International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 179-186, 2022; Article no.IJPSS.94803
ISSN: 2320-7035

Allelopathic Effects of *Schima khasiana* and *Michelia champaca* on Germination and Growth of Some Legume and Cereal Crops of North Eastern Himalayan Region

M. S. Sachan [a*], D. Dey [a], P. Michui [b] and S. K. Sachan [b]

[a] Krishi Vigyan Kendra, Divyodaya, Khowai, Tripura- 799 207, India.
[b] Krishi Vigyan Kendra, Mon (Aboi), Nagaland- 798 603, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242627

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94803

Original Research Article

Received: 17/10/2022
Accepted: 20/12/2022
Published: 22/12/2022

ABSTRACT

Allelopathic influences of *Michelia champaca* and *Schima khasiana* were tested in bioassay on two cereal crops (maize-*Zea mays* and paddy-*Oryza sativa*), and two legume food crops (rice bean-*Vigna umbellata* and soybean- *Glycine max*). The aqueous leaf extracts of fresh dried leaves of above tree species suppressed the growth of test crops. The study revealed that *Michelia champaca* and *Schima khasiana* are least toxic to germination, growth and yield of various test crops. Although, germination and growth of paddy and soybean was adversely affected by aqueous extracts of tree species, however, magnitude of toxicity was very less which is evident from the dry matter production of various test crops. Rice bean and maize have been found resistant to phytotoxicity. It is therefore; well evident from the data that maize, paddy, rice bean and soybean can be grown successfully in the proximity of *Michelia champaca* and *Schima khasiana*.

**Corresponding author: E-mail: sachankvkmon@gmail.com;*

Keywords: Allelopathy; aqueous leaf extracts; germination; radical; plumule; pot culture; maize; paddy; ricebean; soybean; Michelia champaca; Schima khasiana.

1. INTRODUCTION

During the past nine decades, appreciable research has been done in the field of allelopathy and only in the last three decades much investigation have been directed toward elucidating some of many roles of allelopathy in ecological processes in natural systems, agriculture and forestry [1]. Infact, the allelopathic interactions in tree-crop associations have more bearing on crop production under integrated land use systems, such as, agroforestry, rather than agriculture alone. It has been established through scientific investigations that many woody perennials used in agroforestry exhibit allelopathic effect on the understory crops [2, 3, 4], and these interactions are usually crop specific [5, 6, 7, 8].

Since, these species co- exist with agricultural crops, their allelopathic compatibility may be crucial to determine the success of an agroforestry system. The allelopathic effects are selective and vary with different trees because these plants vary in the amount and type of secondary metabolities [9, 10, 11].

Biochemical interactions (deleterious or beneficial) between the plants are called allelopathy and allelopathic interactions play a vital role in agro- ecosystems, where farming replace the nature flora, than in stable pasturelands [12]. This information is necessary to develop sustainable cropping systems for this region.

These two species are most important for agroforestry systems in the region especially in Jhum. *M. champaca* has traditionally medicinal plant used to treatment in different diseases i.e. cough, dyspepsia, diarrhea, bronchitis, hypertension, fever, rheumatism, dysmenorrheal, inflammation and abscesses. *Schima khasiana* also used folk medicine in treatment of different diseases and wood used in making plywood.

Present documents deals with allelopathic influences of *Michelia champaca* and *Schima khasiana* species on germination growth and dry matter production of major summer kharif food crops of NEH region.

2. MATERIALS AND METHODS

This study was conducted in the Premises of Krishi Vigyan Kendra, Mon (Aboi), Nagaland, India (26.59ºN latitude, 94.9670ºE longitude and 582.53 m altitude) during June to July 2020. The mean annual average rainfall was 2467 mm and mean temperature ranged from 13.5 to 16.0ºC. The test crop investigated were local variety of maize (*Zea mays*), paddy (*Oryza sativa*), ricebean (*Vigna umbellata*) and soybean (*Glycine max*). The allelopathic effects of two multipurpose tree species *Michelia champaca* and *Schima khasiana* were studied in bio-assay and pot culture with soil. The trees of both species were 13 to 15 years old having 6 to 8 m height and 5 to 8 m² canopy size.

For bioassay studies, fresh leaves were collected during the first week of June 2004 (full canopy of both species). The mature leaves were dried and ground separately in a mechanical grinder. The powdered sample, 1, 2 and 5 gm of each species was weighed and added to 100 ml distilled water and kept for 48 hours at room temperature (24 ± 2^0C) to make 1, 2, 5% aqueous extracts of each species, respectively. The resulting brownish and dark extractions were filtered through three layers of Whatman No. 1 filter paper and stored in dark in conical flasks, until required. Twenty five seed of each test crop (in four replicates) were placed in sterilized petri dishes (13.0 cm dia.), lined of Whatman No. 1 filter paper. Ten ml extract of each plant was added per petri plate on first day. Distilled water served as control. Moisture in the petri dishes was maintained by adding 2 ml of extract or distilled water as required. The seed germination, radical and plumule growth was recorded at seven days after sowing [13, 14].

In pot culture study, there were three factors viz.; two tree species (*Michelia champaca* and *Schima khasiana*), four test crops (maize, paddy, ricebean and soybean) and four following growing media:

(1) Top soil (0-15 cm deep, up to 1.0 m radius tree stem),
(2) Rhizosphere soil (40-70 cm deep, near the fine root zone of each tree species),
(3) Field soil (from experimental garden) + powdered fresh dried leaves (5 ton/ha)
(4) Field soil alone to serve as control.

As per treatments in pots, the powdered leaves were mixed in the upper layer of soil and the treatments were replicated five times. Each pot contains 2.0 kg of soil and 2 seeds of the test crops were sown per pot as per treatment. The pots were arranged in traditional type of Naga hut in randomized block design and irrigated whenever necessary. Data on seed germination and seedling growth [shoot and root length, and dry matter production (DMP)] of the test crops were evaluated thirty days after sowing. The data was statistically analyzed using critical difference at 5% level of significance.

3. RESULTS AND DISCUSSION

The aqueous extracts of fresh leaves of *Michelia champaca*, suppressed the plumule and radical length of tests food crops compared to germination. Per cent germination of all test crops was significantly (P<0.05) high by exposure to various fresh leaf extracts of *Michelia champaca*. Inter-comparing magnitude of toxicity, it has been recorded that 5% concentration was most toxic to germination of rice bean (76.67%). Whereas, magnitude of suppression in germination of maize by different leaf extract concentrations was comparable to the control (Table 1). Radical and plumule growth of all the test species was significantly (P<0.05) adversely affected by fresh dry leaf extracts of *Michelia champaca* and magnitude of inhibition in radical extension was maximum to paddy as compared to other test crops. Seed germination, radicle and plumule growth of maize and soybean was stimulated by the leaf extract of *M. champaca* while the germination, radicle and plumule growth paddy and rice bean test were reduced by the leaf extracts of *M. champaca*.

Table 2 depicts data on percent germination, radical length and plumule of test crops as influenced by toxicity of dried fresh leaves of *Schima khasiana*. Percent germination of paddy (78.7%), maize (76.3%) and rice bean (78.0%) has been decreased in 5% concentration of dried leaves than other 1 and 2% concentration. Inter-comparing magnitude of suppression by various sources of leaf extracts, it has been recorded that 1% concentration inhibited maximum percent germination of ricebean (89.33%) followed by soybean (88.00%). Radical extension of all the test crops was lowered significantly (P<0.05) by all the components of dried fresh leaves. Inter-comparing intensity of suppression in plumule length by various component of *Schima khasiana*, any specific component of *Schima khasiana* was not found specifically toxic to plumule growth of all the test species, however, aqueous extracts of 2% and 5% concentration were utmost toxic to hypocotyls length in maize, rice bean and soybean as compared to phytotoxicity of 1% concentration. The overall germination, radicle and plumule growth of maize and soybean were stimulated under the leaf extracts *S. khasiana w*hile the germination, growth of paddy and rice bean were reduced by the leaf extracts.

Table 3 depicts the data on germination and growth performance of maize and paddy compared to germination values, shoot and root length were suppressed more in different growth mediums. However, root length of paddy (58.85 cm) and maize (12.31 cm) was higher in rhizosphere soil compared to control values (50.00 and 10.38 cm). The dry matter production of maize (0.66 g/ plant) was higher in top soil compared to other treatments. Similarly, dry matter of paddy (0.40 g/ plant) was recorded higher in soil mulched with dry leaves compared to other treatments including control. Overall the germination and growth of the test crops under pot culture not show any trends.

Germination and growth of legumes test crops have been shown in Table 4. Germination of soybean was found sensitive to phytotoxicity of *Michelia champaca* compared to rice bean. However, root-shoot length of both legumes test crops was recorded higher in different growing medium compared to control. More over dry matter production was showed very less differences in all the treatments to both pulses. Effect of *Schima khasiana* on germination, growth and yield of test crops has been shown in Table 5 and 6. On average, germination of maize and paddy was significantly reduced by rhizosphere soil and soil mulched with dry leaves. Similarly, shoot length of both the test crops and root length of paddy was reduced markedly when grown in rhizosphere soil and/ or soil mulched with dry leaves. Interestingly, dry matter production of both the test crops was comparable with control (Table 5).

Among legume test crops, germination of soybean was inhibited by the root exudates of *Schima khasiana*. Rice bean was found resistant to phytotoxicity of the important tree exudates of *Schima khasiana*. Rice bean was found resistant to phytotoxicity of this important tree species. Moreover, root-shoot length and dry matter production of rice bean was recorded higher in

Table 1. Effects of aqueous dried fresh leaf extracts of *Michelia champaca* on percent germination, radicle and plumule length of different test crops at 7 days after sowing

Leaf extracts	Test Species											
	Maize			Paddy			Rice bean			Soybean		
	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)
1%	**97.33 ±2.31**	13.63 ±1.55	8.12 ±0.68	**93.33 ±2.31**	5.42 ±1.13	2.39 ±0.62	92.00 ±6.93	7.63 ±0.65	10.84 ±0.87	**93.33 ±6.11**	6.50 ±1.50	6.23 ±1.43
2%	100.00 ±0.00	11.77 ±1.65	7.77 ±0.62	94.67 ±4.62	5.92 ±0.28	2.86 ±0.02	97.33 ±2.31	6.54 ±1.11	9.76 ±0.42	94.67 ±2.31	10.56 ±1.47	6.68 ±0.09
5%	98.67 ±2.31	9.80 ±0.93	7.03 ±1.34	96.00 ±0.00	2.85 ±0.29	2.85 ±0.29	**76.67 ±2.31**	5.70 ±0.89	9.01 ±0.39	97.34 ±2.31	10.37 ±1.44	6.88 ±0.16
Control	100.00 ±0.00	8.64 ±0.39	13.43 ±0.86	98.67 ±1.89	6.99 ±0.65	4.63 ±0.14	97.33 ±1.89	7.87 ±1.41	15.12 ±2.52	**80.00 ±14.24**	6.42 ±0.15	10.35 ±1.42
Mean	99.00	10.96	9.09	95.67	5.30	3.31	93.30	6.94	11.18	91.34	8.46	7.54
CD at 5%	0.25	0.44	0.58	0.45	0.35	0.19	1.00	0.19	0.54	1.53	0.46	0.38

Table 2. Effects of aqueous dried fresh leaf extracts of *Schima Khasiana* on percent germination, radicle length and plumule length of different test crops at 7 days after sowing

Leaf extracts	Test Species											
	Maize			Paddy			Rice bean			Soybean		
	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Germination (%)	Radicle length (cm)	Plumule length (cm)
1%	100.00 ±0.00	10.53 ±1.50	7.06 ±0.58	96.00 ±3.37	8.97± 0.25	6.49 ±0.15	89.33 ±7.54	8.75 ±0.64	12.24 ±1.50	94.70 ±3.80	9.80 ±0.54	11.55 ±1.85
2%	96.00 ±3.27	8.83 ±0.26	6.37 ±1.06	94.67 ±1.89	8.72 ±0.46	7.27 ±0.49	82.70 ±8.22	5.84 ±1.29	10.35 ±3.19	88.00 ±16.53	9.17 ±0.73	10.80 ±1.10
5%	78.70 ±1.89	9.51 ±1.15	6.10 ±1.16	76.3 ±3.77	8.79 ±0.60	7.59 ±0.34	78.00 ±8.64	8.91 ±0.94	11.45 ±1.34	91.30 ±5.00	8.35 ±0.62	8.80 ±1.41
Control	100.00 ±0.00	8.64 ±0.39	13.43 ±0.86	98.67 ±1.89	6.99 ±0.65	4.63 ±0.14	97.33 ±1.89	7.87 ±1.41	15.12 ±2.52	80.00 ±14.24	6.42 ±0.15	10.35 ±1.42
Mean	98.68	9.38	8.24	96.67	8.37	6.49	89.34	7.84	12.29	89.00	8.44	10.38
CD at 5%	0.37	0.17	0.69	0.34	0.18	0.26	1.19	0.28	0.40	1.32	0.29	0.23

Table 3. Response of cereal test crops to *Michelia champaca* in pot culture at 30 days after sowing

Treatments	Maize				Paddy			
	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)
Top soil	94.43 ± 7.87	33.93±1.25	52.18 ±1.60	0.66 ±0.08	64.67 ±13.59	17.88 ±3.12	9.20 ±2.08	0.05 ±0.01
Rhizosphere soil	100.00 ±0.00	23.75±0.16	58.85 ±2.07	0.48 ±0.05	77.77 ±20.78	18.49 ±1.52	12.31 ±0.11	0.13 ±0.08
Mulch with dry leaf	100.00 ±0.00	24.05±0.95	39.72 ±5.96	0.40 ±0.02	88.87 ±7.87	20.98 ±0.95	11.38 ±1.65	0.40 ±0.02
Control	100.00 ±0.00	32.22±2.32	50.00 ±3.22	0.51 ±0.13	83.30 ±13.59	25.04 ±18.01	10.38 ±0.89	0.08 ±0.04
Mean	98.61	28.49	50.19	0.51	78.65	20.59	10.82	0.17
CD at 5%	0.55	1.06	1.57	0.02	2.05	0.64	0.27	0.03

Table 4. Response of legume test crops to *Michelia champaca* in pot culture at 30 days after sowing

Treatments	Rice bean				Soybean			
	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)
Top soil	83.30 ±0.00	21.15 ±1.31	28.23 ±2.89	0.21 ±0.05	72.23 ±7.83	17.66 ±1.60	37.08 ±3.31	0.36 ±0.04
Rhizosphere soil	77.77 ±20.78	18.65 ±1.89	27.71 ±4.77	0.13 ±0.02	88.90 ±15.70	18.48 ±0.16	37.32 ±2.90	0.26 ±0.06
Mulch with dry leaf	77.77 ±7.83	18.02 ±0.61	32.47 ±3.70	0.14 ±0.04	77.77 ±7.82	19.07 ±0.63	50.42 ±3.36	0.27 ±0.02
Control	66.70 ±0.00	16.60 ±1.28	25.85 ±4.79	0.15 ±0.01	88.87 ±7.87	16.67 ±1.62	33.83 ±5.91	0.22 ±0.05
Mean	76.39	18.61	28.57	0.16	81.94	17.97	39.66	0.28
CD at 5%	1.38	0.43	0.55	0.007	1.67	0.21	1.45	0.01

Table 5. Response of cereal test crops to *Schima Khasiana* in pot culture at 30 days after sowing

Treatments	Maize				Paddy			
	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)
Top soil	100.00 ±0.00	44.78 ±1.18	67.30 ±1.19	0.83 ±0.09	83.30 ±13.60	17.48 ±3.49	10.08 ±1.28	0.07 ±0.03
Rhizosphere soil	88.87 ±7.87	34.04±1.03	48.96 ±11.03	0.59 ±0.08	77.77 ±7.83	18.04 ±2.77	17.47 ±5.61	0.05 ±0.01
Mulch with dry leaf	93.30 ±13.59	26.14 ±0.75	64.91 ±5.22	0.39 ±0.07	66.70 ±13.60	14.34 ±2.49	9.00 ±1.19	0.11 ±0.13
Control	100.00 ±0.00	32.22 ±2.32	50.00 ±3.22	0.51 ±0.13	83.30 ±13.59	25.04 ±18.01	10.38 ±0.89	0.08 ±0.04
Mean	93.04	34.29	57.79	0.58	77.77	18.73	11.73	0.08
CD at 5%	1.65	1.54	1.91	0.04	1.55	0.89	0.77	0.005

Table 6. Response of legume test crops to *Schima Khasiana* in pot culture at 30 days after sowing

Treatments	Rice bean				Soybean			
	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)	Germination (%)	Shoot length (cm)	Root length (cm)	DMP (mg/plant)
Top soil	94.43 ±7.87	21.27 ±0.97	41.70 ±8.32	0.39 ±0.05	77.77 ±7.83	21.60 ±1.47	28.76 ±1.47	0.28 ±0.08
Rhizosphere soil	88.90 ±15.70	20.86 ±2.25	30.66 ±1.24	0.18 ±0.02	77.77 ±7.83	17.79 ±0.93	39.51 ±2.04	0.27 ±0.03
Mulch with dry leaf	77.77 ±7.83	18.65 ±1.89	30.06 ±2.56	0.16 ±0.03	94.43 ±7.87	15.57 ±1.28	42.00 ±6.39	0.19 ±0.12
Control	66.70 ±0.00	18.30 ±0.51	27.71 ±4.77	0.15 ±0.01	88.87 ±7.87	18.48 ±0.16	33.83 ±5.91	0.16 ±0.04
Mean	81.95	19.73	32.53	0.22	84.71	18.36	36.03	0.23
CD at 5%	2.44	0.29	1.22	0.02	1.65	0.49	1.17	0.001

different growing mediums compared to control values. In case of soybean, shoot length was inhibited significantly when cultivated either in rhizosphere soil or in soil mulched with dry leaved. Root length, however, was recorded lower in top soil of *Schima khasiana*. Dry matter production was higher in different growing mediums compared to control values.

The study revealed that *Michelia champaca* and *Schima khasiana* are least toxic to germination, growth and yield of various test crops. Although, germination and growth of paddy and soybean was adversely affected by aqueous extracts of tree species, however, magnitude of toxicity was very less which is evident from the dry matter production of various test crops. Rice bean and maize have been found resistant to phytotoxicity. It is therefore; well evident from the data that maize, paddy, rice bean and soybean can be grown successfully in the proximity of *Michelia champaca* and *Schima khasiana*. However, further studies are needed on biophysical interactions between these test crops and tree crops.

The results of the present study show that the allelopathic effects of both species are species specific. The germination of the test crops are show the stimulation and redaction in germination and growth of test crops. The leaf extracts of *Terminalia bellirica, Terminalia chebula, Aegle marmelos* and *Sapindus mukorossi were* inhibitory effects at higher concentrations but at low concentrations have stimulatory effects reported [15]. Earlier studies, [16] reported that test crops grown in soil, mulched with dry fresh leaves of *Adina cordifolia*, *Prunus cerasoides*, *Alnus nepalensis*, and *Celtis australis* significantly inhibited the germination growth and yield of *Eleusine coracana*, *Hordeum vulgare* and *Glycine max* [17]. Also reported that the higher concentration significantly inhibit the germination and growth of test crops. The test crops grown in petridishes and soil mulched with dry fresh leaves of *Quercus* sp. significantly inhibited the germination, growth and DMP of wheat, mustard and lentil [18]. The foliar, bark and leaf extracts of *Quercus leucotrichophora* have also been reported toxic to germination and root-shoot length of *Vigna unguiculata* and *Glycine max* [15]. Sahoo et al. [19] observed allelopathic inhibition of maize by teak and *Leucaena* leaf extracts. Kumar et al. [20] recorded to reduce germination, radical and plumule extension of soybean by *Melia azadirechta*, *Morus alba* and *Moringa oleofera*. Singh et al. [21, 14] reported that the higher concentration significantly stimulate the radicle and plumule growth of text crops.

Similarly, Satapathy et al. [22] reported that the allelopathic effects of two *Ficus* species on test crops are concentration dependent. Lalnunhluva et al. [8] based on their study allelopathic effects occurring on understory crops maize, arhar, bhindi and *Solanum anguivi* due to release of certain compounds that are present in the leaf residues of woody perennials such as *Parkia timoriana*, *Acacia pinnata* and *Trevesia palmata* was found to cause maximum reduction in the germination and growth of test crops compared to control. Singh et al. [23, 24] reported that the allopathic effects of agroforestry trees are species specific and each agriculture crops have different effects. The allelopathic effects of both tree crops may be due to presence of tannin and phenolic contents.

4. CONCLUSION

Phytotoxic effects of leaf extract of agroforestry tree species (*Michelia champaca* and *Schima khasiana*) were investigated on germination and growth of food crops (*Zea mays, Oryza sativa*, *Vigna umbellata* and *Glycine max*). Both tree species are least toxic to germination, growth and yield of four test crops. Although, germination and growth of paddy and soybean was adversely affected by aqueous extracts of tree species, however, magnitude of toxicity was very less which is evident from the dry matter production of four test crops. Rice bean and maize have been found resistant to phytotoxicity. The data shows that maize, paddy, rice bean and soybean can be grown successfully in the proximity of *Michelia champaca* and *Schima khasiana*.

ACKNOWLEDGEMENT

The authors are thankful to Head, Krishi Vigyan Kendra, Mon, Nagaland for providing the facilities to conduct the experiment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rice EL. Some role of allelopathic compounds in plant communities.

Biochemical Systematics and Ecology. 1974;5:201- 206.

2. Bhatt BP, Hussain S, Walling I, Singh JK. Allelopathic effects of agroforestry trees on field crops in Eastern Himalaya, India. Allelopathy Journal. 2009;24(2):373-388.
3. Banga A, Bana OPS, Yadava A, Sah VK, Chaturvedi S Jyoti, Tripathi P, Bisht N. Allelopathic potentialities of extract of leaf litter of some selected tree species on wheat in field condition. Indian Journal of Agroforestry. 2015;17(2):27-30.
4. Kumari N, Srivastava M, Mehta S, Moanaro, Das B. Allelopathic effects of some promising agroforestry tree species on different annual crops. Ecology, Environment and Conservation. 2016;22(1):225- 236.
5. Aleem MO, Alamu LO, Olabode OS. Allelopathic effects of some selected tree species on the germination and growth of cowpea (*Vigna unguiculata* L. Walp.). Open Journal of Forestry. 2014;4:310-315.
6. Prasad R, Tripathi VD, Singh P, Handa AK, Alam B, Singh R. Allelopathic effect of *Butea monosperma* L. leaf extract on seed germination and seedling vigour of selected summer legume crops. Indian Journal of Agroforestry. 2015;17(2):76- 81.
7. Lalremsang P, Gopichand B, Upadhyaya K. Effect of aqueous leaf extracts of Flemingia semialata Roxb. On seedling growth of maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Indian Journal of Ecology. 2017;44(2):398- 400.
8. Lalnunhluva H, Upadhyaya K, Sahoo UK. Allelopathic effect of multipurpose woody perennials on understory crops of Mizoram, North- East India. Indian Journal of Agroforestry. 2019;21(1):81- 85.
9. Sachan MS. Structure and functioning of traditional agroforestry systems along an altitudinal gradient in Garhwal Himalaya, India. Ph. D. Thesis, HNB Garhwal University, Srinagar, Garhwal (UK). 2006;157.
10. Narval SS, Tauro P. Allelopathy in agriculture and forestry. Scientific Publishers, Jodhpur, India; 1994.
11. Singh B, Uniyal AK, Bhatt BP, Prasad S. Effects of agroforestry tree spp. on crops. Allelopathy Journal. 2006;18(2):355.
12. Harborne JB. An introduction to ecological biochemistry. New York: Academic Press. 1988;356.
13. Bhatt BP, Chauhan DS, Todaria NP. Phytotoxic effects of tree crops on germination and radicle extension of some food crops. Tropical Science. 1993;33:69-73.
14. Thapaliyal S, Bali RS, Singh B, Todaria NP. Allelopathic effects of tree of economic importance on germination and growth of food crops. Journal of Herbs, Spices & Medicinal Plants. 2008;13(4):11-23.
15. Kaletha MS, Bhatt BP, Todaria NP. Allelopathic effects of some agroforestry tree crops of Garhwal Himalaya. Range Management & Agroforestry. 1996;17(2):193-196.
16. Bhatt BP, Kaletha MS, Todaria NP. Allelopathic exclusion of understorey 6. Crops by agroforestry trees of Garhwal Himalayas. Allelopathy Journal. 1997;4(2):321-328.
17. Singh B, Jhaldiyal V, Kumar M. Effects of aqueous leachates of multipurpose trees on test crops. 2006;38–46.
18. Bhatt BP, Chauhan DS. Studies on allelopathic effects of Oak (*Quercus* spp.) of Garhwal Himalaya. Allelopathy Journal. 2000;7(2):265-272.
19. Sahoo UK, Vanlalhriatpuia K, Upadhyaya K, Roy S. Effects of leaf extracts of common home garden trees on food crops. Allelopathy Journal. 2011;28(1): 123- 134.
20. Kumar M, Mallik V, Joshi M. Allelopathic effects of *Melia azarirechta, Morus alba* and *Moringa oleofera* on germination, radical and plumule growth of Glycine amx. Range Management and Agroforestry. 2009;30(2):167- 168.
21. Singh B, Jhaldiyal V, Kumar M. Effects of aqueous leachates of multipurpose trees on test crops. Estonian Journal of Ecology. 2009;58(1).
22. Satapathy SR, Khanduri VP, Singh B, Riyal MK, Kumar S, Kumar P, Rawat D. Allelopathic potential of Ficus auriculata and Ficus semicordata on growth of four traditional food crops of Garhwal Himalaya. Journal of Agriculture and Food Research. 2022;9:100352.
23. Singh B, Uniyal AK, Todaria NP. Studies on allelopathic influence of Zanthoxylum armatum DC on important field crops seeking its sustainable domestication in existing agroforestry systems of Garhwal

Himalaya, India. Journal of Sustainable Agriculture. 2007;30(3):87-95.

24. Singh B, Bhatt S, Uniyal P. Allelopathic effect of *Phyllanthus emblica* on germination and growth of field crop. Range Management and Agroforestry. 2010;31(1):27-30.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/94803