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RESEARCH ARTICLE

ALLELOPATHIC EFFECT OF *NEOLMARCKIA CADAMDA* (ROXB.), *BAUHINIA VARIEGATA* L. AND *GREWIA OPTIVA* (DRUMM EX BUR.) ON *ZEA MAIZE* L., *TRITICUM AESTIVUM* L. AND *SESAMUM INDICUM* L

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ABSTRACT

The presence of allelochemicals in many tree species show antagonistic effect on germination and growth of understorey agriculture crops and affect the yield of these crops. It is well known fact that every tree species shows antagonistic or synergic effect on understorey crops. *Neolmarckia cadamba*, *Bauhinia variegata* and *Grewia optiva* are fast growing species and being introduced under agroforestry for their multi-purpose use. An experiment to observe the allelopathic effect of *N. cadamba*, *B. variegata* and *G. optiva* was conducted in laboratory conditions by using their 25% (T_1), 50% (T_2), 75% (T_3) and 100% (T_4) leaf extract along with a control on *Triticum aestivum, Zea maize* and *Sesamum indicum*. The results showed that application of T_1, T_2 and T_3 leaf extract of *N. cadamba*, showed the maximum germination in seeds of *S. indicum* while in T_4, no germination was observed in *S. indicum except Z. maize* where it was maximum in comparison of *T. aestivum*. In all 4 treatments (T_1, T_2, T_3 and T_4) of *B. variegata*, the germination of seeds of *S. indicum* was maximum. Similarly, in T_1 and T_2 leaf extract of *G. optiva*, the germination in seeds of *S. indicum* was maximum. In T_3 and T_4 leaf extract, the germination in seeds of *Z. maize* was maximum. Overall, the germination of maize, wheat and sesame was also found varied from 61.67% (*T. aestivum*) to 100% (*S. indicum*). The T_4 (100%) leaf extract of *N. cadamba* had inhibited the germination completely in *S. indicum* under laboratory conditions. Under field conditions, there was no major difference observed in number growth of tillers of *Z. maize*, *T. aestivum* and *S. indicum* germinated at tree line and away tree line showing no allelopathic effect on germination.

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INTRODUCTION

Allelopathy is a well known phenomenon mostly found in tree species under which antagonistic effect occurs on germination, growth and survival of understory crops by releasing leachates of leaves of these trees when they rotten after falling on ground. In modern era, the agroforestry became commercially popular due to potential economic returns of fast growing tree species. These species are being promoted to produce timber, fodder and non forest produces at short rotation. These species are also playing vital role in carbon sequestration on farmland and climate change mitigation. The synchronization of trees and crops on farmland for successful establishment of any agroforestry system is a major concern. To identify the synchrony and antagonism, it is very essential to study the allelopathy of tree species specially, for agroforestry system.
Neolmarckia cadamba (Roxb.) also known as Kadamb, is a fast-growing tropical hardwood tree and extensively used for various purposes such as plywood and pulp production and light furniture fabrication and as a raw material for the preparation of indigenous medicines (Mondal *et al.*, 2020). It is also known as one of the potential trees for carbon sequestration in tropical region of India (Bijalwan *et al.*, 2014). The wood of Kadam is extensively used for ceiling boards, light construction work, packing cases, planking, carving and turnery. The wood makes good veneers and plywood suitable for the manufacture of commercial grade plywood, writing and printing paper and brown wrapping papers (Sarvan, 2019).

Bauhinia variegata (Drumm ex Burret) locally known as Kachnar is a multipurpose tree. Almost every part of this tree including root, stem, leaf, bark, branches and flower has some use. Tree is a good source of fodder for livestock and gives a valuable fuel-wood. The leaves, flowers and flower buds are eaten as vegetables. Leaves make good fodder and are greedily eaten by sheep, goats and other cattle. Being a leguminous tree, *B. variegata* enhances the soil fertility enriching it through nitrogen fixation. *Grewia optiva* L. commonly known as Bhimal, is a popular tree of the farmers of the Sub – Himalayan tract well known for its fodder and fibre value. The tree grows on a variety of soil, sandy loam with adequate moisture supply support good growth. The growth of tree grown along irrigated field bunds is generally more than those grown under rain-fed conditions. Overall, the tree is hardy and can grow and survive in almost any conditions. The wood of the tree is white, heavy, hard, strong, fine textured and elastic. It is used for oars, shafts, axe handles, shoulders poles, cot frames, bows and other miscellaneous purposes. It is reported to be suitable for paper making (Luna, 2005). The elastic branches of the trees are used for making baskets. Besides it, the species is a good source of fuel, fibre and fodder. In recent days, *B. variegata*, *G. optiva* and *N. cadamba* are being practiced under agroforestry in North region of the country. Therefore, present study is undertaken to find out the allelopathic effect on under-storey crops using bioassay of above mentioned tree species on wheat (*Triticum aestivum* L.), maize (*Zea maize* L.) and sesame (*Sesamum indicum* L.) were conducted under laboratory conditions as well as in field.

MATERIAL AND METHODS

The laboratory study was conducted in ICFRE- Forest Research Institute, Dehradun located at $30^0$20'38" N and $77^0$59'46" in Uttarakhand. Fresh and healthy leaves of *N. cadamba*, *B. variegata* and *G. optiva* were collected from experimental sites of Daluwala majbata and Daluwala kalan for laboratory experiments. The collected leaves were sun dried for about a week to make into a fine powder using an electrical grinder. Leaf powder (400g of each species) were soaked in 2 litre of distilled water at room temperature for 24h (Amoo *et al.,* 2008). The resulting brownish and dark extract was filtered through Muslin cloth and filtrates were considered as 100% concentration. Further dilutions of 25% (T_1), 50% (T_2) 75% (T_3) and 100% (T_4) were prepared with distilled water from pure filtrate and stalk solution (pure filtrate) was considered as 100%. These concentrations were used to study the germination and growth of plumule and radical of *T. aestivum* (wheat), *S. indicum* (seasame) and *Z. maize* (maize) in laboratory. The bio-assay test in different concentrations of leaf extract on seed germination, radicle and plumule length was tested by placing 20 seeds with three replications of each test crop in petri dishes containing Whatsman No. 1 filter paper saturated with particular extract at room temperature (25±1°C). A separate control series was placed up using distilled water. Moisture in the Petri dishes were maintained by adding extract as required. The numbers of germinated seeds was counted daily up to 10 days. The growth parameter *viz.,* germination per cent, radicle length and plumule length were determined on 10 days after germination.

The germination percentage was calculated by applying following formula:

$$\text{Germination (\%)} = \frac{A \times 100}{B}$$

Where: A= Number of seeds germinated
B= Total number of seeds placed for germination

Likewise, data to observe allelopathic effect in field were taken in experimental plots on performance of *T. aestivum, S. indicum* and *Z. maize* number and growth of tillers at tree line and away tree line were recorded in experimental plots located at Dhaluwala majbata and Dhaluwala kalan in tarai region of district Haridwar (Uttarakhand).

The comparative number of tillers increment percentage of numbers of tillers at away tree line in field was calculated by applying following formula:

$$\text{Increment in tillers (\%)} = \frac{(X - Y) \times 100}{Y}$$

Where: X= Number of tillers away tree line
Y= Number of tillers at tree line

The recorded data in laboratory and fields ~~and~~ were computed and calculated statistically.

RESULTS AND DISCUSSION

The results on bioassay test are represented in Table 1. The results reveal that in 25% concentration (T_1) of leaf extract of *N. cadamba*, the germination of *Z. maize*, *T. aestivum* and *S. indicum* comes 66.67%, 60% and 96.67% respectively. In 50% concentration (T_2) of extract, the germination in these species comes 71.67%, 65% and 75% respectively. In 75% concentration (T_3) of leaf extract, the germination was found respectively 51.67%, 26.67% and 48.33%.

In 100% concentration (T_4), the germination was recorded 55% and 21.67% respectively in *Z. maize* and *T. aestivum* while there was no germination in *S. indicum* treated with 100% extract. With normal water treatment (control), it was recorded as 68.33%, 61.67% and 100% respectively in these species. In 25% (T_1) leaf extract of *B. variegata* leaves, the germination of *Z. maize*, *T. aestivum,* and *S. indicum* was recorded as 90%, 85% and 96.67% respectively. In 50% (T_2) extract, the germination was found as 83.33%, 81.67% and 95% respectively. In 75% (T_3) extract, the germination was found 81.67%, 73.33% and 95%. In 100% (T_4), the germination was recorded 80%, 65% and 88.33% respectively in maize, wheat and sesame.

In control, it was found 93.33%, 71.67% and 100% respectively. Similarly, in 25% (T_1) concentration of leaf extract of *G. optiva* leaves, the germination of *Z. maize*, *T. aestivum* and *S. indicum* 95%, 83.33% and 96.67% germination was recorded. In 50% (T_2) extract, the germination comes 86.67%, 76.67% and 93.33% respectively. In 75% (T_3) extract, the germination was found 76.67%, 68.33% and 71.67%. In 100% (T4), the germination was recorded 76.33%, 63.33% and 25.00% respectively. In control, the germination in these three agriculture crop species was 93.33%, 90% and 91.67% respectively.

Overall, the germination of *Z. maize*, *T. aestivum* and *S. indicum* was also found varied from 61.67% (*T. aestivum*) to 100% (*S. indicum*). Results of bioassay test showed that the germination in *S. indicum* was effected in 100% extract of *N. cadamba* leaves in case of sesame with nil germination and it was also minimum with 21.67% in wheat in the solution of same concentration. In 75% extract of *N. cadamba*, the germination was below 50% i.e. only 48.33% while in other cases the germination was above 50% in all concentrations of *N. cadamba*, *B. variegata* and *G. optiva* leaves. The data recorded on shoot and root length of *T. aestivum, Z. maize* and *S. indicum* in all treatments and control are given in Table 2. In leaf extract of *N. cadamba*, the shoot length of *T. aestivum* was maximum 7.60cm in T_1 while root length was maximum 4.90cm in T_3. The shoot length of *Z.*

Table 1. Results of bioassay test on *T. aestivum, S. indicum* and *Z. maize* for allelopathic effect of *N. cadamba* (Kadam), *B. variegata* (Kachnar) and *G. optiva* (Bhimal) at room temperature.

Tree species	Seeds of crop taken for study	Germination (%) in various treatments				
		T_1(25%)	T_2(50%)	T_3(75%)	T_4(100%)	Control
N. cadamba	*Z. maize*	66.67±20.68	71.67±7.63	51.67±12.58	55.00±8.66	68.33±18.93
	T.aestivum	60.00±5.00	65.00±8.66	26.67±2.89	21.67±10.40	61.67±10.41
	S. indicum	96.67±2.89	75.00±5.00	48.33±44.81	00.00±0.00	100.00±0.00
B. variegata	*Z. maize*	90.00±10.00	83.33±7.64	81.67±2.89	80.00±5.00	93.33±2.89
	T.aestivum	85.00±5.00	81.67±2.89	73.33±7.64	65.00±10.0	71.67±15.27
	S. indicum	96.67±2.89	95.00±5.00	95.00±5.00	88.33±10.41	100.00±0.00
G. optiva	*Z. maize*	95.00±5.00	86.67±2.89	76.67±10.41	76.67±10.41	93.33±2.29
	T.aestivum	83.33±7.64	76.67±10.41	68.33±2.87	63.33±5.77	90.00±10.77
	S. indicum	96.67±5.77	93.33±5.77	71.67±12.58	25.00±8.66	91.67±2.89

Table 2. Shoot and root length (cm) under bioassay test of *N. cadamba* and *B. variegata* and *G. optiva* on wheat, maize and sesame

Tree species	Average shoot/ root length in germinated seeds (cm)	Concentration of leaf extract (%)				Control	
N. cadamba		T1 (25%)	T2 (50%)	T3 (75%)	T4 (100%)	No treatment	
	T. aestivum					*T. aestivum*	
	Shoot	7.60±0.53	6.10±0.10	5.52±0.43	4.46±0.11	Shoot	6.20±0.35
	Root	4.30±0.26	3.60±0.20	4.90±0.36	4.02±0.06	Root	5.60±0.34
	Z. maize					*Z. maize*	
	Shoot	2.92±0.06	1.91±0.10	1.68±0.15	1.40±0.53	Shoot	1.80±0.81
	Root	1.40±0.43	0.90±0.10	0.98±0.05	1.38±0.35	Root	1.30±0.61
	S. indicum					*S. indicum*	
	Shoot	0.52±0.06	0.32±0.06	0.24±0.06	0.00±0.00	Shoot	0.40±0.17
	Root	0.24±0.06	0.14±0.06	0.12±0.06	0.00±0.00	Root	0.22±0.06
B. variegata							
	T. aestivum						
	Shoot	8.70±0.58	8.60±0.58	8.80±1.73	4.60±1.15		
	Root	7.50±0.58	6.40±1.15	7.60±0.58	4.60±0.58		
	Z. maize						
	Shoot	2.32±0.58	1.60±0.57	3.40±0.57	2.90±0.57		
	Root	1.30±0.57	0.96±0.06	2.40±0.75	2.00±0.00		
	S. indicum						
	Shoot	0.38±0.06	0.26±0.05	0.20±0.00	0.16±0.05		
	Root	0.16±0.05	0.12±0.06	0.20±0.10	0.14±0.06		
G. optiva							
	T. aestivum						
	Shoot	8.50±0.87	3.70±1.47	3.00±0.00	5.20±0.72		
	Root	5.00±0.01	3.20±0.35	1.60±0.36	1.60±0.36		
	Z. maize						
	Shoot	2.00±0.00	1.22±0.68	2.20±0.72	2.20±0.35		
	Root	0.90±0.17	1.68±0.58	1.16±0.76	1.06±0.51		
	S. indicum						
	Shoot	0.20±0.00	0.26±0.06	0.14±0.05	0.24±0.05		
	Root	0.14±0.05	0.14±0.05	0.20±0.00	0.14±0.05		

Table 3. Results of crop growth parameters within tree line and away from tree line

Tree crops	Agri. crops	Average no. of tillers/m^2		Increment in no. of tillers from away tree line over tree line (%)	Average length of tillers (cm)		Increment in length tillers from away tree line over tree line (%)
		Tree line	Away tree line		Tree line	Away tree line	
N. cadamba	*T. aestivum*	331.00±24.08	347.00±40.86	4.83	72.00±4.52	72.00±3.24	0.00
	Z. maize	09.40±2.40	10.00±1.22	6.83	186.00±15.16	195.00±13.22	4.84
	S. indicum	12.20±2.59	13.00±1.58	6.56	161.60±10.73	167.40±5.59	3.59
B.variegata	*T. aestivum*	347.00±33.83	376.00±29.45	8.35	78.40±2.07	82.20±3.35	4.85
	Z. maize	10.20±1.79	11.4±1.95	11.76	195.80±12.68	201.00±12.85	1.94
	S. indicum	12.00±1.58	12.20±2.05	1.67	148.00±12.04	152.20±5.67	2.84
G. optiva	*T. aestivum*	361.20±22.30	388.20±6.02	7.47	81.04±5.41	86.00±4.58	6.12
	Z. maize	10.80±1.64	12.20±0.84	12.96	202.20±7.69	203.20±5.63	0.49
	S. indicum	12.00±1.58	12.60±1.52	5.00	168.80±6.38	175.60±7.70	4.02

maize was maximum 2.92cm in T_1 and root length was also maximum 1.40cm in T_1. The shoot length of *S. indicum* was maximum 0.52cm in T_1 and root length was also maximum in T_1. In leaf extract of *B. variegata*, shoot length of *T. aestivum* was maximum 8.80cm in T_3 and the root length was also maximum 7.60cm in T_3. In *Zea maize*, shoot length was maximum 3.40cm in T_3 and root length was also maximum 2.40cm in T_3. The shoot length of *S. indicum* was maximum 0.38cm in T_1 while root length was maximum 0.20cm in T_3. In leaf extract of *G. optiva*, the shoot and root length of *T. aestivum* was maximum 8.50cm and 5.00cm respectively in T_1. The length of shoot of *Z. maize* was maximum was equal i.e. 2.20cm in T_3 and T_4 but root length was maximum 1.68cm in T_2. The shoot length of was maximum 0.26cm in T_2 while shoot length was maximum 0.20 in T_3. In control conditions, the shoot and root length of *T. aestivum* was 6.20cm and 5.60cm respectively. In *Z. Maize* the length of shoot and root was 1.80cm and 1.30cm respectively. The shoot and root of *S. indicum* was 0.40cm and 0.22cm respectively. As the effect of leaf extract of *N. cadamba, G. optiva* and *B. variegata* was observed on germination and shoot root length of *T. indicum*, *S. indicum* and *Z. mays* in laboratory conditions, therefore, data on growth of *T. indicum*, *Z. mays* and *S. indicum* were recorded for assessing the effect of leaves extract in experimental plot having 3 year plantation of *N. cadamba, G. optiva* and *B. variegata* and presented in Table 3. As shown in Table 3, the growth performance of under storey crops like wheat, maize and sesame on the basis of number of tillers/ m^2 and length of tillers at tree line and away from tree line reveals that difference of germination of *T. aestivum, Z. maize* and *S. indicum* seeds was 4.83%, 6.83% and 6.56% respectively between tree line and away tree line of *N. cadamba*. The difference in length of tillers of these agriculture crops was 4.85% and 3.59% respectively in case of Z. maize and *S. indicum* between tree line and away tree line while there was no difference in case of *T. aestivum*. In case of *B. variegata,* the difference in number of tillers of *T. aestivum*, *Z. maize* and *S. indicum* was 8.35%, 11.76% and 1.67% respectively. Likewise, in case of *G. optiva*, the difference in number of tillers of these agriculrure crops was 7.47%, 12.96% and 5.00%. The tillers of *T. aestivum* showed no difference in length while *Z. maize* and *S. indicum* showed the difference of 4.84% and 3.59% respectively in their length at tree line and away tree line along with *N. cadamba*. Along with *B. variegata*, the difference in length of these agriculture crop species was 4.85%, 1.94% and 2.84% respectively. Along with *B. variegata*, the difference in length of these agriculture crop species was 6.12%, 0.49% and 4.02% respectively.

On the basis of above observation taken during laboratory and field experimentation, it is asserted that *B. variegata, G. optiva and N. cadamba* showed antagonistic effect on germination of *Z. maize, T. aestivum and S. indicum* under laboratory conditions but these release no adverse effect on performance of under storey crops of *Z. maize, T. aestivum* and *S. indicum.* Therefore, these tree species assure their suitability under agroforestry with the understorey crops of *Z. maize, T. aestivum* and *S. indicum*. Studies conducted earlier showed that like *N. cadamba*, *B. variegata* and *G. optiva* other tree species also release allelopathic effect on understorey crops. Kumar *et al*. (2006), studied the phytotoxic influences of *Alnus nepalensis*, *Artocarpus heterophyllus* and *Emblica officinalis* by growing test crops of *Oryza sativa*, *Phaseolus vulgaris* and *Pisum sativum* for bioassay culture. They found that the germination of *Oryza sativa* was stimulated in *Alnus nepalensis,* whereas, *Pisum sativum* was restrained in all the tree crops. However, *Phaseolus vulgaris* was found most resistant crops for all trees aqueous extract. The study revealed the radicle growth of all the food crops depressed significantly in aqueous extract of all the tree crops. The study is supported by the study conducted by Naeem *et al*. (2017) to quantify the allelopathic effect of rapeseed on germination and seedling growth of maize which indicated the reduction in germination of Maize with increasing the extract concentration of rapseed. Study of allelopathic effect of *N. cadamba* is in accordance to Kumar *et al*. (2019) study conducted to assess the allelopathic effect of aqueous leaf extract of *N. cadamba* and *M. dubia* on *Triticum aestivum* under laboratory conditions. Their study consisted of seven concentrations of leaf extracts (0.5, 1, 2, 3, 4, 5 and 6%) along with control i.e. 0%. The results of the study showed that lower concentrations (0.5, 1 and 2%) of leaf extract of *N. cadamba* had no allelopathic effect, however higher concentrations (6%) showed maximum inhibitory allelopathic impact of seed germination i.e. 90%. Higher concentration of *M. dubia* leaf extract also exhibited allelopathic effect on seed germination and resulted in maximum (63%) germination at 6% concentration. Similarly, higher concentrations of leaf extract of both species resulted in more pronounced allelopathic effect on growth of root and shoot. In a study conducted by Nikita *et al*. (2019), it was found that allelopathic interactions of some indigenous herbs namely *Piper nigrum*, *Murraya koenigii*, *Matricaria chamomilla*, *Origanum vulgare* inhibits the germination of *Vigna radiata*.

Hudson *et al.* (2021) conducted experiment on allelopathic effects of *Sphaeranthus suaeolens* on seed germination and seedling growth of *Phaseolus vulgaris* and *Oryza sativa* found that *O. sativa* is more sensitive to the applied alleloppathic stress than *P. vulgaris.* The results of a study conducted by Kumar (2021) showed that, there is an adverse effect of leaf extract of *G. optiva* on the germination and primary seedling characters which indicates that the overall development and yield of the crop will also be affected adversely. So the crop should be grown away from the plantation of *Grewia optiva* wherever feasible. The study also supported by the study conducted by Jinxin *et al*. (2021) which reveals that allelochemicals can stimulate or inhibit the germination and growth of plants. Zhao *et al*. (2021) demonstrated in a study that with increase of extract concentrations, the germination indices and growth characteristics decreased, while the allelopathy inhibition effect and the synthesis effect increased. Shah *et al.* (2022) concluded that extract of weed *Trianthema portulacastrum* inhibits the germination and seedlings growth of wheat and chick pea. Allelopathic effect of extract from leaves and shoots of *Alternanthera philoxeroides, Ludwigia octovalvis* and *Persicaria hydropiper* lowered the yield of *Oroza sativa* by possible allelopathic influence of leaf extract of these weed plants (Lalbiakdika *et al*., 2022). Patane *et al.* (2023) studied on allelopathic effect of *Cannabis sativa* leaf aqueous extract on seed germination and seedling growth in wheat and barley, it was observed that phenols in the water extract of *C. sativa* leaves can have a negative impact on wheat and barley seed germination and seedling growth, particularly at temperature below the optimal. The weed species too such as *Cynodon dactylon*, *Celocia argentia*, *Echinochloa crusgalli* and *Amaramthus viridis* showed allelopathic enfluences on mungbean and inhibit its germination and growth (Saif *et al*., 2023). Watakhere *et al.* (2023) tested allelopathic effect of *Argemon maxicana* root extract on seed germination and growth of *T. aestivum* under *in vitro* condition and found that aqueous extract of root of *A. maxicana* severely reduced the germination as well as seedling growth indicators such as root and shoot length in shrabati and lokwan varieties of *T. aestivum*. Wang *et al*. (2024) mentioned that allelopathy was the main chemical means in the invasion of exotic plants such as *Ligularia sagitta* which releases an allelopathic effect on seed germination and seedling growth of four Garmineae forages like *Poa pretensis*, *Festuca ovina*, *Elymus mutans* and *Agrofpyron cristatum* and resultantly, causes grassland degradation. A gregarious weed *Lantana camara* also show its negative effect on seed germination and seedling growth of *Capsicum annum* and *Daucas carota* and influence the yield of these crops adversely (Alemayehu *et al.,* 2024).

CONCLUSION

Allelopathy is a common phenomenon found in most of the species as part of crop competition. Some species show the allelopathic effect and inhibit the germination and growth of other species under laboratory conditions but they are safe to plant on farmland under agroforestry as they showed no negative effect on germination and growth of under storey crops under proper canopy management at least with 50% lopping. Similarly, *N. cadamba, B. variegata* and *G. optiva* showed their allelopathic effect on germination and seedling growth of *T. aestivum, Z. maize* and *S. indicum* under laboratory conditions only but on farmland they showed no allelopthic and other growth inhibiting effects on these agriculture crops under proper canopy management. Therefore, *N. cadamba, B. variegata* and *G. optiva* are promising tree species under agroforestry in Tarai region of Uttarakhand and capable to fulfill the demand of timber, fuelwood and fodder of local people particularly in lean period from April to June of the year when fodder from agriculture crops is not available in a required quantity for livestock.

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