced crop yield and low micronutrient concentration in agricultural produce. Nowadays, the cost of chemical fertilisers is increasing, which small and marginal farmers are not able to afford. The soil is also facing adverse effects due to the use of synthetic chemical fertilisers. In this situation, cow urine-based liquid formulations can be used as a replacement for chemical fertilisers. Cow urine (CU) is a quality natural source that supplies nutrients to plants and is economical to prepare as a naturally available source. CU accelerates the biological activity inside the soil and makes the nutrients available to the plants. In the present research study, we have analysed fresh, distilled, and market-available CU for the detection of elements, and it was observed that micronutrients such as Mg, Zn, B, S, and Fe were present. Additionally, contact angle and surface tension studies gave promising results in the case of fresh CU. The same samples were utilised for the bioefficacy study using the direct cup method and the petri dish method for the evaluation of speed of germination, phytotoxicity, and seed safety. These results give promising evidence that CU can be used in the preparation of agro-formulated products.

Keywords: *Cow Urine, natural, micronutrients, fertilisers, seed germination.*

1. Introduction

The use of cow urine (CU) has been documented in India for centuries, where it has traditionally been regarded as a substance of therapeutic and agricultural importance. Ancient texts and indigenous practices describe cow urine as possessing diverse medicinal properties, with applications in treating human and plant diseases. In addition to its role in traditional medicine, cow urine has been recognised for its agricultural benefits, functioning as both a biofertilizer and a biopesticide, contributing to soil fertility and crop protection [1].

From a scientific perspective, cow urine is a complex biological fluid enriched with macro- and micronutrients, as well as compounds with disinfectant and prophylactic activity. These attributes contribute to its ability to enhance soil fertility, purify the surrounding environment, and address multi-nutrient deficiencies prevalent in Indian soils. As a low-cost input, cow urine is believed to support plant nutrition, stimulate metabolic activity, and provide protection against pests and pathogens [2].

Beyond agriculture, cow urine has also been incorporated into traditional medicine systems such as Ayurveda, where it is processed into formulations like *Gomulka Ark* and *Patch-gavya*. These preparations are believed to support digestive health, immunity, and overall wellness, although scientific validation of such claims remains limited [3].

Despite these traditional and potential benefits, the widespread adoption of synthetic fertilisers in modern agriculture has led to a decline in the use of cow-derived products. This shift has contributed to ecological imbalances and nutrient-related challenges in farming systems. Considering current sustainability concerns, there is renewed interest in revisiting and scientifically validating the role of cow urine in agriculture. A systematic exploration of its properties and applications may provide valuable insights into sustainable farming practices, bridging traditional knowledge with modern scientific approaches [4].

Centuries of exploitative agricultural practices in India have significantly reduced soil fertility to the extent that even high rates of chemical fertiliser application are unable to sustain productivity. While chemical inputs provide short-term yield improvements, their intensive use has led to long-term adverse effects on soil health, ecosystem balance, and production costs. Consequently, researchers have increasingly turned toward natural resource-based agricultural formulations as sustainable alternatives. Among these, cow urine has emerged as a unique dairy by-product with diverse properties, functioning as manure, an antimicrobial agent, and disinfectant [4].

In organic farming systems, cow urine is widely utilised in the preparation of growth promoters and bio-pesticides, which have proven effective in enhancing soil fertility and managing a broad spectrum of pests and diseases. Studies have demonstrated that cow urine application improves the biochemical composition of plants, including chlorophyll and protein content [2]. Its use has been reported to positively influence crop productivity in mustard, maize, and rice, among others, though further systematic research is required to validate these outcomes [1].

Chemically, cow urine consists of approximately 95% water, 2.5% urea, and 2.5% salts. These salts include sodium, potassium, calcium, nitrogen, sulphur, manganese, iron, silicon, and magnesium, along with trace elements such as gold and silver. Organic constituents include citric acid, succinic acid, lactose, carbolic acid, enzymes, creatinine, vitamins, steroids, estrogens, and hormones [3]. Experimental evidence indicates that cow urine enhances nitrogen and potassium concentrations in grasses and clover [8]. For example, the nutritional effect of cow urine on *Trigonella foenumgraecum* (Methi) and *Abelmoschus esculentus* (Bhindi) plants showed increased chlorophyll and protein content with increased concentration of urine as compared to the control. Combined applications with recommended fertiliser doses of 1200 lha^{-1} on basal (100%) and foliar (50%) spray significantly increase N, P, and K uptake in mustard crops [7].

Cow urine has also been explored as a fermentation input, offering a potential alternative to synthetic fertilisers. Application of 125 kg N ha^{-1} through urine has been shown to improve vegetative growth, while 100 kg N ha^{-1} enhanced yield and quality parameters. Substituting 50% of urea with cow urine produced superior morphological and yield characteristics compared to other combinations [9]. Furthermore, seed priming with phosphorus, zinc, human, and cow urine has demonstrated improved maize growth on low-fertility acid soils in Northeast India [5]. Similarly, cow urine at 5–10% concentrations significantly improved vegetative parameters in gladiolus, including emergence rate, plant height, leaf number, and leaf dimensions [6].

Collectively, these findings suggest that cow urine could serve as a potent source for improving soil fertility, crop productivity, and quality, while reducing dependence on costly and environmentally harmful synthetic inputs.

Its integration into modern farming practices warrants further scientific validation to establish standardised application methods and quantify long-term benefits.

Despite these encouraging findings, systematic research that (i) quantifies the elemental make-up of CU from diverse sources, (ii) characterises its physicochemical behaviour (wetting, surface tension), and (iii) validates its bio-efficacy under controlled germination conditions is still limited. Addressing these gaps is essential for developing standardised, scalable CU-based formulations that can be integrated into modern farming practices.

The present study therefore (i) analyses fresh, distilled and commercially available CU for macro- and micronutrient content using inductively coupled plasma mass spectrometry (ICP-MS), (ii) evaluates key physicochemical parameters (density, dynamic surface tension, contact angle) that influence nutrient delivery to seeds and roots, and (iii) assesses the germination performance and early seedling growth of maize (Zea mays L.) under a range of CU concentrations using both petri-dish and direct-cup methodologies. The outcomes are intended to provide a scientific basis for the adoption of CU-derived bio-fertilisers in Indian agro-ecosystems.

2. Materials & methods

The well-maintained, neighbouring Goshala provided the Gir cow urine (B) & Divya Godhan Ark (A) marketed by Patanjali. Standard filter paper was used to filter cow urine. Maize seeds of good quality were purchased from a local market shop. KRUSS Scientific Model Bubble Pressure Tensiometer BP100 is used for Dynamic surface tension (DST) & Drop Shape Analyzer DSA25E is used for Contact angle (CA). The Compact Digital Density Meter, Anton Paar, is used for density measurement.

The elemental analysis was conducted using two analytical procedures:

Total Nitrogen (N): Quantitative determination was performed via the Kjeldahl method, involving digestion, distillation, and titration to measure organic and ammoniacal nitrogen.

Mineral Composition (P, K, Ca, Mg, Trace Elements): Quantitative analysis of macro-minerals and trace metals was performed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), a technique providing high sensitivity and low detection limits for multi-elemental analysis.

2.1 Dynamic Surface Tension measurement: Instrumentation

Dynamic surface tension (DST) was measured using a KRÜSS BP100 Bubble Pressure Tensiometer (KRÜSS GmbH, Hamburg, Germany). The instrument operates on the maximum bubble pressure method, which determines surface tension at defined surface ages by measuring the pressure inside air bubbles formed at the tip of a submerged capillary.

Sample Preparation

All glassware and capillaries were thoroughly cleaned with ethanol and rinsed with deionised water prior to use. Test solutions CU were used at such concentrations.

Measurement Procedure

The capillary was immersed in the CU, and air was introduced at controlled flow rates to generate bubbles. Bubble lifetimes were varied between 10 ms and several seconds to obtain surface tension values at different surface ages. The internal pressure of each bubble was continuously recorded, and the maximum pressure at the point of maximum bubble curvature was used for calculation.

Dynamic surface tension profiles were generated by plotting surface tension as a function of surface age. Each measurement was repeated at least three times to ensure reproducibility, and mean values with standard deviations were reported.

2.2 Contact angle measurement:

Contact angle measurements were carried out using a Drop Shape Analyser DSA25E (KRÜSS GmbH, Hamburg, Germany). The instrument employs high-resolution imaging and automated analysis software to determine the wetting behaviour of liquids on solid surfaces.

Sample Preparation

Solid substrates were cleaned with ethanol and rinsed thoroughly with deionised water to remove surface contaminants. The substrates were dried under ambient laboratory conditions prior to measurement. Test liquids were prepared at the desired composition and equilibrated to room temperature (± 0.1 °C).

Measurement Procedure

Droplets of 2-5 μL were dispensed onto the substrate surface using a precision microliter syringe. The instrument's camera captured the droplet profile immediately after deposition. Both static and dynamic contact angles were determined:

Static contact angle: Measured directly from the droplet profile at rest.

Advancing and receding angles: Obtained by controlled addition or withdrawal of liquid from the droplet using the syringe system.

Data Acquisition and Analysis

Contact angles were calculated using the instrument's software, which applies the Young–Laplace equation fitting to the droplet shape. Measurements were repeated at least three times at different positions on each substrate to account for surface heterogeneity. Mean values and standard deviations were reported.

2.3 Process for germination evaluation of CU in maize seeds [10,11]:

The 10 No's of each maize seed are placed between two layers of filter paper in a petri dish. 20 ml of solution was poured on the seeds. The petri dishes are placed in the germinator in an upright position at a temperature of 20-30°C & at an RH of 90-95% for 6 days. Observation taken on the sixth day.

2.3.1 Speed of germination:

The number of seeds that started germinating was counted daily until maximum germination was achieved.

2.3.2 Direct cup method Root & shoot length [11]:

Sterile soil is filled in a plastic cup & 10 no. of each maize seed are sown. Then 1%, 2%, 5% & 7.5% of CU is added at 20 ml/cup. The cups are placed in the germinator in an upright position at a temperature of 20-30°C & at RH (90-95%) for 6 days. Observation taken on the sixth day.

2.3.3 Length of seedling (cm):

The height of the seedling is measured from the root tip to the shoot tip and expressed in centimetres at 6 days after sowing, and the average value was computed.

2.3.4 Fresh weight of seedling (g):

The plants were carefully washed to remove the soil adhering to their roots and shoots. The weight was measured using an electronic balance, and the average value was calculated.

2.3.5 Dry weight of seedling (g):

For dry weight, plants were chopped and oven dried at 60 ± 20ºC temperature till a constant weight. The weight was taken with the help of an electronic balance, and the average value was computed.

3. Results and Discussion

Here, we have collected Fresh CU in winter (FCU_W), summer (FCU_S) and distilled CU (DCU) from the market. It is noted that in both seasons the appearance of FCU_W and FCU_S was found to be pale yellow, while DCU was a light pale-yellow colour and a slight difference was observed in the density value of winter and summer season CU. However, in the case of DCU, the density was lower; it might be because the distillation process removed salts or other ingredients from CU, which makes it lighter in density. Likewise, the drastic pH change was noted in DCU as compared to FCU_W and FCU_S. The physicochemical parameters of collected CU are summarised in Table 1.

Table 1: Physical parameters of Cow Urine

Sr. No.	Parameters	Fresh cow urine (FCU_W)	Fresh cow urine (FCU_S)	Market product (DCU)
1	Source/Season	Winter Season	Summer Season	Patanjali
2	Appearance	Pale Yellow	Pale Yellow	Light Pale Yellow
3	Density at 25°C (g/cm^3)	1.0047	1.0325	1.0018
4	pH	8.67	8.20	9.51
5	Surface Tension (mN/m)	62	56.93	70.05
6	Contact Angle (^{0})	89	86.31	109.65

3.1 DST of different samples of cow urine:

The dynamic surface tension is the value referred to a particular surface age or interface age. In the case of liquids with surface-active substances, this can differ from the equilibrium value [12].

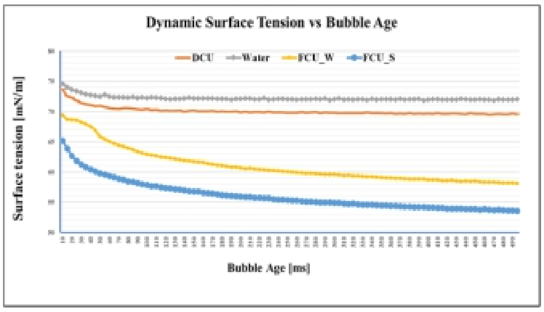

Figure 1: Dynamic surface tension of different CU samples

From the results of DST analysis, it is observed that the surface tension of FCU_W is 62, FCU_S is 56.93 & DCU is 70.05 mN/m which are lower than water 72.18 mN/m [13]. From the recorded results of DST, it is noted that FCU samples have good surface activity, which indicates that this cow urine could be utilised for agro formulation development.

3.2 CA of different samples of cow urine

For further checking of surface activity, we here extend the analysis for CA determination of the collected samples of CU. When an interface exists between a liquid and a solid, the angle between the surface of the liquid and the outline of the contact surface is described as the contact angle θ (lower case theta). The contact angle (wetting angle) is a measure of the wettability of a solid by a liquid [14]. The CA (^{0}) measurement confirms that the FCU_W is 89, FCU_S is 86.31 & DCU is 109.65, which is lower than water 114 [15]. As observed from Figure 2, these numbers of CA clearly showed that the FCU_W and FCU_S possess wetting activity which is better than DCU and water. These results of CA also proved that CU samples possess surface activity, and the same evidence was noted in the results of DST.

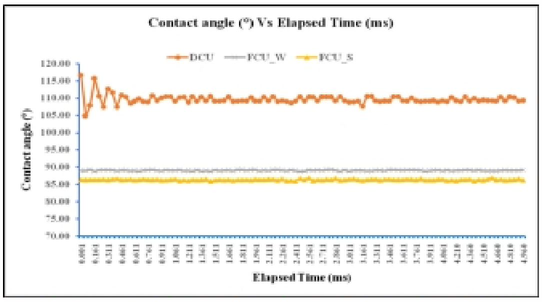

Figure 2: CA measurement of different CU samples

3.3 Speed of Germination Test by the Between Paper (BP) Method

3.3.1 Study 1: Seed germination study in maize at a higher concentration of FCU samples.

In this primarily maize seed germination study, we have decided to check the activity of FCU at concentration 100, 75, 50, & 25% with control water. This study was conducted to identify the effect of the concentration of FCU on the seed germination index. From visual observation of Figure 3, it is observable that at higher concentration i.e. 100 and 75%, 2 to 3 of the 10 seeds tried to germinate, but unfortunately growth of the seedlings was stopped. It is thought that this scenario occurs due to the higher salinity of FCU. However, at reduced concentration of FCU i.e. 50 and 25%, the germination number increases, but still it was not upto the mark as observed in control germination. From these results, it is resolved that, for better germination effect, the FCU concentration should be less than 25%. Additionally, from **Figure 3**, it is found that FCU shows antifungal activity; when the concentration of FCU from control to 100%, the growth of fungus *Rhizoctonia solani* was drastically reduced. This observation suggests that the FCU possess antifungal activity.

3.3.2 Study 2: Seed germination study of FCU at concentration 1%, 2.5%, 5%, 7.5% & control water on maize seeds.

From Figure 4, it is observed that this lower % of FCU did not affect the germination rate. Because the control % germination matches all treatments of FCU. So, these % concentration of FCU could be utilised for further studies. Additionally, the concentration of FCU giving positive response for white root development. As verified in Figure 4, whenever the concentration of FCU increases the bunch of white roots hairier. The best % FCU was found in the range of 2.5 to 7.5%. This germination study verified that the CU could be utilised for agro formulation development. Because of these results CU gives a confident response for seed germination, fungicidal and root bunch development.

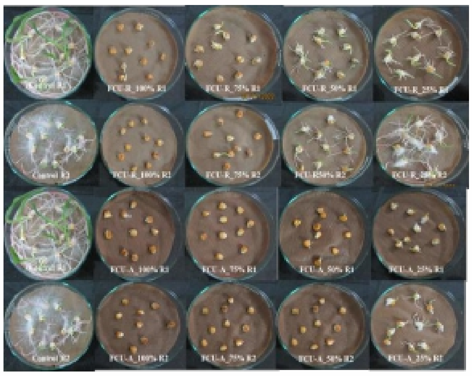

Figure 3: Effect of FCU on Maize seeds with various concentration (6th day)

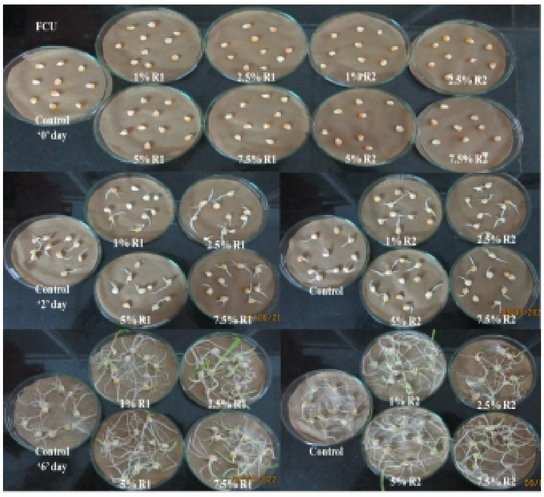

Figure 4: FCU were studied at concentration 1%, 2.5%, 5%, 7.5% & control water on maize seeds

4. Statistical Analysis

The observational data from each treatment were tabulated, and the mean values were calculated. To assess whether significant differences existed among the treatments, the data were analysed using analysis of variance (ANOVA), and the F-test was applied at a 5% level of significance ($\alpha = 0.05$) using Microsoft Excel 2016. When the ANOVA indicated significant differences, Tukey's Honest Significant Difference (HSD) test was conducted to determine pairwise differences between treatment means.

Effect of Fresh Cow Urine (FCU) is tested by direct cup method on Maize seed @ 20 ml/cup.

Table 2: Shoot length of FCU at 1%, 2.5%, 5%, 7.5% & water as a control

Seed Number	T1_Untreated	T2_FCU 1%	T3_FCU 2.5%	T4_FCU 5%	T5_FCU 7.5%
	SL (cm)	SL (cm)	SL (cm)	SL (cm)	SL (cm)
1	18.0	16	13	13	19
2	17.0	19	12	18	20
3	18.0	18	15	20	21
4	12.0	20	16	10	21
5	18.0	14	13.5	16	13
6	17.0	19.5	15	22	16
7	14.0	16	13	18	20
8	13.0	19	15	15	16
9	18.0	17	13	15	15
10	18.0	13	14	14.5	17
Mean	16.3	17.2	14.0	16.2	17.8
CV %	14.5	13.88	9.01	21.55	15.62
p value	0.020				
F value	3.258				

Table 2 shows the mean shoot lengths after 7 days. The 7.5 % FCU treatment produced the longest shoots (mean = 17.8 cm), significantly greater than the 50 % treatment (16.2 cm). (p = 0.020). The coefficient of variation was highest for the 5 % treatment (21.55 %), indicating greater variability. The untreated treatment showing smaller shoot length as compared to any FCU treatment. The actual results we can observe in Figure 2 (a). The p (0.020) and F (3.258) value was calculated for these results, and it is observed that no statistically significant differences were observed among FCU treatments.

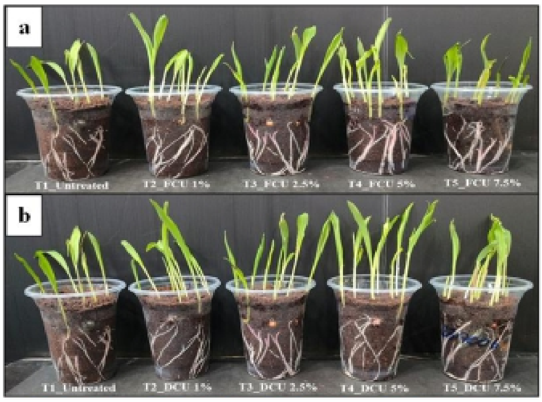

Figure 5: Shoot length of maize seed treated with (a) FCU & (b) DCU at different concentrations

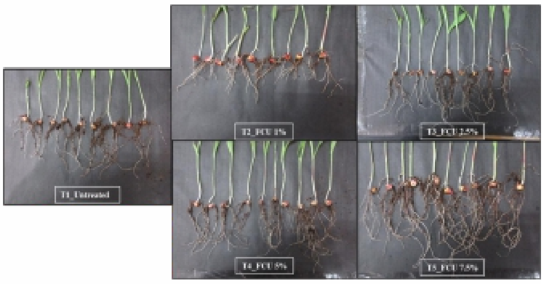

Figure 6: Root length of maize seeds treated with FCU sample

Table 3: Root length of FCU at 1%, 2.5%, 5%, 7.5% & water as a control

Seed Number	T1_Untreated	T2_FCU 1%	T3_FCU 2.5%	T4_FCU 5%	T5_FCU 7.5%
	RL (cm)	RL (cm)	RL (cm)	RL (cm)	RL (cm)
1	11	12	11	11	11
2	12	11.7	10	12	13
3	11	11.5	9.6	14	12
4	12	13	10.6	11.5	12
5	11	12	11	10	13
6	14	12	11	12.3	11
7	14	11	10.5	11	13
8	11	13	11	12	16
9	13	11	13	12	13
10	13	10	9.7	9.6	17
Mean	12.2	11.72	10.74	11.54	13.1
CV %	10.76	7.81	8.98	10.8	15.03
p value	0.005				
F value	4.346				

As observed in Table 3 and Figure 6, the smallest size of root was noted at the 2.5% FCU treatment and the highest length of root was recorded in the case of 7.5% treatment. Medium-sized root length was found for the untreated treatment. In all treatments, CV% noted in minimum difference, likewise p value, 0.005 and F value 4.346 showed no statistical difference in all treatments. From the results of shoot and root length, it was noted that the treatment having 7.5% FCU showed significant efficacy for the development of root and shoot growth.

Effect of Distilled Cow Urine (DCU) is tested by the direct cup method on Maize seed @ 20 ml/cup

Table 4: Shoot length of DCU at 1%, 2.5%, 5%, 7.5% & water as a control

Seed Number	T1_Untreated	T6_DCU 1%	T7_DCU 2.5%	T8_DCU 5%	T9_DCU 7.5%
	SL (cm)	SL (cm)	SL (cm)	SL (cm)	SL (cm)
1	18	15	14	11	27
2	17	20	15	12	14
3	18	15	13	14	11
4	12	20	19	15	17
5	18	19	16	16	26
6	17	16	13	12	17
7	14	20	14	11	15
8	13	19	11	10	19
9	18	18	11	14	13
10	18	17	15	12	16
Mean	16.3	17.9	14.1	12.7	17.5
CV%	14.470	11.310	16.86	15.32	30
p value			0.001		
F value			5.351		

The effect of DCU at different concentrations was tested for shoot length development on maize seeds, and results are depicted graphically in Figure 5 (b), and experimental data are summarised in Table 4. From these data, it was found that the mean shoot length at concentration 1 (17.9 cm) and 7.5% (17.5 cm) was superior to others. The ANOVA confirmed a highly significant effect (p = 0.001, F = 5.351). The CV% proved that no statistical different noted in all treatments.

Table 5: Root length of DCU at 1%, 2.5%, 5%, 7.5% & water as a control

Seed Number	T1_Untreated	T6_DCU 1%	T7_DCU 2.5%	T8_DCU 5%	T9_DCU 7.5%
	RL (cm)	RL (cm)	RL (cm)	RL (cm)	RL (cm)
1	11	12.5	10.5	9.6	13.6
2	12	11	11	13	14
3	11	10	12	15	8
4	12	11	13	11.9	11
5	11	11	11.5	9.7	11.5
6	14	11	9.6	11	13
7	14	10	14	10	12
8	11	10.76	14	10.76	12
9	13	11	11.9	11	11
10	13	10.11	9.7	10.11	13
Mean	12.2	10.84	11.72	11.21	11.91
CV %	10.07	6.76	13.57	15.12	14.47
p value			0.235		
F value			1.444		

The results of the effect of DCU samples on root length are summarised in Table 5, and picturized in Figure 7. From root length, it is noted that all treatments showed a similar kind of length. The efficacy of DCU samples on root length was noteworthy, it could be observed due to the distilled cow urine. Maybe during distillation, beneficial ingredients were removed. However, in the case of shoot length, no adverse effect was noted.

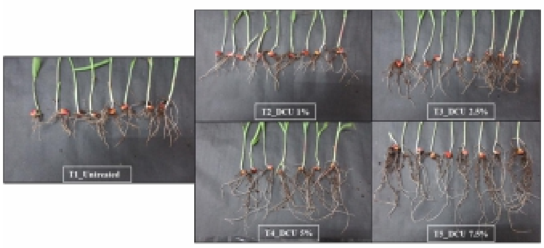

Figure 7: Root length of maize seeds treated with DCU samples

Germination & Biomass:

The experiment utilised five treatment groups: Control (Untreated), 1%, 2.5%, 5%, and 7.5% concentrations of both FCU and DCU. Germination percentages were recorded, and biomass was measured via fresh and dry weight analysis. Data were analysed using descriptive statistics and variance analysis.

Table 6 summary FCU: The mean germination is 90.4%. T5 (7.5%) showed a significant improvement over the control. DCU: The mean germination is 87.8%. DCU treatments generally trended lower than or equal to the control.

Table 6: Germination (%) data of FCU & DCU at 1%, 2.5%, 5%, 7.5% & water as a control

Treatment	FCU (% Germination)	DCU (% Germination)
Control (T1)	90	90
1% (T2)	92	86
2.5% (T3)	85	87
5% (T4)	90	86
7.5% (T5)	95	90

Table 7: Fresh weight (FW) and Dry Weight (DW) data of FCU & DCU at 1%, 2.5%, 5%, 7.5%& water as a control

Treatment	FCU (FW/DW)	DCU (FW/DW)
T1	16.47 / 2.10	16.47 / 2.10
T2	15.34 / 2.27	17.18 / 2.01
T3	18.29 / 2.27	17.35 / 2.19
T4	17.48 / 2.18	16.47 / 2.26
T5	16.99 / 2.21	17.18 / 2.24

Dry Weight Trends: Both treatments (FCU and DCU) generally increased the dry weight compared to the control (2.10g), indicating higher nutrient retention or structural density despite variances in fresh moisture content.

5. Elemental Analysis of CU & DCU (Patanjali) samples is done by the Kjeldahl method [16] & inductively coupled plasma mass spectrometry (ICP-MS) [17],[18].

Table 10: Elemental analysis of Cow Urine and Distilled Cow Urine sample

Sr. No.	Test Parameter	Unit	Fresh Cow Urine	Cow Urine (Patanjali)	Method/Instrument
1	Total Nitrogen (N)	% by wt.	0.04	0.05	Kjeldahl method
2	Total Phosphorus (as P_2O_5)	% by wt.	0	0.01	ICP-MS
3	Total Potassium (as K_2O)	% by wt.	0.14	0	ICP-MS
4	Calcium (as Ca)	mg/kg	130.67	146.93	ICP-MS
5	Magnesium (as Mg)	mg/kg	177.64	55.6	ICP-MS
6	Arsenic (as as)	mg/kg	1.04	0.76	ICP-MS
7	Cadmium (as Cd)	mg/kg	0.01	0	ICP-MS
8	Chromium (as Cr)	mg/kg	0.67	2.15	ICP-MS
9	Copper (as Cu)	mg/kg	0.31	0.44	ICP-MS
10	Mercury (as Hg)	mg/kg	0	0	ICP-MS
11	Nickel (as Ni)	mg/kg	0.19	0.2	ICP-MS
12	Lead (as Pb)	mg/kg	0.07	0.21	ICP-MS
13	Zinc (as Zn)	mg/kg	1.43	2.7	ICP-MS
14	Manganese (as Mn)	mg/kg	1.52	0.78	ICP-MS
15	Boron (as B)	mg/kg	3.27	1.45	ICP-MS
16	Molybdenum (as Mo)	mg/kg	0.16	0.05	ICP-MS
17	Sulphur (as S)	mg/kg	78.39	45.58	ICP-MS
18	Iron (as Fe)	mg/kg	30.74	31.81	ICP-MS

Table 10 demonstrates that both CU and DCU contain trace amounts of essential macronutrients.

Nitrogen (N): Fresh CU showed a Total Nitrogen content of 0.04%, which increased slightly to 0.05% in the distilled sample. This suggests that the distillation process concentrates nitrogenous compounds.

Phosphorus (P_2O_5): Present at 0.01% in DCU, whereas it was negligible in fresh CU.

Potassium (K_2O): Interestingly, fresh CU contained 0.14% Potassium, while it was absent in the DCU sample. This indicates that volatile or soluble potassium salts may be lost or partitioned during the distillation process.

Micronutrients and Secondary Nutrients

Fresh CU acts as a significant reservoir for secondary nutrients, particularly Magnesium (177.64 mg/kg) and Sulphur (78.39 mg/kg). The distribution of trace minerals Iron (Fe), Zinc (Zn), and Boron (B) is notable. The presence of Iron (~30–31 mg/kg) in both samples suggests a stable mineral content that remains unaffected by distillation.

Heavy Metal Assessment

The safety of agricultural inputs depends on adhering to regulatory thresholds for heavy metals:

Arsenic (As): Concentrations were found to be 1.04 mg/kg (CU) and 0.76 mg/kg (DCU), both remaining within permissible limits for organic inputs.

Chromium (Cr): A slight increase was observed in DCU (2.15 mg/kg) compared to fresh CU (0.67 mg/kg).

Mercury (Hg): Results were below the detection limit (0 mg/kg) for both samples, indicating a clean baseline.

Lead (Pb) and Nickel (Ni): Levels remained at trace concentrations (0.07–0.21 mg/kg), posing minimal risk for soil accumulation at the recommended dilution levels for fertiliser applications.

6. Conclusion:

The initial parameters of cow urine samples, such as appearance, density, pH, surface tension and contact angle were examined. The DST & CA study revealed that the collected samples of cow urine has surface active property. Elemental analysis of CU samples was examined by ICP-MS & found potent essential nutrients. The data suggests that Fresh Cow Urine is superior in terms of Potassium (K) and Sulfur (S) delivery, making it a more comprehensive nutrient supplement for soil application. Distilled Cow Urine, while possessing higher nitrogen content, shows a loss in overall mineral diversity. However, given the low absolute percentages of NPK, these substances should be classified as bio-stimulants or soil bio-activators rather than primary NPK fertilisers. Their efficacy lies primarily in their micronutrient profile, specifically the bioavailability of Fe, Zn, and Ca, which are essential for chlorophyll synthesis and enzyme activation in crops. Different concentration of CU samples was tested for speed of germination, phytotoxicity and seed safety & found safe at low concentrations. Different concentrations of CU samples were tested for root shoot length, fresh & dry mass by the direct cup method. And from these results, it was confirmed that cow urine samples could be utilised in the agrochemicals sector for formulation development. In summary, the investigation confirms that cow urine can be utilised as an ideal substance for the agrochemical sector, beyond the traditional claims of farmers. It establishes a base scientific protocol that can bridge the existing divide between the two methodologies and lay a foundation for the subsequent research and formulation of stable, bio-origin inputs. There should be research directed towards developing standardised liquid formulations of cow urine samples for use in large-scale agriculture. Also, the possibility of enhancing the performance of cow urine-based formulations by combining with other bio-organic inputs could be explored.

Disclaimer (Artificial Intelligence):

The author (s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Competing Interests:
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