Evaluation of Phytotoxic Potential of Aqueous Extract of Stem Bark of *Terminalia arjuna* on Seed Germination, Seedling Growth and Vigour Index of Mung bean (*Vigna radiata*) and Wheat (*Triticum aestivum*)

Udaysing H. Patil*

Department of Botany, Bhogawati Mahavidyalaya, Kurukali, Dist. Kolhapur, Maharashtra, India-416001

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2026.1311000107

Received: 08 November 2026; Accepted: 13 November 2026; Published: 24 November 2026

ABSTRACT

The present study was conducted to investigate the allelopathic potential of aqueous stem bark extract of *Terminalia arjuna* on seed germination and early seedling growth of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.). Aqueous stem bark extracts at six concentrations (0.25%, 0.5%, 0.75%, 1.0%, 2.0%, and 5.0%) were evaluated for their effects on seed germination, shoot length, root length, fresh weight, and seedling vigour index. The results revealed concentration- and species-dependent responses to *T. arjuna* bark extract. In mung bean, a progressive decline in growth parameters (seed germination, shoot and root elongation, fresh weight, and seedling vigour index) was observed with increasing extract concentration. The inhibitory effects were relatively less pronounced at lower concentrations (0.25–1.0%) but became markedly evident at 2.0% and 5.0%. Wheat exhibited a differential response, with shoot elongation being stimulated at 0.25–1.0% concentrations but inhibited at 2.0% and 5.0%. Root length and fresh weight of wheat seedlings were enhanced only at 0.25%, whereas higher concentrations progressively inhibited these parameters. Seedling vigour index also showed pronounced concentration-dependent decline, with maximum inhibition recorded at 5.0% extract concentration. Generally, the results demonstrate significant allelopathic activity of *T. arjuna* stem bark, with the intensity of the response varying according to extract concentration and test species. The observed inhibitory effects could have been linked with the presence of biologically active secondary metabolites in the bark. These findings suggest that *T. arjuna* possesses considerable allelopathic potential and may play a role in regulating the establishment and early growth of neighbouring plant species. The study also highlights the significance of *T. arjuna*-derived allelochemicals for further investigation in weed-management in sustainable agriculture system and plant-interaction studies.

Keywords: *Terminalia arjuna*; allelopathy; allelochemicals; stem bark extract; *Vigna radiata*; *Triticum aestivum*; seed germination; seedling growth; vigour index

INTRODUCTION

Plants interact continuously with one another through a complex network of biochemical and ecological processes. Among these interactions, allelopathy represents an important mechanism by which one plant influences the germination, growth, development, and physiological responses of another plant through the production and release of biologically active chemical compounds. The term *allelopathy* was coined by the Austrian botanist Hans Molisch (1937) in his book *The Effect of Plants on Each Other – Allelopathy*. The compounds responsible for these interactions are generally referred to as allelochemicals and are predominantly secondary metabolites capable of producing either inhibitory or stimulatory effects, depending on their concentration, the recipient species, and

prevailing environmental conditions (Brown et al., 1991; Stamp, 2003). Allelochemicals constitute an important component of plant chemical ecology and contribute to plant defence, competition, establishment of plant communities, and regulation of natural ecosystems (Ridenour and Callaway, 2001; Aslam et al., 2017). These compounds may be synthesized and accumulated in different plant organs, including leaves, flowers, fruits, stems, roots, rhizomes, seeds, and pollen. Their release into the surrounding environment occurs through several pathways, including leaching, root exudation, volatilization, and decomposition of plant residues (Reigosa et al., 1999). The production and accumulation of allelochemicals are influenced by both biotic and abiotic factors, resulting in considerable variation in their quantity and biological activity (Fraenkel, 1959). The expression of allelopathic activity is highly concentration dependent. An allelochemical may inhibit the growth of one plant species at a particular concentration while producing a stimulatory or negligible response in another species or at a different concentration (Azania et al., 2003). Such concentration- and species-dependent responses make allelopathy a complex biological phenomenon and highlight the importance of evaluating allelopathic effects under well-defined experimental conditions. The inhibitory or stimulatory effects of allelochemicals are also influenced by the chemical composition of the donor plant, sensitivity of the recipient species, and environmental conditions surrounding the interaction (El-Daly and Soliman, 1997). From an agricultural perspective, allelopathy has attracted considerable attention because naturally occurring allelochemicals may provide an alternative or complementary approach to conventional weed-management practices. Exploitation of allelopathic plants and their bioactive compounds may contribute to weed suppression, reduction in the excessive use of synthetic herbicides, minimization of pesticide-associated environmental pollution, and development of more sustainable crop-production systems (Cheema et al., 2001; Radhakrishnan et al., 2018). Therefore, identification and evaluation of plant species possessing significant allelopathic potential are important for understanding plant interactions and exploring their possible agricultural applications.

MATERIALS AND METHODS

Collection and processing of the plant material

Bark sample of *Terminalia arjuna* 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 50^0C 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.

Preparation of the aqueous extracts

The oven dried bark of *Terminalia arjuna* 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 (28-30^0C) to get bark leachate. The resultant extracts were filtered through Whatman No.1 filter paper and stored in conical flask in refrigerator.

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-

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

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

Vigor index (VI) = (Root length + Shoot length) X Germination percentage

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

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

RESULTS

Germination percentage

The effect of aqueous bark extract of *Terminalia arjuna* on seed germination of mung bean and wheat is presented in Table 1. A concentration-dependent inhibition of seed germination was observed in both test species following treatment with the bark extract. Germination percentage declined progressively with increasing extract concentration, indicating an inverse relationship between extract concentration and germination response. In mung bean, germination was inhibited by 17.5%, 25.0%, 30.0%, 34.5%, and 40.0% at 0.25%, 0.50%, 0.75%, 1.0%, and 2.0% extract concentrations, respectively, relative to the untreated control. The highest concentration (5.0%) resulted in a maximum inhibition of 50.0%. Thus, the inhibitory effect increased consistently across the concentration gradient. A similar response was recorded in wheat, although the magnitude of inhibition was comparatively lower at the lower extract concentrations. Germination was reduced by 10.0% and 15.5% at 0.25% and 0.50% extract concentrations, respectively. At 0.75%, 1.0%, and 2.0%, germination inhibition increased to 22.5%, 27.5%, and 29.5%, respectively. The maximum inhibition (45.0%) was recorded at 5.0% extract concentration.

Seedling fresh weight

The effect of the aqueous stem bark extract of *Terminalia arjuna* on the fresh weight of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.) seedlings is presented in Tables 2 and Table 3 and Fig 1 and Fig. 2. Both mung bean and wheat exhibited separate responses to increasing concentrations of the bark extract, demonstrating a concentration dependent species-specific response to the phytoconstituents present in the extract.

In mung bean, the aqueous bark extract markedly reduced fresh weight, with the increasing degree of inhibition with corresponding progressive increase in extract concentration. At 0.25% and 0.50% concentrations, fresh weight decreased by 8.08% and 13.54%, respectively, compared with the untreated control. A substantial reduction was observed at 0.75%, 1.0%, and 2.0%, where fresh weight reduced by 43.47%, 56.77%, and 58.67%, respectively. The strongest effect was observed at 5.0% extract concentration, where fresh weight was reduced by 68.17% in relative to the control. This dose-dependent decline in fresh biomass indicates a pronounced phytotoxic effect of *T. arjuna* bark constituents on mung bean seedlings.

Wheat seedlings exhibited comparatively greater tolerance to the bark extract. A mild stimulatory effect was observed at the lowest concentration (0.25%), at which fresh weight increased by 9.09% over the control. However, with further increases in extract concentration, fresh weight gradually declined. Reductions in fresh weight of 3.41% and 7.39% were recorded at 0.50% and 0.75%, respectively, while not much difference in reduction was observed at 1.0%, 2.0%, and 5.0%, where fresh weight was reduced by 13.07%, 15.34%, and 19.89% respectively. As compared to the

mung bean, significantly lower degree of biomass inhibition in wheat specifies a high degree of tolerance of wheat seedlings to the inhibitory secondary metabolites in the bark extract *T. arjuna*. The overall behaviour of the two plants indicates that the *T. arjuna* bark extract exerts a concentration dependent and species-specific effect on seedling biomass. In total, bark extract of *Terminalia arjuna* revealed a dose-dependent and species-specific effect on the two species under study. These findings indicate that the extract may contain bioactive phytochemicals and possess hormone like properties, promoting growth at lower concentrations in wheat, while triggering phytotoxic effects at elevated concentrations in both, mung bean and wheat species. This reflects interspecific difference in the uptake, translocation, metabolism, and also differences in their physiological responses to phytotoxic stress. Therefore, the results indicate that aqueous stem bark extract of *T. arjuna* possesses biologically active phytoconstituents with differential allelopathic potential on mung bean and wheat seedlings, where mung bean exhibiting greater sensitivity to allelochemicals than the wheat.

Table No. 1. Effect of aqueous bark extract of *Terminalia arjuna* 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%	62.5	82.5	57.5	90
0.50%	55	75	62.5	84.5
0.75%	52.5	70	55	77.5
1%	50	65.5	50	72.5
2%	50	60	42.5	70.5
5%	35	50	37.5	55

Seedling growth (Shoot-Root length)

The effect of aqueous stem bark extract of *Terminalia arjuna* 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. A dose dependent inhibition of shoot elongation was observed in mung seedlings. At lower extract concentrations (0.25% and 0.50%), shoot elongation was inhibited by 15.54% and 25.49%, respectively, relative to the control. The bark extract at 0.75%, 1.0%, and 2.0% concentrations, more or less equally inhabited the shoot length by 30.98%, 33.26%, and 34.40% respectively as compared to control. The marked reduction (49.55%) in shoot length was observed at highest bark extract concentration (5.0%).

On the contrary, where bark extracted showed pronounced inhibitory effect on shoot elongation in mung bean seedling, a stimulatory response was observed in wheat seedlings at lower extract concentrations. The bark extract promoted shoot elongation by 10.89%, 8.69%, 15.84%, and 10.12%

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XIII Issue X November 2026

at concentrations of 0.25%, 0.50%, 0.75%, and 1.0%, respectively, compared with the untreated control. This growth promoting effect could not sustained at higher concentrations (2.0% and 5.0%). The shoot length was reduced by 19.47% at 2.0%, followed by maximum reduction in shoot length by 58.90% at highest bark concentration of 5%.

Table No. **2.** Effect of aqueous extract of stem bark of *Terminalia arjuna* on the he 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	8.17±1.64	7.19±1.19	6.66±0.95	6.44±1.18	6.33±0.99	4.83±0.89
Root length	4.6±1.10	3.59±0.64	2.86±0.59	3.17±0.67	3.25±0.86	2.46±0.91	1.87±0.91
Fresh Weight	4.21±0.30	3.87±0.27	3.64±0.60	2.38±0.66	1.82±0.83	1.74±0.40	1.34±0.91
Vigor Index	1445	1176	1005	983	969	879	670
Readings are mean of three replicates ± SD							

Table No. **3.** Effect of aqueous extract of stem bark of *Terminalia arjuna* 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	10.08±0.44	9.88±0.78	10.53±0.55	10.01±1.28	7.32±0.95	3.81±0.55
Root length	16.25±1.23	17.49±1.83	14.29±1.31	10.82±1.41	7.52±1.10	4.71±0.96	1.87±0.64
Fresh weight	1.76±0.56	1.92±0.32	1.70±0.19	1.63±0.45	1.53±0.56	1.49±0.56	1.41±0.66
Vigor Index	1445	1176	1005	983	969	879	670
Readings are mean of three replicates ± SD							

Overall, the aqueous stem bark extract of *Terminalia arjuna* 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

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XIII Issue X November 2026

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 *Terminalia arjuna* 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. From the results it is clear that both the plants have shown different responses to the different bark extract concentrations. In mung bean seedlings, All the concentrations studied concentrations of the bark extracts caused pronounced inhibition in root length elongation. The effect was increased with increase in the concentration of the bark extract from lower (0.25%) to higher (5.0%) concentration. The lowest concentration of 0.25% suppressed the root elongation by 21.96%, over the untreated control. The two concentrations i.e. 0.50% and 0.75% caused more or less similar effect and reduced the root length by 29.35% and 31.09% respectively, relative to control. Inhibitory effect noticed was quite high at 1.0%, 2.0% and 5.0% bark extract concentration, where the root length was reduced by 37.83%, 46.52%, and 59.35% respectively, over the untreated control. In wheat seedlings, a similar dose-dependent inhibition of root elongation was observed, except at the lowest concentration (0.25%), where root length was mildly stimulated by 7.63% compared with the untreated control. At 0.50%, 0.75%, and 1.0% concentrations, the bark extract suppressed root elongation by 12.06%, 33.42%, and 53.72%, respectively. The inhibitory effect became more pronounced at higher concentrations, with root length reductions of 71.02% and 88.49% at 2.0% and 5.0% extract concentrations, respectively. These results demonstrate a clear concentration-dependent inhibitory effect of *Terminalia arjuna bark* extract on wheat root elongation and indicate its strong phytotoxic potential at elevated concentrations. The pronounced inhibition of root growth at higher extract concentrations suggests that the bioactive constituents present in the bark may interfere with cell division and/or cell elongation processes in the developing roots.

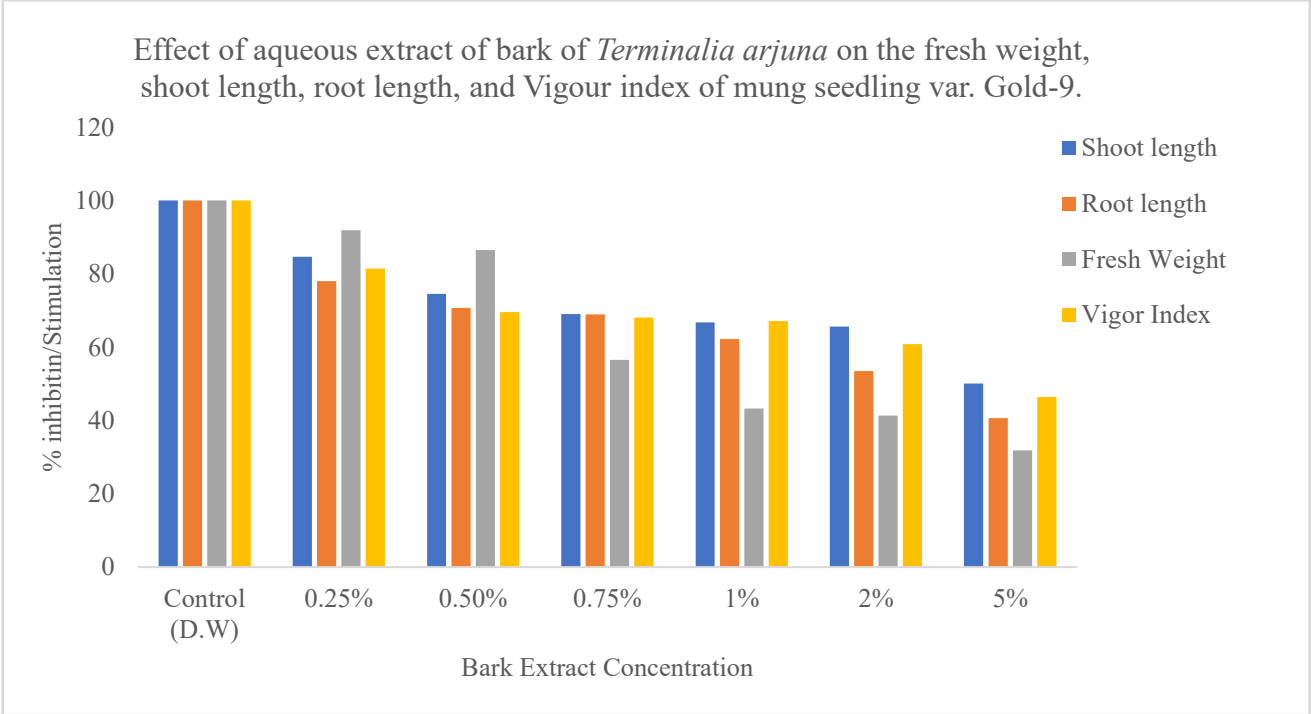

Fig. 1. Effect of aqueous extract of bark of *Terminalia arjuna* on the fresh weight, shoot length, root length, and Vigour index of mung seedling var. Gold-9.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XIII Issue X November 2026

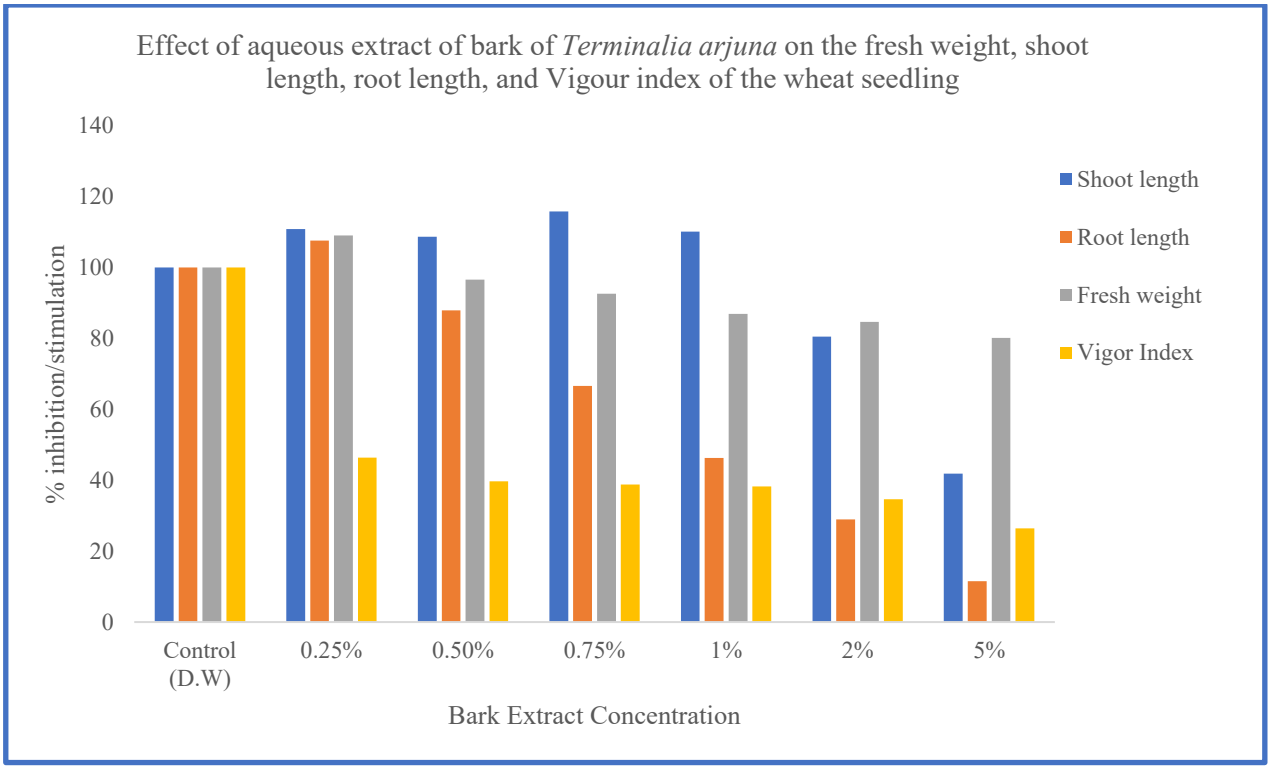

Fig. 2. Effect of aqueous extract of bark of *Terminalia arjuna* on the fresh weight, shoot length, root length, and Vigour index of the wheat seedling

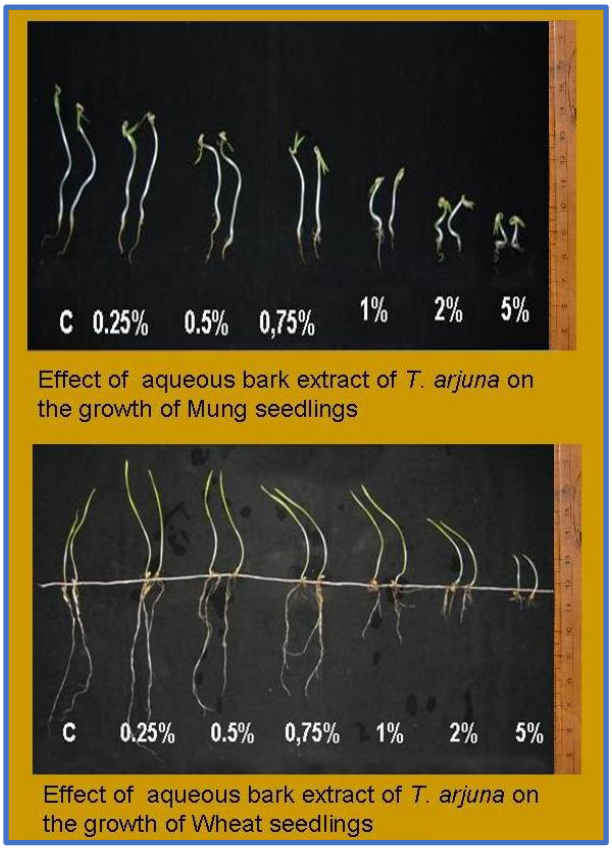

Plate No. 1

Seedling Vigour

The effect of the aqueous stem bark extract of *Terminalia arjuna* on the vigour index of mung bean (*Vigna radiata* L.) and wheat (*Triticum aestivum* L.) seedlings is presented in Tables 2 and 3 and

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XIII Issue X November 2026

Figures 1 and 2. The results proved a clear concentration-dependent phytotoxic effect of the bark extract on seedling vigour in both species, with wheat exhibiting greater sensitivity than mung bean. The degree of inhibition increased with increasing bark extract concentration. In mung bean, the vigour index decreased by 18.62% at 0.25% extract concentration relative to the untreated control. At 0.50%, 0.75%, and 1.0% concentrations, reductions of 30.45%, 31.97%, and 32.94%, respectively, were recorded. The inhibitory effect became more pronounced at higher concentrations, with reductions of 39.17% at 2.0% and 53.63% at 5.0%, the latter representing the maximum inhibition observed in mung bean seedlings.

A considerably stronger inhibitory response was observed in wheat seedlings. Even at the lowest concentration (0.25%), the vigour index was reduced by 53.59% compared with the control. At 0.50%, 0.75%, and 1.0% concentrations, reductions of 60.34%, 61.21%, and 61.76%, respectively, were observed. Further increases in extract concentration resulted in greater inhibition, reaching 65.31% at 2.0% and 73.56% at 5.0%. Overall, the greater reduction in vigour index in wheat than in mung bean indicates higher sensitivity of wheat seedlings to the phytotoxic constituents of *T. arjuna* bark extract. The concentration-dependent suppression of seedling vigour suggests that the bioactive compounds present in the extract may interfere with key physiological processes involved in seedling establishment and growth.

DISCUSSION

Seed germination

Overall, aqueous bark extract of *Terminalia arjuna* significantly suppressed seed germination in both mung bean and wheat, with the inhibitory response becoming more pronounced at higher extract concentrations. Mung bean exhibited comparatively greater sensitivity to the bark extract than wheat, particularly at the lower concentrations. The observed concentration-dependent inhibition indicates a potential allelopathic effect of water-soluble constituents present in the bark of *Terminalia arjuna*. The results of our present investigations are supported by many earlier researchers. Aqueous root extract of radish (*Raphanus* sativus) reduced the wheat seed gemination dose dependently and completely inhibited seed germination at 40% highest concentration (Saman and Kawa, 2020). Significant reduction in seed germination of wheat, *Brassica*, and sorghum was observed when treated with aqueous bark leachates of *Ficus subincisa*, *Bauhinia purpurea*, and *Toona hexandra* (Singh *et.al.*2009). Similarly, aqueous extracts of sunflower leaves, stems, and roots reduced germination in wheat (Kamal and Bano 2008). The aqueous extract of whole plant of three weed species (Phalaris minor, Melilotus indicus and Chenopodium album) inhibited the seed germination of five wheat varities HD 2967, Sava Kanak 2200, Kanak Gold, Wheat 2001 and Bioseed 2003 (Sachan et.al, 2026).

Some flavonoids also known to have inhibitory effect on seed germination (Kumar, et al., 2010) Aaqueous root and shoot extract of *Calotropis procera* prominently reduced wheat seed germination (Radwana et.al, 2019). According to Parvez *et al.* (2003), salicylic acid present in the aqueous bark leachate of *Tamarindus indica* markedly suppressed seed germination in several crop species. Aqueous extracts of many other plants like *Avena fatua*, *Melilotus officinalis*, *Polypogon hissaricus* (Siyar *et al.*, 2019) and *Parthenium hysterophorus* (Muhammad *et al.*, 2021) caused significant inhibition in wheat seed germination. Again, dark-coloured bark leachates become more phytotoxic due to higher concentrations of dissolved organic compounds (Field *et al.*,1988). According to Chiang et al. (2003), various effect of plant extracts on seed germination are results of various chemical constituents present in the plants. Also, secondary metabolites can affect the seed germination and productivity of the many plants. Additionally, plants from desert conditions produce hazardous or beneficial or selective effect on plants, (Willis, 2007).

The present study revealed that *Terminalia arjuna* bark extract significantly reduced seed 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 defence 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 physiological processes at germination level by reducing water uptake, inhibiting hydrolytic enzymes, declining respiration, and altering endogenous hormonal balance. Such biochemical conflicts suppress embryo growth and radicle emergence, thereby reducing the germination percentage.

Seedling Growth

Root elongation is a critical factor of early seedling establishment, as an actively developing root system enhances water and mineral acquisition and thereby contributes substantially to subsequent plant growth and productivity (Kent and Lauchi, 1985). In the present study, root growth showed a marked inhibitory response to increasing concentrations of the aqueous bark extract, indicating a concentration-dependent phytotoxic effect. The greater sensitivity of roots than the shoots may be attributed to their direct and prolonged exposure to extract-derived bioactive compounds, which can interfere with cellular division and elongation in the root meristem and elongation zones (Turk and Tawaha, 2002). Root growth inhibition is therefore considered a sensitive indicator of allelopathic interactions during the early stages of plant development. The present observations are in agreement with Jaykumar et al. (1998), who reported significant inhibition of root and shoot elongation in *Vigna radiata* following exposure to higher concentrations of aqueous bark extract of *Ficus* spp. Similarly, Kakati and Baruah (2013) demonstrated that aqueous leaf extracts of *Azadirachta indica*, *Murraya koenigii*, and *Paederia foetida* suppressed root and shoot elongation of mung bean at higher extract concentrations.

Similar responses have been documented in other crop species by many researchers. Thapaliyal et al. (2008) reported significant inhibition of root and shoot elongation in *Triticum aestivum*, *Lens culinaris*, and *Echinochloa frumentacea* treated with aqueous bark extracts of *Aegle marmelos*, *Terminalia bellirica*, *Terminalia chebula*, and *Sapindus mukorossi*, particularly at higher concentrations. Likewise, Mutlu and Atici (2009) observed reductions in root length and total seedling length of wheat, canola, and safflower exposed to leaf leachates of *Nepeta meyeri*. In addition, Kumar et al. (2008) reported decreased seed germination and radicle elongation in *Glycine max*, *Oryza sativa*, and *Brassica campestris* following treatment with aqueous bark extracts of *Aporosa octandra*, *Anthocephalus chinensis*, and *Albizia procera*.

Fresh Weight

Work of many researchers are in agreement of our findings. Bahuguna et al. (2013) demonstrated that aqueous leaf extract of *Juglans regia* reduced the fresh weight wheat seedling at higher concentration. Joshi and Joshi (2016) reported that aqueous leaf extract of *Ipomoea carnea* reduced the fresh weight more than 50% at concentrations of 3 % and 5%. Othman et al. (2023) found that many plant extracts reduced the fresh weight of weeds. Our findings are also supported by Kanata (2020), Ben Ghnaya et al., (2016) and Cheema et al. (2001). The fresh weight of the four wheat cultivars (viz. Siran, Ata Habib, Sahar and Lasani) was deceased when treated with aqueous leaf extract of *Parthenium hysterophorus* (Late et.al., 2022; Khan et.al. 2012). Similar observations are made by Khan et.al, (2015) in case Wheat and wild Oat where aqueous extracts of Sorghum, Sunflower and Parthenium where, decreased the fresh weight. Aqueous barks extract of *Pterocarpus marsupium* and *Crataeva religiosa* reduced the fresh weight of mung bean at higher concentration while, Anogeissus *latifolia* reduced the fresh weight of both wheat and mung bean (Patil et al., 2025; Patil, 2026; and Patil, 2026). Our findings, indicate that the bark extracts of *Terminalia arjuna* might containing phytotoxic compounds acting as phytotoxins. This potential of *Terminalia arjuna* bark and 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 and of prime importance

to isolate and purify the bioactive compounds from this bark which will throw more light on nonhormonal analogues responses.

Seedling Vigour index

The results of our present work are supported by many researchers. Reduction in vigour index was also reported in wheat, rice and sorghum crops in response to aqueous bark extract of *Eucalyptus* (Djanaguiraman *et al.* 2005). Similar observations were made by Patil et al. (2025) and reported that aqueous stem bark extract of *Pterocarpus marsupium* reduced the vigor index in Mung bean seedling, while, increased the vigour index of Wheat seedling. Similar observations were made by Sasikumar et al. (2001) in case of red gram when treated with aqueous bark extract of four *Eucalyptus* species. Our results are in agreement with the reports by Patil (2026), where, aqueous bark extract of *Anogeissus latifolia* reduced the vigour index of Wheat and Mung bean. The results of present investigations are relative to the findings of Joshi and Joshi (2016). They reported that aqueous leaf extract of Ipomoea, Cymbopogon, Ricinus, Hyptis, Malachra, and Alternanthera reduced the vigour index of wheat. Extract of *Euphorbia hirta* decreased the vigor index of Groundnut with increase in extract concentration (Rose and Anitha, 2012). Similar reports were recorded by Tanveer et al., (2010) while studying the extract of *Euphorbia heliscopia* against wheat, chick pea and lentil. The bark extract of *Crataeva religiosa* reduced the vigour index of mung bean seedling Patil (2026). In the present study, the vigour index of mung bean and wheat seedling was severely affected and declined by aqueous bark extract of *Terminalia arjuna* extracts Heavy reduction in vigor index of Mung bean and wheat seedling indicates higher sensitivity of both these plants towards phytochemicals in the bark. The allelopathic potential of different plant parts extracts is mainly attributed to the presence of secondary metabolites, including phenolic compounds, terpenoids, alkaloids, fatty acids, sterols, and saponins. The inhibition observed in many growth parameters may be attributed to presence of water-soluble phytotoxic compounds (Rehman et al., 1991). These compounds exsert stimulatory or inhibitory effects and regulate plant growth, depending on their concentration and extent of sensitivity of the exposed plants (Inderjit, 1996). Many plant secondary metabolite act by inhibit plant growth (Phenylpropanes), damage mitochondrial respiration (acetogenins), interfere with cell division and cellular metabolism (terpenoids), alkaloids inhibit DNA and RNA synthesis and also damage cellular membranes (Duke and Dayan, 2006; Macias *et al*., 2004). Among the allelochemicals, phenolic possesses strong phytotoxic potential (Inderjit, 1996). These compounds disrupt energy metabolism, mineral uptake, cell division, and biosynthetic pathways, reduce water absorption, nutrient acquisition, photosynthetic efficiency, leaf expansion, and dry matter accumulation, ultimately resulting in poor seedling establishment through reduced seed germination and seedling growth (Chou and Lin, 1996; Rice, 1984). Several studies have explained inhibitory effects of phenolic-rich plant extracts. Vaughan and Ord (1990) observed that caffeic, hydroxybenzoic, vanillic, and syringic acids markedly reduced root elongation in wheat, rye, and mung bean. Nancy and Nelson (1993) 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 findings and results of our present investigations collectively indicate that phenolic-rich plant extracts possess strong allelopathic potential against plants. High concentrations of the plant extract is generally responsible to 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). Our observations clearly demonstrate the hormone like nature of allelochemicals, where low concentrations have promoted some growth parameters while, higher concentrations exerted phytotoxic effects on some growth parameters. This phytotoxicity of the plant extracts is governed by the type of secondary metabolite, its concentration in the extract and interaction of secondary metabolites with plant metabolism. Understanding these concentration-dependent mechanisms, it is essential to evaluate the ecological significance of allelopathy and for exploring the potential use of allelochemicals as environment friendly sustainable bioherbicides and plant growth regulators.

CONCLUSION

The present investigation demonstrates that the aqueous stem bark extract of *Terminalia arjuna* possesses significant allelopathic potential and exerts species-specific, concentration-dependent effects on seed germination and seedling growth of mung bean (*Vigna radiata*) and wheat (*Triticum aestivum*). 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, suggesting the prevalence 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 *Terminalia arjuna* 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 *Terminalia arjuna* stem bark is a promising natural source of biologically active allelochemicals with potential applications in sustainable agriculture. Thus, the concentration-dependent effect may be attributed to the cumulative phytotoxic action of phenolics, terpenoids, alkaloids, and other secondary metabolites effective for altering membrane permeability, cellular metabolism, nutrient uptake, and hormonal regulation. These, results further suggest that the bark extract possesses appreciable allelopathic potential. Therefore, 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.

REFERENCES

1. Molisch. H. (1937). The influence of one plant on another - Allelopathic., Fischer, Jena.
2. Brown, P. D.; Morra, J. M., McCaffery, J. P. and Auld Williams, D. L. (1991). Allelochemicals produced during glucosinolate degradation in soil. *J Chem Ecol.*, 17:2021-2034.
3. Stamp, N. (2003) Out of the quagmire of plant defense hypotheses. *The Quarterly review of biology*, 78(1):23-55.
4. Fraenkel, G.S. (1959). The raison d'etre of secondary plant substances. *Science*, 129:1466-1470.
5. Reigosa, M.J., Souto, X.C. and Gonz, L. (1999). Effect of phenolic compounds on the germination of six weeds species. *Plant Growth Regulation*, Jun 1, 28(2):83-88.
6. Radhakrishnan, R., Alqarawi, A. A., and Abd Allah E. F. (2018). Bioherbicides: Current knowledge on weed control mechanism. *Ecotoxicology and Environmental Safety,* 158(April):131–138.
7. Cheema, Z. A. and Khaliq A. Use of sorghum allelopathic properties to control weeds in irrigated wheat in a semi-arid region of Punjab. Agriculture, Ecosystems & Environment. 2000 Jul 1;79(2-3):105-12.
8. Azania, A.A.P.M., Azania, C.A.M., Alives, P.L.C.A., Palaniraj, R., Kadian, H.S., Sati, S.C., Rawat, L.S., Dahiya, D.S. and Narwal, S.S. (2003). Allelopathic plants. Barley (*Hordeum vulgar* L.) *Allelopathy Journal*, 11:1-20.
9. Vaughan, D. and Ord, B.G. (1990). Effects of allelochemicals in roots. Plant Root Growth- An Ecological perspective. Blackwell Scientific Publications, Landon, Pp. 399-421.
10. Nancy, L.S. and Nelson, B. (1993). Plant growth responses to several allelopathic chemicals. *Weed Sci*., 31: 293-298
11. Huxley, P. (1999). Tropical Agroforestry. Blackwell Science, Oxford.
12. Fernandez, C.B., Lelong, B., Vilsa, J.P., Mevy, C., Robles, S., Greff, S.D. and Bousquet-Melou, A. (2006) Potential allelopathic effect of *Pinus halepensis* in the secondary succession: an experimental approach. *Chemoecol*.,16: 97-105.

13. El-Daly, F.A. and Soliman, M.H. (1997). Effect of different concentrations of lupine seed extract on the growth criteria and pigmentation of soybean plant at different growth stages. *Egypt. J. Physiol. Sci.*, 21:187-196.
14. Saman, A.R. and Ali, K.A. (2020). Effect of Radish Aqueous Extract on Germination and Seedling Growth of Wheat, Wild Oat and Wild barley. *J Adv Pharm Edu Res.,*10(S2):183-189.
15. Sachan, R., Lata, S. and Parihaar, R. (2026). Allelopathic effects of aqueous extracts of three major weed species on seed germination and seedling growth of wheat varieties. *Environment Conservation Journal*, 27 (2): 599-606.
16. Chiang, W., Liu, M.C. and Lin, C.C. (2003). In vitro antiviral activities of C. pulcherrima and its related flavonoids. *J. Antimicr. Chemoth.,* 52:194–198.
17. Willis, R.J. (2007). The History of Allelopathy, First ed. Springer, pp. 206.
18. Radwana, A.M., Alghamdib, H.A. and Kenawya, S.K.M. (2019) Effect of *Calotropis procera* L. plant extract on seeds germination and the growth of microorganisms. *Annals of Agricultural Sciences*, 64:183-187.
19. Kumar, D., Kumar, N., Akamatsu, K., Kusaka, E., Harada, H. and Ito, T. (2010). Synthesis and biological evaluation of indolyl chalcones as antitumor agents. *Bioorg. Med. Chem. Let.,* 20:3916–3919.
20. Turk, M.A. and Tawaha, A.M. (2003). Allelopathic effect of black mustard (*Brassica nigra* L.) on germination and growth of wild oat (*Avena fatua* L.). *Crop Prot.*, 22:673–677.
21. Bahuguna, A., Bahuguna, S. and Prasad, B. (2013). Response of walnut (Juglans regia L.) leaf aqueous extracts, on seed germination and seedling growth of wheat (Triticum aestivum L.) in agri-silvi system of Uttarakhand. Journal of Applied and Natural Science 5 (2): 411-415 (2013).
22. Nitesh Joshi and Ambika Joshi (2016). Allelopathic effects of weed extracts on germination of wheat. Annals of Plant Sciences 5.5 (2016): 1330-1334
23. Othman, S.H., Lazim Z.S., and Al-Wakaa, A.H.A. (2023). Allelopathic Potential of Aqueous Plant Extracts Against Seed Germination and Seedling Growth of Weeds. 10 4th International Conference of Modern Technologies in Agricultural Sciences IOP Conf. Series: Earth and Environmental Science, 1262, 032041 IOP Publishing doi:10.1088/1755-1315/1262/3/032041.
24. Kanatas, P. (2020). Potential role of *Eucalyptus* spp. and *Acacia* spp. allelochemicals in weed management. *Chilean journal of agricultural research,* 80(3):452–458.
25. Ben Ghnaya, A., L. Hamrouni, I. Amri, H. Ahoues, M. Hanana, and A. Romane. 2016. Study of allelopathic effects of Eucalyptus erythrocorys L. crude extracts against germination and seedling growth of weeds and wheat. Natural product research. 30(18):2058–2064.
26. Cheema, Z.A., Kaliq, A. and Akhtar, S. (2001). Use of Sorgaab (*Sorghum* Water Extract) as a Natural Weed Inhibitor in Spring Mun bean. *International journal of agriculture and biology,* 3(4):515-518.
27. Rose, M.L. and Anitha, S. (2012). Effect of Euphorbia hirta L. extract on the germination and seedling growth of groundnut. *Adv. Biotec.*, 12: 27-29.
28. Tanveer, A., Rehman, A., Javaid, M. M, Abbas, R. N., Sibtain, M, Ahmad, AU., Sahid, M. Zamir, Chaudhary K.M. and Aziz, A. (2010). Allelopathic potential of Euphorbia heliscopia L. against wheat (Triticum aestivum L.), Chick pea (Cicer arietinum L.) and Lentil (Lens culinaris Medic.). *Turk. J. Agric.*, 34: 75-81.
29. Rehman, M.U., Swati, M.S., Ahmad, M. and Marwat, K.B. (1991). Allelopathic effects of Sisymbrium irio L. on wheat variety Blue Silver. Absts. 3rd All Pak. Weed Sci. Conf. NWFP Agriculture Univ., Peshawar, Pakistan, October 16-17.
30. Rice, E.L. (1984). Allelopathy, 2nd ed.; Academic Press: Orlando, FL, USA, 1984.
31. Ridenour,W. M. and Callaway, R. M. (2001). The Relative Importance of Allelopathy in Interference: The Effects of an Invasive Weed on a Native Bunchgrass. *Oecologia*, 126:444–450.
32. Aslam, F., Khaliq, A., Matloob, A., Tanveer, A., Hussain, A. and Zahir. Z. A. (2017). Allelopathy in agro-ecosystems: A critical review of wheat allelopathy-concepts and implications. *Chemoecology*, 27:1–24.

33. Siyar, S., Majeed, A., Muhammad, Z., Alic, H. and Inayat, N. (2019). Allelopathic effect of aqueous extracts of three weed species on the growth and leaf chlorophyll content of bread wheat. *Acta Ecologica Sinica,* 39:63–68.
34. Khan, N., Hashmatullah, Naveed, K., Hussain, Z. and Khan, S.H (2012). Assessment of allelopathic effects of parthenium (*Parthenium hysterophorus* L.) plant parts on seed germination and seedling growth of wheat (*Triticum aestivum* L.) cultivars., *Pak. J. Weed Sci. Res.,*18(1):39-50.
35. Late, V., Randive, A., Najan, H. and Bhusari, P. (2022). Assessment of allelopathic efficacy of *Parthenium hysterophorus* L. plant parts on seed germination and seedling growth of *Triticum aestivum* L., *International Journal of Botany Studies*, 7(4):117-123.
36. Khan, H., Adil, Gul, B., Khan, M.H. and Marwat, K.B. (2015). Efficacy of aqueous extracts of different allelopathic plants on germination and growth of wheat and wild oat., *Pak. J. Bot.,* 47(SI): 181-185.
37. Kakati, B. and Baruah, A. (2013). Allelopathic effect of aqueous extract of some medicinal plants on seed germination and seedling length of mung bean (*Vigna radiata* (L.) Wilczek.). *Indian Journal of Plant Sciences*, July-September 2(3):8-11.
38. Kent, H. and Laulchli, V. (1985) Germination and seedling growth of cotton:saliniy calcium interaction. *plant cell environment*, 8:155-159.
39. Jaykumar, M., Eyini, M. and Manikandan, M. (1998). Allelopathic effect of extracts from *Ficus bengalensis* L. *Korean J. Ecol.*, 21(2): 133-137.
40. Thapaliyal, S., Bali., S.R., Singh, B. and Tidaria, N.P. (2008). Allelopathic effect of tree on economic importance on germination and growth of food crops. *J. Herbs, Spices and Medicinal Plants*, 13(4):11-23.
41. Mutlu, S. and Atici, O. (2009). Allelopathic effect of Nepeta meyeri Benth. extracts on seed germination and seedling growth of some crop plants. *Acta Physiol Planta*., 31:89-93.
42. Abdul-Baki, A.A. and Andersion, J.D. (1973). Vigor determination of soybean by multiple criteria. *Crop Sci.,*13:630-633.
43. Muhammad, I., Muhammad, I., Fazal, H., Nazakat, H.M. and Zhiyong Z. (2021). Allelopathic effect of *Parthenium hysterophorus* extract on seed germination and seedling growth of selected eight plants. *Pak. J. Bot.*, 53(6):1-11.
44. Chou, C.H. and Lin, H.J. (1996). Autointoxication mechanism of *Oryza sativa*. Phytotoxic effects of decomposing rice residues in soil. *J. Chem. Ecol.,* 2:352-367.
45. Patil, U.H., Kengar, Y.D. and Sonar, B.A. (2025). Effect of aqueous extract of stem bark of Pterocarpus marsupium on seed germination and seedling growth of Mung bean and Wheat. *International Journal of Research and Analytical Reviews (IJRAR)*, September 2025, 12(3):108-117.
46. Patil, U.H. (2026). Allelopathic Effect of Stem Bark Extract of *Anogeissus Latifolia* L. on Seed Germination and Seedling Growth of Mung Bean and Wheat. *International Journal of Science and Research* (IJSR), August 2026, 15(8):71-76.
47. Djanaguiraman, M., Vaidyanathan, R., Sheeba, A.J. and Durga, D. (2005). Bangarusamy U. Physiological responses of *Eucalypatus globules* leaf leachate on seedling physiology of rice, sorghum and blackgram. *International J of Agri and Biol.* 1:35-38.
48. Duke, S.O. andDayan, F.E. (2006). Modes of action of phytoalexins from plants. Reigosa, M., Pedrol, N. Gonzalez, L. Editors. Allelopathy: A Physiological Process with Ecological Implications. Springer, Amsterdam. Pp 511-536.
49. Field, J.A., Leyendeckers, M.J.H., Sierra-Alvarez, R., Lettinga, G. and Habets, L.H.A. (1988). The methanogenic toxicity of bark tannins and the anaerobic biodegradability of water-soluble bark matter. *Water Science and Technology*, 20:219-240.
50. Inderjit, R. and Keating, K.I. (1996). Allelopathy: principles, Procedures, Processes and Promises for Biological Control. *Advances in Agronomy,*67:141-231.
51. Kamal, J. and Bano, A. (2008). Allelopathic potential of sunflower (*Helianthus annus* L.) on soil metals and its leaves extracts on physiology of wheat (*Triticum aestivum* L.) seedlings. *African J of Biotech*., 7(18):3261-3265.

52. Kumar, M., Singh, S. and Singh, B. (2008). Screening indigenous tree species for suitable tree-crop combinations in the agroforestry system of Mizoram, India. *Estonian J of Ecology*, 57(4):269-278.
53. Macias, F.A., Oliverson-Bastidas, A., Marin, D., Castellano, D., Simonet, A.M. and Molinlill J.M.G, (2004). Degradation studies on benzoxazinoids soil degradation dynamics of 2,4-dihydroxy-7-methoxy-(2H)-1,4-benzoxazin-3(4H)-one (DIMBOA) and its degradation products, phytotoxic allelochemicals from *Graminea*. *J. Agri. Food Chem.*, 52: 6402-6413.
54. Parvez, S.S., Parvez, M.M., Fujii, Y. and Gemma, H. (2003). Differential allelopathic expression of bark seed of *Tamarindus indica* L. *Plant Growth Regulation*., 42:245-252.
55. Sasikumar, K., Vijayalakshmi, C. and Parthiban, K.T. (2001) Allelopathic effects of eucalyptus on red gram. *J of Tropical Agriculture*., 72: 277-281.
56. Shrivastava, A.K. and Sareen, K. (1974). Physiology and biochemistry of deterioration of Soybean seeds during storage, I-mobilization and nitrogen metabolism. *Seed Research,* 2:26-32.
57. Singh, B., Jhaldiyal, V. and Kumar, M. (2009). Effect of aqueous leachates of multipurpose trees on test crops. *Estorian J of Ecol*., 58(1):38-46.