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Assessment of allelopathic effect of stem bark extract of *Crataeva religiosa* on seed germination, seedling growth and seedling vigour of Mung bean (*Vigna radiata*) and wheat (*Triticum aestivum*)

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Abstract
The present study was undertaken to evaluate the allelopathic potential of aqueous stem bark extract of *Crataeva religiosa* on seed germination and early seedling growth of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.). Aqueous stem bark extracts were prepared at six concentrations (0.25%, 0.5%, 0.75%, 1.0%, 2.0%, and 5.0%), and their effects were assessed using seed germination percentage, shoot length, root length, fresh weight, and seedling vigour index as growth parameters. The results revealed a concentration-dependent inhibitory effect of the bark extract on both seed germination and seedling growth. In mung bean, lower extract concentrations (0.25% and 0.5%) exerted only a marginal effect on seed germination, whereas higher concentrations (0.75%, 1.0%, 2.0%, and 5.0%) significantly reduced germination by 25%, 28%, 30%, and 35%, respectively. Similarly, wheat seeds exhibited minimal inhibition at lower concentrations but showed pronounced reductions in germination of 25%, 27.5%, 35%, and 47.5% at 0.75%, 1.0%, 2.0%, and 5.0% extract concentrations, respectively. A corresponding decline in shoot length, root length, fresh weight, and seedling vigour index was observed with increasing extract concentration in both species. Among the two test plants, wheat was more susceptible to the allelopathic effects of the bark extract than mung bean. The findings demonstrate that the aqueous stem bark extract of *Crataeva religiosa* possesses significant allelopathic activity, with phytotoxic effects becoming more pronounced as extract concentration increases. The inhibitory responses observed are likely associated with allelochemicals present in the stem bark that interfere with seed germination and early seedling development. These results provide evidence for the allelopathic potential of *C. religiosa* and suggest its possible ecological role in regulating the growth, development and establishment of neighbouring plant species.

Keywords: *Crataeva religiosa*, allelopathic stress, fresh weight, shoot length, root length, vigour index

Introduction

Allelopathy can be defined as "it is biochemical process by which a chemical or group of chemicals synthesized by one plant and released into the environment to affect the seed germination, reproduction, growth and survival of the other plant. These biochemicals are known as Allelochemicals and may have beneficial effect or negative effect on the plant growth and development (Stamp, 2003) [1]. Allelochemicals are actually secondary metabolite, which play important role in the plant defense mechanism. Allelochemicals are produced in all parts of the plant and vital role in establishment of plant communities and natural ecosystem (Rice, 1984; Ridenour and Callway, 2001 and Aslam et.al., 2017) [42, 12, 13]. The production of these allelochemicals is controlled by biotic and abiotic factors (Fraenkel, 1959) [2]. Allelochemicals show inhibitory effect at certain concentration in one species might show stimulatory effect at same concentration or at different concentration in same or different species (Narwal, 1994 and Azania *et al*., 2003) [3, 4]. Allelopathy is considered as negative allelopathy when allelochemicals inhibit the growth of the plant and it is considered as positive allelopathy when allelochemicals stimulate the growth of the plant (Huxley, 1999 and Fernandez *et al.*, 2006) [7, 8]. This inhibitory or stimulatory effects of these allelochemicals are depended upon their concentration in the surrounding medium (El-Daly and Soliman, 1997) [9]. Allelochemicals obstruct the hydrolysis of the seed reserves inhibiting seed germination (Irshad and Cheema, 2004) [10]. In the present investigation at attempt has been made to scrutinize inhibitory or stimulatory potential of *Crataeva religiosa* on growth and development of Mung bean and Wheat.

Materials and Methods

Materials

1. Collection and processing of the plant material

Bark sample of *Crataeva religiosa* was collected from the Kolhapur district. The bark was collected in the month of May. The bark sample was cut into pieces, initially shade dried followed by sun drying and then dried in an oven, maintained at 50^{0}C temperature for 5 to 7 days. Dried bark sample was milled into powder and stored in an air tight plastic container for further experimental studies.

2. Preparation of the aqueous extracts

The oven dried bark of *Crataeva religiosa* was ground on mechanical grinder. The six bark extract concentrations (0.25%, 0.5%, 0.75%, 1.0%, 2.0% and 5.0%) were prepared by adding accurately weighed 0.25g, 0.5g, 0.75g, 1g, 2g and 5g of bark powder to well labeled (0.25%, 0.5%, 0.75%, 1.0%, 2.0% and 5.0%) respective conical flask containing 100mL distilled water. The suspensions were kept for 24 hours at room temperature (28-30^{0}C) to get bark leachate.

The resultant extracts were filtered through Whatman No.1 filter paper and stored in conical flask in refrigerator.

3. Germination studies

The effect of resultant bark extracts on seed germination was studied by placing 20 seeds of each test crop petri dishes containing three layers of Whatman No. 1 filter paper. The experiment was set in triplicate. Aqueous bark extract (15ml) of different concentrations (0.25%, 0.5%, 0.75%, 1.0%, 2.0% and 5.0%) was added in respective petri dishes well labelled according to the concentrations. Control plates were prepared by using distilled water in the place of plant extract. The effect of bark extract on seed germination, shoot length, root length and vigour index was verified after 120 hours (5 days) of germination.

Germination percentage was calculated by the formula-

$$\text{Germination \%} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds taken for germination}} \times 100$$

Vigour index was calculated by using the formula proposed by (Abdul-Baki and Andersion, 1973)

$$\text{Vigor index (VI)} = (\text{Root length} + \text{Shoot length}) \times \text{Germination percentage}$$

Mobilization Efficiency was determined with the help of formula given by Shrivastava and Sareen (1974).

$$\text{Mobilization Efficiency (ME)} = \frac{\text{Dry Wt. of embryonic axis}}{\text{Dry Wt. of Residual grain}} \times 100$$

Result and Discussion

1. Germination percentage

Effect of aqueous bark extract of *Crataeva religiosa* on seed germination of Mung and Wheat seed is shown in table No. 1**.** It is observed that the seed germination decreases as concentrations of the bark extract increases. In case of moong and wheat, bark extract at lower concentrations of 0.25% and 0.5 % has less effect on seed germination. It is evident from the table that the bark extract above 0.75 % concentration showed inhibitory effect on the germination of the mung and wheat seeds. The germination was highly affected at 0.75%, 1%, 2% and 5% concentration by 25%, 28%, 30 and 35% respectively, in Mung bean. In case of wheat plant also, the lower concentrations at 0.25% and 0.5% slightly affected the seed germination. Bark extract at higher concentration of .75%, 1%, 2% and 5% showed maximum inhibition of seed germination by 25%, 27.5%, 35% and 47.5% respectively.

2. Seedling fresh weight

The effect of aqueous bark extract of *Crataeva religiosa* on the fresh weight of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.) seedlings is presented in Table 2, Table 3, Figure 1, and Figure 2. The response of the two-test species varied considerably with increasing extract concentration, indicating species-specific sensitivity to the allelochemicals present in the bark extract. In mung bean seedlings, lower concentrations of the bark extract (0.25% and 0.50%) exerted a slight stimulatory effect on fresh biomass accumulation, resulting in increases of 12.59% and 0.24%, respectively, over the control. However, exposure to higher concentrations (0.75%, 1.00%, 2.00%, and 5.00%) caused a progressive decline in fresh weight by 14.25%, 32.07%, 36.34%, and 42.99%, respectively, compared with the control. This concentration-dependent reduction suggests that elevated levels of allelochemicals adversely affected seedling growth and biomass accumulation. In contrast, wheat seedlings exhibited a marked stimulatory response across a broad range of extract concentrations. Fresh weight increased by 19.32%, 23.86%, 33.52%, 43.18%, and 20.45% at 0.25%, 0.50%, 0.75%, 1.00%, and 2.00% extract concentrations, respectively, relative to the control. The maximum enhancement in fresh biomass was observed at the 1.00% concentration. However, at the highest concentration (5.0%), the extract exerted an inhibitory effect, reducing fresh weight by 12.50% compared with the control. Overall, the aqueous bark extract of *Crataeva religiosa* exhibited a concentration-dependent effect on seedling fresh weight, characterized by growth stimulation at lower concentrations and inhibition at higher concentrations. The magnitude and direction of the response differed between the two species, with wheat seedlings demonstrating substantially greater tolerance and a more pronounced stimulatory response than mung bean seedlings. These findings indicate differential susceptibility of the test species to the bioactive constituents of *C. religiosa* bark and suggest that the extract may possess hormone like properties, promoting growth at lower concentrations while exerting phytotoxic effects at elevated concentrations.

Table 1: Effect of aqueous bark extract of *Crataeva religiosa* on the germination of the Mung and Wheat seed

Extract Concentration	Germination %			
	Mung		Wheat	
	24hr	48hr	24hr	48hr
Control	67.5	100	65	100
0.25%	60	82.5	67.5	100
0.50%	55	87.5	62.5	87.5
0.75%	52.5	75	55.5	75
1%	55	72	55	72.5
2%	45	70	45	65
5%	40	65	37.5	52.5

3. Seedling growth

The influence of aqueous stem bark extract of Crataeva religiosa on the shoot length of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.) seedlings is presented in Table 2, Table 3, Figure 1, Figure 2, and Plate 1. The results demonstrated a clear dose-dependent and species-specific response to the aqueous stem bark extract.

In mung bean seedlings, treatment with the lowest extract concentration (0.25%) produced a marginal stimulatory effect on shoot elongation, increasing shoot length by 3.52% relative to the control. However, increasing the extract concentration resulted in a progressive suppression of shoot growth. Shoot length decreased by 9.84%, 23.73%, 29.64%, 38.45%, and 56.99% at extract concentrations of 0.50%, 0.75%, 1.0%, 2.0%, and 5.0%, respectively, compared with the control. The greatest reduction in shoot length was recorded at the highest concentration (5.0%), indicating a strong inhibitory effect of the bark extract on shoot development.

On the other hand, wheat seedlings exhibited a marked promontory response to the aqueous stem bark extract over a wide concentration range. Compared to the control, shoot length increased by 19.80%, 35.86%, 39.16%, 37.29%, and 30.47% at extract concentrations of 0.25%, 0.50%, 0.75%, 1.0%, and 2.0%, respectively. The maximum stimulatory effect was observed at the 0.75% concentration, where shoot length increased by 39.16% over the control. However, the highest concentration (5.0%) resulted in a significant reduction in shoot length (28.05%), indicating loss of growth-promoting effect at elevated concentrations.

Table 2: Effect of aqueous extract of stem bark of *Crataeva religiosa* on the fresh weight, shoot length, root length, and Vigour index of the mung seedling Var-Gold 9

Growth Parameter-Mung	Treatments (%/) Shoot length in 'cm'						
	Control (D.W)	0.25%	0.5%	0.75%	1%	2%	5%
Shoot length	9.65±0.76	9.99±1.17	8.7±1.32	7.36±1.14	6.79±1.42	5.94±0.96	4.15±0.67
Root length	4.6±1.10	5.35±.78	3.69±0.66	3.87±1.15	4.16±0.88	3.56±1.16	2.95±0.65
Fresh Weight	4.21±0.30	4.74±0.77	4.22±1.3	3.61±0.55	2.86±0.47	2.68±0.44	2.40±0.11
Vigor Index	1445	1104	1070	1051	940	823	458
Readings are mean of three replicates ± SD							

Table 3: Effect of aqueous extract of stem bark of *Crataeva religiosa* on the fresh weight, shoot length, root length, and Vigour index of wheat seedling

Growth Parameter -Wheat	Treatments (%)/Shoot length (cm)						
	Control (D.W)	0.25%	0.5%	0.75%	1%	2%	5%
Shoot length	9.09±0.87	10.89±0.73	12.35±0.57	12.65±0.62	12.48±0.63	11.86±0.71	6.54±1.50
Root length	16.25±1.23	15.05±1.93	16.50±1.64	17.03±1.12	16.61±1.75	15.89±1.06	5.68±1.67
Fresh weight	1.76±0.56	2.10±0.37	2.18±0.11	2.35±0.40	2.52±0.56	2.12±0.24	1.54±0.71
Vigor Index	2534	2737	2755	2889	2926	2837	1222
Readings are mean of three replicates ± SD							

Overall, the aqueous stem bark extract of *Crataeva religiosa* elicited a biphasic, concentration-dependent response in shoot growth. While low to moderate extract concentrations promoted shoot elongation in wheat seedlings, increasing concentrations progressively inhibited shoot growth in mung bean seedlings. Wheat exhibited greater tolerance to the phytochemical constituents present in the bark extract, maintaining enhanced shoot growth up to 2% concentration, whereas mung bean proved considerably more susceptible, with inhibition occurring at concentrations above 0.50%. These contrasting responses indicate differential sensitivity of the two species to the bioactive compounds present in the stem bark extract.

The effect of aqueous stem bark extract of *Crataeva religiosa* on the root length of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.) seedlings is presented in Tables 2, Tables 3, Fig. 1, Fig 2 and Plate 1. The results demonstrated dose-dependent response of root growth in both species. The extent and pattern of response was differed in both the plants studied.

In mung bean seedlings, the lowest concentration (0.25%) of the aqueous stem bark extract significantly enhanced root elongation, recording a 16.30% increase over the control. However, further increases in extract concentration resulted in progressive inhibition of root elongation. Root length was inhibited by 19.78%, 15.87%, 9.57%, 22.61%, and 35.87% at extract concentrations of 0.50%, 0.75%, 1.00%, 2.00%, and 5.00%, respectively, relative to the control. The maximum inhibitory effect was observed at the highest concentration (5.00%), indicates that the phytotoxicity of the bark extract increased with increasing extract concentration.

In wheat seedlings, the response of the wheat to the aqueous stem bark extract was comparatively less marked. Root elongation exhibited slight stimulation at concentrations of 0.50%, 0.75%, and 1.00%, with increase of 1.54%, 4.80%, and 2.22%, respectively, over the control. In contrast, slight inhibition of root growth was recorded at 0.25% and 2.00%, resulting 7.38% and 2.22%, reductions respectively. A noticeable inhibition in root length was observed at the highest concentration (5.00%), where root growth was reduced by 65.05% compared with the control. It demonstrates a strong inhibitory effect of the extract at elevated concentrations of bark.

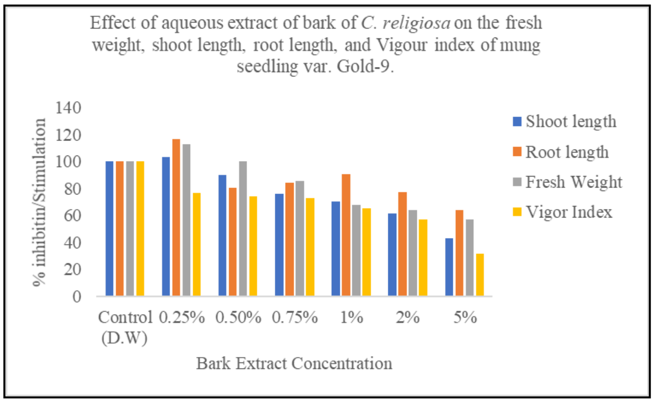

Fig 1: Effect of aqueous extract of bark of *C. religiosa* on the fresh weight, shoot length, root length, and Vigour index of mung seedling var. Gold-9

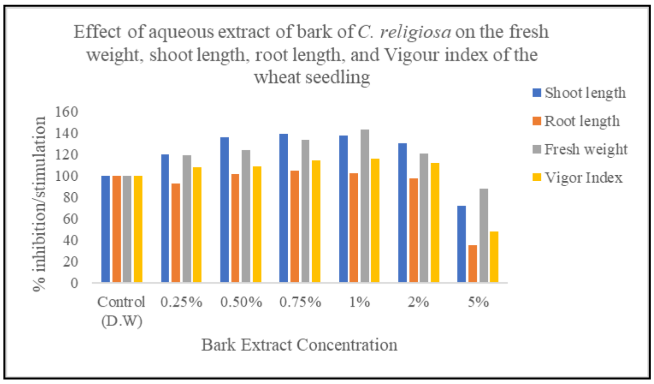

Fig 2: Effect of aqueous extract of bark of *C. religiosa* on the fresh weight, shoot length, root length, and Vigour index of the wheat seedling

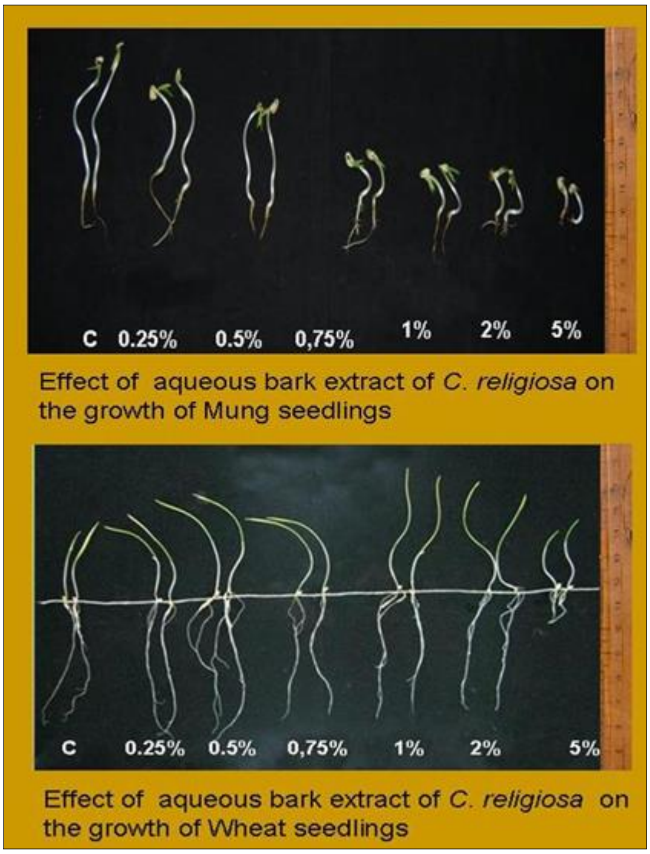

Plate 1:

The present investigations suggest that the aqueous stem bark extract of *Crataeva religiosa* exhibits a dose-dependent allelopathic effect on root development. Lower concentrations were found stimulatory to root growth, particularly in mung bean, whereas higher concentrations exerted inhibitory effects on root elongation in both species. The marked inhibition observed at elevated levels of concentrations may be attributed to the accumulation of phytotoxic secondary metabolites that might interfered with cell division, cell elongation, and other physiological processes involved in root elongation.

4. **Seedling Vigour**

The effect of aqueous stem bark extract of *Crataeva religiosa* on the vigour index of mung bean and wheat seedlings is presented in Table 2, Table 3, Fig. 1, and Fig. 2. The results revealed a distinct species-specific response to the bark extract. Mung bean seedlings exhibited greater sensitivity than wheat seedlings, as evidenced by a progressive, concentration-dependent decline in vigour index. Relative to the control, the vigour index of mung bean seedlings decreased by 23.60%, 25.95%, 27.27%, 34.95%, and 43.04% at extract concentrations of 0.25%, 0.50%, 0.75%, 1.00%, and 2.00%, respectively. The inhibitory effect was most distinct at the highest concentration (5.00%), where the vigour index was reduced by 68.30%, indicating a strong phytotoxic impact of the bark extract on mung bean seedling establishment.

In contrast, wheat seedlings responded differently to the bark extract. At lower concentrations (0.25% and 0.50%), the extract exerted a mild stimulatory effect, resulting increases in vigour index of 8.01% and 8.72%, respectively, compared with the control. A greater stimulatory response was observed at intermediate concentrations, with the vigour index increasing by 14.01%, 15.47%, and 11.96% at 0.75%, 1.00%, and 2.00% extract concentrations, respectively. However, this stimulatory effect was not sustained at the highest concentration (5.00%), where the vigour index reduced harply by 51.78% relative to the control. These observations indicate that the aqueous stem bark extract of *Crataeva religiosa* induces a concentration dependent response in wheat seedlings, characterized by stimulation at low to intermediate concentrations and inhibition at higher concentrations, whereas mung bean seedlings exhibited a consistent inhibitory response to across all tested concentrations. The differential response between the two species highlights the selective phytotoxic potential of *C. religiosa* stem bark extract and suggests variations in their physiological tolerance to its bioactive constituents.

Discussion

1. Seed germination

The present investigation demonstrated that the aqueous stem bark extract of *Crataeva religiosa* exerted a concentration-dependent inhibitory effect on seed germination and early seedling growth of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.). The inhibitory response became progressively more pronounced with increasing extract concentration, indicating the presence of phytotoxic allelochemicals in the stem bark. Such dose dependent allelopathic effects have been widely documented in several tree and weeds species.

The inhibitory effect of *C. religiosa* bark extract on seed germination observed in the present study is consistent with earlier reports on the allelopathic activity of bark and plant extracts. Singh *et al.* (2009) [45] reported that aqueous bark leachates of *Ficus subincisa*, *Bauhinia purpurea*, and *Toona hexandra* significantly reduced seed germination in wheat, *Brassica*, and sorghum. Similarly, Astaraei-Ali and Sampietro (2008) [29] demonstrated that almond bark extract inhibited seed germination and root elongation in cress. Kamal and Bano (2008) [37] also reported reduced germination in wheat varieties exposed to aqueous extracts of sunflower leaves, stems, and roots. Likewise, Parvez *et al.* (2003) [40] found that aqueous bark leachate of *Tamarindus indica* markedly suppressed seed germination in several crop species, attributing the inhibitory effect to salicylic acid present in the bark. Comparable phytotoxic effects have also been reported for aqueous extracts of *Avena fatua*, *Melilotus officinalis*, *Polypogon hissaricus* (Siyar *et al.*, 2019) [14], sunflower (Muhammad *et al.*, 2014) [15], and *Parthenium hysterophorus* (Muhammad *et al.*, 2021) [21], all of which significantly inhibited wheat seed germination. Furthermore, Field *et al.* (1988) [35] suggested that dark-coloured bark leachates possess higher concentrations of dissolved organic compounds, making them more phytotoxic than wood leachates.

In agreement with these findings, the present study revealed that lower concentrations (0.25% and 0.5%) of *C. religiosa* bark extract caused only slight inhibition of seed germination, whereas concentrations of 0.75% and above significantly reduced germination in both mung bean and wheat. Wheat exhibited greater sensitivity than mung bean, particularly at higher extract concentrations, indicating species-specific differences in tolerance to allelochemicals. Such variation in sensitivity among plant species has frequently been reported in allelopathic studies and may

arise from differences in seed coat permeability, metabolic activity, detoxification mechanisms, and antioxidant defense systems.
The inhibition of seed germination is likely associated with the presence of secondary metabolites such as phenolic compounds, flavonoids, tannins, alkaloids, terpenoids, and other water-soluble allelochemicals present in the stem bark. These compounds may interfere with the early physiological events of germination by reducing water uptake, inhibiting hydrolytic enzymes responsible for reserve mobilization, disrupting membrane integrity, impairing mitochondrial respiration, and altering endogenous hormonal balance. Such biochemical disturbances ultimately delay or suppress embryo growth and radicle emergence, thereby reducing the overall germination percentage.

2. Seedling Growth

The seedling vigour determined by its well enhanced root growth, which is important in establishment of crop plant. The rapid root growth of young seedling would be crucial for growth, development and establishment and subsequently for higher crop yield (Kent and Lauchi, 1985) [23]. Our present findings are consistent with investigation of many researchers. Jaykumar *et al.* (1998) noticed inhibition of root and shoot length of *Vigna radiata* by the aqueous bark extract of *Ficus bengalensis* at inhibited at higher concentration and stimulation of shoot length and root length at lower concentrations. Kakati and Baruah (2013) [19] noticed inhibition of root and shoot length of Mung bean (*Vigna radiata*) treated with aqueous leaf extract of *Azadirachta indica*, *Murraya koenigii* and *Paederia foetida.* Similar observation in reduction of root length and shoot length crop plants were made by Khan *et al*., (2004) [20] with *Eucalyptus* plant, Siddiqui *et al*., (2009) [21] with *Prosopis juliflora*, Hoque *et al*., (2003) [22] with *Acacia species*. Studies of Thapaliyal *et al.* (2008) [25] reported stimulation in root length and shoot length of *Triticum aestivum*, *Lens culinaris* and *Echinochloa. frumentaceae* when treated with lower concentrations of aqueous bark extract of *Aegle marmelos*, *Terminalia bellirica*, *Terminalia chebula* and *Sapindus mukorossi*. Finding of our present research work are also supported by Mutlu and Atici (2009) [26], where leaf leachate of *Nepeta meyeri* increased the root length and total seedling length of wheat, Canola and safflower at lower concentrations and but higher concentrations were found lethal. Our results are also supported by Kumar *et al.* (2008) [38]. They noticed that aqueous leaf extract of *Aporosa octandra*, *Anthocephallus chiensis* and *Albizia procera* stimulated the root length of maize rice, sorghum except wheat while aqueous bark extract of *Aporosa octandra*, *Anthocephallus chiensis* and *Albizia procera* decreased the germination and radical length of *Glycine max, Oryza sativa, Bassica campestris* but *Anthocephallus* chiensis bark extract stimulated the radical length of *Glycine max*. According to Quasam *et al.* (1993) [41], three *Amaranthus* specie *A. etroflexus*, *A. bilitiods* and *A. gacilis* reduced the shoot length and root length in *Tricum aestivum* at higher concentrations but *A. gracilis at* lower concentration increased the root-shoot length of *Tricum aestivum.*

3. Fresh Weight

Work of many researchers also supports our findings. The aqueous leaf extract of *Eucalyptus camaldulensis* reduced the fresh weight wheat seedling at 10, 15 and 20% concentration (Khan *et al*., 2008). According to Khan et.al., (2012) [16], aqueous leaf extract of *Parthenium hysterophorus* reduced the fresh weight of the four wheat cultivars (viz. Siran, Ata Habib, Sahar and Lasani). Late et.al., (2022) [17] reported negative effect of *Parthenium hysterophorus* on fresh weight of wheat seedling. Jabeen and Ahmed (2009) [47] reported increase in the fresh weight of Maize treated with aqueous extract of *Asphodelus tenuifollius, Euphorbia hirta* and *Fumaria indica*. Khan et.al, (2015) [18] reported decrease in fresh weight of Wheat and wild Oat treated with aqueous extracts of Sorghum Sunflower and Parthenium. Our observation indicates that the water uptake of wheat seedling is increased in response to *Crataeva religiosa* bark extract which is further reflected higher mobilization efficiency due to 0.25% extract of this bark. Thus, these findings indicate that the bark extracts of *Crataeva religiosa* might containing bioactive compounds acting as biotonic and beneficial for water uptake, enhanced hydrolytic activity, mobilization of seed reserves and cell division. The phytotoxicity due to the secondary metabolite might be useful in the development new bioherbicide to mitigate the hazardous effect of chemical herbicide. Thus, it is essential to isolate and purify the bioactive compounds from this bark which will throw more light on nonhormonal analogues responses.

4. Seedling Vigour index

The results of our present work are supported by many researchers. Patil et.al., (2025) [31] reported that aqueous stem bark extract of *Pterocarpus marsupium* reduced the vigor index in Mung bean seedling, while, increase in vigour index was noticed in Wheat seedling. Djanaguiraman *et al.* (2005) [33] observed reduction in dry weight, vigour index due to *Eucalyptus* allelopathy of bark extract in wheat, rice and sorghum at 20%. Aqueous extract of bark of four *Eucalyptus* species *Eucalyptus tereticornis, E. camaldulensis, E. polycarpa* and *E. microtheca* also reduced vigour index and total dry matter of redgram (Sasikumar *et al.*, 2001) [43]. Patil (2026) [32] also made similar observation of reduction in vigour index of Wheat and Mung bean, when treated with aqueous with bark extract of *Anogeissus Latifolia*. In the present study, the vigour index of wheat seedling was stimulated by aqueous bark extract of *Crataeva religiosa* extracts which is further reflected in stimulation of root length. Thus, the extracts of *Crataeva religiosa* found beneficial for improvement of vigour index and mobilization efficiency during seed germination which will be effective in development of biotonics during practices of organic farming. On the contrary, reduced vigor index of Mung bean seedling indicates higher sensitivity towards phytochemicals in the bark. This inhibitory potential of bark allelochemicals can be used to formulate natural herbicide.
The allelopathic activity of plant extracts is primarily attributed to the presence of secondary metabolites, including phenolic compounds, terpenoids, alkaloids, fatty acids, sterols, and saponins. These bioactive compounds regulate plant growth by exerting either stimulatory or inhibitory effects, depending on their concentration and the sensitivity of the recipient species (Inderjit, 1996) [36]. Phenylpropanes inhibit plant growth, acetogenins impair mitochondrial respiration, terpenoids interfere with cell division and cellular metabolism, whereas alkaloids inhibit DNA and RNA synthesis and damage cellular membranes

(Duke and Dayan, 2006; Macias *et al*., 2004) [34,39]. Among the various allelochemicals, phenolic compounds are regarded as the major contributors to allelopathic interactions due to their strong phytotoxic potential (Inderjit, 1996; Rice, 1984) [36,42]. These compounds suppress seed germination and seedling growth by disrupting energy metabolism, mineral uptake, cell division, and biosynthetic pathways. In addition, phenolics reduce water absorption, nutrient acquisition, photosynthetic efficiency, leaf expansion, and dry matter accumulation, ultimately resulting in poor seedling establishment (Chou and Lin, 1996; Rice, 1984) [30, 42]. Such multiple modes of action explain the pronounced inhibitory effects of phenolic-rich plant extracts reported in numerous studies. Several investigations have demonstrated the phytotoxic effects of individual phenolic acids on crop species. Vaughan and Ord (1990) [46] observed that caffeic, hydroxybenzoic, vanillic, and syringic acids markedly reduced root elongation in wheat, rye, and mung bean. These findings collectively indicate that phenolic-rich plant extracts possess broad-spectrum allelopathic potential against agriculturally important crops. Nancy and Nelson (1993) [6] observed that naturally occurring compounds such as salicylic acid, *p*-hydroxybenzoic acid, hydroquinone, and umbelliferone significantly reduced shoot growth and dry matter accumulation in oat. These observations clearly demonstrate the hormetic nature of allelochemicals, where low concentrations may promote plant growth while higher concentrations exert phytotoxic effects. Therefore, the available evidence suggests that the allelopathic effects of plant extracts are governed by the type, concentration, and interaction of secondary metabolites. High concentrations generally induce negative allelopathy by suppressing germination and seedling growth, whereas lower concentrations may exhibit positive allelopathy by stimulating growth responses (Huxley, 1999; Fernandez *et al*., 2006) [7,8]. Understanding these concentration-dependent mechanisms is essential for evaluating the ecological significance of allelopathy and for exploring the potential use of allelochemicals as environmentally sustainable bioherbicides and plant growth regulators.

Summary

The present study demonstrates that the aqueous bark extract of *Crataeva religiosa* exhibits species-specific and concentration-dependent allelopathic effects. Wheat seedlings responded more positively than mung bean, showing enhanced shoot length, root length, fresh weight, and vigour index, whereas mung bean exhibited growth inhibition. The inhibitory effects in mung bean are likely due to the presence of phytotoxic allelochemicals, particularly phenolic compounds, while the stimulatory effects in wheat may be attributed to growth-promoting secondary metabolites and the hormone-like activity of certain phenolics. These findings indicate both negative and positive allelopathic interactions depending on the recipient species and extract concentration. Therefore, *Crataeva religiosa* bark extract has potential as a natural plant biostimulant or bio-tonic and bioherbicide provided that its optimum concentration and active growth-promoting or growth inhibiting constituents are identified through further phytochemical and field investigations.

Conclusion

The present investigation demonstrates that the aqueous stem bark extract of *Crataeva religiosa* possesses significant allelopathic potential and exerts species-specific, concentration-dependent effects on seed germination and seedling growth of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.). The inhibition of seed germination observed in both species indicates the presence of bioactive secondary metabolites capable of interfering with essential physiological and biochemical processes, including hydrolytic enzyme activity, respiration, cell division, and early seedling establishment. Mung bean exhibited greater sensitivity to the bark extract, as evidenced by the marked reduction in fresh weight, shoot length, root length, and vigour index, suggesting the predominance of phytotoxic allelochemicals responsible for negative allelopathic effects. In contrast, wheat seedlings showed comparatively greater tolerance and exhibited growth stimulation at lower extract concentrations, indicating occurrence of positive allelopathy. This stimulatory effect may be attributed to the hormone-like activity of certain secondary metabolites or the ability of wheat to tolerate and utilize these phytochemicals more effectively than mung bean. The differential responses of the two-test species emphasize that the biological activity of *Crataeva religiosa* bark extract depends not only on the concentration of allelochemicals but also on the inherent sensitivity of the recipient plant species. Overall, the findings suggest that *Crataeva religiosa* stem bark is a promising natural source of biologically active allelochemicals with potential applications in sustainable agriculture. isolation, characterization, and quantification of the active phytoconstituents is necessary to explain their mechanisms of action and improve their use as environmentally friendly plant bio-tonics or natural bioherbicides for integrated crop management.

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