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Allelopathic Effect of Leaf-Biomass of *Parthenium hysterophorus, Cassia occidentalis* and *Chenopodium murale* on Soil-Fertility and Growth of *Vigna unguiculata*

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ABSTRACT

Incomplete removal of alien weeds from the crop-fields gravely impacts the succeeding crop growth. Impact of powdered leaf biomass (PLB) of three alien weeds *Parthenium hysterophorus*, *Cassia occidentalis* and *Chenopodium murale* was investigated on germination and growth of *Vigna unguiculata* and the soil fertility. Soils were amended with different doses of weed PLB (0.5, 1 and 2 g/kg soils) individually and in combinations of binary and tertiary mixtures. PLB of *Parthenium* and *Chenopodium* significantly retarded crop growth and yield, whereas PLB of *Cassia* significantly stimulated it. PLB of all weeds significantly improved the soil fertility individually as well as in combinations. Binary mixtures of weed PLB showed antagonistic and synergistic impacts on crop growth, indicating Cassia's potential to manage the most invasive Parthenium and aggressively advance *Chenopodium.* Total phenolic content, enzymatic activity and antioxidant activity of these weeds were recorded in the order *Parthenium* > *Chenopodium* > *Cassia,* reflective of stress tolerance order of these weeds. Thus, aggressive plant invasions in urbanizing areas could be attributed to their ability to alter soil properties. Further, antagonistic property of *Cassia* here, has management implication for invasive *Parthenium* and aggressive intruder *Chenopodium* in Indian dry tropics.

Key words: Plant-invasion, Alien-weeds, Crop-weed interaction, Phenolic content, Soil-nutrient, Antioxidant activity

INTRODUCTION

Weeds are globally recognized as the most severe, widespread and considerable curb to sustainable crop yield. The allelopathic nature of these weeds, especially of the invasive ones, affects the growth of crops adversely by releasing allelochemicals, altering the physico-chemical properties of soil and competing for growth resources (Gupta and Narayan 2010). *Parthenium hysterophorus* L., native to subtropical North and South America (Agrawal and Narayan 2017), *Cassia occidentalis* L., native to tropical America (Yadav et al. 2022) and *Chenopodium murale* L., native to Europe and parts of Asia and Northern Africa (Holm et al. 1997) are the predominant botanical invaders in and around the national capital region of Delhi in India, where anthropogenic activities have been suggested to facilitate the abundance and dominance of such alien invasive species (Agrawal and Narayan 2017). The nuisance of these problematic invasive weeds jeopardizing the ecology of the agro-ecosystems in the areas of their occurrence has been reported globally by several researchers e.g., *Cassia occidentalis* by Musa et al. (2017), *Chenopodium murale* by Bajwal et al. (2019) and *Parthenium hysterophorus* by Srivastava and Raghubanshi (2021). The invasiveness of such weeds from their huge monoculture strands has been realized to cause various environmental and agricultural problems *viz.* loss of crop productivity, fodder scarcity, biodiversity depletion, etc. (Belz et al. 2007). These three weeds are reportedly considered highly competitive and difficult to control, especially in Indian dry tropics due to their tremendous germination ability, vigorous growth habit, high nutrient uptake and tolerance of abiotic stress (Batish et al. 2007, Chatterjee et al. 2012, Devi et al. 2014).

Incomplete removal of these alien weeds from the crop fields adversely affects the yield and growth of the succeeding crop (Chikoye et al. 2000). The leaf-residue (powdered leaf-biomass) of such weeds is about 50% of carbon (Singh et al. 2009), significantly increasing soil organic carbon. Along with carbon, such leaf residues on decomposition influenced other soil properties, ostensibly by releasing water-soluble allelochemicals (Appel 1993). The persistence of the weed leaf-residue over a long time in the field may cause alteration in soil properties to such an extent that the performance of the agroecosystem gets drastically affected to the detriment of the succeeding crop (Batish et al. 2007). The mixture of PLB of *Parthenium hysterophorus* L. with that of the other weeds has been reported to have variable effects (additive, antagonistic and synergistic) on the growth of associated crops; accordingly, investigation studies on weed leaf biomass have often been suggested to have a considerable implication for weed management (Gupta and Narayan 2010).

In recent years, there have been an increasing number of reports on agroecosystems and their adjoining vegetation being drastically affected by the rapid spread of these three weeds *via* their abundance, density and growth in the Indian tropical ecosystems (Agrawal and Narayan 2017). Much scientific information exists on *P. hysterophorus*, considered one of the world's worst invasive weeds. *C. murale* has been reported to turn invasive in Indian dry-tropics (Gupta and Narayan 2012) expanding through its differential biomass allocation ability across various resource states of soils. Yet, information on its allelopathic influences is highly lacking. *Cassia occidentalis*, a leguminous weed, has also been opined to have an antagonistic influence on the growth of *P. hysterophorus* (Gupta and Narayan 2009). However, investigative ecological studies on this aspect lack adequacy. Such investigative studies pertaining to allelopathic effects of these common alien weeds that are finding wide occurrence in diverse anthropo-systems in Indian dry tropics assume significance where the productivity of agro-ecosystems is greatly impacted adversely, especially in the western part of U.P. in India lying in the agriculturally fertile region of Ganga-Yamuna Doab in the National Capital Region of Delhi.

The present study aimed to investigate the effect of powdered leaf biomass (PLB) of *P. hysterophorus*, *C. occidentalis* and *C. murale* separately and in binary and tertiary mixtures on (i) the growth of the staple protein-rich crop *Vigna unguiculata* and (ii) soil fertility.

MATERIALS AND METHODS

Fresh leaves of *Parthenium hysterophorus*, *Cassia occidentalis* and *Chenopodium murale*, were collected from the weed-infested sites in Meerut (28° 59' N lat. and 77° 40' E long.), India, at their mature adult stages: *P. hysterophorus* in September, *C. occidentalis* in October 2019 and *C. murale* in March 2020. The leaves were shade-dried, powdered and stored in airtight containers at room temperature for use in soil experiments hereafter referred to as powdered leaf-biomass (PLB).

Pot culture

PLB of three weeds (*P. hysterophorus*, *C. occidentalis* and *C. murale*) was added at 0.5, 1 and 2 g per kg soil on July 20, 2022. Plastic pots (perforated bottom) were filled with one kg of these soils for pot culture investigations. The soil was collected from a non-infested field (pH 7.88 ± 0.04, conductivity 0.14 ± 0.01, salinity 0, organic carbon 0.48 ± 0.014, total nitrogen 0.09 ± 0.004). The PLB doses were decided on the basis of the weed-leaf biomass estimated in crop fields. To study the impact of individual, binary and tertiary mixtures of the PLB of these three weeds, the possible combinations of their PLB were added separately to 1 kg of soil. Unamended soil served as control. Three replicates of each PLB of weeds treatment were prepared. The treatments were labelled as Ph0.5, Ph1, Ph2, Co0.5, Co1, Co2, Cm0.5, Cm1, Cm2, Ph0.5Co0.5, Ph1Co1, Ph2Co2, Ph0.5Cm0.5, Ph1Co1, Ph2Co2, Co0.5Cm0.5, Co1Cm1, Co2Cm2, Ph0.5Co0.5Cm0.5, Ph1Co1Cm1, Ph2Co2Cm2 and control. The digits suffixed to species codes (Ph, Co, Cm, respectively for *P. hysterophorus*, *C. occidentalis* and *C. murale*) indicated the amount (g) of applied PLB of a species. Pots were watered to field capacity whenever needed throughout the experiment, and the unwanted, emerging plants were eliminated periodically. The treatment consisted of two major factors: (i) Donor weeds -3 (*P. hysterophorus*, *C. occidentalis* and *C. murale*) and (ii) applied PLB doses - 3 (0.5, 1, 2 g/kg soil). Recipient crop was *Vigna unguiculata*. Six seeds of *V. unguiculata* were sown in the amended soils in triplicate. Germination was recorded until no further seeds germinated. Two healthy individuals were allowed to grow for growth studies, and the remaining germinated plants were eliminated from each pot. Periodically the shoot length and number of leaves were recorded. The first measurement was taken 20 days after sowing (DAS), followed by at 35, 50, 65, 80 and 95 DAS for the crop. Shoot length, root length, number of leaves, pods and seeds were measured along with the biomass of each part of the crop plant at 95 DAS on 23 October 2020. The experiment was carried out under shaded-house conditions with a natural light supply. During the crop growth study, the recorded mean maximum temperature was 34.5ºC with a minimum of 25.2ºC and the mean maximum relative humidity was 69.3%.

Soil analysis

At the time of crop harvesting, soil samples were collected, air-dried and analysed for soil pH, conductivity, salinity, organic carbon (Walkley and Black method) and total nitrogen (micro-Kjeldahl's method) following Piper (1944).

Assessment of biochemical parameters of the weeds

Total phenolic content and antioxidant activity

To determine total phenolic content (Bray and Thrope 1954) and antioxidant activity i.e., á, á-diphenyl-â-picrylhydrazyl (DPPH) radical scavenging activity (Nile and Park 2014), Ferric ion reducing antioxidant power (FRAP) assay (Pulido et al. 2000) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay (Re et al. 1999) of mature leaves of selected weeds, dried leaf samples were extracted in ethanol by using shaker-assisted extraction (5gm of powdered leaves of each weed sample was extracted with 100ml of absolute ethanol for 48 hrs. at 120 rpm. These extracts were filtered and stored at low temperature).

Enzymatic activity

Enzymatic activity of Peroxidase and Catalase was assessed according to Maehly and Chance (1976) and Aebi (1984), respectively. For extraction of the enzyme, 100mg of a fresh sample of leaves was homogenized in 10 ml chilled common extraction-cum-buffer *i.e.*, 0.2M Tris-Malate-NaOH Buffer, pH 7.2 and centrifuged at 1000 rpm at 4^{o}C temperature for 5 minutes. Pellet was discarded and the supernatant was collected for assay of the enzymatic activity.

Statistical analysis

The data were statistically analyzed by using SPSS 20. Colby's formula (E=A*B/100) was used to calculate the expected growth in an additive response based on the growth values obtained for the two single treatment means (A and B in terms of biomass of crop plants as % of control). A paired t-test compared the expected growth value (E) with the observed growth value for the binary PLB mixture (A+B) and determined if responses were significantly synergistic or antagonistic.

RESULTS

The PLB amendments of three weeds tested individually, binary and tertiary mixtures in general, didn't significantly affect the seed germination of *Vigna unguiculata* (Fig. 1). However, a considerable stimulatory impact on seed germination was recorded in soil amended with the lower dose of Ph (Ph0.5) and inhibitory impact at higher doses of leaf residue *e.g.*, Ph2Cm2 in binary mixtures and Ph1Co1Cm1as well as Ph2Co2Cm2 in tertiary mixtures ($p \leq 0.05$). It is also noteworthy that PLB at doses of ≥ 3g/kg soil tended to significantly inhibit seed germination of the crop.

The cowpea plants showed variable growth trends in soils amended with different doses of individual PLB of Ph, Co and Cm (Table 1). The number of leaves, pods, seeds, and shoot length declined with increasing doses of Ph and Cm. However, all Co doses showed significant crop growth stimulation over control ($p \leq 0.05$). Maximum inhibition was recorded in soils amended with Ph2 dose. Root length, however, showed a different trend. Its stimulation was recorded at the lower dose of all three weeds and it declined with increasing dose in soils amended with Ph and Cm. In contrast, this stimulation increased with increasing dose in soils amended with Co leaf-biomass. In soils amended with different doses of binary mixtures of PLB of Ph, Co and Cm, this crop showed a varying growth

Table 1. Impact of applied powdered leaf-biomass of three weeds individually, binary and tertiary mixtures on growth attributes of *Vigna unguiculata*. The value indicates % inhibition/stimulation over control. Mean values with the same letters in the same column do not differ from each other by means of ANOVA compared to the DMRT test at 0.05 probability level. Digits affixed to weed type (Ph-*Parthenium hysterophorus*, Co-*Cassia occidentalis*, Cm-*Chenopodium murale*), separately refers to applied powdered leaf-biomass (g/kg soil).

Treatments	Number of leaves (Mean±S.E.)	Number of pods (Mean±S.E.)	Number of seeds (Mean±S.E.)	Shoot length (cm) (Mean±S.E.)	Root length (cm) (Mean±S.E.)
Control	0.00±0.00 a	0.00±0.00 a	0.00±0.00 a	0.00±0.00 a	0.00±0.00 b
Ph0.5	-15±5.03 b	-17.81±6.93 b	-13.47±2.67 b	-22.25±3.62 b	26.67±3.76 a
Ph1	-28.66±6.25 c	-43.55±4.54 c	-32.12±4.91 c	-29.58±3.06 bc	19.26±4.04 a
Ph2	-39.33±2.04 c	-53.46±5.62 c	-36.96±3.54 c	-35.31±1.95 c	8.15±1.87 b
Co0.5	10±3.46 bc	11.9±6.93 bc	9.5±6.19 bc	3.19±0.85 b	5.19±1.48 c
Co1	18.33±4.77 ab	28.74±6.07 ab	20.73±5.91 ab	6.1±1.07 a	14.81±4.04 b
Co2	29±7.19 a	36.66±8.12 a	32.3±5.93 a	7.7±0.67 a	24.44±2.57 a
Cm0.5	-13.33±5.38 b	-8.89±3.7 a	-11.23±5.13 b	-12.02±0.85 b	40.74±4.08 a
Cm1	-23.33±3.68 b	-27.71±6.02 b	-28.32±3.8 c	-15.96±0.89 c	15.56±6.79 b
Cm2	-35±4.28 c	-40.58±4.34 c	-34.54±2.53 c	-27.04±2.16 d	5.19±1.48 bc
Ph0.5+Co0.5	-11±4.64 b	-7.9±4.54 a	-8.46±4.29 a	-9.39±2.89 b	52.59±2.48 a
Ph1+Co1	-23±3.61 c	-34.64±9.46 b	-22.45±3.27 b	-21.97±0.43 c	45.93±2.67 a
Ph2+Co2	-34.67±3.37 d	-47.51±9 b	-28.67±2.35 b	-29.34±2.73 d	22.96±2.96 b
Ph0.5+Cm0.5	-22.33±2.33 b	-14.83±7.62 a	-18.83±2.55 b	-19.34±1.56 b	46.67±3.04 a
Ph1+Cm1	-35.67±5.52 c	-36.62±8.63 b	-34.89±1.55 c	-26.1±0.64 c	33.33±4.29 b
Ph2+Cm2	-44.67±5.63 c	-49.49±15.83 b	-46.11±3.12 d	-33.15±0.98 d	11.85±2.12 c
Co0.5+Cm0.5	-7±5.58 ab	-2.95±4.06 ab	-6.91±3.35 a	-3.66±0.48 ab	68.89±4.29 a
Co1+Cm1	-18±4.59 b	-13.84±3.68 bc	-20.53±1.97 b	-5.45±0.64 b	33.33±6.18 b
Co2+Cm2	-30.67±3.71 c	-24.74±5.24 c	-29.53±1.97 b	-23.85±2.94 c	17.04±5.7 c
Ph0.5+Co0.5+Cm0.5	-34.33±4.42 b	-34.61±5.03 b	-22.63±3.41 b	-24.04±2.49 b	31.11±4.26 a
Ph1+Co1+Cm1	-40±5.37 bc	-57.42±4.18 c	-32.3±4.59 b	-29.58±2.08 b	14.07±3.57 b
Ph2+Co2+Cm2	-49.67±3.48 c	-64.35±3.43 c	-47.32±3.93 c	-38.69±2.66 c	5.93±1.78 b

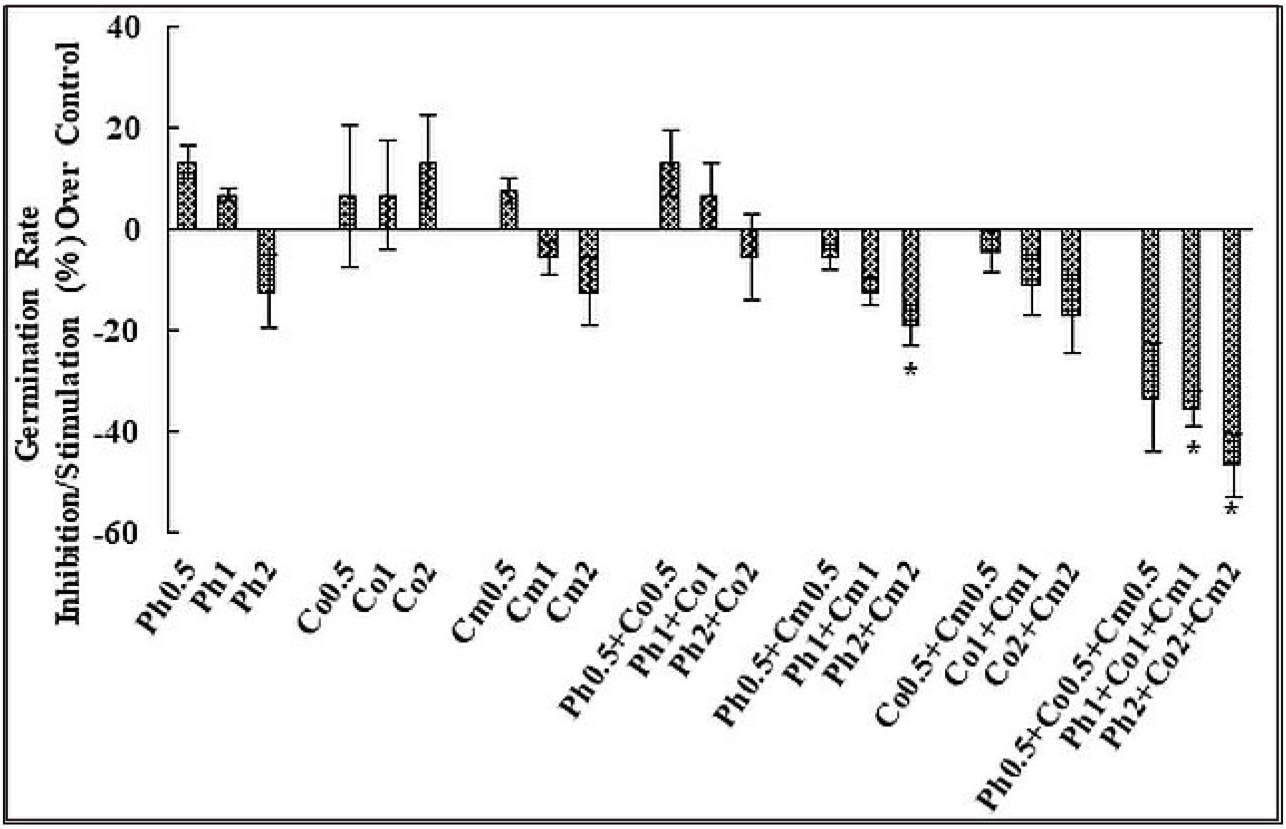

Figure 1. Impact of varying doses of applied powdered leaf-biomass of *Parthenium hysterophorus* (Ph), *Cassia occidentalis* (Co) and *Chenopodium murale* (Cm) singly and in combinations on seed germination of the crop *Vigna unguiculata*. Digits affixed to weed type (Ph, Co, Cm), separately or in combination, refers to applied powdered leaf-biomass (g/kg soil). According to Dunnett's test, * indicates significant inhibition/stimulation over control at $p \leq 0.05$.

trend (Table 1). Number of leaves, pods, seeds and shoot length of investigated crop significantly declined with increasing doses of PhCo, PhCm and CoCm over control (*p* d" 0.05). Maximum inhibition was recorded in soils amended with binary mixture of Ph2Cm2. Root length, however, showed a different trend. Its stimulation was recorded at the lower dose of all the binary mixtures of three weeds and this stimulation declined with increasing doses of PLB of selected weeds in binary combinations. A comparable trend was recorded in tertiary mixtures of PLB of Ph, Co and Cm too (Table 3). The number of leaves, pods, seeds and shoot length declined significantly with increasing PhCoCm doses over control (*p* d" 0.05). Root length, in contrast, exhibited stimulatory impact at lower doses of tertiary mixture and it declined with increasing dose of PLB in tertiary combinations.

A very significant stimulatory impact by applied PLB of Co at doses e" 1gm on above-ground biomass of cowpea plants was recorded in this study in contrast to growth retardatory impact by applied PLB of Ph and Cm with increasing dose (Fig. 2a). However, binary and tertiary mixtures exhibited inhibitory impact with increasing doses of PLB of these three weeds (*p* d" 0.01). On the other hand, the below-ground biomass of the crop plants showed consistent stimulatory impact by the applied PLB of the three weeds singly, as well as in binary and tertiary mixtures. It was noteworthy in the present study that a significantly much higher stimulatory impact by PLB of Co was recorded (54.6-145.71%) when it was applied singly compared to the other two weeds Ph and Cm (Fig. 2b).

The crop growth in Ph and Cm-amended soils declined compared to control soil but Co-amended soils showed enhanced growth (Table 2). No additive

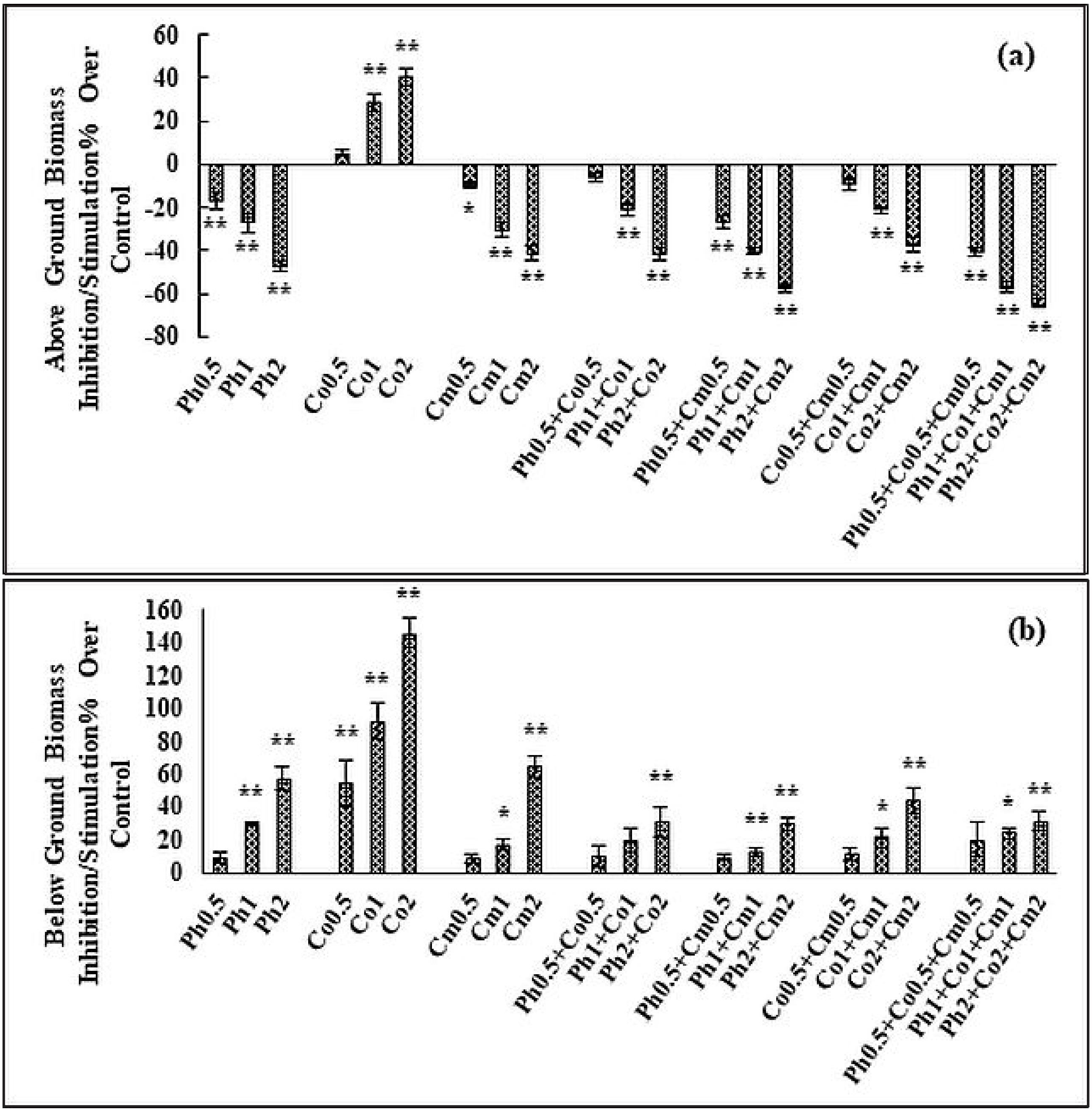

Figure 2. Impact of varying doses of applied powdered leaf-biomass of *Parthenium hysterophorus* (Ph), *Cassia occidentalis* (Co) and *Chenopodium murale* (Cm) singly and in combinations on above-ground biomass (a) and below-ground biomass (b) of the crop *Vigna unguiculata*. Digits affixed to weed type (Ph, Co, Cm), separately or in combination, refers to applied powdered leaf-biomass (g/kg soil). According to Dunnett's test, * indicates significant inhibition/stimulation over control at $p \leq 0.05$.

effect was recorded in any of the binary mixtures of these three weeds on the total biomass of the investigated crop. The antagonistic impact of binary mixtures of Co with both Ph and Cm leaf-biomass was evinced in this study. In contrast, the binary mixture of Ph and Cm exhibited a synergistic impact on crop biomass.

In both fallow soils (Fig. 3a) and soils with crop (Fig. 3b) under variously amended conditions, soil organic C and total N increased significantly with

Table 2. Impact of applied powdered leaf-biomass of *Parthenium hysterophorus* (Ph), *Cassia occidentalis* (Co) and *Chenopodium murale* (Cm) when applied alone and in binary mixtures on total plant biomass of *Vigna unguiculata*

Leaf biomass treatment	Total plant biomass (g/individual)	Measured total plant biomass (% of control)	Expected value[a] (% of control)	Quality of interaction[b]
Ph2	2.02	59.41		
Co2	5	147.06		
Cm2	2.24	65.88		
Ph1Co1	2.77	81.47	87.37	Antagonistic
Ph1Cm1	2.15	63.23	39.13	Synergistic
Co1Cm1	2.78	81.76	96.88	Antagonistic

[a] as determined by Colby's formula.

[b] significantly different from the measured value as determined by t-test ($p \leq 0.05$).

Table 3. Biochemical Analysis: Analysis of total phenolic content, enzymatic activity and free radical scavenging activity of mature plants of *Parthenium hysterophorus* (Ph), *Cassia occidentalis* (Co) and *Chenopodium murale* (Cm) leaves. Mean values with the same letters in the same column do not differ from each other by means of ANOVA compared to the DMRT test at 0.05 probability level

Leaves	Phenolics (mg/g)	Enzymatic activity		Antioxidant activity		
		Peroxidase	Catalase	DPPH (%)	ABTS (%)	FRAP (µ/ml)
Ph	2±0.38 a	0.28±0.01 a	0.63±0.01 a	63.8±0.24 a	92.74±0.26 a	1.58±0.36 a
Co	1.17±0.09 b	0.17±0.00 c	0.42±0.15 c	25.19±0.57 c	89.75±0.36 b	1.35±0.06 b
Cm	1.31±0.03 ab	0.24±0.00 b	0.5±0.00 b	38.78±0.18 b	90.55±0.36 b	1.46±0.03 ab

an increase in doses of PLB of all three weeds compared to control soils. However, this increase in soil nutrients was recorded to be higher in fallow soils compared to that under crop growth conditions. Among soil organic C and total N, the latter showed, in general, much higher stimulation under the amended soil conditions (maximum organic C increase range 22.2 to 72.2% under PLB of Ph-amended conditions and corresponding soil total N increase range 36.1 to 80.6% under PLB of CoCm-amended soils. Weed PLB dose of 2g/kg soil singly or in binary mixture exhibited a much higher soil-nutrient increase. On the other hand, under the tertiary-mixture amended condition, the soil nutrient declined compared to the binary mixture.

Total phenolics, enzymatic activity and antioxidant activity were recorded in mature leaves of all three weeds leaf for analysing the allelopathic impact on the protein-rich crop *Vigna unguiculata* (Table 3). All these were recorded highest in Ph followed by Cm and Co.

DISCUSSION

Allelopathic influence of alien flora on the edaphic environment has often been suggested as one of the most important invasive characteristics to adversely impact native biodiversity and growth of crops in weed-infested as evinced in diverse urban anthropo-ecosystem in Indian dry tropics (Gupta and Narayan 2010). The present study revealed that such alien flora differs in their allelopathic influence at different stages of their growth. They also have varying allelopathic impacts on the growth stage of the associated crop plants. The impact of such weeds is also dose-dependent implying their greater allelopathic influence on plants growing in vicinity these weeds have dense colonized growth. In the present investigation on the growth of a staple pulse crop *Vigna unguiculata* of this region, varying

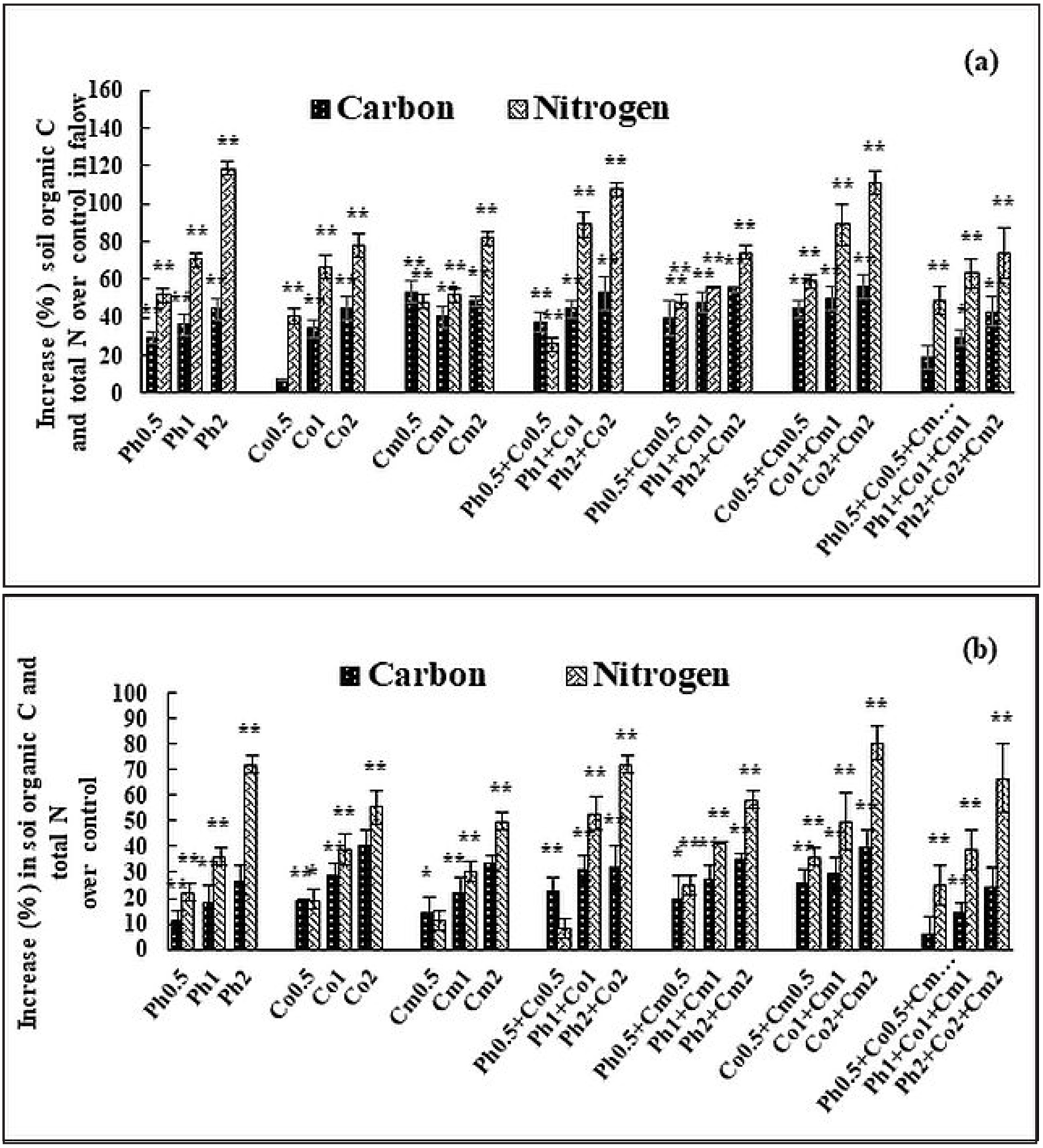

Figure 3. Impact of varying doses of applied powdered leaf-biomass of *Parthenium hysterophorus* (Ph), *Cassia occidentalis* (Co) and *Chenopodium murale* (Cm) singly and in combinations on fallow soil (no crop) (a) and soil with crop (b) of *Vigna unguiculata*. Digits affixed to weed type (Ph, Co, Cm), separately or in combinations, refers to applied powdered leaf-biomass (g/kg soil). According to Dunnett's test, * indicates significant inhibition/stimulation over control at $p \leq 0.05$.

impacts of different alien weeds were implicit from the present investigation.

The seed germination of *Vigna unguiculata* was not significantly affected by any PLB of the three investigated weeds (Fig. 1). However, significant stimulation was observed at the lower dose of Ph0.5 g/kg soil, possibly due to the stimulatory impact at lower dose of PLB of *Parthenium hysterophorus* that possessed compounds such as parthenin and other sesquiterpenes, which often affected the seed coat as suggested for cowpea (Belz et al. 2010). However, at higher doses of weed PLB in the present study *viz*., Ph2Cm2 and Ph2Co2Cm2 g/kg soil, significant inhibitory impact was evident on seed germination, ostensibly through the release of some allelochemicals, mainly phenolics during decomposition of leaf-biomass in soils (Demissie et al. 2013).

The declining growth characteristics estimated in this study in terms of number of leaves, pods, seeds, shoot length (Table 1) and above-ground biomass (Fig. 2a), with increasing dose in soils amended with the PLB of Ph and Cm individually could be attributed to the release of growth-inhibiting allelochemicals, mostly the water-soluble ones (Rice 1984). This adverse growth impact of Ph on cowpea plants in this study was in accordance with its adverse effects reported earlier on *Acacia catechu* Willd, *Achyranthes aspera* L. and *Cassia tora* L. (Dogra and Sood 2012), on wheat and pea (Gupta and Narayan 2010) and on three spp. of *Brassica* (Singh et al. 2005). The growth retardatory impact of Cm PLB on the cowpea plants was comparable to its detrimental impact on chickpea and pea (Batish et al. 2007). In contrast to the inhibitory impact on crop growth by Ph and Cm, the significant growth stimulatory influence of Co with increasing dose was evinced for all investigated growth parameters in this study could be attributed to the presence of higher amounts of proteins, nucleic acids, carbohydrates and carotenoids in its leaves (Arora 2015). However, in binary mixture, the inhibitory impact of Ph and Cm PLB in combination was significantly reduced.

Further, it was noteworthy that PhCo and CmCo had antagonistic impact on *Vigna* growth (Table 2) suggesting an important role of Co on management of these two weeds (Gupta and Narayan 2010). Leaf-leachate of Co has been reported to have various detrimental effects on seed germination, growth, chlorophyll, and protein content (Singh et al. 2013). This antagonistic impact of Ph1Co1 and Cm1Co1 binary mixtures was recorded in this study to inhibit cowpea growth (although Co2 alone had stimulatory impact on it) over control. On the other hand, synergistic activity was exhibited by PhCm for all growth parameters including the total biomass of the test crop.

The observed stimulating impact on below-ground biomass in this study (Fig. 2b) in variously amended soils could be attributed to adaptation response of these roots to edaphic stress by enhancing the crop's nutrient-absorption organ (root). Such physiologically stressed soil conditions due to leaf-biomass of invasive weeds may have less soluble N, P, Ca and Mn (Lynch et al. 2015).

This study recorded a significant increase in soil organic C and total N in soils amended with weed PLB compared to unamended soils (Fig. 3a). This increase possibly could be due to the faster decomposition of weed leaf-biomass (Kourtev et al. 2002, Garcia et al. 2005, Li et al. 2006). Elevated soil microbial activity of urease and phosphatase has often been reported in soils associated with invasive plants. A relatively higher increase in soil organic C and total N in fallow soils recorded in this study, compared to soils under crop growth (Fig. 3b), ostensibly could be attributed to the consumption of nutrients during the growth of crops. However, further enhancement of total N under such crop-grown soil conditions compared to fallow soils could be due to the nitrogen-fixing ability of the leguminous crop *Vigna unguiculata* in this study. Residue incorporation in the soil increases its stability of aggregation, organic C, and better regulation of soil hydrothermal regime so, on a long-term basis, increases crop yield by improving the physical properties of soil (Singh et al. 2019). Despite the enhancement of soil fertility in terms of soil organic C and total N, the growth retardatory impact observed on crop plants could be explained in terms of increasing release of allelochemicals by weed leaf biomass e.g., parthenin in Ph, accompanied by ambrosin, hymenin (Wunbeh 2019), ferulic acid, protocatechuic acid and synergic acid (Batish 2007). In the present study, the phenolics estimated in three weeds in this study was in the order Ph > Cm > Co reflective of the highest invasibility of Ph in Indian dry tropics, where it is considered India's one of the worst invasive weeds (Table 3). The phenolic acids isolated from Ph plant parts extracted in different organic solvents include caffeic acid (C9H8O4), p-coumaric acid (C9H8O3), p-anisic acid (C8H8O3), ferulic acid (C4H4O4), fumaric acid (C4H4O4), p-hydroxy benzoic acid (C7H6O3), chlorogenic acid (C16H18O9), neochlorogenic acid (c16H18O9), protocatechuic acid (C7H6O4), ferulic acid, and vanillic acid (C4H4O4) as reported by Das and Das (1995). These primary phenolic acids play a crucial role in the allelopathic activity of the *Parthenium* (Richa et al. 2015). In addition, the present study also estimated the antioxidant and enzymatic activity of mature leaves of all these three weeds. All these activities were higher in Ph followed by Cm and Co This is probably due to the presence of a variable range of terpene, fatty acids, sterols, and their derivatives in different parts of *Parthenium*, mainly terpene and terpenoids as major antioxidants combating oxidative stress by donating hydrogen to free radicals (Ahmad et al. 2018). Its detrimental effect on cowpea plants suggests its inhibitory impact on the growth of associated plants in natural and agro-ecosystem because peroxidase, catalase activity and antioxidant activity are considered very sensitive to stress conditions where these activities get enhanced under stress (Srivalli et al. 2003).

CONCLUSION

This study revealed that the powdered leaf-biomass of exotic weeds *Parthenium hysterophorus* and *Chenopodium murale* significantly retarded the growth of the *Vigna* crop. On the other hand, the powdered leaf-biomass of *Cassia occidentalis* stimulated crop growth. The binary mixtures of powdwred leaf-biomass of weeds had variable effects. *Parthenium hysterophorus* with *Chenopodium murale* had a synergistic effect; however, *Cassia occidentalis* with both *Parthenium hysterophorus* and *Chenopodium murale* showed an antagonistic effect on crop growth. The impact of powdered leaf-biomass of weeds was weed-specific and dose-dependent in altering soil resource states. Additionally, antagonistic traits of *Cassia occidentalis* has management implications for aggressively advancing *Parthenium hysterophorus* and *Chenopodium murale* especially in and around urbanizing areas in Indian dry-tropics.

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REFERENCES

Aebi, H. 1984. Catalase in vitro. Methods in Enzymology, 105, 121-126. https://doi.org/10.1016/s0076-6879(84) 05016-3.

Agarwal, S. and Narayan, R. 2017. Spatio-temporal organization and biomass dynamics of plant communities in a dry tropical peri-urban region: deterministic role of alien flora in anthropo-ecosystems. Current Science, 113, 53-60. http://doi.org/10.18520/cs/v113/i01/53-62.

Aggarwal, S., Gupta, V. and Narayan, R. 2012. Ecological study of wild medicinal plants in a dry tropical peri-urban region of Uttar Pradesh in India. International Journal of Medicinal and Aromatic Plants, 2(2), 246-253.

Ahmad, J., Bagheri, R., Bashir, H., Baig, M.A., Al-Huqail, A., Ibrahim, M.M. and Qureshi M.I. 2018. Organ-specific Phytochemical Profiling and Antioxidant Analysis of *Parthenium hysterophorus* L. BioMed Research International, 10, 1-10. https://doi.org/10.1155/2018/9535232.

Appel, H.M. 1993. Phenolics in ecological interactions, importance of oxidation. Journal of Chemicals Ecology, 19, 1521-1552. https://doi.org/10.1007/bf00984895.

Arora, K. 2015. Comparative account of allelopathic potential of different parts of Cassia occidentalis and its correlation with bio-molecular profile though FTIR. Journal of Chemical and Pharmaceutical Research, 7(12), 91-95.

Bajwa, A.A., Zulfiqar, U., Sadia, S., Bhowmik, P. and Chauhan, B.S. 2019. A global perspective on the biology, impact and management of *Chenopodium album* and *Chenopodium murale*: two troublesome agricultural and environmental weeds. Environmental Science and Pollution Research, 10, 1007-1021. https://doi.org/10.1007/s11356-018-04104-y.

Batish, D.R., Lavanya, K., Singh, H.P. and Kohli, R.K. 2007. Phenolics allelochemicals released by *Chenopodium murale* affect the growth, nodulation and macromolecule content in chickpea and pea. Plant Growth Regulation, 51, 119-128. http://doi.org/10.1007/s10725-006-9153-z.

Belz, R.G. and Cedergreen, N. 2010. Parthenin hormesis in plants depends on growth conditions. Environmental and Experimental Botany, 6, 293-301. http://doi.org/10.1016/

j.envexpbot.2010.04.010.

Belz, R.G., Reinhardt, C.F., Foxcroft, L.C. and Hurle K. 2007. Residue allelopathy in *Parthenium hysterophorus* L.- Does parthenin play a leading role? Crop Protection, 26, 237-245. http://dx.doi.org/10.1016/j.cropro.2005.06.009.

Bray, H.G. and Thrope, W.V. 1954. Analysis of Phenolic compounds of interest in metabolism. Methods of Biochemical Analysis, 52, 1-27. https://doi.org/10.1002/9780470110171.ch2.

Chatterjee, S., Chatterjee, S., Bhattacharya, A. and Dutta, S. 2012. Allelopathic Effect of *Cassia occidentalis* Leaves on Mustard Seeds. Trends in Biotechnology Research, 1, 29-35.

Chikoye, D., Manyong, V.M. and Ekeleme, F. 2000. Characteristics of speargrass (*Imperata cylindrica*) dominated fields in West Africa: crops, soil properties, farmer perceptions and management strategies. Crop Protection, 19, 481-487. https://doi.org/10.1016/S0261-2194(00)00044-2.

Das, B. and Das R. 1995. Chemical investigation in *Parthenium hysterophorus* An-allelopathic plant. Allelopathy Journal, 2(1), 99-104.

Demissie, A.G., Ashenafi, A., Arega, A., Etenash, U., Kebede, A. and Tigist, A. 2013. Effect of *Parthenium hysterophorus* on germination and elongation of onion (*Allium sepa*) and bean (*Phaseolus vulgaris*). Research Journal of Chemical and Environmental Sciences, 1(2), 17-21.

Devi, Y.N., Dutta, B.K., Sagolshemcha, R. and Singh, N.I. 2014. Allelopathic Effect of *Parthenium hysterophorus* L. on Growth and Productivity of *Zea mays* L. and its Phytochemical Screening. International Journal of Current Microbiology and Applied Sciences, 7, 837-846.

Dogra, K.S. and Sood, S.K. 2012. Phytotoxicity of *Parthenium hysterophorus* residues towards growth of three native plant species (*Acacia catechu* willd, *Acyranthes aspera* L. and *Cassia tora* L.) in Himachal Pradesh, India. International Journal of Plant Physiology and Biochemistry, 4(5), 105-109. http://dx.doi.org/10.5897/IJPPB11.009.

Garcia, C., Roldan, A. and Hernandez, T. 2005. Ability of different plant species to promote microbiological processes in semiarid soil. Geoderma, 124, 193-202. https://doi.org/10.1016/j.geoderma.2004.04.013.

Gupta, S. and Narayan, R. 2009. Plant diversity and dry-matter dynamics of peri-urban plant communities in an Indian dry tropical region. Ecological Research, 26, 67-78. http://doi.org/10.1007/s11284-010-0760-9.

Gupta, S. and Narayan, R. 2010. Effects of applied leaf biomass of *Parthenium hysterophorus, Cassia obstusifolia* and *Achyranthes aspera* on seed germination and seedling growth of wheat and pea. Allelopathy Journal, 26(1), 59-70.

Holm, L., Doll, J., Holm, E., Pancho, J. and Herberger, J. 1997. World Weeds: Natural Histories and Distribution: John Wiley & Sons, New York.

Kourtev, P.S., Ehrenfeld, J.G. and Hahhblom, M. 2002. Exotic plant species alter the microbial community structure and functional in the soil. Ecology, 83, 3152-3166. https://doi.org/10.2307/3071850

Li, W.H., Zhang, C.B., Jiang, H.B., Xin, G.R. and Yang, Z.Y. 2006. Changes in soil microbial community associated with invasion of the exotic weed, *Mikania micranth* H.B.K. Plant Soil, 281, 309-324. http://doi.org/10.1007/s11104-005-9641-3.

Lynch, J.P. and Wojciechowski, T. 2015. Opportunities and challenges in the subsoil: pathways to deeper rooted crops. Journal of Experimental Botany, 66, 2199-2210. https://doi.org/10.1093/jxb/eru508.

Maehly, A.C. and Chance, B. 1976. The assay of catalase and peroxidases. Methods of Biochemical Analysis, 1, 357-424. https://doi.org/10.1002/9780470110171.ch14.

Musa, D.D., Aliero, A.A. and Bashir, K.A. 2017. Preliminary allelopathic activity of aqueous leaf extract of *Senna occidentalis* on the germination and early seedling growth of cowpea (*Vigna unguiculata*). International Journal of Current Science and Studies (IJCSS), 1, 23-25.

Nile, S.H. and Park, S.W. 2014. Antioxidant: á-glucosidase and xanthine oxidase inhibitory activity of bioactive compounds from maize (*Zea mays* L.). Chemical Biology and Drug Design, 83, 119-125. https://doi.org/10.1111/cbdd.12205.

Piper, C.S. 1944. Soil and Plant Analysis: A Laboratory Manual of Methods for the Examination of Soils and the Determination of the Inorganic Constituents of Plants. University of Adelade, Australia. 368 pages.

Pulido, R., Bravo, L. and Sauro-Calixo, F. 2000. Antioxidant Activity of dietary polyphenols as determined by a modified ferric reducing / antioxidant power assay. Journal of Agriculture and Food Chemistry, 48, 3396-3402. https://doi.org/10.1021/jf9913458.

Re, R., Pellergrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C. 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology and Medicine, 26, 1231-1237. https://doi.org/10.1016/s0891-5849(98)00315-3.

Rice, E.L. 1984. Allelopathy, 2nd edn., Academic Press, Orlando, FL, USA. 422 pages.

Richa, P., Asvene, K.S. and Dharm, D. 2015. Phenolic acids from *Parthenium hysterophorus*: Evaluation of bioconversion potential as free radical scavengers and anticancer agents. Advances in Bioscience and Biotechnology, 6, 11-17. http://doi.org/10.4236/abb.2015.61002.

Singh, H.P., Batish, D.R., Pandher, J.K. and Kohli, R.K. 2005. Phytotoxic effects of *Parthenium hysterophorus* residues on three *Brassica* species. Weed Biology and Management, 5, 105-109. http://doi.org/10.1111/j.1445-6664.2005.00172.x.

Singh, L., Yadav, D.K., Pagare, P., Ghosh, L. and Thakus, B.S. 2009. Impact of land use changes on species structure, biomass and carbon storage in tropical deciduous forest and converted forest. International Journal of Ecology and Environmental Sciences, 35, 113-119.

Singh, N.B., Kumar, S., Singh, D. and Yadav, K. 2013. Allelopathic effect of different phenological stages of *Cassia occidentalis* L. on *Parthenium hysterophorus* L. Iranian Journal of Plant Physiology, 3(4), 817-828.

Singh, R., Serawat, M., Singh, A. and Babli (2019). Effect of tillage and crop residue management on soil physical properties. Journal of Soil Salinity and Water Quality, 10 (2), 200-206.

Srivalli, B., Sharma, G. and Khanna-Chopra, R. 2003. Antioxidative defense system in an upland rice cultivar subjected to increasing intensity of water stress followed by recovery. Physiologia Plantarum, 119, 503-512. http://doi.org/10.1046/j.1399-3054.2003.00125.x.

Srivastava, P. and Raghubanshi, A.S. 2021. Impact of *Parthenium hysterophorus* L. invasion on soil nitrogen dynamics of grassland vegetation of Indo-Gangetic Plains, India. Environmental Monitoring and Assessment, 193, 286-295. https://doi.org/10.1007/s10661-021-09070-6.

Wahab, W.Y. 2019. *Parthenium hysterophorus* in Ethiopia: Distribution, impact and management - A review. World Scientific News, 36, 127-130.

Yadav, C., Lomas, M.K., Kumar, A. and Narayan, R. 2022. Ecological importance and economic uses of selected native and invasive alien grasses across five diverse anthro-ecosystem in the Indian dry tropics. Annals of Plant Sciences, 11(07), 5252-5269. http://dx.doi.org/10.21746/aps.2022.11.7.6

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