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In vitro and *in vivo* Pharmacological Studies of Leaves of *Staurogyne argentea* Wall.

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Abstract

Staurogyne argentea Wall. (Family: Acanthaceae) is an important medicinal plant that has many traditional uses in tribal areas of Bangladesh. The current study emphasizes the pharmacological investigations of *n*-hexane, chloroform and aqueous soluble fractions of ethanol extract of leaves of *S. argentea* to justify the traditional uses of this plant species in Bangladesh. *In vitro* anti-inflammatory activity of *S. argentea* was confirmed by inhibition of egg albumin denaturation and erythrocyte membrane stabilizing methods. In both experiments, the aqueous fraction at concentration of 160 µg/ml exhibited significant inhibition of egg albumin denaturation by 76.91% with IC_{50} value of 24.22 µg/ml compared to standard Diclofenac-Na. In membrane stabilization assay, the aqueous fraction showed prominent anti-inflammatory activity by protecting the human erythrocyte membrane against hypotonic solution induced lysis. In addition, among all the aqueous fraction at 100 µg/ml also showed maximum antioxidant potential via the inhibition of DPPH scavenging by 75.05% (IC_{50}= 42.92 µg/ml). The test materials were subjected to evaluate for the anti-diabetic activity by both *in vitro* starch iodine method as well as by oral glucose tolerance test in Swiss albino mice. In both experiments, the aqueous fraction showed maximum blood glucose lowering activity which is comparable to standard glibenclamide. The chloroform fraction (Conc. 500 mg/kg bw) exhibited moderate inhibition of both acetic acid-induced writhing reflex and yeast-induced pyrexia in mice. During sedative activity screening, different solvent fractions produced mild to moderate activity in comparison with standard diazepam. These findings revealed that *S. argentea* is a valuable source of bioactive compounds with diverge pharmacological actions, which validates its use in Bangladesh folk medicinal practices.

Key words: *Staurogyne argentea*, anti-inflammatory, antioxidant, anti-diabetic, analgesic, anti-pyretic, sedative.

Introduction

Medicinal plants are prominent sources of bioactive compounds that can serve as leads in the development of new drugs (Ahmed *et al*., 2021) (Achour *et al*., 2022; Veeresham 2012). Acanthaceae is a big family of flowering plants with about 2500 species and 250 genera all over the world. Chemically this family contained important secondary metabolites such as glycosides, flavonoids, alkaloids, triterpenoids, naphthoquinone (Awan and Aslam 2014). These compounds play an important role in many biological reactions and work against many lethal diseases. Traditionally the most important part used in Acanthaceae family is leaf which are used externally for wounds. According to the published reports, this family possess antioxidant, antifungal, cytotoxic, antipyretic, anti-inflammatory, hepatoprotective and immunomodulatory potentials (Awan and Aslam 2014). This medicinal importance's attracted the researchers to explore the various aspects of Acanthaceae family (Khan *et al.*, 2017).

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Staurogyne argentea Wall. is known locally as "Ranga Jari". *S. argentea* is a subshrub and grows primarily in the wet tropical biome. The plant is traditionally important and is reported to have significant effects in the management of mental disorder in Bangladesh (Uddin and Zidorn 2020**)**. Tribal people used the leaf juice of this plant for jaundice, cancer, gout and body pain (Alam *et al*., 2022). In the present study, the selection of plant for evaluation was based on its traditional uses. As far we know, no scientific work on this plant has been accomplished yet. If the outstanding result is obtained from this plant, it can be used as potential source to discover new and effective lead molecule. Therefore, the objective of this present study was focused on the chemical and pharmacological investigations of various solvent fractions of ethanol extract of *S. argentea* leaf to explore the possibility of developing new drug candidates from this plant species.

Materials and Methods

Plant collection and identification: Fresh leaves of *S. argentea* were collected from Sitakunda, Chattogram, in September, 2019 which is the flowering period of the plant. It was taxonomically identified by the experts of Bangladesh Forest Research Institute (BFRI) Herbarium, Chattogram.

Extraction and fractionation: After proper washing, the leaves were shade dried for several days. The dried leaves were subjected to coarse powder through a grinding machine. For hot extraction, about 200 g of dried leaf powder of *S. argentea* was macerated with 900 ml of ethanol (99%) in a Soxhlet apparatus (Quickfit, England). A gummy concentrate designated as ethanolic crude extract of *S. argentea* was obtained after evaporation of the solvent. According to modified Kupchan partitioning protocol (VanWagenen *et al*., 1993), about 15 g of ethanolic crude extract was partitioned with different organic solvents to obtain *n*-hexane, chloroform and aqueous soluble fractions of *S. argentea*.

Chemicals and reagents: Ascorbic acid, acarbose, glibenclamide, aspirin, diclofenac-Na, paracetamol and diazepam were obtained from different pharmaceutical companies of Bangladesh. All chemicals and solvents used in this study were of analytical grade and purchased from Merck, Germany.

Experimental animal: Swiss albino mice (20-25 g) of either sex were purchased from Bangladesh Council of Scientific and Industrial Research (BCSIR), Chattogram, Bangladesh. The animals were allowed to have free access to standard laboratory feed and water. They were kept at room temperature (26 ±2°C) with 12 h light/dark cycle for 1 week to acclimatize the laboratory conditions before starting the experiment. The food delivered was withdrawn 18 h before the experiment but allowed free access of water. All experiments were carried out according to the standard guidelines.

Preliminary phytochemical investigations: All the solvent fractions of the crude ethanol extract of *S. argentea* leaf were subjected to explore plant secondary metabolites according to the published method (Ibrahim *et al*., 2018)

In vitro anti-inflammatory activity: Egg albumin denaturation inhibition assay (Ibrahim *et al*., 2018) was employed to determine the *in vitro* anti-inflammatory activity of *S. argentea* using aspirin as reference drug. About 0.2 ml of egg albumin (from fresh hen's egg) and 2.8 ml of phosphate buffered saline (pH 6.4) were added to 2 ml of varying concentrations of different plant samples so that final concentrations become of 10, 20, 40, 80 and 160 µg/ml, respectively. All the reaction mixtures (pH = 5.6±0.2) were incubated at 37±2 ºC in a BOD incubator (Labline Technologies). The absorbance was measured at 660 nm (Saleem *et al*., 2011). The percent inhibition of protein denaturation was calculated by using the following formula:

$$\% \text{ inhibition} = \frac{A_{control} - A_{test}}{A_{control}} \times 100\%$$

Here, A= Absorbance for respective group.

Erythrocyte membrane stabilizing activity: Membrane stabilizing activity of the extractives was determined by using the method of hypotonic solution-induced haemolysis of human erythrocyte membranes. The method was developed by Shinde *et al*. (1999) and modified by Rahman *et al.* (2011) with minor modifications.

Antioxidant activity: Antioxidant activity was conducted by DPPH free radical scavenging method (Islam *et al.*, 2019) with minor modification using ascorbic acid as reference standard.

α-amylase inhibition assay: In vitro evaluation of antidiabetic activity was performed by *α*-amylase inhibition assay (Komaki *et al*., 2003). Briefly, 320 µl of different solvent fractions of ethanol extract of *S. argentea* leaf is added with α-amylase solution mixed with Tris-HCl buffer (pH 6.8). Following 20 min incubation at 37ºC, starch solution (0.1%) was added and the mixture was again incubated at the same condition, after which 0.01% acidic iodine solution was mixed. Absorbance was measured at 578 nm. The percent (%) inhibition of α-amylase activity by each test sample was compared with standard acarbose activity and was calculated as:

$$\%\ \text{inhibition} = \frac{A_{\text{sample}} - A_{\text{control}}}{A_{\text{blank}} - A_{\text{control}}} \times 100\%$$

Here, A= Absorbance for respective group.

In vivo pharmacological studies

Hypoglycemic activity: Oral glucose tolerance test (Haque *et al*., 2019) was used to examine the hypoglycemic activity of *S. argentea* in mice. Briefly, plant sample/drug was orally administered to mice of all test groups followed by oral administration of 10% glucose solution. Blood glucose level was monitored prior to administration of extract/drug (at 0 min) and then at 1, 2 and 3 h after the glucose load. Hypoglycemic potential of *S. argentea* can be estimated by the equation below:

$$\%\ \text{reduction in } BG = \frac{BG_{\text{control}} - BG_{\text{test}}}{BG_{\text{control}}} \times 100\%$$

Where, BG = Average blood glucose level for each group.

Analgesic activity: To determine the analgesic activity of plant extractives *of S. argentea*, the acetic acid induced writhing in mice method (Koster *et al*., 1959; Islam *et al*., 2019) was selected. About thirty min prior to the administration of acetic acid (0.7%, 10 ml/kg bw, i.p.), control and standard group received vehicle (1% Tween 80 in water, p.o.) and diclofenac sodium (25 mg/kg bw p.o.), respectively, while the test groups received plant samples (500 mg/kg bw) orally. The number of writhes by each group was recorded for 30 min after acetic acid administration in mice. Analgesic activity was calculated as follows:

$$\%\ \text{inhibition of writhing} = \frac{N_{\text{control}} - N_{\text{test}}}{N_{\text{control}}} \times 100\%$$

Where, N = Mean number of writhing for each group.

Antipyretic activity: For antipyretic activity test by yeast induced pyrexia method (Bashar *et al*., 2014), experimental mice were divided into 4 groups containing 3 in each group. Subcutaneous injection of Brewer's yeast can augment the prostaglandin synthesis and considered as an important test for the identification of antipyretic effect of plant extracts (Khan *et al*., 2009). Rectal temperature was recorded at 0, 1, 2 and 3 h after oral administration of plant sample at a dose of 500 mg/kg bw.

Sedative activity: Sedative activity of *S. argentea* was determined by both hole cross test and open field test following the published method in mice (Ali *et al*., 2014).

Statistical analysis: All data were expressed as mean ± standard error of mean (SEM) and one-way ANOVA analysis was used to determine the significant difference between the control group and experimental groups. The difference was considered significant at $p<0.05$.

Results and Discussion

Phytochemical analysis exposed that the aqueous soluble fraction of *S. argentea* possesses glycosides, alkaloids, steroids, saponins, tannins, amides, gums and flavonoids. Whereas, the chloroform fraction contained all these secondary metabolites except saponins. And the *n*-hexane fraction contained

alkaloids, glycosides, steroids, tannins, gums and amides. These phytochemicals are common in the plants and possess significant biological importance (Lee *et al.*, 2017).

In this study, the *in-vitro* anti-inflammatory effect of *S. argentea* was evaluated against the denaturation of egg albumin. As shown in figure 1, all the plant samples showed significant ($p<0.05$) and concentration-dependent repressing action against the denaturation of egg albumin. Diclofenac-Na was used as a reference standard in the experiment at the same concentration range which also exhibited concentration-dependent inhibition of protein denaturation. The aqueous fraction exhibited the highest (76.91%) inhibition of albumin denaturation at 160 µg/ml concentration, whereas the reference standard diclofenac-Na showed 89.22% inhibition of albumin denaturation at same concentration. The half maximal effective concentration (EC_{50}) calculated for *n*-hexane, chloroform and aqueous fractions of *S. argentea* were 95.63, 66.78 and 24.22 µg/ml, respectively, whereas for diclofenac-Na the EC_{50} value was 8.05 µg/ml. Therefore, *S. argentea* might be considered as a rich source of anti-inflammatory agent.

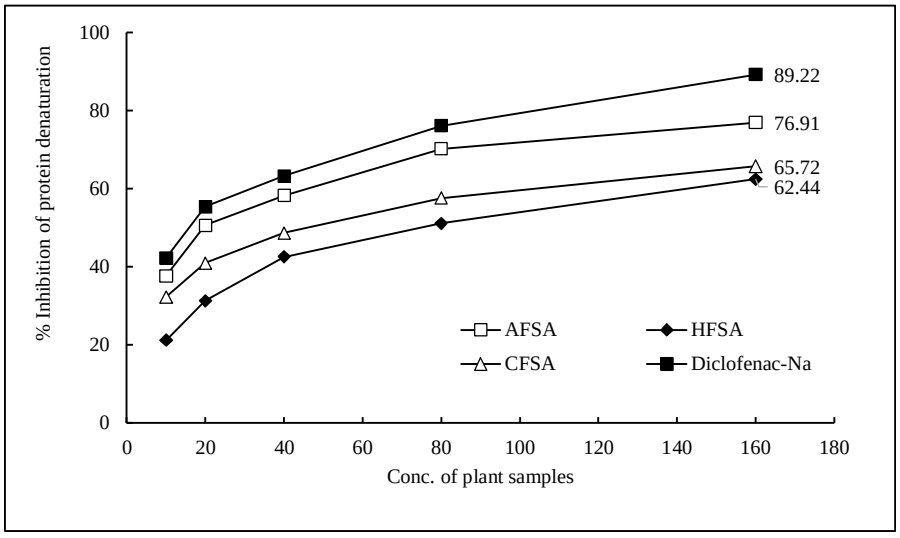

Figure 1. *In vitro* anti-inflammatory activity of different solvent fractions of *S. argentea*.

Table 1. Erythrocyte membrane stabilizing activity of different solvent fractions of *S. argentea.*

Test groups	Concentrations (µg/ml)	% Inhibition of haemolysis	IC_{50} (µg/ml)
Aspirin	1000	77.7	15.65
	500	63.63	
HFSA	1000	55.02	279.71
	500	51.53	
CFSA	1000	59.30	52.45
	500	54.39	
AFSA	1000	66.09	28.49
	500	57.81	

Here, HFSA = *n*-hexane soluble fraction of ethanol extract of *S. argentea*; CFSA= Chloroform soluble fraction of ethanol extract of *S. argentea*; AFSA= Aqueous soluble fraction of ethanol extract of *S. argentea.*

In vitro anti-inflammatory activity of *S. argentea* was further confirmed by human erythrocyte membrane stabilizing assay. Here, both experimental doses of 500- and 1000 mg/kg bw of various solvent fractions of *S. argentea* leaf showed significant (p<0.05) activity against lysis of human erythrocyte membrane induced by hypotonic solution. At the dose of 1000 µg/ml, the aqueous, chloroform and *n*-hexane fractions showed significant inhibition of haemolysis by 66.09%, 59.30% and 55.02%, respectively as compared to standard aspirin which exhibited 77.7% inhibition of haemolysis (Table 1). Stabilization of RBC membrane leads to the inhibition of outflow of serum proteins and fluids into the tissues caused by inflammatory mediators (Yesmin *et al*., 2020). Phytochemical screening showed that the plant extract contains flavonoids which have been reported to possess potent anti-inflammatory property (Maleki *et al*., 2019). The anti-inflammatory activity of *S. argentea* is probably due to the inhibitory effect on enzymes involved in the synthesis of arachidonic acid (Yesmin *et al*., 2020).

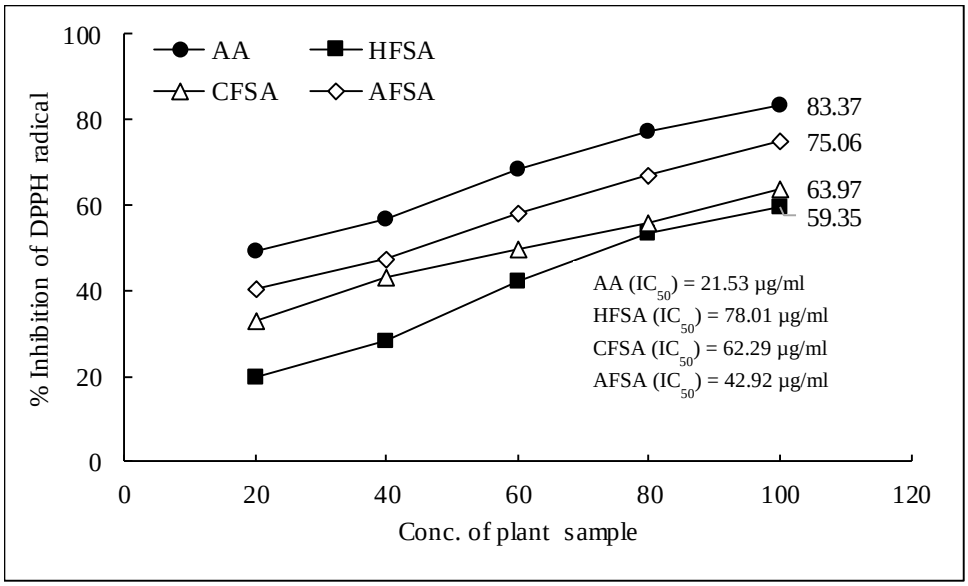

Figure 2. DPPH radical scavenging activity of different solvent fractions of *S. argentea*.

Compared to synthetic antioxidants, antioxidants from natural origin have received substantial consideration because of their minimal side effects (Lourenco *et al*., 2019). The results (Figure 2) of DPPH assay established the free radical scavenging ability of *S. argentea*. As shown in figure 2, the DPPH quenching ability of test samples was concentration-dependent and the *n*-hexane, chloroform and aqueous fractions at 100 µg/ml presented over 50% inhibition of DPPH radical which is evident from 59.35% 63.97% and 75.06% inhibition, respectively and the IC_{50} values are 78.01, 62.29 and 42.92 µg/ml, respectively. The profound antioxidant effect of test samples was attributable to the occurrence of significant amount of phenol compounds and flavonoid contents in these samples (Anjum *et al*., 2022). Thus, *S. argentea* contained antioxidant components which are appropriate to develop drugs for the prevention of human diseases related to oxidative stress.

During α-amylase inhibition assay, dose-dependent increase in the percentage inhibitory activity against α-amylase enzyme was noted. Among all, the aqueous fractions at a concentration of 400 µg/ml exhibited significant inhibitory activity with the value of 79.55%, which is comparable to

that of standard acarbose (94.85%) (Figure 3). IC_{50} for *n*-hexane, chloroform and aqueous soluble fractions of *S. argentea* were 344.77, 137.59 and 64.19 µg/ml, respectively, whereas for reference standard acarbose, the IC_{50} value was 27.56 µg/ml. α-amylase catalyzes the breakdown of starch into maltose. Therefore, this assay is useful for the screening of drugs having antidiabetic activity.

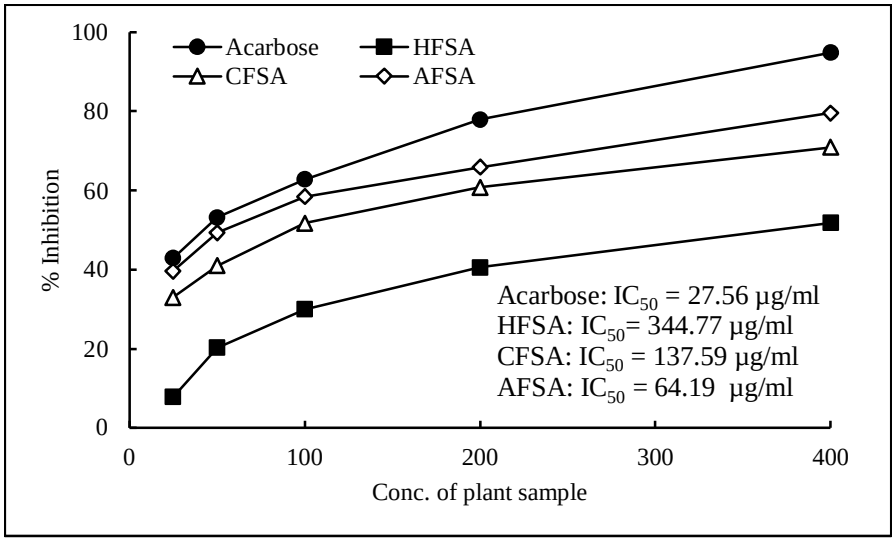

Figure 3. α-amylase inhibitory activity of different solvent fractions of *S. argentea*.

Table 2. Hypoglycemic activity of different solvent fractions of *S. argentea.*

Test groups	Plasma level of glucose mean (mmol/l) ± SEM				% Lowering of BGL	t-test (p-value)
	0 min	30 min	60 min	120 min		
Control	7.9±0.14	7.5±0.21	7.3±0.14	7±0.07	--	--
Glibenclamide	8.9±0.08	7.7±0.12	6.9±0.15	3.65±0.15	47.86	20.20 ($p<0.05$)
HFSA	7.33±0.29	6.46±0.18	5.7±0.14	4.83±0.11	30.95	16.78 ($p<0.05$)
CFSA	6.87±0.22	6.07±0.22	5.47±0.18	4.6±0.07	34.29	23.99 ($p<0.05$)
AFSA	7.67±0.08	5.16±0.20	4.77±0.18	4.33±0.15	36.67	15.72 ($p<0.05$)

Values are expressed as mean ± SEM (n=3). $p<0.05$ significant when compared with control; BGL = Blood glucose level.

In order to circumvent the untoward effects related with synthetic drug, finding a better hypoglycemic agent from natural sources is so desirable (Khatun *et al.*, 2014). The current study deals with a preliminary work about the blood glucose lowering effect of *S. argentea* in mice by oral glucose tolerance test. The test materials of *S. argentea* showed a notable hypoglycemic action in experimental animals which continue up to 2 h compared to standard glibenclamide. Oral administration of plant samples of *S. argentea* at a dose of 500 mg/kg bw generated various outcomes of blood glucose levels in mice (Table 2). In oral glucose tolerance test, different solvent fractions of *S. argentea* significantly ($p<0.05$) and dose-dependently reduced blood glucose levels in glucose-loaded mice when compared to standard glibenclamide. The *n*-hexane, chloroform and aqueous fractions lowered blood glucose level in mice by 30.95%, 34.29% and 36.67%, respectively (Table 2). Therefore, the hypoglycemic potential of *S. argentea* may be attributed to the bioactive phytoconstituents such as flavonoids, tannins, and alkaloids (Khatun *et al.*, 2014).

Here, acetic acid-induced writhing test was utilized to determine the analgesic effect of *S. argentea*. Intra-peritoneally administered acetic acid elevates the production of prostaglandin which ultimately leads to inflammation in mice (Haque *et al*., 2020). The plant extracts noticeably repressed the number of abdominal writhes in mice (Table 3). At the dose of 500 mg/kg bw the *n*-hexane, chloroform and aqueous fractions of ethanol extract of *S. argentea* leaf exhibited inhibition of writhing reflex by 26.23%, 68.30% and 62.30%, respectively in comparison with the reference standard diclofenac-Na (25 mg/kg) that exhibited 78.68% inhibition of writhing reflex. The results suggest that *S. argentea* may contain bioactive components that are well reported to exhibit pain relieving actions via the inhibition of prostaglandin production (Saleh *et al.*, 2019). Additional laboratory studies are indispensable to find out the accountable mechanisms.

Table 3. Analgesic effect of different solvent fractions of ethanol extract of *S. argentea* leaf in mice.

Clinical groups	No. of mice	BW (gm)	WC	MW	% Writhing	% WI	No. of Writhing	SD	SEM	t-test (*p*-value)
Control	1	25	56	61	100	0	305	5	3.536	-
	2	22	61							
	3	24	66							
Standard	1	26	12	13	21.31	78.69	65	1.732	1.225	12.827 (p<0.05)
	2	28	15							
	3	27	12							
HFSA	1	28	45	45	73.77	26.23	225	1	0.707	4.437 (p<0.05)
	2	22	46							
	3	20	44							
CFSA	1	22	20	19.33	31.69	68.30	96. 67	1.15	0.817	11.481 (p<0.05)
	2	22	18							
	3	20	20							
AFSA	1	24	22	23	37.70	62.30	115	1	0.707	10.538 (p<0.05)
	2	22	23							
	3	20	24							

* Standard = Diclofenac-Na, BW = Body weight. WC = Writhing count, MW = Mean writhing, WI = Writhing inhibition, No. of writhing = (MW×5 ± SEM), SEM = Standard error of mean

Table 4. Antipyretic activity of different solvent fractions of ethanol extract of *S. argentea* leaf in mice.

Test group	Dose (mg/kg)	Rectal temperature in ºF after 24 h of yeast injection				
		-18 h	0 h	1 h	2 h	3 h
Control	10	98.60±0.13	101.24±0.07	101.17±0.04	100.70±0.15	100.40±0.13*
Standard	150	98.66±0.26	101.27±0.21	99.30±0.68	98.40±0.44*	97.76±0.15*
HFSA	500	99.50±0.25	101.27±0.11	99.14±0.13*	98.90±0.19*	98.36±0.07*
CFSA	500	99.26±0.32	101.40±0.14	98.90±0.37*	98.12±0.07*	97.22±0.19*
AQSA	500	98.72±0.26	101.03±0.39	98.42±0.13*	98.12±0.26*	97.34±0.13*

Values are expressed as mean ± SEM (n=3). p<0.05 significant when compared with control

Table 5. Sedative activity of different solvent fractions of ethanol extract of *S. argentea* leaf in mice.

Clinical groups	Hole cross test	Open field test
	Mean no of hole crossed ± SEM	Mean no of field crossed ± SEM
Control (DDW)	9±0.71	95.00 ±1.22
Diazepam	3.33±0.40*	40.33±1.08*
HFSA	9.67±0.41	112.33±1.78*
CFSA	5.67±0.41*	77±0.71*
AFSA	4.67±0.40*	75.33±1.48*

Values are expressed as mean ± SEM (n=3). $p<0.05$ significant when compared with control

In this test, different solvent fractions (*n*-hexane, chloroform and aqueous) of *S. argentea* at a dose of 500 mg/kg bw significantly ($p<0.05$) attenuated yeast-induced hyperthermia in mice up to 3 h of administration. Throughout the experiment, the *n*-hexane fraction reduced temperature up to 2.91°F and the chloroform fraction decreased temperature up to 4.18°F (Table 4), whereas, the aqueous fraction decreased temperature up to 3.69°F. It was found that the anti-pyretic properties of the plant extracts were comparable to that of the standard paracetamol which showed significant antipyretic activity starting after 0 h to 3h (3.51°F). The result of preliminary phytochemical screening revealed the presence of bioactive components such as flavonoids, alkaloids in the test materials of *S. argentea*. Studies have revealed that alkaloids can block the synthesis of prostaglandin (Aryal *et al*., 2022; Backhouse *et al.*, 1994), finally dropping raised body temperature in animals. Likewise, flavonoids have been implicated as an antipyretic agent by suppressing TNF-α (Ginwala *et al*., 2019). The antipyretic properties of *S. argentea* could possibly be associated with the flavonoids and alkaloids detected in the plant extract.

Sedative activity was evaluated in mice model by both hole cross test and open field test. The aqueous fractions significantly reduced the hole cross ability of experimental animals and the number of hole cross (4.67) is very close to that of the positive control group (3.33). The chloroform fraction moderately reduced the hole cross ability of experimental mice and *n*-hexane fraction did not show prominent activity (Table 5). In the open field test, administration of plant extracts in mice exhibited substantial increase in number of squares crossed in comparison to standard and control (Table 5). Although, the aqueous and chloroform fractions showed moderate activities, but *n*-hexane fraction showed no activity compared to standard diazepam. The sedative action of *S. argentea* may be related with phytochemicals such as saponins and flavonoids (Mikail *et al*., 2019).

Conclusion

Different solvent fractions of ethanol extract of *S. argentea* leaf were found to have good anti-inflammatory activity and can also protect the lysis of erythrocyte membrane induced by hypotonic solution. The plant samples also exhibit significant hypoglycemic, analgesic, antipyretic and sedative activities in mice model. These findings validate the traditional uses of *S. argentea* in tribal areas of Bangladesh. However, further study may be carried out to isolate and characterize the active principles of the plant and to elucidate the exact mechanisms of action.

References

Achour, S., Chebaibi, M., Essabouni, H., Bourhia, M., Ouahmane, L., Salamatullah, A.M., Aboul-Soud M.A.M. and Giesy, J.P. 2022. Ethnobotanical study of medicinal plants used as therapeutic agents to manage diseases of humans. *Evid.-based Complement. Altern. Med.* 2022, Article ID 4104772, 8 pages.

Ahmed, S.R., Rabbee, M.F., Roy, A., Chowdhury, R., Banik, A., Kubra, K., Chowdhury, M.M.H. and Baek, K.H. 2021. Therapeutic promises of medicinal plants in Bangladesh and their bioactive compounds against ulcers and inflammatory diseases. *Plants (Basel)* **10**, 1348.

Alam, M.S., Rahman, M.M., Hossain, M.K. and Ray, T.K. 2022. Medicinal plants used by the tribal communities of Thanchi Upazila in Bandarban Hill District, Bangladesh. *Asian J. Med. Biol. Res.* **8**, 123-140.

Ali, M.S., Dey, A., Sayeed, M.A., Rahman, A.A., Kuddus, M.R. and Rashid, M.A. 2014. *In vivo* sedative and cytotoxic activities of methanol extract of leaves of *Crataeva nurvala* Buch-Ham. *Pakistan J. Biol. Sci*. **17**, 439-442.

Anjum, A., Hossain, M.J., Aktar, F., Haque, M.R., Rashid, M.A. and Kuddus, M.R. 2022. Potential *in vitro* and *in vivo* bioactivities of *Schleichera oleosa* (Lour.) Oken: a traditionally important medicinal plant of Bangladesh. *Res. J. Pharm. Tech*. **15**, 113-121.

Aryal, B., Raut, B.K., Bhattarai, S., Bhandari, S., Tandan, P., Gyawali, K., Sharma, K., Ranabhat, D., Thapa, R., Aryal, D., Ojha, A., Devkota, H.P. and Parajuli, N. 2022. Potential therapeutic applications of plant-derived alkaloids against inflammatory and neurodegenerative diseases. *Evid. Based Complement. Alternat. Med.* **2022**, 7299778.

Awan, A.J. and Aslam, M.S. 2014. Family Acanthaceae and genus *Aphelandra*: ethnopharmacological and phytochemical review. *Int. J. Pharm. Pharm. Sci*. **6**, 44-55.

Backhouse, N., Delporte, C., Givemau, M., Cassels, B.K., Valenzuela, A. and Speisky, H. 1994. Anti-inflammatory and antipyretic effects of Boldine. *Inflam. Res.* **42**, 114-117.

Bashar, M.K., Ibrahim, M., Sultana, I., Hossain, M.I., Tasneem, Z., Kuddus, M.R., Ridwan Rashid, R. and Rashid, M.A. 2014. Preliminary phytochemical screenings and antipyretic, analgesic, anti-inflammatory activities of methanol extract of *Vernonia cinerea* Less. (Fam: Asteraceae). *European J. Med. Plants* **10**, 1178-1185.

Ginwala, R., Bhavsar, R., Chigbu, D.I., Jain, P. and Khan, Z.K. 2019. Potential role of flavonoids in treating chronic inflammatory diseases with a special focus on the anti-inflammatory activity of apigenin. *Antioxidants (Basel, Switzerland)*, **8**, 35.

Haque, M.R., Islam, M. and Kuddus, M.R. 2020. *In vitro* and *in vivo* evaluation of pharmacological potential of *Begonia barbata* Wall. *Futur. J. Pharm. Sci.* **6**, 112.

Hoque, M.E., Hossain, M.A. and Rana, M.S. 2019. Evaluation of analgesic, antidiarrheal and anti-hyperglycemic activities of *Dactyloctenium australe* (Poaceae). *Bangladesh Pharm. J.* **22,** 85-91.

Ibrahim, M., Hossain, A., Shajib, S. and Rashid, M.A. 2018. Preliminary phytochemical and pharmacological screenings of *Plumbago indica* L. and *Alpinia conchigera* Griff. *Dhaka Univ. J. Pharm. Sci*. **17**, 73-79.

Islam, M., Jannat, T., Kuddus, M.R., Rashid, M.A. and Haque, M.R. 2019. *In vitro* and *in vivo* evaluation of pharmacological potentials of *Campsis radicans* L. *Clin. Phytosci.* **5**, 42.

Khan, I., Shinwari, Z.K., Ali, M., Khan, Y. and Kumar, T. 2017. Ethnobotany and medicinal uses of folklore medicinal plants belonging to family Acanthaceae: An updated review. *MOJ Biol. Med.* **1**, 34-38.

Khan, I., Nisar, M., Ebad, F., Nadeem, S., Saeed M., Khan, H., Khuda, F, Karim, N. and Ahmad, Z. 2009. Anti-inflammatory activities of sieboldogenin from *Smilax china* Linn.: experimental and computational studies. *J. Ethnopharmacol*. **121**, 175-127.

Khatun, M.H., Nesa, M.L., Islam, R., Ripa, F.A., Mamun, A. and Kadir, S. 2014. Antidiabetic and anti-diarrheal effects of the methanolic extract of *Phyllanthus reticulates* leaves in mice. *Asian Pac. J. Reprod.* **3**, 121-127.

Komaki, E., Yamaguchi, S., Maru, I., Kinoshita, M., Kakeyi, K., Ohta, Y. and Tsukada, Y. 2003. Identification of anti-alpha-amylase components from olive leaf extracts. *Food Sci. Technol. Res.* **9**, 35-39.

Koster, R., Anderson, M. and De Beer E.J. 1959. Acetic acid-induced analgesic screening. *Fed. Proc.* **18**, 412-417.

Lourenço, S.C., Moldão-Martins, M. and Alves, V.D. 2019. Antioxidants of natural plant origins: from sources to food industry applications. *Molecules* **15**, 4132.

Lee, M.T., Lin, W.C., Yu, B. and Lee, T.T. 2017. Antioxidant capacity of phytochemicals and their potential effects on oxidative status in animals -a review. *Asian-Australas J. Anim. Sci.* **30**, 299-308.

Maleki, S.J., Crespo, J.F. and Cabanillas, B. 2019. Anti-inflammatory effects of flavonoids. *Food Chem.* **299**, 125124.

Mikail, H.G., Akumka, D.D., Adamu, M. and Zaifada, A.U. 2019. Evaluation of phytochemical constituents and sedative-hypnotic activity of the methanol leaf extract of *Ficus exasperata* in mice. *Vet. World*. **12**, 830-833.

Rahman, M.S., Rashid, M.A., Sikder, A.A., Rahman, A., Kaisar, M.A. and Hasan, C.M. 2011. *In vitro* antioxidant, reducing power, free radical scavenging and membrane stabilizing activities of seeds of *Syzygium cumini* L. *Lat. Am. J. Pharm.* **30**, 781-785.

Saleh, H.A., Yousef, M.H. and Abdelnaser, A. 2021. The anti-inflammatory properties of phytochemicals and their effects on epigenetic mechanisms involved in TLR4/NF-κB-mediated inflammation. *Front. Immunol*. **12**, 606069.

Saleem, T.M., Azeem, A.K., Dilip, C., Sankar, C., Prasanth, N.V. and Duraisami, R. 2011. Anti-inflammatory activity of the leaf extacts of *Gendarussa vulgaris* Nees. *Asian Pac. J. Trop. Biomed.* **1**, 147-149.

Shinde, U.A., Phadke, A.S., Nair, A.M., Mungantiwar, A.A., Dikshit, V.J. and Saraf, M.N., 1999. Preliminary studies on the immunomodulatory activity of *Cedrus deodara* wood oil. *Fitoterapia* **70**, 333-339.

Uddin, M.J. and Zidorn, C. 2020. Traditional herbal medicines against CNS disorders from Bangladesh. *Nat. Prod. Bioprospect.* **10**, 377-410.

VanWagenen, B.C., Larsen, R., Cardellina, J.H., Randazzo, D., Lidert, Z.C. and Swithenbank, C. 1993. Ulosantion, a potent insecticide from the sponge *Ulosa ruetzleri*. *J. Organomet. Chem*. **58**, 335-337.

Veeresham, C. 2012. Natural products derived from plants as a source of drugs. *J. Adv. Pharm. Technol. Res*. **3,** 200-201.

Yesmin, S., Paul, A., Naz, T., Rahman A.B.M.A., Akhter, S.F., Wahed, M.I.I.I., Emran, T.B. and Siddiqui, S.A. 2020. Membrane stabilization as a mechanism of the anti-inflammatory activity of ethanolic root extract of Choi (*Piper chaba*). *Clin. Phytosci*. **6**, 59.