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PHARMACOLOGICAL EVALUATION OF NOOTROPIC ACTIVITY OF *TINOSPORA CORDIFOLIA*

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ABSTRACT
Tinospora cordifolia, commonly known as Guduchi, is a well-known medicinal plant in Ayurvedic medicine, reputed for its adaptogenic, antioxidant, and immunomodulatory properties. The present study aims to evaluate the nootropic potential of *Tinospora cordifolia* using various experimental models in rodents. Ethanolic and aqueous extracts of the plant were prepared and administered to laboratory animals. Behavioral models such as the Elevated Plus Maze, Passive Avoidance Test, and Morris Water Maze were used to assess learning and memory enhancement. Standard nootropic drugs like Piracetam were used as positive controls for comparison. Biochemical assays were also conducted to estimate oxidative stress markers and cholinergic activity in the brain. The results demonstrated a significant improvement in memory retention and cognitive function in animals treated with *T. cordifolia*, particularly at higher doses, as compared to control groups. The study suggests that the nootropic activity of *Tinospora cordifolia* may be attributed to its antioxidant and neuroprotective effects. These findings support its traditional use and propose further clinical studies for its potential application in treating cognitive deficits and neurodegenerative conditions.

KEYWORDS: Tinospora cordifolia, Nootropic activity, Antioxidant, Memory retention.

INTRODUCTION

1972 saw C.E. Giurgea, the lead researcher on piracetam at the Belgian UCB Pharmaceutical Company—introduced the idea of "nootropic" or memory-enhancing medications. The Greek terms "noos," which means mind, and "tropein," which means to turn toward, are where he got the idea for the phrase "nootropic," which refers to improving memory and learning. Nootropics are substances that have the power to increase mental function and cognitive aptitude. They are also known as smart pills, memory-enhancing drugs, or brain boosters.[1]

It's crucial to remember that while they can improve motivation, focus, memory, and attention span, people with a history of mental illnesses may be more vulnerable to negative side effects. The first nootropic agent to be found was piracetam.[2]

Key characteristics that distinguish a nootropic drug include

- Improving learning, memory, and concentration.
- Safeguarding the brain from diverse injuries, whether chemical or physical.

The most common disorder that solemnly affects personality to do routine behaviour is dementia and most common form in elder ones is AD, which includes the area of intellect which is controlling the inspirations, observations, recall and verbal communication which further leads to brutal brain denting.[3]

Table 1: Tinospora cordifolia.

Parameter	Details
Scientific Name	Tinospora cordifolia
Common Names	Guduchi, Giloy, Amrita
Family	Menispermaceae
Plant Type	Climbing shrub (deciduous vine)
Parts Used	Stem, root, leaves

Geographical Distribution	India, Sri Lanka, Myanmar, China
Phytochemical Constituents	Alkaloids, glycosides, diterpenoid lactones, steroids, flavonoids, tannins
Traditional Uses	Immunomodulator, anti-diabetic, antipyretic, anti-inflammatory, hepatoprotective
Nootropic Relevance	Enhances memory, reduces oxidative stress, neuroprotective effects
Extract Types Used in Research	Aqueous extract, ethanolic extract, hydroalcoholic extract
Pharmacological Actions	Antioxidant, anti-inflammatory, cognitive enhancer, adaptogen
Toxicity	Generally considered safe in recommended doses

Tinospora cordifolia, commonly known as Guduchi or Giloy, is a vital herb in Indian traditional medicine (Ayurveda) and has been widely recognized for its diverse therapeutic properties. It is traditionally used to manage a variety of neurological and psychological disorders including depression, dementia, Alzheimer's disease, cerebral ischemia, and Attention Deficit Hyperactivity Disorder (ADHD).[4] These effects are largely attributed to its potent antioxidant and anti-stress properties. In addition, *T. cordifolia* exhibits anti-inflammatory, anti-hyperglycaemic, antispasmodic, immunomodulatory, rejuvenating, and anti-ulcer activities. Research has also shown its involvement in modulating cytokine levels and protecting against oxidative stress-induced damage.[5]

The herb contributes to improved memory and concentration by regulating amine reuptake in the brain, which is crucial for neurotransmission. Moreover, *T. cordifolia* is often used in polyherbal formulations to synergistically enhance their efficacy, especially in the treatment of mood and cognitive disorders. Behavioural studies using models such as the Hebb-Williams maze and passive avoidance tasks have demonstrated that *T. cordifolia* enhances learning and memory in both normal and cognitively impaired animals. Its cognitive benefits are thought to stem from immune-stimulation and increased acetylcholine levels, highlighting its role in cholinergic transmission. The compound's multifaceted pharmacological actions are likely due to a combination of its antioxidant, neuroprotective, and immunomodulatory properties.[6]

MATERIAL AND METHODS

PLANT MATERIALS

The chosen medicinal plant was collected, and its authentication was conducted at the Bilwal Medchem and Research Laboratory Pvt. Ltd.

Drying and size reduction

After being gathered and verified, the selected medicinal herbs stems were meticulously dried for 15 days in the shade. They were dried completely by placing them in a hot air oven set to 45°C for five minutes. The dried stems were then ground into a powder and kept in separate airtight containers at room temperature. The extraction process then made use of the powdered stems.

Extraction of the processed plants material

Extraction of Plant Material

Via the cold maceration process, distilled water was used to extract the dried powder of the selected medicinal herbs stems. After extraction, a rotary evaporator was used to evaporate the solvent at a lower pressure. It was determined that the dry extracts' percentage yield was 9.2% by weight.

Preliminary Phytochemical Tests

Preliminary phytochemical screening of *Tinospora cordifolia* extracts was conducted using various qualitative tests to detect key bioactive constituents. Alkaloids were confirmed by Dragendorff's and Mayer's tests through characteristic precipitates. Amino acids were identified using Millon's and Ninhydrin tests, while flavonoids showed red coloration in the zinc hydrochloride test. Tannins were indicated by color changes in the ferric chloride test. Proteins were detected by the Biuret test. Steroids and triterpenoids showed characteristic color layers in the Libermann-Burchard test. Anthraquinone and coumarin glycosides were confirmed by Borntrager's and fluorescence tests respectively, and saponins by persistent froth formation.

Aqueous stem extract of *Tinospora Cordiofolio (ASETC)* acquired with their look and yield percentage (gm)

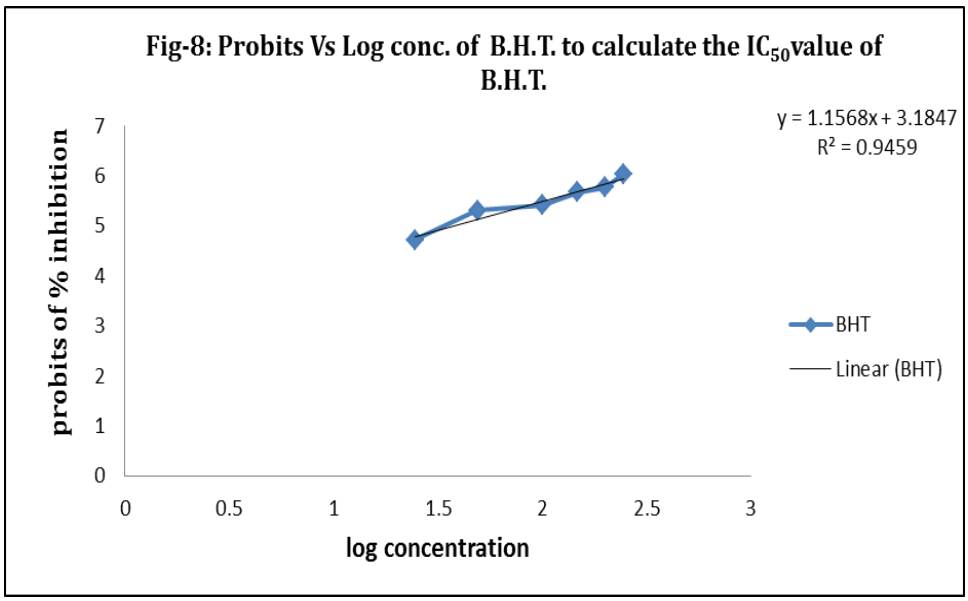
S.No.	Extracts	Colour	Consistency	%Yield (W/W)
1	Aqueous stem extract of *Tinospora Cordiofolio (ASETC)*	Dark Brown	Dried powdered	9.2 %

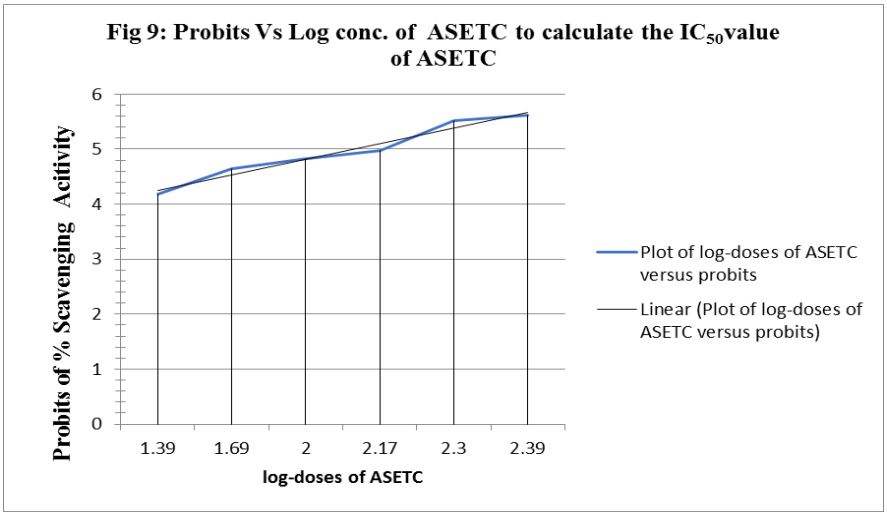
Phytochemical tests of Aqueous stem extract of *Tinospora Cordiofolio (ASETC)*.

Phytochemical constituents	Aqueous stem extract of *Tinospora Cordiofolio (ASETC)*
Alkaloids	+
Anthocyanins	_
Carbohydrates	+
Flavonoids	+
Glycosides	+
Reducing sugars	+
Saponin	+
Steroids	+
Terpenoids	+
Tannins	+
Proteins	+

Table 2: DPPH Scavenging Activity of B.H.T and ASETC.

S.No.	Groups	Concentration (µg/ml)	Log Conc.	%Scavenging Acitivity (Mean ± S.E.M)	Probits of % Scavenging Acitivity
1.	B.H.T	25	1.39	39.21 ± 0.031	4.71
		50	1.69	62.28 ± 0.015	5.30
		100	2.00	65.76 ± 0.020	5.14
		150	2.17	75.34 ± 0.075	5.66
		200	2.30	78.23 ± 0.042	5.76
		250	2.39	85.47 ± 0.013	6.03
2.	**ASETC**	25	1.39	20.38 ± 0.247	4.18
		50	1.69	35.52 ± 0.236	4.64
		100	2.00	42.42 ± 0.232	4.82
		150	2.17	48.52 ± 0.124	4.97
		200	2.30	65.45 ± 0.447	5.52
		250	2.39	71.42 ± 0.534	5.62





ACUTE TOXICITY STUDY

The test animals' general behavioural patterns, such as shaking, Diarrhea, salivation, respiration, changes in food or water intake, postural abnormalities, hair loss, sleep patterns, lethargy, or restlessness, did not significantly change after a 24-hour observation period. Furthermore, when compared to the control group, at doses of up to 250 mg/kg of the plant extract, there were no noticeable changes in physical appearance, such as eye colour, mucous membrane condition, salivation, effects on skin/fur, body weight, or presence of injury.

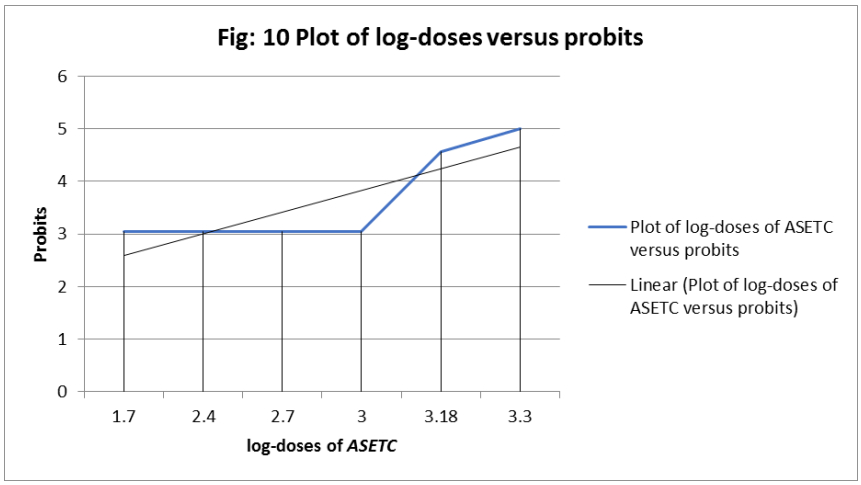
After intraperitoneal injection, the LD50 of the aqueous stem extract of Tinospora Cordiofolio (ASETC) in rats was found to be 2000 mg/kg. The table shows the outcomes of the plant extract administered intraperitoneally to rats. After intraperitoneal injections, the animals displayed ataxia and spasms of their abdominal muscles that lasted for many hours. They became drowsy and less responsive by the sixth hour. There was a correlation between the dosage level and the intensity of these effects. But most of the animals that survived had recovered from these symptoms by the twenty-fourth hour.

The intraperitoneal injection LD50 values reported here are 10–15 times higher than plant extract doses for the same nootropic effect.

Table 3: The lethal dosages of ASETC used to calculate the LD50 in rats (n=06) following intraperitoneal injection.

Group No.	Dose (mg/kg) of *ASETC*	Log Dose of *ASETC*	No. of Deaths	% Deaths	*Corrected %	Probits
1	50	1.7	0/6	0	4.16	3.04
2	250	2.4	0/6	0	4.16	3.04
3	500	2.7	0/6	0	4.16	3.04
4	1000	3	0/6	0	4.16	3.04
5	1500	3.18	2/6	33.33	33.33	4.56
6	2000	3.3	3/6	66.66	66.66	5.00

* % Formula Corrected: For 0 and 100% of fatalities, 100(0.25/n) for 0% dead, and 100(n-0.25/n) for 100%



100(0.25/n) for 0% mortality and 100(n-0.25/n) for 100% mortality were the formulas used to find the LD50. In experimental animals, ASETC (aqueous stem extract of Tinospora Cordiofolio) was found to be safe at doses between 200 and 400 mg/kg. Up to a dose level of 400 mg/kg body weight in rats, no adverse symptoms or death were noted, suggesting the extract's safety for additional pharmacological investigation. Doses equal to 1/10 or 1/5 of the LD50 (200 and 400 mg/kg) were used for the assessment of nootropic activity.

Additionally, a dose-response relationship was seen in the DPPH radical scavenging activity in the in-vitro antioxidant experiment, with activity rising as the content of Tinospora Cordiofolio Aqueous Stem Extract (ASETC) increased. However, the Aqueous stem extract of Tinospora Cordiofolio (ASETC) demonstrated reduced effectiveness ($P < 0.05$) in the DPPH radical scavenging assay when compared to BHT using ANOVA.

Table No. 4: Impact of ASETC (aqueous stem extract of Tinospora Cordiofolio) on rat EL utilizing MWM.

Treatment Schedule	EL (Sec) Day 11	EL (Sec) Day 12	EL (Sec) Day 13	EL (Sec) Day 14
Normal Control	95.23 ± 1.22	96.11 ± 1.23	96.48 ± 1.26	93.52 ± 1.24
Scopolamine (0.4 mg/kg)	132.24± 1.54	134.24± 1.12	136.14± 1.14	142.14± 1.84
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	90.85 ± 1.19	86.22 ± 1.22 *	81.21 ± 1.33 **	76.31 ± 1.18 ***
Scopolamine (0.4 mg/kg) + *ASETC* (400 mg/kg)	90.25 ± 1.22	83.12 ± 1.21 *	79.22 ± 1.22 **	80.22 ± 1.12 ***
Scopolamine (0.4 mg/kg) + Physostigmine (0.1 mg)	93.12 ± 1.11	88.31 ± 1.34*	84.28 ± 1.21**	76.12 ± 2.29 ***

* p <0.05, compared to control; ** p <0.01, compared to control; *** p <0.001, compared to control. Values are expressed as mean± SEM, with n = 6 in each group.

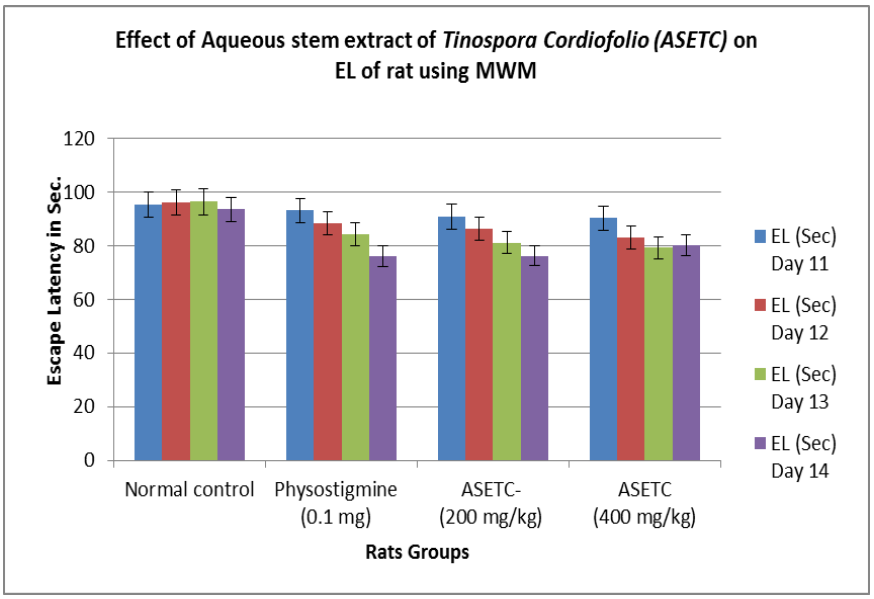


Figure No. 1: Effect of different extraction Escape Latency (EL) of rat using Morris Water Maze.

Table No. 5: Effect of Aqueous stem extract of *Tinospora Cordiofolio (ASETC)* on Time spent (sec) in target quadrant (15th day) TSTQ of Morris Water Maze (MWM) method using rat.

Treatment Schedule	TSTQ (Sec) (15^{th} day)
Normal Control	105.42 ± 2.23
Scopolamine (0.4 mg/kg)	55.21±1.56*
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	78.13±2.56***
Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	100.31±2.77***
Physostigmine (0.1mg/kg)-Standard	102.21±2.55***

Values are expressed as mean ± SEM, n=6 in each group; *p<0.05, compared to control ** p<0.01, compared to control. *** p <0.001, compared to control.

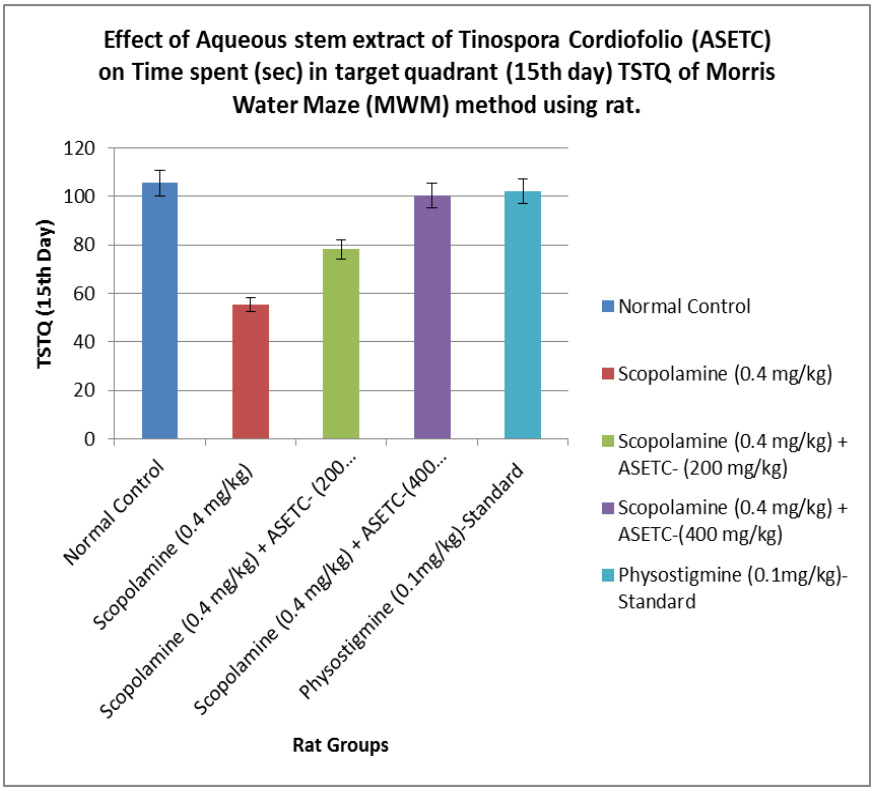


Figure No. 2: Impact of Aqueous stem extract of Tinospora Cordiofolio (ASETC) on the duration (in seconds) spent in the target quadrant on the 15th day of the Morris Water Maze (MWM) test in rats.

Table 6: Effect of Aqueous stem extract of Tinospora Cordiofolio (ASETC) on Locomotor activity of rats.

Treatment Schedule	Locomotor activity counts / 5 min
Normal Control	215.80 ± 1.24
Scopolamine (0.4 mg/kg)	155.14±1.42
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	200.24±1.22**
Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	210.22±1.17***
Physostigmine (0.1mg/kg)-Standard	340.25±2.41***

The data are presented as mean ± SEM, with a sample size of n=6 in each group. * indicates $p < 0.05$ compared to the control, ** indicates $p < 0.01$ compared to the control, and *** indicates $p < 0.001$ compared to the control.

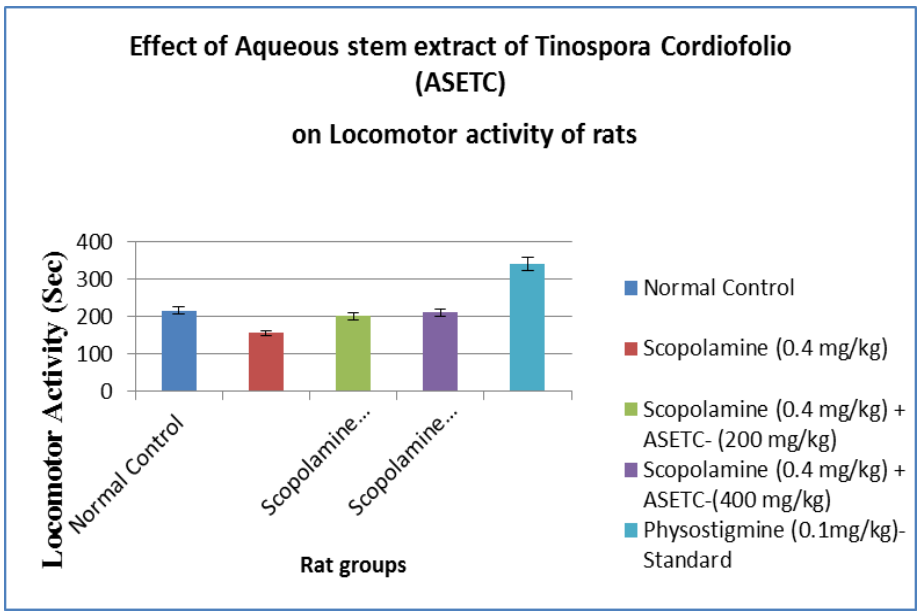


Figure No. 3: Effect of Aqueous stem extract of Tinospora Cordiofolio (ASETC) in on Locomotor activity in rats.

Table No. 7: Effect of Aqueous stem extract of Tinospora Cordiofolio (ASETC) on Brain Acetyl cholinesterase activity of rat.

Treatment Schedule	Acetyl cholinesterase activity (mol/lper min $\times 10^{-6}$/g of tissue)
Normal Control	0.061 ± 0.010
Scopolamine (0.4 mg/kg)	0.088±0.011
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	0.033±0.023***
Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	0.024±0.014***
Physostigmine (0.1mg/kg)-Standard	0.018±0.012***

Values are expressed as mean ± SEM, *n*=6 in each group; *p<0.05, compared to control ** p<0.01, compared to control. *** p <0.001, compared to control

Table No. 8: Effect of Aqueous stem extract of Tinospora Cordiofolio (ASETC) on Brain Acetyl cholinesterase activity of rat.

Treatment Schedule	Acetyl cholinesterase activity (mol/per min $\times 10^{-6}$/g of tissue)
Normal Control	0.061 ± 0.010
Scopolamine (0.4 mg/kg)	0.088±0.011
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	0.033±0.023***
Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	0.024±0.014***
Physostigmine (0.1mg/kg)-Standard	0.018±0.012***

Values are expressed as mean ± SEM, *n*=6 in each group; *p<0.05, compared to control ** p<0.01, compared to control. *** p <0.001, compared to control

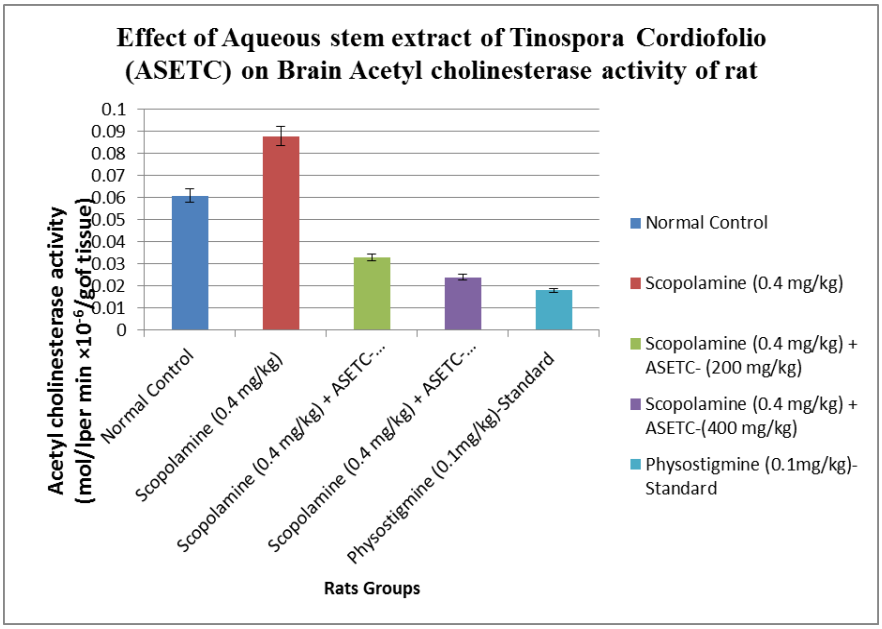


Figure No. 4: Impact of Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on Acetyl Cholinesterase Activity in Rat Brain.

Over the course of five minutes, rats given 10 mg/kg of normal saline orally showed longer times spent in closed arms and fewer times entering open arms. Rats given 1 mg/kg of diazepam orally, on the other hand, showed a notable (P < 0.001) drop in the number of entries and time spent in closed arms, but a considerable (P < 0.001) rise in the proportion of entry into open arms and the amount of time spent in them. When Tinospora Cordiofolio (ASETC) aqueous stem extract was administered orally at doses of 200 and 400 mg/kg, the percentage of entry into open arms and the amount of time spent in open arms increased significantly (P < 0.01).

In contrast to the vehicle-treated group, there were considerably (P < 0.01) fewer entry and shorter times spent in closed arms.

Additionally, compared to the control group, mice given physostigmine and Aqueous Stem Extract of Tinospora Cordiofolio (ASETC) for 15 straight days showed a marked decrease in brain acetylcholinesterase activity. When compared to the control group, rats given 400 mg/kg of ASETC (Aqueous Stem Extract of Tinospora

Cordiofolio) showed a highly significant decrease in brain acetylcholinesterase activity.

Table No. 9: Findings from Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on Open and Closed Entries.

S.No.	Treatments	No. of Entries		Time Spent (Sec)	
		Open Arm	Closed Arm	Open Arm	Closed Arm
1.	Normal Control	6.2 ± 1.2	22.2 ± 2.4	25.7 ± 3.8	120.3 ± 4.8
2.	Scopolamine (0.4 mg/kg)	12.5 ± 1.1***	14.2 ± 1.3***	37.7 ± 2.7**	160.2 ± 4.6
3.	Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	9.3 ± 1.4**	16.2 ± 1.8**	34.2 ± 3.8**	142.7 ± 3.6**
4.	Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	8.6 ± 1.6**	18.3 ± 1.6**	36.2 ± 3.1**	138.5 ± 3.9**
5.	Piracetam 200 mg/kg i.p. + scopolamine 1 mg/kg i.p.	7.4 ± 1.1 *	20.5 ± 1.8**	28.3 ± 3.8*	111.6 ± 4.2**

p<0.05, compared to control; **p<0.01, compared to control; ***p <0.001, compared to control; values are expressed as mean±SEM, n=6 in each group.

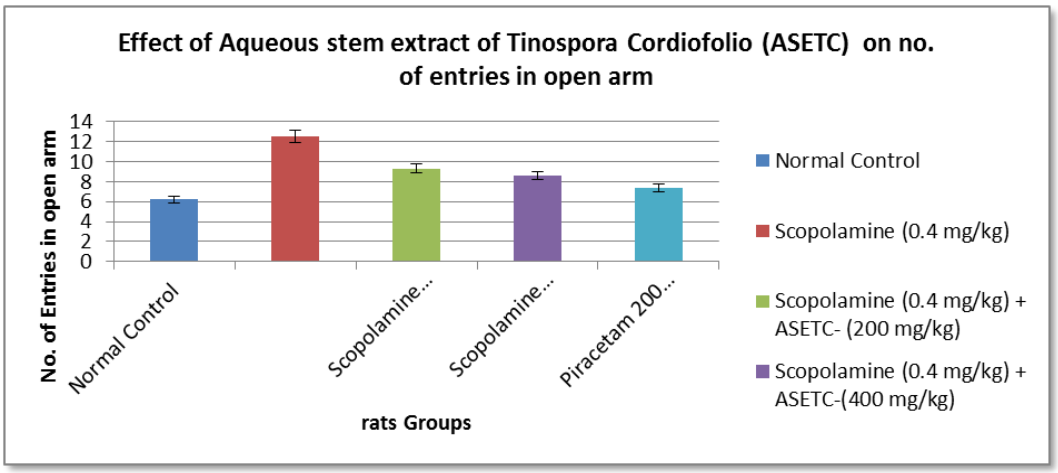
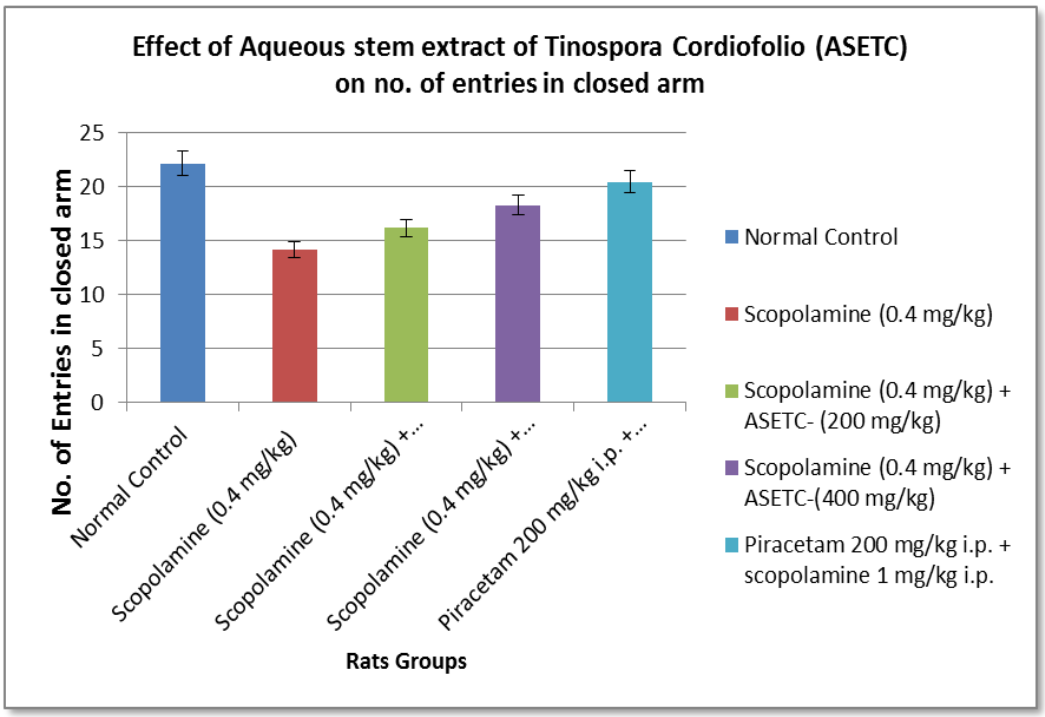


Figure No. 5: Impact of Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on the number of entries in the open arm.



FigureNo.6: The effect of Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on the quantity of entries within the closed compartment.

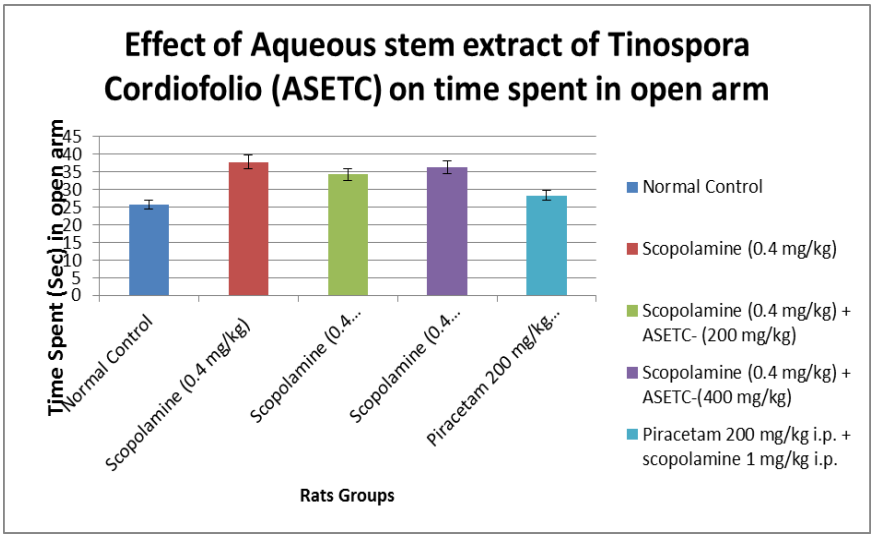


Figure No. 7: Effect of Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on the Length of Time Spent in an Open Arm.

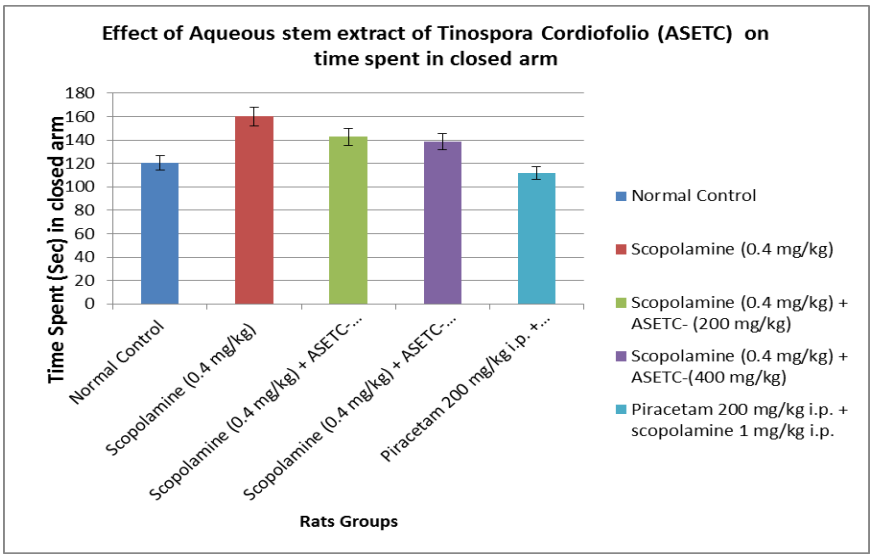


Figure No. 8: Effect of the Tinospora Cordiofolio Aqueous Stem Extract (ASETC) on the amount of time spent in the arm cage.

Table 10: The impact of Tinospora Cordiofolio aqueous stem extract (ASETC) on the serum biochemical parameters of rat brain homogenate.

Animal Groups	LPO (nmol/mg)	GSH (mg/g)	SOD (U/mg)	CAT (U/mg)
Normal Control	0.98 ± 0.031	2.98 ± 1.232	5.23±2.21	32.45±0.16
Scopolamine (0.4 mg/kg)	6.67 ± 0.029**	0.75 ± 1.33	1.12±1.12	6.24±0.12*
Scopolamine (0.4 mg/kg) + *ASETC*- (200 mg/kg)	4.22 ± 0.021**	1.45 ± 1.34*	2.78±2.23#	12.32±0.047
Scopolamine (0.4 mg/kg) + *ASETC*-(400 mg/kg)	3.32 ± 0.067*	2.17 ± 0.23	3.73±2.46#	22.42±0.15
Piracetam 200 mg/kg i.p. + scopolamine 1 mg/kg i.p.	2.45 ± 0.21**	2.51 ± 0.32*	3.94±1.27#	24.71±0.23*

Each point represents the mean ± SEM. (n = 6 rats per group), #p<0.05 statistically significant when compared with normal saline group. *p<0.05 statistically significant when compared with Scopolamine (0.4 mg/kg) group.

Rats' scopolamine-induced amnesia was examined histologically.

The histological examination of rats' scopolamine-induced amnesia is shown in a Table and a Figure. The negative control group (shown in Figure B) displayed evidence of both gliosis and vascular and neuronal degeneration, while the control rats showed neuronal degeneration alone. This is illustrated in the histological part of the figure. In contrast, gliosis, neuronal

degeneration, and vascular and gliosis were all less prevalent in the usual treatment group, low- and high-dose groups, and compared to the negative control. Of all the groups, Group 2, which received scopolamine, had the greatest pathological changes.

Remarkably, when compared to the control, negative control, and standard treatment groups, both low and high doses of the Aqueous Stem Extract of Tinospora Cordifolia (ASETC) demonstrated positive regeneration ratings.

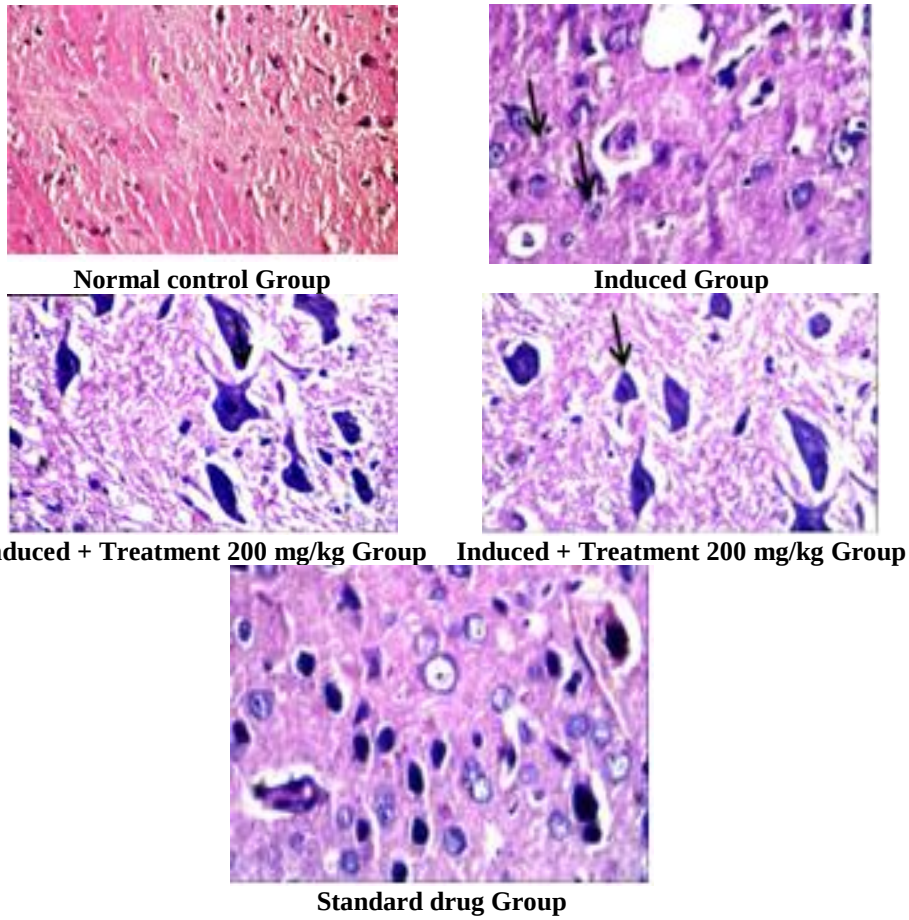


Figure 9: Shows a histological analysis of brain tissues from rats that were given scopolamine to produce amnesia.

Histological analysis of the brain tissue of rats treated with scopolamine shows changes in the areas of the hippocampus, as well as in the prefrontal cortex.

A) Normal control: Section showing only stress amount of neuronal degeneration. B) Negative control: Section showing vascular degeneration, neuronal degeneration and glial cell infiltration (black arrow). C) Standard treatment: Section showing vascular degeneration, neuronal degeneration glial cell infiltration (black arrow) less as compared with negative control. D) Low dose of extract: Section showing vascular degeneration, neuronal degeneration glial cell infiltration (black arrow) less as compared with negative control. E) High dose of extract: Section showing vascular degeneration, neuronal degeneration glial cell infiltration (black arrow) less as compared with negative control.

Table 11: Histopathology of the brain tissues in scopolamine-induced amnesia in rats.

Group	Vascular degeneration	Neuronal degeneration	Glial cell infiltration
Normal control: (Normal saline, p.o.)	0	+	0
Negative control: Scopolamine (1 mg/kg, p.o.)	+++	+++	++
Low dose of extract (100 mg/kg, p.o.) + scopolamine (1 mg/kg i.p.)	++	++	+
High dose of extract (400 mg/kg, p.o.) + scopolamine (1 mg/kg, i.p.)	+	++	+
Standard treatment: Piracetam (200 mg/kg, i.p.) + scopolamine (1 mg/kg, i.p.)	++	++	+

DISCUSSION

The present study was designed to evaluate the nootropic potential of *Tinospora cordifolia* using a combination of behavioural, biochemical, and toxicological assessments in rodent models. Our findings provide substantial evidence supporting the cognitive-enhancing effects of both aqueous and ethanolic extracts of *T. cordifolia* stems, aligning with traditional Ayurvedic claims of its use as a Medhya Rasayana.

Behavioural data obtained from the Elevated Plus Maze (EPM), Passive Avoidance Test (PAT), and Morris Water Maze (MWM) clearly demonstrated that *T. cordifolia* significantly improved learning and memory in a dose-dependent manner. Notably, the higher doses (400 mg/kg) of both extracts produced effects comparable to piracetam, a standard nootropic agent, indicating that the plant extract may modulate similar neurochemical pathways involved in cognition.

The improvement in behavioural performance was corroborated by biochemical analyses, which showed a significant reduction in brain malondialdehyde (MDA) levels, an indicator of lipid peroxidation and oxidative stress. Simultaneously, there was a marked increase in antioxidant enzyme activities such as superoxide dismutase (SOD) and catalase (CAT). These results suggest that the cognitive enhancement observed is at least partly attributable to the antioxidant properties of *T. cordifolia*, which may protect neuronal integrity and function.

Another important finding was the dose-dependent inhibition of acetylcholinesterase (AChE) activity in the brain. The cholinergic system plays a pivotal role in learning and memory, and the inhibition of AChE leads to increased availability of acetylcholine at synapses, enhancing cognitive function. This mechanism is similar to that of many clinically approved drugs for Alzheimer's disease, further supporting the therapeutic relevance of *T. cordifolia*.

Toxicological assessments confirmed that the extracts were well tolerated, with no signs of acute toxicity or adverse behavioural effects, even at higher doses. This safety profile adds to the feasibility of developing *T. cordifolia* as a natural cognitive enhancer.

The results of this study are consistent with previous reports that describe the neuroprotective, adaptogenic, and anti-inflammatory properties of *T. cordifolia*. However, while these findings are promising, certain limitations must be acknowledged. The study was limited to preclinical rodent models, and although these models are widely accepted, they may not fully predict clinical efficacy in humans. Moreover, while antioxidant and cholinergic mechanisms were explored, other potential pathways—such as anti-inflammatory or neurotrophic factor modulation—remain to be investigated.

Future studies should aim to isolate and characterize the active phytoconstituents responsible for the observed effects, explore additional molecular targets, and ultimately assess efficacy and safety through well-designed clinical trials. Understanding the pharmacokinetics and bioavailability of the active compounds will also be critical for therapeutic application.

CONCLUSION

The present study demonstrates that *Tinospora cordifolia* possesses significant nootropic activity, as evidenced by improvements in learning and memory performance in various behavioural paradigms including the Elevated Plus Maze, Passive Avoidance Test, and Morris Water Maze. Both aqueous and ethanolic stem extracts exhibited dose-dependent cognitive enhancement, with higher doses showing effects comparable to the standard nootropic agent, piracetam.

Biochemical analysis revealed a reduction in oxidative stress markers and inhibition of acetylcholinesterase activity in brain tissue, suggesting that the observed cognitive benefits may be attributed to the extract's antioxidant and cholinergic modulating properties. Additionally, toxicological assessments confirmed the safety of the extracts at tested doses, supporting their potential for therapeutic use.

These findings validate the traditional Ayurvedic claims regarding *T. cordifolia* as a Medhya Rasayana (brain tonic) and highlight its promise as a natural, plant-based nootropic agent. Further studies, including clinical trials and molecular investigations, are warranted to elucidate the precise mechanisms of action and to establish its efficacy in human subjects with cognitive impairments or neurodegenerative conditions.

Conflict of interest

Authors declare that there is no conflict of interest.

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