



The effects of *Sceletium tortuosum* (L.) N.E. Br. extract fraction in the chick anxiety-depression model



Jessica M. Carpenter^a, Mary K. Jourdan^b, Emily M. Fountain^b, Zulfiqar Ali^a, Naohito Abe^a, Ikhlas A. Khan^a, Kenneth J. Sufka^{a,b,*}

^a National Center for Natural Products Research, University of Mississippi, University, MS 38677, USA

^b Department of Psychology, University of Mississippi, University, MS 38677, USA

ARTICLE INFO

Article history:

Received 17 June 2016

Received in revised form

28 July 2016

Accepted 16 August 2016

Available online 20 August 2016

Keywords:

Sceletium tortuosum

Depression

Anxiety

Chick

Kanna

Kougoed

ABSTRACT

Ethnopharmacological relevance: *Sceletium tortuosum* (L.) N.E. Br. has been reported to elevate mood, reduce anxiety and stress and alleviate pain.

Aim of study: This study sought to examine the effects of an *S. tortuosum* alkaloid enriched fraction in the chick anxiety-depression model, a model that shows high predictive validity as a pharmacological screening assay.

Material and methods: Socially-raised male Silver Laced Wyandotte chicks (4–6 days old) were given IP vehicle, imipramine (10 mg/kg), or *S. tortuosum* fraction (10, 20, 30 mg/kg in Exp. 1 or 50, 75, 100 mg/kg in Exp. 2) 15 min prior to a 60 min isolation test period in which distress vocalizations (DVoc) were continuously recorded.

Results: Vehicle chicks displayed high DVoc rates in the anxiety phase (first 3 min). DVoc rates declined about 50% (i.e., behavioral despair) in the depression phase (30–60 min). *S. tortuosum* fraction at 75 and 100 mg/kg decreased DVoc rates during the anxiety phase indicative of an anxiolytic effect. Imipramine, but not *S. tortuosum* groups, increased DVoc rates in the depression phase indicative of an antidepressant effect.

Conclusions: The findings suggest that an alkaloid enriched *S. tortuosum* fraction may benefit some forms of stress-related disorders.

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1. Introduction

Sceletium tortuosum (L.) N.E. Br., colloquially known as *kougoed* or *kanna*, is a flowering, succulent plant indigenous to South Africa. The plant is traditionally chewed, smoked, or used as a tea or snuff predominantly for pleasure, but also for ailments such as toothache and abdominal pain (Gericke and Viljoen (2008) for review). *S. tortuosum* has been reported to elevate mood and reduce anxiety, stress and tension (Gericke and Viljoen, 2008). The antidepressant and anxiolytic clinical effects of *S. tortuosum* have been shown both in case reports (Gericke, 2001) and more recently, double-blind studies (Nell et al., 2013).

S. tortuosum has a rich alkaloid profile that contains mesembrine, mesembrenone, mesembrenol, alkaloid A4, tortuosamine, and chennaine (Gericke and Viljoen (2008) for review; Smith et al., 1996). These alkaloids have been shown to affect a

number of central nervous system (CNS) targets. For example, Zembrin[®], an ethanolic extract of *S. tortuosum* with the purified alkaloids mesembrine, mesembrenone and mesembrenol, shows inhibitory effects on serotonin (5HT) reuptake and phosphodiesterase 4 (PDE4) activity (Harvey et al., 2011). At higher concentrations, this extract also binds to gamma butyric acid (GABA), μ -opioid, δ_2 -opioid, cholecystokinin-1, EP4 prostaglandin, and melatonin-1 receptors (Harvey et al., 2011; Gericke and Viljoen (2008) for review). Mesembrine was found to be the most abundant alkaloid constituent of *S. tortuosum* yielding 0.7% m/m (total alkaloid constituent extracted was 1.0–1.5% m/m) (Smith et al., 1996).

Previous work sought to broadly characterize activity of *S. tortuosum* extract, an alkaloid enriched fraction and the isolated constituent mesembrine respectively on measures of addiction, nociception, motor coordination, depression and anxiety (Loria et al., 2014). Mesembrine produced an antinociceptive effect similar to that of morphine on the hotplate. In line with previous anecdotal evidence of mood elevating properties, the *S. tortuosum* enriched fraction produced a modest antidepressant effect similar to that of imipramine in the forced swim test. However, this

* Corresponding author at: Department of Psychology, University of Mississippi, University, MS 38677, USA.

E-mail address: psufka@olemiss.edu (K.J. Sufka).

enriched fraction also produced ataxia similar to its positive control muscimol on the rotor-rod. Given the emerging evidence that *S. tortuosum* may mitigate stress-related disorders, it would be useful to demonstrate whether such properties generalize to other efficacy screening models.

The chick anxiety-depression model is a well-validated simulation and pharmacological screening assay (Hymel et al., 2010; Sufka and White, 2013). In this model, socially raised chicks are separated from conspecifics at 4–6 days old for a 1–2 h test session. Isolated chicks display high rates of distress vocalizations during the initial 3 min period (i.e., anxiety-like phase); distress vocalizations then decline by about 50% of the initial rate over the next 25–30 min period to enter into a stable rate for the remainder of the test session (i.e., depression phase) and is typical of behavioral despair models (Sufka et al., 2006). Anxiolytics attenuate distress vocalizations during the anxiety-like phase whereas antidepressants attenuate behavioral despair as evidenced by an increase in distress vocalizations during the depression-like phase (Sufka et al., 2006; Warnick et al., 2009). This assay has proven efficacious in screening clinically established anxiolytics and antidepressants (Sufka et al., 2009; Sufka and White, 2013; Warnick et al., 2006; Warnick et al., 2009) as well as novel compounds from natural products that possess anxiolytic/antidepressant properties (Feltenstein et al., 2003; Kochanowska et al., 2008; Lewellyn et al., 2013; Smith et al., 2001; Sufka et al., 2001).

2. Materials and methods

2.1. Plant materials and extraction

The leaves of *S. tortuosum* (L.) N.E. Br. (www.theplantlist.org, accessed May 2016) were purchased from Bouncing Bear Botanicals, Lawrence, KS, USA. The plant species was identified by Dr. Vijayasankar Raman at the National Center for Natural Products Research, University of Mississippi (voucher no. 10851). The plant extraction followed procedures detailed elsewhere (Loria et al., 2014). Briefly, the dried leaf powder of *S. tortuosum* was extracted with chloroform and the solvent was removed under reduced pressure to give the chloroform extract. The chloroform extract (20 g) was applied to vacuum liquid chromatography (VLC) over reversed phase silica (RP-18) and eluted with methanol-water (7:3, 1 L), (8:2, 1 L), (9:1, 1 L) and (1:0, 1 L). The fraction eluted with methanol-water (8:2) was defined as the alkaloid enriched fraction while the other three fractions did not contain alkaloids. Mesembrine was found to be a major compound in the alkaloid enriched fraction (11.8%) during HPLC fingerprinting analysis.

2.2. Subjects

Male Silver Laced Wyandotte chicks (Ideal Poultry, Cameron, TX, USA) were obtained two days post-hatch and housed in stainless steel cages (44 × 61 × 40 cm) with 12 chicks per cage. Food (Purina 5065, Lab Diet, Chick Chow S-G) and water were available ad libitum. Room temperature was maintained at approximately 30–32 °C and overhead illumination was maintained on a 12:12 h light-dark cycle.

2.3. Drugs

Imipramine (Sigma-Aldrich, St. Louis, MO) dissolved in deionized water served as the reference control for both experiments and was tested at a dose of 10 mg/kg. This dose was selected from pilot data showing 10 and 15 mg/kg imipramine had significant dose-dependent antidepressant activity in this genetic line. Deionized water served as the vehicle control for the imipramine

group. The *S. tortuosum* enriched fraction was dissolved in a solution of 20% Tween 80 and deionized water and tested at doses of 10, 20 and 30 mg/kg in Experiment 1 and 50, 75 and 100 mg/kg in Experiment 2. As in previous work, a solution of 20% Tween 80 and deionized water served as the vehicle control for the *S. tortuosum* groups (Loria et al., 2014). All compounds were administered IP in a volume of 1 ml/kg.

2.4. Apparatus

A six-unit testing apparatus containing Plexiglas chambers (25 × 25 × 22 cm) surrounded by sound attenuating media was used to record separation-induced vocalizations. Each unit was illuminated by a 25-W light bulb, and ventilated by an 8-cm-diameter rotary fan. Miniature video cameras mounted outside the observation chambers at floor level and routed through a multiplexor provided televised display of chicks for observation. Distress vocalizations (DVocs) were detected via microphones [Radio Shack Omnidirectional Model 33-3013 (modified for AC current)] mounted at the top of the Plexiglas chamber and routed to a computer equipped with software that continuously counted distress vocalizations at a sample rate > 10 events/s.

2.5. Procedure

Two separate dose response experiments were conducted at 4–6 days post-hatch and chicks were tested only once. Time constraints prevented testing a greater number of doses within a test session. In experiment 1, sample sizes were $n=22$ for both vehicle groups combined and $n=15–18$ for imipramine and *S. tortuosum* enriched fraction groups. In experiment 2, sample sizes were $n=21$ for both vehicle groups combined and $n=16$ for imipramine and *S. tortuosum* enriched fraction groups. Chicks received vehicle or pharmacological substances 15 min prior to a social-separation stressor. This injection to test interval is based on extensive validation studies of this procedure as a drug efficacy screening assay (Sufka et al., 2006; Warnick et al., 2009; Sufka et al., 2009). Chicks were placed into individual isolation chambers for a 60 min test session and distress vocalizations were continuously recorded. Upon completion of experimental testing, chicks were returned to their home cage. These procedures were approved by the University of Mississippi's Institutional Animal Care and Use Committee (protocol no. 16-015).

2.6. Data analyses

Distress vocalizations were converted to a rate/minute function (DVoc rate). From these data, DVoc rates were derived for the anxiety-like phase (0–3 min), and the first and second halves of the depression-like phases (31–45 min and 46–60 min). Independent *t*-tests revealed that DVoc rates of the two vehicle groups from these three test phases were not significantly different from one another and were collapsed to form a single control group. A two way ANOVA (between-within) was used to determine main effects for both treatment and test phase. One-way ANOVAs were used to reveal group differences at each test phase. Fisher's LSD was used to determine specific group differences and Cohen's *d* was calculated to determine effect size.

3. Theory/calculation

Given the historic cultural use of *S. tortuosum* as an anxiolytic and antidepressant and that its extract fraction shows antidepressant-like activity in a rodent model of depression, it would be of value to determine whether these effects can be observed in

the current model. If the *S. tortuosum* extract fraction demonstrates anxiolytic and/or antidepressant-like activity, it may support the development of a standardized formulation of said botanical extract for the treatment of stress-related disorders.

4. Results

4.1. Experiment 1

The effects of imipramine and *S. tortuosum* on DVoc rates in the anxiety- and depression-like phases are summarized in Fig. 1. Vehicle treated chicks displayed high DVoc rates in the anxiety phase that were reduced by 51% during the depression phase. Imipramine did not affect DVoc rates in the anxiety phase but did increase DVoc rates in both early and late halves of the depression phase. This latter effect is indicative of an antidepressant effect. *S. tortuosum* did not affect DVoc rates in any of the three test phases. A two-way ANOVA performed on these data revealed significant main effects for Test Phase [$F(2,85)=279.27$, $p<0.001$] and Treatment [$F(4,86)=7.46$, $p<0.001$]. The Test Phase \times Treatment interaction term was significant [$F(8,170)=2.49$, $p<0.05$]. Separate one way ANOVAs were performed for each test phase. A one way ANOVA performed on these data did not reveal a significant main effect for treatment during the anxiety phase, [$F(4,86)=1.14$, $p=n.s.$]. However, significant treatment effects were detected in both halves of the depression phase [$F(4,86)=6.06$, $p<0.001$ and $F(4,86)=7.18$, $p<0.001$, respectively]. Fisher's LSD revealed imipramine resulted in significantly higher mean DVoc rates compared to vehicles during early and late halves of the depression phase (Imp 87.14 vs Veh 66.23, $p=0.004$, $d=0.89$ and Imp 86.65 vs Veh 54.99, $p=0.000$, $d=1.29$, respectively).

4.2. Experiment 2

The effects of imipramine and *S. tortuosum* on DVoc rates in the anxiety- and depression-like phases are summarized in Fig. 2. As in Experiment 1, vehicle treated chicks displayed high DVoc rates in the anxiety phase that were reduced by 49% during the depression phase. *S. tortuosum* groups receiving 75 and 100 mg/kg

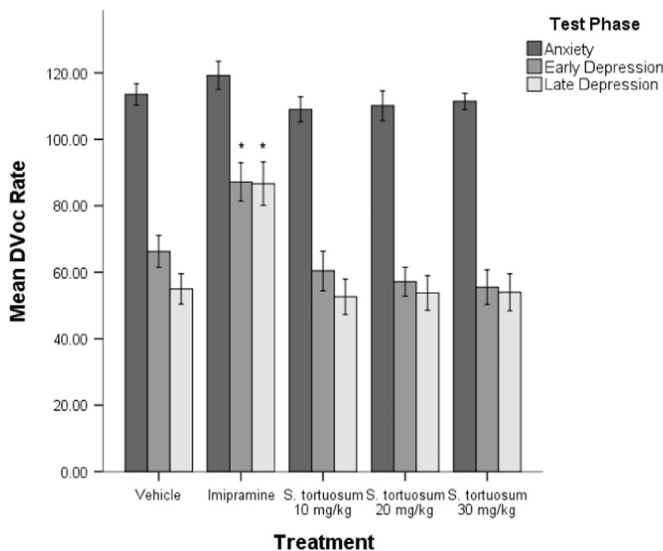


Fig. 1. The effects of imipramine and *S. tortuosum* doses (10, 20 and 30 mg/kg) on distress vocalization (DVoc) rates during the anxiety phase (0–3 min), early depression phase (31–45 min), and late depression phase (46–60 min). Values represent mean (\pm SEM). * Indicates a significant increase in DVoc rates ($p<0.05$) from the vehicle group (i.e. antidepressant effect). Sample sizes were $n=15-22$.

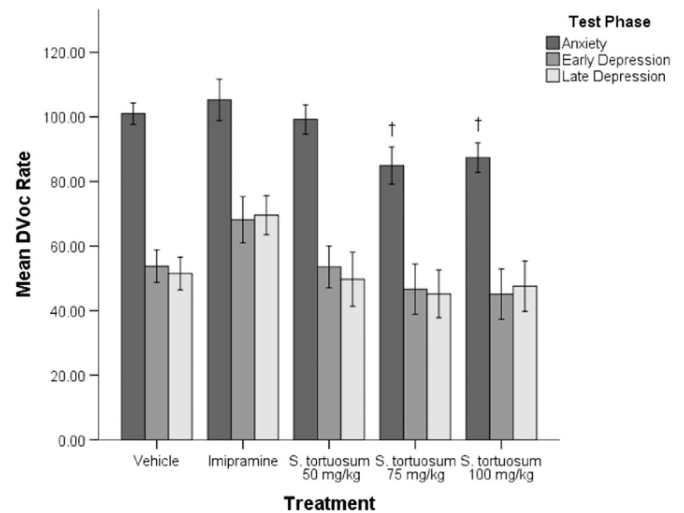


Fig. 2. The effects of imipramine and *S. tortuosum* doses (50, 75 and 100 mg/kg) on distress vocalization (DVoc) rates during the anxiety phase (0–3 min), early depression phase (31–45 min), and late depression phase (46–60 min). Values represent mean (\pm SEM). † indicates a significant decrease in DVoc rates ($p<0.05$) from the vehicle group (i.e. anxiolytic effect). Sample sizes were $n=16-21$.

displayed reduced DVoc rates in the anxiety phase indicative of an anxiolytic effect. *S. tortuosum* did not affect DVoc rates in the depression phase. Imipramine did not affect DVoc rates in any of the test phases. A two-way ANOVA performed on these data revealed a significant main effect for Test Phase [$F(2,79)=138.93$, $p<0.001$] and Treatment [$F(4,80)=2.59$, $p<0.05$]. The Test Phase \times Treatment interaction term was not significant [$F(8,158)=0.575$, $p=n.s.$]. Separate one way ANOVAs were performed for each test phase. A one way ANOVA performed on these data revealed a significant effect for treatment in the anxiety phase, [$F(4,80)=3.22$, $p<0.05$]. Fisher's LSD revealed the *S. tortuosum* 75 and 100 mg/kg groups resulted in significantly lower mean DVoc rates compared to vehicles (*S. tortuosum* 84.91 vs Veh 100.99, $p=0.018$, $d=0.84$ and *S. tortuosum* 87.36 vs Veh 100.99, $p=0.045$, $d=0.82$, respectively). One way ANOVAs did not reveal a significant effect for treatment in either half of the depression phase [$F(4,80)=1.72$, $p=n.s.$, and $F(4,80)=1.88$, $p=n.s.$, respectively]. Fisher's LSD revealed in the late half of the depression phase that DVoc rates for imipramine were higher than vehicle (Imp 69.55 vs Veh 51.39, $p=0.058$, $d=0.76$) in which the effect size was large and approached significance.

5. Discussion

This research sought to determine whether *S. tortuosum* antidepressant effects in a rodent model generalize to an avian screening assay. The chick anxiety-depression model is a dual efficacy screen with high predictive validity (Feltenstein et al., 2004; Sufka et al., 2009; Warnick et al., 2006, 2009). This procedure has also been employed to screen botanical extracts, fractions and their constituents that mitigate stress-related disorders (Feltenstein et al., 2003; Kochanowska et al., 2008; Lewellyn et al., 2013; Smith et al., 2001; Sufka et al., 2001).

In both experiments, vehicle groups displayed high DVoc rates during the first 3 m (anxiety phase) of the isolation test period. DVoc rates gradually declined to about 50% at 30 m (depression phase) and remained stable for the rest of the test session (see Figs. 1 and 2). This DVoc pattern is consistent with existing literature (White and Sufka (2012), for review) and is typical of other models of behavioral despair (Willner, 1991). The antidepressant effect of imipramine in the current study mirrors that found in previous studies (Sufka et al., 2009; Warnick et al., 2009). In

Experiment 1, imipramine attenuated behavioral despair as evidenced by higher rates of DVocs during the depression phase. A large effect size of imipramine was found in Experiment 2 that approached significance; this difference may be due to a smaller sample size. The two highest doses of *S. tortuosum* fraction (75 and 100 mg/kg) decreased DVocs during the anxiety phase of the model. This reduction in DVoc rates is similar to effects produced by a wide range of anxiolytic compounds previously tested in this model (Feltenstein et al., 2004; Sufka et al., 2006; Warnick et al., 2006, 2009). In contrast, the *S. tortuosum* fraction did not affect DVoc rates during the depression phase and thus appears void of antidepressant activity at the doses tested.

This pattern of *S. tortuosum* effects in the chick model is equivocal given the diverse action of alkaloid enriched *S. tortuosum* fractions on CNS targets. The *S. tortuosum* proprietary extract Zembrin[®], which contains the alkaloids mesembrine, mesembrenone and mesembrenol, shows dose-dependent activity at multiple receptor targets. Lower doses show preferential binding to the serotonin transporter while higher doses affect GABA and opioid receptors (Harvey et al., 2011). That the higher doses of the *S. tortuosum* fraction possess anxiolytic effects is unsurprising given that GABA (Watson et al., 1999; Watson and Sufka, 1996), as well as mu- (Sufka et al., 1994; Warnick et al., 2005) and delta-opioid (Perrine et al., 2006; Randall-Thompson et al., 2010) receptor agonists possess anxiolytic effects.

It is somewhat surprising the *S. tortuosum* fraction failed to show anti-depressant effects in this model given (a) an alkaloid-enriched fraction has shown modest activity in the rat FST and (b) these alkaloids at low doses are known to inhibit the serotonin transporter. There are several possible explanations for this finding. The FST has shown false positives to GABA-acting compounds (Bogdanova et al., 2013; Borsini et al., 1986; De Pablo et al., 1991; Schechter and Chance, 1979) and the current findings may reflect a true negative outcome in the chick model. It may also be that other constituents in the fraction may alter mechanisms that modify or oppose the antidepressant action of a key constituent like mesembrine. A formulation high in mesembrine but low other major constituents may possess full antidepressant properties. Further, it is possible that antidepressant activity is within a narrow dose-response range not detected by the wide range of doses employed herein. That *S. tortuosum* possesses anxiolytic activity in this model aligns well with anecdotal claims that this botanical modifies stress-related disorders. Finally, given anxiety and depression share many symptoms and possess co-morbidities of greater than 70% (Kessler et al., 1994, 2005), reports that *S. tortuosum* elevates mood may simply reflect user conflating symptoms of these two related disorders.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

This research is supported, in part, by the U.S. Food and Drug Administration Grant no. 4U01FD004246-05 and the Sally McDonnell Barksdale Honors College at the University of Mississippi.

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