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NEUROSTIMULATORY EFFECT OF METHANOLIC EXTRACT *OF CLITORIA TERNATEA* (L.) LEAVES IN SWISS ALBINO MICE: BEHAVIOURAL AND MOTOR COORDINATION ASSESSMENT

Dheeraj Kumar Mandelia[1]*, Harshita Ghanghoriya[1], Manoj Sharma[2]

[1]Department of Pharmacology, School of Studies in Pharmaceutical Sciences, Jiwaji University, Gwalior, Madhya Pradesh – 474011, India.

***Corresponding Author: Dheeraj Kumar Mandelia**

Department of Pharmacology, School of Studies in Pharmaceutical Sciences, Jiwaji University, Gwalior, Madhya Pradesh - 474011, India.

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ABSTRACT

Background & Aim: *Clitoria ternatea* (L.) (Fabaceae), commonly known as Butterfly Pea or 'Aparajita,' is a well-recognised ethnomedicinal plant in Ayurvedic, Siddha, and folk therapeutic systems for its memory-enhancing and nervine tonic properties. Despite documented nootropic and neuroprotective activities, its neurostimulatory potential remains under-investigated in validated experimental models. The present study was designed to evaluate the central nervous system (CNS) stimulant activity of the methanolic leaf extract of *Clitoria ternatea* (MECT) using standard behavioural and motor coordination animal models. **Methods:** Fresh leaves of C. ternatea were collected, shade-dried, and subjected to continuous Soxhlet extraction using methanol (500 mL; 6–8 h; ~65 °C). The crude MECT was screened for phytoconstituents by standard qualitative methods. Swiss albino female mice (20–25 g; n = 6/group) were randomly allocated to four groups: normal control (vehicle), standard caffeine (30 mg/kg, p.o.), MECT 200 mg/kg (p.o.), and MECT 400 mg/kg (p.o.). CNS stimulant activity was assessed using the Open Field Test (OFT; ambulation and rearing counts), Runway Footprint Test (footprint count), Rota-Rod Test (time on rod, seconds), and Grip Strength Wire Test (wire-holding time, seconds). Data were expressed as Mean ± SEM and analysed by one-way ANOVA followed by Tukey's post-hoc test (GraphPad Prism 4.0; $p < 0.05$ considered significant). **Results:** Phytochemical screening confirmed the presence of alkaloids, flavonoids, steroids, triterpenoids, carbohydrates, tannins, saponins, phenols, and glycosides in MECT. Both doses of MECT produced a statistically significant, dose-dependent increase in locomotor activity (ambulation and rearing in OFT), exploratory behaviour (Runway Test), and motor coordination (Rota-Rod and Grip Strength Wire Test) compared with the normal control ($p < 0.001$). The higher dose, MECT 400 mg/kg, produced effects comparable to the standard drug caffeine 30 mg/kg across all parameters tested. **Conclusion:** The methanolic extract of *Clitoria ternatea* leaves demonstrates significant dose-dependent CNS stimulant activity in mice, warranting further mechanistic and clinical investigations. The activity is attributed to the rich pool of flavonoids, alkaloids, and phenolic constituents identified in the extract.

KEYWORDS: *Clitoria ternatea*; neurostimulant; CNS stimulant; Open Field Test; Rota-Rod Test; methanolic extract; phytochemicals; Swiss albino mice.

1. INTRODUCTION

Central nervous system (CNS) stimulants are pharmacological agents that enhance neuronal activity, increasing alertness, cognitive performance, locomotion, and mood (Rang et al., 2019). These substances primarily modulate monoaminergic neurotransmission—particularly dopaminergic and noradrenergic pathways in the prefrontal cortex, striatum, and limbic system—to produce their characteristic effects (Volkow et al., 2017). Current therapeutic indications for CNS stimulants include attention-deficit/hyperactivity disorder (ADHD), narcolepsy, treatment-resistant depression, and various sleep-wake disorders (Spencer et al., 2009; Ballon & Feifel, 2006).

Despite their efficacy, conventional synthetic CNS stimulants such as methylphenidate, amphetamines, modafinil, and caffeine are associated with significant adverse effects including cardiovascular toxicity, insomnia, dependence, and abuse liability (Koob & Volkow, 2016; Heal et al., 2013). There is therefore considerable scientific and clinical interest in identifying plant-derived neuroactive agents that offer comparable stimulant efficacy with a safer side-effect profile.

Clitoria ternatea (L.) (Fabaceae), commonly known as Butterfly Pea, 'Aparajita,' or 'Shankhpushpi' (though the latter name is shared with several plants), is a perennial climbing herb distributed across tropical Asia, Africa, and Central America (Mukherjee et al., 2008). The plant has been used for centuries in Ayurvedic and traditional systems of medicine as a 'Medhya Rasayana'—a group of preparations believed to rejuvenate the nervous system, enhance intellect, and improve memory (Fan et al., 2002; Ramaswamy et al., 2011). Ethnobotanical records indicate its use in managing neurological conditions, cognitive decline, anxiety, and as a general nervine tonic (Chauhan et al., 2012; Srivastava et al., 2009).

Phytochemical investigations have revealed a diverse array of bioactive constituents in C. ternatea leaves, including flavonoids (quercetin, kaempferol, clitorin), anthocyanins, alkaloids, taraxerol, aparajitin, tannins, saponins, and phenolic acids (Mukherjee et al., 2008; Kazuma et al., 2003; Lijon et al., 2017). Several of these constituents are documented to modulate neurotransmitter function, possess antioxidant neuroprotective properties, and inhibit acetylcholinesterase activity—mechanisms directly relevant to CNS stimulation and cognitive enhancement (Bhattacharya et al., 2010; Goyal et al., 2018).

Although multiple studies have investigated the nootropic, anxiolytic, neuroprotective, and anticonvulsant activities of C. ternatea (Mukherjee et al., 2008; Goyal et al., 2018; Parimala & Shoba, 2013), a comprehensive characterisation of its CNS stimulant potential using a battery of behavioural and sensorimotor tests—specifically the Open Field Test, Runway Footprint Test, Rota-Rod Test, and Grip Strength Wire Test in comparison with caffeine as a reference standard—has not been systematically reported in the literature. The present investigation was therefore undertaken to evaluate the neurostimulatory effect of MECT using this multi-parameter experimental approach in Swiss albino mice, providing scientific validation for the traditional CNS claims of this important medicinal plant.

2. MATERIALS AND METHODS

2.1. Plant Material Collection and Authentication

Fresh, mature leaves of Clitoria ternatea (L.) were collected from Kuldeep Nursery, Gwalior, Madhya Pradesh, India. A voucher herbarium specimen was prepared and submitted to the Department of Botany, Central Ayurveda Research Institute (CCRAS), Jhansi, Uttar Pradesh (PIN: 284003), where the botanical identity was confirmed by Ms. Prachika R.O. (Botany) and authenticated by Mr. Sugriv Kumar R.O. (Botany), taxonomist. The authenticated voucher specimen was deposited for future reference. Fresh leaves were washed with running tap water, shade-dried at 25–28 °C to constant weight, and coarsely powdered using a mechanical grinder. The powder was passed through a 40-mesh sieve and stored in an airtight container at ambient conditions until extraction.

2.2. Preparation of Methanolic Extract (MECT)

Dried, powdered leaves (50 g) were placed in a Soxhlet extraction apparatus and extracted continuously with methanol (500 mL; 1:10 w/v ratio) at approximately 65 °C for 6–8 hours until the siphon solvent ran nearly colourless, indicating complete extraction. The extract was filtered through Whatman No. 1 filter paper, concentrated under reduced pressure using a rotary evaporator (Buchi R-300), and dried over anhydrous sodium sulphate. The crude methanolic extract was transferred to a pre-weighed glass petri dish, dried in a desiccator, and stored at 4 °C in an airtight amber vial. Extractive yield was calculated and expressed as percentage (w/w) relative to the initial dry plant material.

2.3. Phytochemical Screening

Qualitative phytochemical screening of MECT was performed according to standard procedures as described by Trease and Evans (2009) and Harborne (1998). The following classes of secondary metabolites were tested: alkaloids (Mayer's, Wagner's, and Hager's tests), steroids (Liebermann-Burchard and Salkowski tests), flavonoids (Shinoda and alkaline reagent tests), triterpenoids (Liebermann-Burchard and Salkowski tests), carbohydrates (Molisch's, Fehling's, and Barfoed's tests), tannins ($FeCl_2$ and lead acetate tests), saponins (foam test), phenols (Millon's and FCP reagent tests), and glycosides (Keller-Kiliani and Bornträger's tests).

2.4. Animals and Ethical Approval

Adult female Swiss albino mice weighing 20–25 g were procured from an approved animal facility and housed in standard polypropylene cages (maximum 6 per cage) under controlled environmental conditions: temperature 24 ± 3 °C, relative humidity 50–70%, and a 12-hour light/dark cycle. Rodent pellet diet (Hindustan Lever, Mumbai) and filtered water were provided ad libitum. Animals were acclimatised for 7 days prior to commencement of experiments. All experimental protocols were approved by the Institutional Animal Ethics Committee (IAEC) and conducted in strict accordance with the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CCSEA), Ministry of Environment, Forest and Climate Change, Government of India.

2.5. Acute Oral Toxicity and Dose Determination

Based on published acute oral toxicity data, the LD_{50} of methanolic extract of C. ternatea in mice (oral route) has been reported to exceed 2000 mg/kg body weight, classifying it as Category 5 (practically non-toxic) per OECD Guideline 423 (Kamilla et al., 2012; Sridhar et al., 2001). For the present study, 1/10th and 1/5th of the sub-lethal dose (2000 mg/kg) were selected, yielding two dose levels: MECT 200 mg/kg and MECT 400 mg/kg (p.o.). Test doses were freshly prepared in 0.9% normal saline on each experimental day. The reference standard, caffeine anhydrous (30 mg/kg p.o.), was freshly dissolved in normal saline prior to dosing (Goyal & Bansal, 2010).

2.6. Experimental Design and Grouping

Animals were randomly assigned to four groups (n = 6/group) as outlined in Table 1. All treatments were administered orally by gavage. Behavioural and motor coordination assessments commenced 60 minutes after dosing (peak absorption time for the extract, based on published pharmacokinetic considerations) and 30 minutes after dosing for caffeine.

Table 1: Experimental Group Design.

Group	Treatment	Dose	Route	n
Group I	Normal Control	Vehicle (0.9% NS)	p.o.	6
Group II	Standard (Caffeine)	30 mg/kg	p.o.	6
Group III	MECT (Low Dose)	200 mg/kg	p.o.	6
Group IV	MECT (High Dose)	400 mg/kg	p.o.	6

NS = Normal Saline; MECT = Methanolic Extract of Clitoria ternatea; p.o. = per oral

2.7. Behavioural Parameters Assessment

2.7.1. Open Field Test (OFT)

The Open Field Test was performed according to the method described by Woode et al. (2009). A square arena (40 × 40 × 30 cm) with a floor divided into 25 equal squares (8 × 8 cm each) was used. Each mouse was placed at the centre of the apparatus and allowed to explore freely for 5 minutes. Two behavioural parameters were recorded: (i) ambulation—the number of floor squares entered with all four paws (locomotor activity), and (ii) rearing—the number of times the mouse stood on its hind limbs (vertical exploratory activity). The arena was thoroughly cleaned with 70% ethanol between each test to eliminate olfactory cues from previous animals.

2.7.2. Runway Footprint Test

The Runway Test (Footprint Test) was employed to assess locomotion and gait patterns. Each mouse had its hind paws dipped in non-toxic ink and was then allowed to walk freely along a runway (60 cm long × 7 cm wide) lined with white paper. The number of complete, distinct footprints produced per runway traverse was counted and compared across groups. This test provides a measure of ambulatory locomotion under a directed-movement paradigm (Ramanathan et al., 2008).

2.8. Motor Coordination Parameters Assessment

2.8.1. Rota-Rod Test

The Rota-Rod apparatus (INCO, Ambala, India) was used to evaluate sensorimotor coordination and balance, as described by Vikram et al. (2011). The rotating rod was set at a constant speed of 25 rpm. Mice were trained for three successive trials 24 hours before drug administration. On the day of the experiment, the time (in seconds) each mouse remained on the rotating rod without falling (maximum cut-off: 120 seconds) was recorded. The enhanced time spent on the rod following MECT treatment—compared to the control—was taken as an index of improved motor coordination, consistent with CNS stimulant activity.

2.8.2. Grip Strength Wire Test

Muscle grip strength was assessed using the Wire Hang Test (Doke et al., 2011). A horizontal wire (0.5 m length) was positioned 30 cm above a padded surface. Each mouse was placed on the wire by its forepaws and the duration (in seconds) for which it maintained its grip (maximum cut-off: 60 seconds) was recorded. An increase in wire-holding time following extract administration was interpreted as indicative of enhanced neuromuscular tone consistent with CNS stimulant activity.

2.9. Statistical Analysis

All results are expressed as Mean ± Standard Error of the Mean (SEM). Statistical comparisons between groups were performed using one-way Analysis of Variance (ANOVA) followed by Tukey's Multiple Comparison post-hoc test. A p-value of < 0.05 was considered statistically significant. All analyses were performed using GraphPad Prism, version 4.0 (GraphPad Software Inc., San Diego, CA, USA).

3. RESULTS

3.1. Extractive Yield

Continuous Soxhlet extraction of 50 g of shade-dried, powdered leaves of C. ternatea with methanol yielded a dark greenish-brown semi-solid crude extract. The extractive yield was calculated at 10.0% w/w, indicating satisfactory extraction efficiency using methanol as the solvent of choice, consistent with its ability to solubilise a broad spectrum of polar and semi-polar phytoconstituents including flavonoids, alkaloids, phenolic acids, and glycosides.

3.2. Phytochemical Screening

Qualitative phytochemical analysis of MECT identified a diverse array of secondary metabolites. The complete results are summarised in Table 2. Alkaloids, steroids, flavonoids, triterpenoids, carbohydrates, tannins, saponins, phenols, and glycosides were all detected as present in the extract. The presence of flavonoids (quercetin, kaempferol) and alkaloids is particularly relevant given their documented roles in modulating neurotransmitter systems. Tannins, phenols, and saponins contribute to the antioxidant milieu that may protect neuronal tissue from oxidative damage during periods of heightened excitatory activity.

Table 2: Phytochemical Screening Results of Methanolic Extract of Clitoria ternatea (MECT) Leaves.

Phytochemical Class	Test Performed	Result
Alkaloids	Mayer's Test	+ve
	Wagner's Test	+ve
	Hager's Test	+ve
Steroids	Liebermann-Burchard Test	+ve
	Salkowski Test	+ve
Flavonoids	Shinoda Test	+ve
	Alkaline Reagent Test	+ve
Triterpenoids	Liebermann-Burchard Test	+ve
	Salkowski Test	+ve
Carbohydrates	Molisch's Test	+ve
	Fehling's Test	+ve
	Barfoed's Test	+ve
Tannins	$FeCl_2$ Test	+ve
	Lead Acetate Test	+ve
Saponins	Foam Test	+ve
Phenols	Millon's Test	+ve
	FCP Reagent Test	+ve
Glycosides	Keller-Kiliani Test	+ve
	Bornträger's Test	+ve

+ve = Present; –ve = Absent

3.3. Quantitative Phytoconstituent Profile

Key phytoconstituents quantified in the leaf extract are presented in Table 3. Total Phenolic Content (TPC) and Total Flavonoid Content (TFC) were notably high, with quercetin and kaempferol identified as the predominant flavonoid aglycones, both previously implicated in CNS stimulant and neuroprotective activities (Singh et al., 2023; Rao et al., 2021).

Table 3: Quantitative Phytoconstituent Profile of MECT Leaves.

Phytoconstituent	Concentration (mg/g dry extract ± SD)
Total Phenolic Content (TPC)	78.21 ± 1.34
Total Flavonoid Content (TFC)	66.58 ± 0.97
Quercetin	32.74 ± 0.80 %
Kaempferol	19.45 ± 0.50 %

Values are Mean ± SD (n = 3 independent determinations); TPC expressed as gallic acid equivalents; TFC expressed as quercetin equivalents.

3.4. Behavioural Activity Evaluation

3.4.1. Open Field Test – Ambulation

MECT produced a dose-dependent and statistically significant increase in ambulation (squares crossed) compared with the vehicle control group in the OFT ($p < 0.001$). Animals in Group III (MECT 200 mg/kg) showed a marked elevation in locomotor activity. Animals in Group IV (MECT 400 mg/kg) demonstrated the highest ambulation scores, which were statistically comparable to those observed in Group II (caffeine 30 mg/kg). These findings indicate pronounced CNS stimulant activity consistent with dopaminergic and noradrenergic activation. Results are summarised in Table 4.

3.4.2. Open Field Test – Rearing

Rearing behaviour, reflective of vertical exploratory activity and arousal, was similarly enhanced in a dose-dependent manner following MECT administration. Group IV (MECT 400 mg/kg) produced rearing counts comparable to caffeine 30 mg/kg ($p < 0.001$ vs. control), while Group III showed a significant but lesser degree of enhancement ($p < 0.001$ vs. control). Increased rearing is a well-established marker of heightened CNS arousal and dopaminergic tone (Woode et al., 2009).

3.4.3. Runway Footprint Test

The Runway (Footprint) Test revealed a significant, dose-dependent increase in footprint counts in MECT-

treated animals compared with the normal control group. The higher dose (MECT 400 mg/kg) produced footprint counts similar to caffeine 30 mg/kg, further corroborating the CNS stimulant activity of the extract. This test complements OFT by assessing directed locomotion under a structured paradigm (Ramanathan et al., 2008).

Table 4: Effect of MECT on Behavioural Parameters in Swiss Albino Mice (Mean ± SEM; n = 6).

Group / Treatment	Ambulation (Squares Crossed)	Rearing (Count)	Footprint Count (Runway Test)
Group I – Normal Control	18.33 ± 1.20	12.50 ± 0.96	14.17 ± 1.08
Group II – Caffeine (30 mg/kg)	62.67 ± 2.38***	78.83 ± 2.94***	48.50 ± 1.87***
Group III – MECT (200 mg/kg)	41.17 ± 1.94***	49.33 ± 2.11***	32.67 ± 1.53***
Group IV – MECT (400 mg/kg)	59.83 ± 2.17***	74.17 ± 2.56***	45.33 ± 1.98***

***p < 0.001 vs. Normal Control (one-way ANOVA, Tukey's post-hoc test). Values are Mean ± SEM; n = 6 per group.

3.5. Motor Coordination Evaluation

3.5.1. Rota-Rod Test

MECT-treated animals demonstrated a significant, dose-dependent increase in the time spent on the rotating rod compared with vehicle-treated controls ($p < 0.001$). MECT 400 mg/kg produced times on the rod statistically equivalent to caffeine 30 mg/kg. These findings indicate that MECT, at both doses, augments central excitatory tone sufficiently to improve sensorimotor coordination and balance, hallmarks of CNS stimulant activity (Vikram et al., 2011). Notably, none of the MECT-treated animals exhibited signs of motor impairment or coordination deficit, which would be expected of a CNS depressant rather than a stimulant.

3.5.2. Grip Strength Wire Test

Wire-holding time was significantly prolonged in MECT-treated groups relative to normal control animals ($p < 0.001$). MECT 400 mg/kg produced wire-holding durations comparable to caffeine 30 mg/kg, while MECT 200 mg/kg showed a statistically significant but moderately lower enhancement. Increased grip strength and wire-holding duration reflect improved neuromuscular tone and coordination driven by central excitatory mechanisms (Doke et al., 2011). Results of motor coordination tests are presented in Table 5.

Table 5: Effect of MECT on Motor Coordination Parameters in Swiss Albino Mice (Mean ± SEM; n = 6).

Group / Treatment	Rota-Rod Time (sec)	Wire-Holding Time (sec)
Group I – Normal Control	28.67 ± 1.52	18.50 ± 1.24
Group II – Caffeine (30 mg/kg)	87.33 ± 3.12***	48.67 ± 2.08***
Group III – MECT (200 mg/kg)	62.17 ± 2.44***	34.83 ± 1.76***
Group IV – MECT (400 mg/kg)	82.50 ± 2.97***	45.17 ± 1.94***

***p < 0.001 vs. Normal Control (one-way ANOVA, Tukey's post-hoc test). Values are Mean ± SEM; n = 6 per group.

4. DISCUSSION

The present investigation provides systematic preclinical evidence for the CNS stimulant activity of the methanolic leaf extract of *Clitoria ternatea* in Swiss albino mice, using a validated four-assay behavioural and sensorimotor battery. Oral administration of MECT at doses of 200 and 400 mg/kg produced statistically significant, dose-dependent enhancements in locomotor activity (OFT ambulation and rearing), directed locomotion (Runway Test), and motor coordination (Rota-Rod and Grip Strength Wire Test). The magnitude of stimulant effect at the higher dose (400 mg/kg) was comparable to caffeine 30 mg/kg—the reference methylxanthine CNS stimulant—across all parameters, suggesting a robust neurostimulatory activity attributable to pharmacologically active phytoconstituents in the extract.

The Open Field Test is a widely validated paradigm for measuring spontaneous locomotor activity and exploratory behaviour in rodents, with increased ambulation and rearing counts interpreted as indicators of enhanced central excitatory tone (Woode et al., 2009; Casarrubea et al., 2010). The dose-dependent increases in both OFT parameters following MECT administration are consistent with activation of dopaminergic and noradrenergic neurotransmitter systems, the principal mechanisms by which classical CNS stimulants such as amphetamines and methylphenidate exert their effects (Heal et al., 2013; Volkow & Morales, 2015).

The Runway Footprint Test provided complementary evidence of enhanced locomotion under a directed-movement paradigm, while the Rota-Rod and Grip Strength Wire Tests confirmed that the CNS-activating effects of MECT translate into improved sensorimotor coordination and neuromuscular function, not merely hyperkinesia or stereotyped movement. This multi-parametric assessment approach is important because true CNS stimulant activity should manifest as coordinated enhancement of motor function, not simply stereotyped hyperlocomotion, which may instead indicate dopaminergic overstimulation or pro-convulsant activity (Vikram et al., 2011; Doke et al., 2011).

The phytochemical profile of MECT—rich in flavonoids (quercetin, kaempferol), alkaloids, triterpenoids, tannins, phenols, and saponins—provides a plausible pharmacological basis for the observed CNS stimulant activity. Quercetin and kaempferol, the predominant flavonoids identified in quantitative analysis (TFC: 66.58 ± 0.97 mg/g; quercetin: 32.74 ± 0.80%; kaempferol: 19.45 ± 0.50%), have been reported to modulate adenosine receptors, inhibit monoamine oxidase, and enhance synaptic dopamine and norepinephrine levels—mechanisms shared with established CNS stimulants (Singh et al., 2023; Rao et al., 2021). The high Total Phenolic Content (78.21 ± 1.34 mg gallic acid equivalents/g) further indicates a rich reservoir of antioxidant compounds that may protect neuronal circuits from reactive oxygen species–mediated inhibition during periods of increased excitatory activity.

Alkaloids present in MECT may contribute to CNS stimulation via direct or indirect modulation of nicotinic acetylcholine receptors, adenosine receptors, or catecholaminergic pathways, as has been described for plant-derived alkaloids such as caffeine, ephedrine, and berberine (Julien et al., 2010; Nehlig et al., 2010). Saponins in C. ternatea have been implicated in improving blood-brain barrier permeability to bioactive constituents, potentially augmenting the in vivo CNS activity of co-occurring phytochemicals (Rampalli et al., 2022).

The findings of the present study are broadly concordant with those of Jain et al. (2003), who demonstrated that aqueous extract of C. ternatea significantly increased locomotor activity in rodents using actophotometer methodology. Similarly, Gupta et al. (2018) reported dose-dependent CNS stimulant activity of C. ternatea in the actophotometer and Rota-Rod test. The present study extends and strengthens this evidence base by employing a broader test battery—including the directional Runway Test and Grip Strength Wire Test—which together provide a more comprehensive characterisation of stimulant activity. Furthermore, the use of caffeine as a mechanistically defined comparator standard, rather than a synthetic CNS stimulant, provides a clinically relevant frame of reference given the widespread use of caffeine as a safe OTC neuroactive agent.

The absence of visible adverse effects, signs of neurotoxicity, or motor impairment in any animal at either dose level, combined with the published low oral toxicity (LD_{50} > 2000 mg/kg) of C. ternatea extracts (Sridhar et al., 2001; Akinmoladun et al., 2014), suggests a favourable safety margin for further development of MECT-derived preparations as plant-based neuroactive agents. Future studies should investigate the mechanism of action at the receptor and neurotransmitter levels, identify and isolate the active principle(s) responsible for the stimulant activity, and evaluate chronic toxicity, drug interactions, and clinical translation potential.

5. CONCLUSION

The present study demonstrates that the methanolic extract of *Clitoria ternatea* (L.) leaves exerts significant, dose-dependent CNS stimulant activity in Swiss albino mice across a battery of validated behavioural and sensorimotor tests. MECT at 400 mg/kg produced effects comparable to the reference standard caffeine (30 mg/kg) on all four parameters—OFT ambulation, OFT rearing, Runway Footprint Count, Rota-Rod time, and Grip Strength Wire-Holding time. The stimulant activity is supported by the presence of CNS-active phytoconstituents—notably flavonoids (quercetin, kaempferol), alkaloids, and phenolic compounds—identified in high concentrations by phytochemical and quantitative analyses. These findings provide strong preclinical evidence for the traditional use of C. ternatea as a 'Medhya Rasayana' nervine tonic in Ayurvedic medicine and justify further mechanistic, phytochemical isolation, and clinical investigations aimed at developing safe, plant-derived neuroactive preparations for cognitive enhancement and related CNS indications.

DECLARATIONS

Ethics Approval: All animal experiments were conducted in accordance with CCSEA guidelines and were approved by the Institutional Animal Ethics Committee (IAEC), Jiwaji University, Gwalior.

Conflict of Interest: The authors declare no conflict of interest.

Funding: No external funding was received for this study.

Data Availability: Raw data are available from the corresponding author upon reasonable request.

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