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Allelopathic influences of *Goniocaulon indicum* C. B. Clarke. on seed germination and seedling growth of maize and wheat

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Abstract
In the present study the allelopathic potential of invasive plant weed *Goniocaulon indicum* C. B. Clarke. on seed germination and seedling growth of maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) has studied. The aqueous extracts of *G. indicum* root, stem, leaves and whole plant at 05%, 10%, 15 and 20%; leachates of root, stem, leaves and whole plant at 05%, 10%, 15 and 20%; root zone soils of *G. indicum* was to evaluated. The allelopathic pattern varied in each of the tests and this depends upon type of test material. The lowest seed germination has been observed at highest concentration (20%) of whole plant in both aqueous extracts and leachates. But radicle and plumule length of wheat seedlings were more hampered in soil collected beneath the root zone of *G. indicum*. It is interesting to note that all bioassays of the weed noticeably inhibited the germination and seedling growth of maize and wheat. To prove the allelopathic effect of root zone soil of *G. indicum*, the soil was analyzed to obtain the values of pH, EC, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, manganese, boron, copper, sodium and free calcium carbonate. The root zone soil shows decreased amount of nitrogen, phosphorus, iron and very high amount of potassium and free calcium carbonate.

Keywords: allelopathy, *Goniocaulon indicum*, seed germination, seedling growth, maize, wheat

Introduction
Allelopathy is the interaction between the plants either negatively or positively, resulting either inhibitory or stimulatory potential on neighbouring plants (Patil *et al*., 2015[13]; Rency *et al*., 2015 [14] and Thombre *et al*., 2016 [17]). Majority of weeds hamper the growth of main crop through escaping chemical substances, which present almost in all parts of plant called as allelochemicals (Rice, 1995 [15]; Batish *et al*., 2007 [4]). The phytoallexins, phyotoxins and growth inhibitors produced by plant acts as allelochemicals and affect different physiological processes of plants (Callaway and Ridenour, 2004 [8]). Different plant parts release allelopathic substances by various ways such as root exudation, volatilization, leaching and decomposition of plant residues (Avchar and Deokule, 2012 [3]).

Allelopathic substances are most commonly found in plant extracts and in plant residues of soil, some are found in live plant exudates and as volatile gases liberated from leaves and rhizome (Hussain *et al.*, 2007[10]). Weeds are known to exhibit allelopathy by releasing water- soluble allelochemicals from leaves, stems, roots, rhizomes, flowers, fruits and seeds (Batish *et al*., 2007a, 2007b [4&5]). Allelochemicals liberated as residues, exudates and leachates by many plants from leaves, stem, roots, fruit and seeds reported to interfere with growth of other plants (Asgharipour and Armin, 2010 [2]). These chemicals mainly affect plants at seed emergence and seedling levels (Alam and Islam, 2002 [1]; Naseem *et al*., 2009 [12]). Allelochemicals released by invasive species also affect native species through different pathways that includes interruption of plants nutrients uptake and elongation process in roots and shoots (Cruz-Ortega *et al.*, 2007 [9]). Hence, allelopathy has been considered as among the key factor to the success of invasive plant species over native species (Yuan *et al.*, 2012 [18]). *Goniocaulon indicum* C. B. Clarke. is common wide spread invasive weed in jowar crop of study region. This plant belongs to family Asteraceae which is an annual erect glabrous herb with an angled branched stem (Cooke, 1958 [16]). In this connection the present piece of work was designed to study the allelopathic effects of the weeds on seed germination and seedling growth of maize and wheat.

Material and Methods
The experiments were conducted under laboratory conditions at Post Graduate Research Centre, Department of Botany, Tuljaram Chaturchand College, Baramati, Dist. Pune, Maharashtra. The healthy and diseased free weed *viz. Goniocaulon indicum* was collected from agricultural fields of Baramati Tahsil.

The test crops *viz.* maize and wheat seeds were surface sterilized with 0.1% $HgCl_2$ (w/v) solution followed by washing with sterilized distilled water for several times, then carefully dried and used for experiments of seed germination and seedling growth. Following types of bioassays were carried out in the present study:

a. Aqueous extract bioassay
The collected weed was repeatedly washed with distilled water to remove the soil and dust particles to prepared aqueous extracts and leachates. The aqueous extracts of root, stem, leaves and whole plant of the weed was prepared using 10g fresh tissue. The aqueous extracts were filtered through Whatman No.1 filter paper and filtrates were brought to 100ml with addition of distilled water. These were served as stock solutions and used for bioassay. Dilutions were made from the stock solutions at 05%, 10%, 15% and 20% w/v.

Surface sterilized 10 seeds of maize and 10 seeds of wheat were placed in sterilized petridish (14cm and 9cm diameter respectively) containing Whatman No.1 filter paper moistened with 10-15ml of aqueous extracts of each weed of variable concentrations in separate petridishes. Control was made by using distilled water. These petridishes were wrapped by brown paper so as to avoid direct light and kept in room temperature (28 ± 2^0C). The emergence of radicle was considered as the criterion for seed germination and was observed up to 72 hours and expressed as percentage seed germination. The seedling growth was measured after 7 days by measuring the radicle and plumule length.

b. Leachates bioassay

To find out the effectiveness of inhibitors leaching out from the *G. indicum*, 100g of healthy and cleaned plant parts were soaked separately in equal amount of distilled water for 72h. Each leachate was filtered through Whatman No.1 filter paperand these were served as stock solutions and used for bioassay. Dilutions were made from the stock solutions at 05%, 10%, 15% and 20% w/v.

Surface sterilized 10 seeds of maize and 10 seeds of wheat were placed in sterilized petridish (14cm and 9cm diameter respectively) containing Whatman No.1 filter paper moistened with 10-15ml of aqueous extracts of each weed of variable concentrations in separate petridishes. Control was made by using distilled water. These petridishes were wrapped by brown paper so as to avoid direct light and kept in room temperature (28 ± 2^0C). The emergence of radicle was considered as the criterion for seed germination and was observed up to 72 hours and expressed as percentage seed germination. The seedling growth was measured after 7 days by measuring the radicle and plumule length.

c. Root zone soil bioassay

To ascertain the allelopathic effects of *G. indicum* through root exudation, root zone soil up to 3 inch was collected and surface sterilized 10 seeds of maize and 10 seeds of wheat were placed in sterilized petridish (14cm and 9cm diameter respectively) containing 40g and 20g of soil respectively were taken in each petridish. For control 40g and 20g soil free from growth of experimental weed was used.

d. Root zone soil analysis

To prove the allelopathic effect of root zone soil of *G. indicum*, the soil is analyzed to obtain the values of pH, EC, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, manganese, boron, copper, sodium and free calcium carbonate.

e. The two-way analysis of variance (ANOVA)

The R software was used to compare the effect of the aqueous extracts and leachates on germination and seedling growth of test crops. Treatment effects were considered on the level of P <0.05 significance.

Results and Discussion

The present study clearly demonstrated an inhibitory effect of whole plant as well as three plant parts (roots, stem and leaf) of common weed *G. indicum* aqueous extracts, leachates and root zone soil bioassay on seed germination and seedling growth of *Zea mays* and *Triticum aestivum*.

a. Effect of aqueous extracts of *G. indicum* C. B. Clarke. on seed germination of *Z. mays* L. and *T. aestivum* L.

Aqueous extracts of root, stem and leaf at various concentrations severely inhibited plumule as well as radicle length of *Zea mays* and *Triticum aestivum* seedlings. Whole plant aqueous extracts at 20% concentration showed remarkable inhibitory effect on seedling growth of test crop species. Aqueous extracts of all plant parts at 5% concentration have been recorded 60% and 62.25% for maize and wheat respectively. The lowest seed germination has been observed at highest concentration (20%) of whole plant aqueous extracts in maize and stem aqueous extracts i.e. 10%. However, the order of inhibition of aqueous extracts of *G. indicum* was stem > whole plant > root > leaf (Table No.1). This gradual decrease in germination percentage was due to allelopathic effect of weed (*G. indicum*) aqueous extract from lower to higher concentrations as compared to control.

Table 1: Effect of aqueous extracts of *G. indicum* C. B. Clarke. on seed germination of *Z. mays* L. and *T. aestivum* L.

Weed plant extract concentration (%)	Sources of extracts				Average germination (%)
	Root extract	Stem extract	Leaf extract	Whole plant extract	
Maize (*Z. mays* L.) seed germination (%)					
Control	100	100	95	100	98.75
05	60	60	50	70	60
10	40	40	30	40	37.5
15	30	40	20	20	27.5
20	20	20	20	10	17.5
Wheat (*T. aestivum* L.) seed germination (%)					
Control	100	95	90	100	96.25
05	60	60	80	50	62.5
10	30	20	50	30	32.5
15	30	20	40	20	27.5
20	20	10	20	20	17.5

*values are mean of three determinations

b. Effect of aqueous extracts of *G. indicum* C. B. Clarke. on seedling growth of *Z. mays* L. and *T. aestivum* L.

Aqueous extracts of root, stem and leaf at various concentration severely inhibited plumule as well as radicle length of *Zea mays* and *Triticum aestivum* seedlings. As compare to root, stem and leaf, whole plant aqueous extract at 20% concentration inhibited maximum radicle than plumule length of *Zea mays* seedlings. Root extract at higher concentration (20%) significantly inhibited plumule than radicle length of maize seedlings. Whereas at lower concentration of leaf (5%) and whole plant (5%) aqueous

extracts, plumule length has been increased in wheat seedlings (Table No.2). The higher concentrations of aqueous extracts (15 and 20%) significantly reduced the radicle and plumule length however, lower concentration of aqueous extracts did not affect the radicle and plumule length.

The radicle and plumule length decreased as the concentrations of the aqueous extracts was increased.

Table 2: Effect of aqueous extracts of *G. indicum* C. B. Clarke. on seedling growth of *Z. mays* L. and *T. aestivum* L.

concentration (%)	Sources of extracts							
	Root extract		Stem extract		Leaf extract		Whole plant extract	
	R	P	R	P	R	P	R	P
Maize (*Z. mays* L.) seedling growth (cm)								
Control	10.2	8.9	10.1	8.8	10.4	9.1	10.3	9.0
05	8.2	5.9	6.8	5.3	7.3	7.4	8.7	7.2
10	5.9	4.8	6.1	5.9	5.2	4.8	6.2	6.9
15	4.1	6.2	5.2	6.2	4.3	3.2	4.3	3.1
20	2.2	1.2	2.1	1.8	2.8	3.9	2.1	1.9
Wheat (*T. aestivum* L.) seedling growth (cm)								
Control	13.2	11.1	13.4	11.6	12.9	11.0	13.3	11.4
05	10.4	8.6	11.2	8.9	13.4	11.3	11.4	12.5
10	9.8	7.8	10.2	7.2	10.2	8.9	9.3	8.6
15	5.9	4.9	7.3	6.2	10.1	8.2	13.8	12.1
20	4.7	5.8	4.2	4.4	7.8	6.1	7.2	6.8

*values are mean of three determinations.

c. Effect of lechates of *G. indicum* C. B. Clarke. on seed germination of *Z. mays* L. and *T. aestivum* L.

Leachates of root, stem and leaf at various concentration severely inhibited plumule as well as radicle length of *Zea mays* and *Triticum aestivum* seedlings. Leachates of all plant parts at 5% concentration have been recorded 70% for both maize and wheat. The lowest seed germination has been observed at highest concentration (20%) of leachates of whole plant i.e. 10% in maize. However, the order of inhibition of leachates *of G. indicum* was whole plant > root > stem > leaf (Table No.3).

This gradual decrease in germination percentage was due to allelopathic effect of weed (*G. indicum*) leachates from lower to higher concentrations as compared to control. The reduction in germination and growth are attributable to restrain cell division, reduction in mineral uptake, hinder or augments respiration, hamper the production of protein

Weed plant leachates concentration (%)	Sources of leachates				Average germination (%)
	Root leachates	Stem leachates	Leaf leachates	Whole plant leachates	
Maize (*Z. mays* L.) seed germination (%)					
Control	90	100	95	90	93.75
05	70	60	70	80	70
10	60	60	60	50	57.5
15	50	50	60	30	47.5
20	30	40	40	10	30
Wheat (*T. aestivum* L.) seed germination (%)					
Control	100	90	95	95	95
05	60	70	80	70	70
10	60	50	70	60	60
15	50	50	40	50	47.5
20	20	40	20	20	25

*values are mean of three determinations.

d. Effect of leachates of *G. indicum* C. B. Clarke. on seedling growth of *Z. mays* L. and *T. aestivum* L.

Leachates of root, stem and leaf at various concentration severely inhibited plumule as well as radicle length of *Zea mays* and *Triticum aestivum* seedlings. As compare to root, stem and leaf, whole plant leachate at 20% concentration inhibited maximum radicle than plumule length of *Zea mays* seedlings. Root leachate at higher concentration significantly inhibited plumule than radicle length of maize seedlings. Whereas at lower concentration of leaf and whole plant leahates, plumule length has been increased in wheat seedlings (Table No.4).

The higher concentrations of leachates (15 and 20%) significantly reduced the radicle and plumule length however, lower concentration of leachates did not affect the radicle and plumule length. The radicle and plumule length decreased as the concentrations of the leachates was increased.

Table 4: Effect of leachates of *G. indicum* C. B. Clarke. on seedling growth of *Z. mays* L. and *T. aestivum* L.

Weed plant leachates concentration (%)	Sources of leachates							
	Root leachates		Stem leachates		Leaf leachates		Whole plant leachates	
	R	P	R	P	R	P	R	P
Maize (*Z. mays* L.) seedling growth (cm)								
Control	12.9	9.9	12.6	9.8	13.2	9.8	12.7	9.6
05	10.8	9.5	8.1	7	10.8	8.8	8.6	8.2
10	9.9	8.3	7.9	7	10	7.6	7.5	5.4
15	9.5	7.6	7.7	6.4	8	5.9	6.9	5.1
20	6.8	5.3	7.2	5.2	5.4	4.1	3.2	2.3
Wheat (*T. aestivum* L.) seedling growth (cm)								
Control	10.3	11.6	9.9	11.5	9.5	11.7	10.8	12.3
05	8	8.8	8.7	9.2	7.6	7.9	8.4	8.9
10	6.3	6.8	6.1	6.7	6.6	6.3	6.2	6.7
15	5.7	6.2	5.8	6.3	3.7	4.2	6.1	6.5
20	4	3.5	4	4.1	2.2	1.7	2.8	2.2

*values are mean of three determinations.

e. Effect of root exudates of *G. indicum* C. B. Clarke. on seed germination and seedling growth of *Z. mays* L. and *T. aestivum* L.

The data represented in above showed reduction in the seed germination of root zone soil (70%) and (70%) as compared to control (90%) and (90%) in maize and wheat respectively. The effect on radicle and plumule length of the maize and wheat seedlings has declined in root zone soil of *G. indicum* C. B. Clarke. In maize, as compared to control, radicle length was recorded as 19.2cm and plumule length was recorded as 17.8cm in root zone soil. In wheat, seedling growth is also reduced in root exudates of *G. indicum* C. B. Clarke. i.e. radicle (5.9cm) and plumule (8.2cm). It may be happened due to allelochemicals are exudates in soil that's why seed germination and seedling growth is hampered (Table No.5).

Table 5: Effect of root exudates of *G. indicum* C. B. Clarke. on seed germination and seedling growth of *Z. mays* L. and *T. aestivum* L.

Type of soil	Germination percentage (%)	Average seedling growth (cm)	
		Radicle	Plumule
Maize (*Z. mays* L.)			
Control	90 ±3.53	27.4 ± 0.48	26.3 ± 0.49
Root zone soil	70 ± 5	19.2 ± 0.52	17.8 ± 058
Wheat (*T. aestivum* L.)			
Control	90± 4.47	10.9 ± 0.45	13.9 ± 3.86
Root zone soil	70 ±7.90	5.9± 2.92	8.2 ±3.65

± Standard deviation

f. Root zone soil analysis

The pH value (8.29) shows basic nature of soil. The values of EC (0.16 dS/m^2) and organic carbon (0.63%) were very less as compared to control soil (1.00 dS/m^2 &0.61%-0.80% respectively). The amount of available nitrogen (151 Kg/ha), phosphorus (13.38 Kg/ha), calcium (29.00ppm), magnesium (60.5ppm), sulphur (9.58ppm), iron (0.11ppm), zinc (0.34ppm), manganese (0.35ppm), boron (0.12ppm), copper (0.18ppm) and sodium (39.10ppm) are very less as compared to the control soil. Potassium (518 Kg/ha) and free calcium carbonate (12.65%) values were very high. The data revealed that the micronutrients and macronutrients as well as organic carbon values are drastically decreased may be because of some allelochemicals are released from plants by various mechanisms like leachation, exudation through roots and decompositions of plant residues (Bais *et al.*, 2004[6]). The amount of all nutrients including macronutrients and micronutrients were very less as compared to control soil and hence responsible for inhibitory impact on growth of crop. The three main nutrients are nitrogen (N), phosphorus (P) and potassium (K) together they make up the trio known as NPK essential for plant growth and development. Other important nutrients are calcium, magnesium and sulfur. Plants also need small quantities of iron, manganese, zinc, copper, boron etc. known as trace elements because only traces are needed by the plant. In field observations, the jowar crop showed reducing growth potentiality that affected crop metabolism and their growth has been suppressed.

g. Statistical analysis of aqueous extract and leachates bioassay by two-way ANOVA Method

The results obtained from aqueous extracts and leachates of *G. indicum* on seed germination and seedling growth on maize and wheat is statistically analyzed by two-way ANOVA method in R software. Data presented in Table No. 6 shows *P* values-0.253, 0.25063 and 0.830228 >0.05 so null hypothesis is accepted and the different extracts concentration of *G. indicum* shows homogenous effect on germination of maize and wheat seeds. *P* values-0.813, 0.9903, 0.10948 and 0.135>0.05 so null hypothesis is accepted and the different extracts concentration of *G. indicum* shows homogenous effect on radicle and plumule length of maize. When *P* values are greater than 0.05 so null hypothesis is accepted and shows homogenous effect on germination and seedling growth of maize and wheat. *P* value<=0.05 reject H_0 and different extracts concentration does not shows homogenous effect on germination and seedling growth of maize and wheat.

Table 6: Statistical analysis of aqueous extract and leachates bioassay by two-way ANOVA Method in R software

Bioassay	Crop	Variables	Factor	*Df*	MS	F value	P value
Aqueous Extract	Maize	Germination	Block	3	72.9	1.615	0.253
			Treatment	3	1322.9	29.308	5.63e-05***
			Residual	9	45.1		
		Radicle	Block	3	0.124	0.317	0.813
			Treatment	3	21.087	53.983	4.46e-06***
			Residual	9	0.391		
		Plumule	Block	3	0.077	0.036	0.9903
			Treatment	3	13.492	6.27	0.0138*
			Residual	9	2.152		
	Wheat	Germination	Block	3	316.7	8.143	0.00623**
			Treatment	3	1500	38.571	1.83e-05***
			Residual	9	38.9		
		Radicle	Block	3	8.107	2.686	0.10948
			Treatment	3	22.161	7.343	0.00861**
			Residual	9	3.018		
		Plumule	Block	3	10.194	6.305	0.01361*
			Treatment	3	13.857	8.571	0.00528**
			Residual	9	1.617		
Leachate	Maize	Germination	Block	3	158.3	1.629	0.25063
			Treatment	3	1141.7	11.743	0.00183**
			Residual	9	97.2		
		Radicle	Block	3	5.389	5.743	0.01781*
			Treatment	3	11.577	12.337	0.00153**
			Residual	9	0.938		
		Plumule	Block	3	3.949	6.801	0.010871*
			Treatment	3	12.111	20858	0.000217***
			Residual	9	0.581		
	Wheat	Germination	Block	3	22.9	0.292	0.830228
			Treatment	3	1506.3	19.195	0.000299***
			Residual	9	78.5		
		Radicle	Block	3	1.017	2.402	0.135
			Treatment	3	16.817	39.7	1.62e-05***
			Residual	9	0.424		
		Plumule	Block	3	1.857	6.177	0.0144*
			Treatment	3	23.315	77.573	9.45e-07***
			Residual	9	0.301		

Significant results showed by bold letters.
Two-way ANOVA was used, *Df*- Degree of freedom, MS- Mean Square.
Significance codes: 0 '***', 0.001 '**', 0.01 '*', 0.05'.', 0.1 '', 1.

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