Original Research Article

Allelopathic potential of croton bonplandianus bail

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ABSTRACT

An extensive survey of floristic of native and invasive weed species was carried out during 2016 to 2019 in the semiarid agro ecosystem of Baramati Tahsil, Dist- Pune (M.S.). About 18 dominant invasive weeds such as Ageratum, Alternanthera, Croton., Xanthium, Parthenium and Tridax were encroaching the natives, becoming a serious threat to the major crops of this area such as wheat, sorghum, pearl millet, mung bean, pigeon pea, chillies and tomato. Amongst these Croton bonplandianus was highly dominant and wide spreading. Hence, its allelopathic potential was investigated. The allelopathic influence of leaf and root leachates as well as extracts of Croton bonplandianus Bail. was examined on seed germination of mung bean (Vigna radiata L.). The germination assay revealed that allelopathic potential and other factors are responsible for its dominance and successful invasion. The allelopathic influence of rhizosphere soil and its aqueous leachates indicated that both are responsible for inhibiting the seed germination and seedling growth of mungbean. Both the experiments have clearly confirmed the allelopathic potential of Croton bonplandianus. The HPTLC analyses confirmed the existence of a broad groups of allelochemicals like terpenoides, steroids, flavonoids, pungent and bitter essential oils and phenolics in its leaves and roots, which confirmed its allelopathic potential. Further characterization of above mentioned allelochemicals is in progress.

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1. Introduction

Baramati region is considered as semiarid, because of rain shadow effect1, in which different types of native and invasive weeds have been observed in different crop ecosystems causing about 16 to 58 % yield losses due to their allelopathic impact.2-22 The phytosociological survey revealed that invasive weeds such as Tridax, Acanthospermum, Ageratum and Flaveria exhibiting xeric features while Cassia uniflora, Croton and Lantana showing adaptations to semiarid crop ecosystems have become dominant. Similarly, Alternanthera, Asclepias, Parthenium and Xanthium were dominant in irrigated crop ecosystems. Considering the dominance of these weeds among major crops like mung bean, pearl millet and sunflower cultivated in semiarid agro-ecosystem, the allelopathic influence of highly dominant (as per our survey) Croton bonplandianus was undertaken, on sensitive crop like mung bean which is close associated to this weed. As recorded previously the allelochemicals released from the donor plants affect the growth and functioning of receptor species, therefore the present investigation was undertaken to know the allelopathic impact of Croton on mung bean.

Croton bonplandianus is an obnoxious weed belonging to family Euphorbiaceae. This plant is native from tropical South America. It has become dominant due to its wide adaptability, deep root system, most efficient and effective seed dispersal, biotic and abiotic stress tolerance and production of some novel allelochemicals.7,23 The detailed allelopathic effects of Croton bonplandianus on the crops and native weeds have not been studied in India.24 Hence, the aim of this work was to do a survey of dominant weeds in...
the region and then to determine, if the most dominant weed
may have an allelopathic effect on the associated crop.

**Fig. 1:** Photosynthetic pigments and organic constituents in *Croton bonplandianus*.

**Fig. 2:** Allelochemicals in *Croton bonplandianus* leaf.

**Fig. 3:** Allelochemicals in *Croton bonplandianus* root.

**Fig. 4:** Allelochemicals detected in Croton leaf by HPTLC: 10 % Methanolic sulphuric acid.

**Fig. 5:** Allelochemicals in Croton root detected by HPTLC: 10 % Methanolic sulphuric acid.

### 2. Materials and Methods

An extensive ecological survey was carried out in and around Baramati Tahsil, during 2016-2019 and the dominant weed species growing in cultivated fields and fallow lands were identified with the help of The Flora of Presidency of Bombay, Flora of Kolhapur District, Flora of Maharashtra. For phytosociological studies, list count quadrat method was followed.

#### 2.1. Preparation of extracts and leachates

*Croton bonplandianus* was selected as a donor allelopathic invasive weed and mung bean (*Vigna radiata* L. var. *Vaibhav*) was selected as test crop. The aqueous extracts of *Croton bonplandianus* were prepared from 100 g fresh leaves and roots after crushing in 500 ml of distilled water and filtered through Buchner funnel using Whatman No.1 filter paper. These extracts were stored as stock solutions (20%) in amber coloured bottles, which were diluted with distilled water to make desired concentrations (5% to 20%). For preparation of leachates of leaves and roots, 100g shade dried material was soaked in 500 ml of distilled water for 48 hours at 27±2º C and the leachates were filtered through Buchner funnel using Whatman filter paper No.1. These leachates were stored as stock solutions (20%), and diluted with distilled water as mentioned above to make different concentrations (5% to 20%).

#### 2.2. Collection of rhizosphere soil and Preparation of its leachates

About 500g of rhizosphere soil of *Croton bonplandianus* was collected randomly from the field to the depth of 15 — 20cm. The soil samples were cleaned, powdered and mixed to make a composite sample. 20g and 50g of this soil sample were suspended separately in 100ml distilled water.
Table 1: Dominant and Invasive weed species of baramati tahsil, dist- Pune.

| Botanical name                  | Local name          | Common english name | Family            |
|--------------------------------|---------------------|---------------------|-------------------|
| *Acanthospermum hispidum DC.   | Germankata          | German prick        | Asteraceae        |
| Achyranthes aspera L.          | Aghada              | Pricklychafflow     | Amaranthaceae     |
| Ageratum conyzoides L.         | Mahakaua            | Goatweed            | Asteraceae        |
| *Ageratum conyzoides, L.       | Osadi               | Goat weed           | Asteraceae        |
| *Alternanthera tenella Veldk.  | Reshimkata          | Jacob’s coat        | Amaranthaceae     |
| *Argemone mexicana L.          | Pwala Dhodtra       | Prickly poppy       | Papaveraceae      |
| *Asclepias curassavica L.      | Haladkunku          | Bastard ipecacuanha | Asclepiadaceae    |
| Cassia tora L.                 | Takala              | Sicklepod           | Fabaceae          |
| *Cassia umbilicata, Mill.      | Senna               | Foetid senna        | Fabaceae          |
| *Celosia argenta L.            | Kurdu               | Cock’s comb         | Amaranthaceae     |
| Cleome viscoso L.              | Pivli-tilwan        | Spiderflower        | Cleomaceae        |
| Commelina benghalensis L.      | Kena                | Dayflower           | Commelinaeae      |
| *Croton bonplandianus Baill.   | Harali              | Bermuda grass       | Poaceae           |
| *Cryptostegia grandiflora R.Br.| Kawai               | African rubber      | Asclepiadaceae    |
| Cynodon dactylon Pers.         | -                   | –                   |                    |
| Cyperus rotundus L.            | Nagarmotha          | Purple nusedge      | Cyperaceae        |
| Digeria arvensis Forsk.         | Karigandhari        | Kanjero             | Amaranthaceae     |
| *Euphorbia antiquorum L.       | Ransher             | Prickly spurge      | Euphorbiaceae     |
| Euphorbia geniculata Orteg.    | Dudhani             | Spurge              | Euphorbiaceae     |
| Euphorbia hirta L.             | Bari-dudhi          | Small spurge        | Euphorbiaceae     |
| *Flaveria trinervia C.Mohr.    | German              | –                   | Asteraceae        |
| Indigofera linifolia Retz.     | Pandharphalli       | Indigo              | Fabaceae          |
| *Ipomoea carnea Jacq.          | Besharam            | Indian jalap        | Convolvulaceae    |
| *Lagcaria mollis Cav.          | Jharvad             | Softheaded flower   | Asteraceae        |
| *Lantana camara L.             | Ghaneri             | Yellow sage         | Verbenaceae       |
| *Martyria annua L.             | Vincu               | Devil’s claw        | Pedalineae        |
| Oxalis corniculata L.          | Amboshi             | Lady’s sorrel       | Oxalidaceae       |
| *Parthenium hysterophorus L.   | Gajargawat          | Congress grass      | Asteraceae        |
| Peristrophe bicalyculata Ness. | Chikni              | –                   | Acanthaceae       |
| Portulaca oleracea L.          | Gholu               | Purslane            | Portulaceae       |
| *Prosopis julifera DC.         | Kubahbujh           | Agaroba             | Mimosaceae        |
| Trianthema portulacastrum L.   | Biskhpra            | Purselane           | Ficoidae          |
| *Tridax procumbens L.          | Ekadandi            | Coat buttons        | Asteraceae        |
| Vernonina cinerea Less.        | Sahadevi            | Ironweed            | Asteraceae        |
| Withania somnifera Dunal.      | Ashwagandha         | Wintercherry        | Solanaceae        |
| *Xanthium indicum, L.          | Landga              | Dot cocklebur/burweed | Asteraceae     |

*Invasive alien species

Table 2: Phytosociological studies of Croton bonplandianus Baill.

| Name of the weed                  | Density/m2 | % frequency | Abundance |
|-----------------------------------|------------|-------------|-----------|
| Croton bonplandianus Baill.       | 10.1       | 70          | 14.4      |
| Achyranthes aspera, L.            | 1.7        | 40          | 2.2       |
| Bidens pilosa, L.                 | 2.3        | 30          | 1.3       |
| Oxalis corniculata, L.            | 3.8        | 50          | 3.2       |
| Tephrosia purpurea, Pers.         | 3.4        | 50          | 4.3       |
| Vernonina sinerea,Less.           | 1.3        | 10          | 5.1       |
| Boerhavia diffusa,L.              | 4.2        | 20          | 3.4       |
| Digeria arvensis, Forsk.          | 2.3        | 40          | 3.6       |
| Tridax procumbens, L.             | 6.8        | 60          | 5.2       |
| Portulaca oleracea, L.            | 3.2        | 30          | 4.3       |
| Cyperus rotundus, L.              | 3.4        | 20          | 4.2       |
| Cynodon dactylon, Pers.           | 4.3        | 50          | 5.1       |

Average of 25 quadrats (1 x 1m)
Table 3: Effects of croton bonplandianus leaf and root extracts on seed germination and seedling growth in mung bean (Vigna radiata L. Var. Vaibhav).

| Plant part | Conc. of extracts (%) | Germination (%) | Root length (cm) | Shoot length (cm) | Vigour index | Dry wt. of 10 seedlings (g) |
|------------|-----------------------|-----------------|-----------------|------------------|--------------|-----------------------------|
| Control    | 100                   | 6.0             | 5.9             | 1190.0           | 0.346        |                             |
| 5          | 40.00                 | 2.0             | 5.8             | 312.0            | 0.332        |                             |
| 10         | 30.00                 | 3.4             | 3.6             | 210.0            | 0.307        |                             |
| 15         | 0.00                  | 0.0             | 0.0             | 0.00             | 0.00         |                             |
| 20         | 0.00                  | 0.0             | 0.0             | 0.00             | 0.00         |                             |
| 5          | 90.00                 | 4.06            | 9.2             | 1193.4           | 0.319        |                             |
| 10         | 85.00                 | 3.7             | 12.9            | 1411.0           | 0.313        |                             |
| 15         | 80.00                 | 3.3             | 12.2            | 1240.0           | 0.301        |                             |
| 20         | 70.00                 | 2.4             | 10.2            | 882.0            | 0.296        |                             |
| CD at 5%   |                       |                 |                 |                  |              |                             |
|            | 7.44                  |                 |                 |                  |              |                             |
| SEM        | 3.21                  |                 |                 |                  |              |                             |
| CV         | 7.21                  |                 |                 |                  |              |                             |

Table 4: Effects of croton bonplandianus leaf and root leachates on seed germination and seedling growth in mung bean (Vigna radiata L. Var. Vaibhav).

| Plant part | Conc. of leachates (%) | Germination (%) | Root length (cm) | Shoot length (cm) | Vigour index | Dry wt. of 10 seedlings (g) |
|------------|------------------------|-----------------|-----------------|------------------|--------------|-----------------------------|
| Control    | 100                    | 6.0             | 5.9             | 1190.0           | 0.346        |                             |
| 5          | 90                     | 3.8             | 4.1             | 711.0            | 0.420        |                             |
| 10         | 40                     | 1.5             | 3.2             | 188.0            | 0.403        |                             |
| 15         | 0.00                   | 0.0             | 0.0             | 0.00             | 0.00         |                             |
| 20         | 0.00                   | 0.0             | 0.0             | 0.00             | 0.00         |                             |
| 5          | 90.00                  | 5.7             | 7.5             | 1188.0           | 0.346        |                             |
| 10         | 90                     | 4.8             | 6.3             | 999.0            | 0.314        |                             |
| 15         | 80.00                  | 3.8             | 6.2             | 800.0            | 0.140        |                             |
| 20         | 70.00                  | 3.3             | 5.5             | 616.00           | 0.101        |                             |
| CD at 5%   |                       |                 |                 |                  |              |                             |
|            | 7.44                  |                 |                 |                  |              |                             |
| SEM        | 3.83                   |                 |                 |                  |              |                             |
| CV         | 7.38                   |                 |                 |                  |              |                             |

Table 5: Effect of croton bonplandianus rhizosphere soil and its leachates on seed germination and seedling growth in mung bean (Vigna radiata L. Var. Vaibhav).

| Treatments | Germination (%) | Root length (cm) | Shoot length (cm) | Vigour index |
|------------|-----------------|-----------------|------------------|--------------|
| Control    | 90.20±3.83 a    | 4.52±0.32 b     | 9.06±0.37 c      | 1227.03±114.59 b |
| Soil leachates 20% | 80.00±4.12 b     | 3.80±0.12 c     | 8.70±0.44 d      | 1001.86±96.59 c |
| Soil leachates 50% | 70.00±5.10 c   | 3.44±0.18 d     | 6.94±0.49 d      | 729.31±99.54 d |
| Control soil | 95.00±3.16 a    | 5.52±0.17 a     | 10.20±0.32 a     | 1494.66±96.94 a |
| Rhizosphere soil | 80.00±5.10 b    | 4.23±0.26 b     | 9.63±0.49 b      | 1111.85±130.55 bc |

*p-value* <0.001, *t*-test means compared with one-way ANOVA analysis. The different letters followed by values represent significant difference by Duncan’s multiple range test at p=0.05.

2.3. Seed germination bioassay

The solutions were stirred properly and kept for 48 hrs. These were filtered through Buchner funnel using Whatman filter paper No.1. The filtrates (20% and 50%) were used for seed germination bioassay along with control. Similar studies were carried out with rhizosphere soil directly and control soil (not having any vegetation).
Table 6: Allelochemicals detected in Croton leaf by HPTLC: 10 % Methanolic sulphuric acid.

| No. of Peaks | Rf    | AUC   | % Area |
|-------------|-------|-------|--------|
| 1           | 0.06  | 164.1 | 5.11   |
| 2           | 0.13  | 3.8   | 0.12   |
| 3           | 0.22  | 106.4 | 3.31   |
| 4           | 0.40  | 176.6 | 5.50   |
| 5           | 0.46  | 13.6  | 0.42   |
| 6           | 0.51  | 1380.5| 42.96  |
| 7           | 0.61  | 381.1 | 11.86  |
| 8           | 0.79  | 762.5 | 23.73  |
| 9           | 0.89  | 69.6  | 2.17   |
| 10          | 0.95  | 155.3 | 4.83   |

germination papers in Petri plates were moistened with 10 ml of respective concentrations of leaf and root extracts and leachates of Croton bonplandianus. The seeds placed in Petri plates moistened with distilled water were considered as control. Each Petri plate containing 10 seeds were kept in triplicate at room temperature (27+2°C) wrapped in black paper to avoid direct sunlight. Seed germination percentage, root and shoot length, vigour index, root: shoot ratio, fresh and dry weight of seedlings were recorded on 7th DAS.8

3. Statistical Analysis

The data were analyzed statistically using ANOVA test. All the calculations were made by using (Sigma stat 3.5) and Microsoft Excel (office 2003).

4. Results and Discussion

4.1. Phytosociological studies on weeds of baramati tahsil, dist. Pune.

Results recorded in Table 1 revealed that about 36 weed species were dominant in irrigated, semi-arid crop ecosystems and fallow lands. Amongst these about 50% of the dominant weeds were of exotic nature. These results have clearly indicated very high rate of invasion of non-native weeds in this region. Similar results were reported by some other workers.5–24,26–30 The phytosociological survey of dominant weeds had given an alarming indication about the invasion rate of non-natives in this region. If their invasion is not controlled effectively, they may substitute and reduce the diversity of natives. These invasive alien species (IAS) may be responsible to degrade the crop ecosystems in this region, causing significant yield reduction.17–22,24,27,28

Croton bonplandianus was the weed with highest density (10.1 /m²), frequency (70%) and abundance(14.4) in the field, followed by Tridax procumbens and Cynodon dactylon on Table 2.

5. Seed Germination Bioassays

5.1. Effects of rhizosphere soil and its leachates

The results presented in Table 5 clearly indicated the inhibition of seed germination percentage with 20% and 50% soil leachates over control in mungbean. The seed germination bioassay conducted in rhizosphere soil had also shown considerable reduction in seed germination percentage, root and shoot length and thereby vigour index as compared to control. This has confirmed that the rhizosphere soil leachates and the soil itself had negative influence on seed germination and seedling growth. The different allelochemicals existing in the weed might be leaching into the soil from the whole plant and exuding from the roots. These may accumulate in the soil and affect seed germination and seedling growth of recipient plant species.9 A similar trend was reported by other workers.31

5.2. Effects of leaf and root extracts

Inhibitory effects of leaf and root extracts of Croton on seed germination and seedling growth were recorded in mungbean at higher concentrations (15, 20%). The root and shoot length of seedlings was also reduced significantly along with vigour index and dry wt. of seedlings with increasing concentrations of leaf and root extractsTable 3.

5.3. Effects of leaf and root leachates

The leachates of Croton leaves significantly affected seed germination percentage and seedling growth in mungbean. The leaf leachates have caused full suppression of vigour index at higher concentrations (15, 20%), whilst at lower concentration (5%) stimulatory effects were recorded. Similarly, root leachates also showed positive effects on seed germination and seedling growth at lower concentration treatments while at higher concentration there was inhibitionTable 4.

Similar inhibitory allelopathic effects of Parthenium leaves on germination and seedling vigour of sunflower were reported.24 The allelopathic impact of extracts or leachates is more harmful to radicle.5,4 The level of
phytotoxicity was directly proportional to concentration of leachates. 8–10 The results of present investigation are in agreement with the above workers. The vigour index indicates the allelopathic effects on seedling establishment same was the trend in present study.

The successful invasion and dominance of Croton over native weed species might be due to different allelochemicals existing in it. Present studies may help for understanding crop weed interaction in semi-arid agro ecosystem of Baramati Tahsil.

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7. Conflict of Interest
None.

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References

1. Sen DN. Environment and plant life in Indian desert. Geobios International; 1982. p. 249. Available from: https://www.cabdirect.org/cababstract/abstract/19830744339.
2. Deokule SS, Kamble SY. Weeds of irrigated and non irrigated agricultural fields of Baramati area in Pune district. J Econ Taxonomic Bot. 1984;5:9–16.
3. Duhan JS, Laxminarayana KS. Allelopathic effects of Acacia nilotica on cereal and legume crops grown in fields. Allelopathy J. 1995;2(1):93–8.
4. Friedman J. Allelopathy autotoxicity and germination In: seed development and germination; 1995. p. 629–44.
5. Ghatwal NA, Dhumal KN. Ecophysiological and allelopathic variations in invasive and native weed species. Int Symp Biol. 2006;10(14):116.
6. Ghatwal N, Dhum KN. Phytotoxic effects of Cassia umiliora leaf leachates on germination and seedling growth of Radish (Raphanus sativus, L.) and mustard (Brassica juncea). Int J Pharm Sci Res. 2013;19(1):79–86.
7. Grummer G. Die gegenseitige beeinflussung hohere pflanzen allelopathic. vol. 72; 1953. p. 449–518.
8. Gupta V, Kak A, Singh BB. Studies on seed germination and seedling vigour in liquorice G. galbra). J Med Aromatic Plant Sci. 1996;19:412–3.
9. Hamdi B, Inderjit, Olofsdotter M, Streibig JC. Laboratory Bioassay for Phytotoxicity. Agronomy J. 2001;93(1):43–6.
10. Ali H, Kumar S, Abdalla MK, Sindhu G, Sindhu A. Allelopathic effect of Amaranthus viridis L. and Parthenium hysterophorus, L. on wheat, maize and rice. Allelopathy J. 2005;16:341–6.
11. Hodge JE, Hofreiter BT. Integration of physical and chemical treatment on the extraction of starch from Canna edulis Ker. rhizome. J Agricultural Sci. 1962;4(9):1–96.
12. Inderjit. Plant phenolics in allelopathy. Bot Rev. 1996;62(2):186–202.
13. Jadhav BB. Allelopathic effects of leaf leachates of different tree species; 2003. p. 292.
14. Jadhav SS. Allelopathic potential of some dominant aquatic weeds of Mula and Mutha River and their bioprospecting. Int Conf Plant Mar Environ Sci. 2015;1(2):50–3.
15. Kaushal R, Verma KS, Singh KN. Allelopathic effects of Grewia optiva and Populus deltoides on germination and seedling growth of some major field crops; 2003. Available from: https://waset.org/plant-physiology-and-pathology-conference-in-july-2021-in-berlin.
16. Kumari M, Das S, Vinla Y, Aarora P. Physiological parameters governing drought tolerance in maize. Indian J Plant Physiol. 2004;9(2):203–7.
17. Lee KA, Klasing KC. A role for immunology in invasion biology. Trends Ecol Evol. 2004;19(10):523–9.
18. Lowry O, Rosebrough NJ, Farr AL, Randall RJ. PROTEIN MEASUREMENT WITH THE FOLIN PHENOL REAGENT. J Biol Chem. 1951;193(1):265–75.
19. Magarey RC, Bull JI. Effect Of Soil Pasteurisation And Maneozeb On Growth Of Sugarcane And Apple Seedlings In Sugarcane Yield Decline And Apple Replant Disease Soils. Acta Horticulturae. 1994;363:183–190.
20. Miller GL. Use of dinitro salicylic acid reagent for determination of reducing sugar. Anal Chem. 1959;31(3):426–8.
21. Mishra R. Diversity, Invasion Status and Uses of Alien Plant Species in Northeastern Hilly State of Tripura: A Confluence of Indo-Barmar Hotspot. Am J Plant Sci. 1968;8(2):309.
22. Murumkar CV, Magdum DK. Ecophysiological studies in some weeds of Baramati. Acta Societas Bot Poloniale. 1996;65(3):297–9.
23. Peng SL, Xiang YC. The invasion of exotic plants and effects on ecosystems. Acta Ecologia Sin. 1999;19(4):560–9.
24. Oudhia P. Allelopathic effects of some obnoxious weeds on germination of soybean. Indian J Plant Physiol. 2000;5(3):295–6.
25. Yadav SR, Sardesai MM. Flora of Kolhapur District; 2002. Available from: https://innovativepublication.typeset.io/edib/5e17b5e–8227-43bd-ad91–07d26cc6452e#.58.
26. Kohli RK, Batish D, Singh HP. Allelopathy and its implications in agro ecosystems. J Crop Production. 1997;1(1):169–202.
27. Pandya SM. Role of Allelopathy in crop weed interactions: priority and prospects; 1994. p. 59–74.
28. Patil HS, Dhumal KN. Ecophysiological and biochemical investigations on some invasive weeds of semi-arid agroecosystem. Int Symp Biol. 2006;10(14):134.
29. Rao VS. Principles of Weed Science; 2000. p. 566. Available from: https://www.routledge.com/Principles-of-Weed-Science/Rao/p/book/9781578080694.
30. Saraswat VN. Weeds: Their ecology and control. In: Integrated pest and disease management APH Publishing Corporation; 1998.
31. Schon MK, Einhellig FA. Allelopathic Effects of Cultivated Sunflower on Grain Sorghum. univ Chicago press j. 1982;143(4):505–10.

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