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Allelopathic effect of sugarcane intercrops on its emergence and growth

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Abstract

Crops sown as intercrops in sugarcane are presumed to modify the emergence and growth of sugarcane by releasing phytotoxic chemicals into its rhizosphere. This study was conducted to investigate the allelopathic effect of leachates (liquid extracts with soluble solids) of intercrops *Triticum aestivum*, *Cicer arietinum*, *Brassica napus* and *Lens culinaris* on sugarcane. Aqueous extracts (5% w/v) derived from different plants parts (leaves, stem, root and whole plant). Among all the extracts used in study, *B. napus* root extract caused the highest reduction in emergence percentage (78%), emergence index (85%) and chlorophyll content (60%) of sugarcane seedlings in comparison with distilled water treated control. Whereas, the maximum inhibition in seedling growth of sugarcane was observed in response to application of stem extract of gram that resulted in the lowest sugarcane seedling length (23 cm), seedling biomass (2.0 g) and seedling vigor index (875). It can be concluded that in autumn planted sugarcane, intercropping of *Brassica napus* and *Cicer arietinum* should be avoided as these exhibited the strongest allelopathic influence on sugarcane.

Keywords: *Brassica napus*, *Cicer arietinum*, intercrops, phytotoxic, seedling growth

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Introduction

Allelopathy refers to the direct or indirect, harmful or beneficial impact of one plant on another plant as a result of the production of various phytotoxic substances that are discharged into the air, water, or soil (Rice, 1984). These phytotoxic elements are known as allelochemicals which may constrain or speed up the emergence, growth and development of the other plant species (Einhellig, 1987; Rao, 2000). Higher plants frequently contain tens of thousands of substances that are not part of their basic metabolism and are phytotoxic or herbicidal to other species or even to the species that produce them. These compounds are involved in inter-specific chemical interactions (Duke, 1986).

Intercropping is one of the best approaches to increase farm income without much input expenditures. Intercropping refers to growing of more than one crop at the same time on the same piece of land. Apart from its advantages like diversification, labour distribution, maintenance of soil fertility, suppression of weeds, two major advantages are higher productivity and greater stability through utilization of solar energy, moisture and nutrients. However, intercrops may affect the growth and yield of main crop through its allelopathic interaction.

Sugarcane is the longest growing duration crop. In different areas of Pakistan, sugarcane growers are practicing intercropping various crops in sugarcane for enhancing income. Intercropping is a technique to enhance the total yield, greater utilization of resources and field diversification. Combination of various crops like onion, mustard, fodder, potato and sugar beet with sugarcane provide more return as compared to sole planting of sugarcane (Singh et al., 1986; Shukla et al., 2022) while Muhammad et al. (2000) documented that tiller of sugarcane were reduced significantly due to the its competition with companion crops. Intercropping of maize, lentil, mustard and rapeseed with autumn planted sugarcane reduced its cane yield up to 0%, 8.7%, 14.8% and 8.7, respectively (Rana *et al*., 2006). Legumes intercropped with sugarcane significantly reduced the cane production up to 14.0, 11.4 and 8.9% when grown with cow pea, urdbean and mungbean, respectively (Kumar *et al.*, 2006). Various crops such as grain amaranth, raya, alfalfa, and sunflower significantly reduced the tillering capacity of autumn planted sugarcane (Singh et al., 2009; Bukhtiar and Muhammad, 1988). Similarly, Nazir et al. (2002) reported that sarsoon, sunflower, wheat, gram, lentil, peas and garlic intercropped with sugarcane significantly reduced the cane yield up to 21.8, 17.9, 18.0, 11.7, 4.8, 2.6 and 1.4%, respectively.

Seedlings and straw aqueous extract of wheat (*Triricum aestivum* L.) and its residues have allelopathic effect on different crops and weeds (Muminovic, 1991; Wu *et al*., 2000 *a,b*). Gram contains different phytochemicals like flavonoids, saponins, phenolic acid and phytosterols (López-Cortez *et al.*, 2016). Number of studies showed that legumes contain significant quantity of polyphenols, flavonoids, and antioxidant activity that vary widely depending on its type. Different *Brassica* species inhibit the emergence and growth of *Physlis angulate* while their toxicity increased with the increase of concentration (Uremis et al., 2005). Root-produced allelochemicals are generally associated with the reduction in neighboring plant growth, and resistance to or suppression of plant pathogens, soil microbes, and other herbivores.

Little research has yet been conducted on adverse of crops that are intercropped in autumn planted sugarcane. This study aims to evaluate the allelopathic effect of different plant parts of wheat (*Triticum aestivum* L.), lentil (*Lens culinaris* L.), gram (*Cicer arietinum* L.) and sarsoon (*Brassica napus* L.) on emergence and growth of autumn planted sugarcane. It has been hypothesized that extracts of these crops may suppress the emergence and growth of sugarcane

Materials and Methods

Site and treatments

The present study was conducted at Agronomic research area, College of Agriculture, University of Sargodha, Sargodha, Pakistan during year 2018-19. Sargodha lies at 32°5.01 N, 72°40 E with the 193 m altitude. Gram (*Cicer arietinum* L.), wheat (*Triticum aestivum* L.), lentil (*Lens culinaris* L.) and sarsoon (*Brassica napus* L.) were used in the study to determine the phytotoxic effect of these crops as their leaves, stem, roots and whole plant's extracts on sugarcane. Pot experiment was laid out following completely randomized design (CRD) with factorial arrangement. Experiment was replicated four times.

Experimental Details

Sowing of different crops

Wheat, gram, lentil and sarsoon were sown for the purpose of getting vegetative mature plant for preparation of aqueous extract at research area college of Agriculture, University of Sargodha. All other agronomic practices kept normal and weeds were manually uprooted.

Collection of plant materials and preparation of aqueous extract

Crops plants were uprooted during their vigorous growth period in the 1st week of January, 2019. Different plant parts like leaves, stem, roots and whole plants were separated and kept into laboratory. Those were initially allowed to dry at room temperature before placing in an electric oven for 48 hours at 70°C for drying. Plant parts after drying were .divided into 3-5 cm pieces. Distilled water was used to soak dried plants in a 1:20 w/v ratio (plant parts: distilled water) and were placed at room temperature for one day (Hussain & Gadoon, 1981). After recommended period of time, those were shaken well and the solutions were filtered through double layer of muslin cloth to obtain 5% (w/v) aqueous extract of each crop species. The sieved solutions (extracts) were saved at room temperature in plastic buckets which were labeled and covered with plastic lid.

Growing conditions

For each treatment, 5 buds of sugarcane were sown in plastic pot having 8-inch diameter and 9-inch depth filled with equal amount of soil collected from vegetation free site and then 200 ml aqueous extract of each plant part was applied to pots. In case of control, the same quantity of distilled water was applied instead of extract. Chemical properties of pot soil are given in Table-1.

Table 1. Physicochemical properties of soil

Characteristics	Units	Means
Soil pH	-	8.1
EC	dS cm^{-1}	0.83
Organic matter	%	0.81
Nitrogen N	%	0.064
Available P	mg kg^{-1}	7.42
Available K	mg kg^{-1}	164.4
Texture	-	Loam

Observations

Data related to sugarcane emergence was recorded on daily basis for period of 15 days. A bud is considered to emerge was when its green part emerged out of the soil. After 15 days of emergence, only one seedling was permitted for growth and development while other seedlings were manually removed from plastic pots. Following observations were recorded: emergence parameters (emergence percentage, emergence index, mean emergence time), Chlorophyll content, seedling vigor index (SVI) and seedling related parameters (root length, shoot length, root fresh weight, shoot fresh weight, root dry and shoot dry weight per seedling, seedling length and biomass).

Emergence percentage (EP)

Emergence was measured daily and translated to a percentage using the following formula:

$$\boldsymbol{EP} = \frac{\boldsymbol{Germinated/Emerged\ seed}}{\boldsymbol{Total\ seed\ sown}} \times \mathbf{100}$$

Emergence index (EI)

The Germination/emergence Index was calculated as described by the Copeland and McDonald (1999) using the following formula:

$$\boldsymbol{EI} = \frac{\boldsymbol{No.of\,germinated/emerged\ seed}}{\boldsymbol{Day\ of\ first\ count}} + \cdots + \frac{\boldsymbol{No.of\,germinated/emerged\ seed}}{\boldsymbol{Day\ of\ final\ count}}$$

Mean emergence time (MET)

Mean emergence time was calculated according to the equation of Ellis and Roberts (1981).

$$MET = \frac{\sum Dn}{\sum n}$$

Where n is the number of seeds that had germinated/emerged on day “D” and D is the number of days counted from the beginning of emergence.

Seedling vigor index (SVI)

The subsequent formula, as given by Orchard (1977), was used to determine the seedling vigor index (SVI) using the emergence percentage and seedling length:

$$\boldsymbol{SVI} = [\boldsymbol{seedling\ length\ (cm)} \times \boldsymbol{emergence\ percentage}]$$

Statistical analysis

Fischer's analysis of variance (ANOVA) method was used for statistical analysis of the acquired data by means of the statistical software Statistix 8.1 (Statistix 8.1, Tallahassee, Florida, USA). Treatments were compared using the least significant difference test (LSD) with a 5% probability.

Results

Emergence parameters

Aqueous extracts of four crops (wheat, gram, lentil and sarsoon) and their plant parts (leave, stem, roots and whole plant) significantly inhibited the emergence percentage and emergence index of sugarcane buds as compared to distilled water treated control (DWTC) (Table-2). Among all extracts used in study, minimum emergence (15%) of sugarcane bud was recorded with root extract of sarsoon. Regarding emergence index, its minimum value (0.37) was observed with root extract of sarsoon. Mean emergence time is an essential indicator of seed emergence performance in terms of time taken to complete emergence. Data concerning to mean emergence time and chlorophyll contents of sugarcane bud was presented in Table-3. Stem extract of wheat crop significantly delayed the emergence (8.07

days) of sugarcane buds while the minimum time taken to complete emergence was recorded with DWTC. Significantly the lowest chlorophyll content (18.72) of sugarcane seedlings was measured from treatment receiving root extract of sarsoon.

Table 2. Comparison of emergence percentage (%) and Emergence index of sugarcane crop as influenced by aqueous extracts of various crop intercropped in autumn planted sugarcane

Treatments	Emergence percentage (%)				Emergence Index			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	60 abc	65 ab	65 ab	70 a	3.80 abc	5.07 a	3.81 abc	4.12 ab
Leave extract	25 cd	35 abcd	35 abcd	55 abc	1.25 d	3.05 abcd	1.50 cd	2.26 bcd
Stem extract	35 bcd	45 abcd	30 bcd	30 bcd	2.21 bcd	1.85 bcd	2.22 bcd	1.84 bcd
Root extract	30 bcd	35 abcd	30 bcd	15 d	2.06 bcd	3.13 abcd	1.49 cd	0.73 d
Whole plant extract	50 bcd	30 bcd	35 abcd	45 abcd	2.89 abcd	2.20 bcd	1.61 bcd	2.15 bcd
LSD	38.89				2.68			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control

Table 3. Comparison of mean emergence time (days) and chlorophyll contents of sugarcane crop as influenced by aqueous extracts of various crop intercropped in autumn planted sugarcane

Treatments	Means emergence time (days)				Chlorophyll contents			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	2.66 c	4.87 abc	6.13 abc	6.31 abc	45.73 a	41.01 ab	39.92 abc	42.69 a
Leave extract	4.87 abc	5.37 abc	7.41 ab	5.62 abc	30.08 abcd	37.94 abcd	36.30 abcd	35.95 abcd
Stem extract	3.42 abc	8.07 a	3.50 abc	2.87 bc	19.21 cd	39.72 abc	21.38 bcd	28.97 abcd
Root extract	3.07 bc	7.06 abc	5.25 abc	3.12 bc	27.56 abcd	34.74 abcd	28.10 abcd	18.72 d
Whole plant extract	5.56 abc	5.37 abc	5.66 abc	5.31 abc	19.19 cd	36.05 abcd	29.20 abcd	25.21 abcd
LSD	4.82				21.92			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control

Table 4. Comparison of shoot length (cm) and root length of sugarcane crop as influenced by aqueous extracts of various crops intercropped in autumn planted sugarcane

Treatments	Shoot lengths (cm)				Root length (cm)			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	88.25 ab	83.75 abcd	87.50 abc	100.25 a	72.75 a	59.25 abcd	53.50 a-e	51.50 a-e
Leave extract	48.25 b-g	68.25 a-e	51.75 b-g	61.00 a-f	45.25 a-f	69.50 ab	52.00 a-e	48.00 a-f
Stem extract	16.00 g	51.50 b-g	37.75 efg	56.50 b-g	7.50 f	50.50 a-e	14.75 ef	50.50 a-e
Root extract	29.25 efg	85.50 abc	43.00 defg	53.75 b-g	22.50 cdef	61.50 abc	31.00 b-f	15.25 ef
Whole plant extract	21.50 fg	87.75 ab	45.75 c-g	53.25 b-g	58.50 abcd	19.75 def	49.75 a-e	45.50 a-f
LSD	41.79				43.33			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control

Table 5. Comparison of seedling length (cm) and root fresh weight of sugarcane crop as influenced by aqueous extracts of various crops intercropped in autumn planted sugarcane

Treatments	Seedling length (cm)				Root fresh weight (g)			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	160 a	143 abc	141 abc	151 a	9.32 a	5.76 a-f	6.20 a-e	7.00 abc
Leave extract	93 abcde	137 abc	103 abcd	109 abcd	1.58 fgh	7.93 ab	3.33 c-h	4.11 b-h
Stem extract	23 e	102 abcd	53 de	107 abcd	1.21 h	2.27 efgh	2.92 c-h	3.36 c-h
Root extract	52 de	147 ab	74 bcde	69 cde	2.86 c-h	6.57 abcd	1.24 h	2.40 defgh
Whole plant extract	146 ab	41 de	96 abcde	98 abcd	5.60 a-g	1.82 fgh	1.45 gh	3.74 b-h
LSD	76.92				4.28			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control

Table 6. Comparison of shoot fresh weight (g) and seedling biomass (g) of sugarcane crop as influenced by aqueous extracts of various crops intercropped in autumn planted sugarcane

Treatments	Shoot fresh weight (g)				Seedling biomass (g)			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	31.67 ab	26.91 abc	27.77 abc	34.40 a	39.6 a	32.7 abc	33.9 ab	41.4 a
Leave extract	2.64 f	9.19 cdef	10.68 cdef	19.89 a-f	4.2 f	11.0 cdef	14.0 bcdef	24.0 a-f
Stem extract	0.84 f	7.26 def	11.40 bcdef	16.78 a-f	2.0 f	9.5 def	14.3 bcdef	20.1 a-f
Root extract	4.02 ef	24.97 abcd	11.95 bcdef	20.70 a-f	6.9 ef	31.5 abc	13.2 bcdef	23.1 a-f
Whole plant extract	22.50 a-e	21.12 a-f	4.05 ef	11.76 bcdef	28.10 a-e	30.5 abcd	5.5 f	15.5 b-f
LSD	19.39				21.8			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control

Table 7. Comparison of shoot dry weight (g) and root dry weight of sugarcane crop as influenced by aqueous extracts of various crops intercropped in autumn planted sugarcane

Treatments	Shoot dry weight (g)				Root dry weight (g)			
	Crops				**Crops**			
	Gram	**Wheat**	**Lentil**	**Sarsoon**	**Gram**	**Wheat**	**Lentil**	**Sarsoon**
DWTC	7.09 a	5.52 abc	6.18 ab	7.25 a	5.20 a	3.12 abcde	3.02 abcdef	3.69 abc
Leave extract	0.62 e	1.78 cde	2.09 cde	3.76 abcde	0.99 def	5.06 ab	2.40 cdef	2.19 cdef
Stem extract	0.20 e	1.57 cde	2.11 bcde	3.83 abcde	0.65 f	1.60 cdef	2.17 cdef	2.20 cdef
Root extract	0.88 de	5.37 abc	2.50 bcde	4.16 abcde	1.58 cdef	3.36 abcd	0.80 ef	1.11 def
Whole plant extract	4.84 abcd	4.33 abcd	0.89 de	2.23 bcde	2.71 bcdef	0.72 ef	0.88 ef	1.62 cdef
LSD	4.07				2.52			

Any two means sharing dissimilar letters differ significantly with a 5% probability, DWTC = distilled water treated control, NS= Non-significant

Growth parameters

Shoot length and root length data of sugarcane as influenced by the application of various extracts are shown in Table-4. Aqueous extracts of different plant parts expressively decreased the shoot length and root length of sugarcane seedlings. Minimum shoot and root lengths (16.00 cm and 7.50 cm) were recorded with treatment that received stem extract of gram. Seedling length is an overall expression of emerged sugarcane bud growth and development against the allelopathic effect of any plant. Data regarding seedling length and root fresh weight of germinated sugarcane bud were presented in Table-5. Minimum seedling length (23 cm) and root fresh weight (1.21 g) of sugarcane were observed in treatment receiving stem extract of gram. The same treatment also resulted in the lowest shoot fresh weight (0.84 g), seedling biomass (2 g), shoot dry weight (0.20 g), root dry weight (0.65 g) and seedling vigor index (875) (Tables 6, 7 and 8).

Discussion

This study was performed to evaluate the phytotoxic influence of different sugarcane intercrop aqueous extracts from sugarcane intercrops on its emergence and growth. In our study, aqueous extracts of various intercrops and their plant parts variably inhibited the emergence and seedling growth of sugarcane might be due to the action of different allelochemicals presents in them. Among all extracts used in the study, sarsoon root extracts exhibited the highest suppressive influence against emergence percentage, emergence index and seedling chlorophyll contents of sugarcane. Our results corroborate the observations of Uremis et al. (2005) who stated that brassica shoot extract were significantly inhibited the seed emergence of cutleaf ground-cherry. The maximum delay in seedling emergence of sugarcane was imparted by the stem extract of wheat probably due to the phytotoxic compounds present in it that retarded the physiological and biochemical processes involved in sugarcane bud sprouting. Narwal et al. (1997) documented that aqueous extract of wheat negatively influenced the emergence of various crops like corn, pearl millet and cowpea. In wheat, a number of phytotoxic substances have been identified by Wu et al. (2000a and 2000b) named as phenolic acid, short chain fatty acid and hydroxamic acids that negatively influenced against the emergence of various crops. Similar findings were published by Majeed et al. (2017) who found that plant extracts and extract concentrations had a significant impact on mean emergence time. According to Kamal (2011), phytotoxic substances in sunflower lowered the chlorophyll content of wheat seedlings. The values of all seedling growth parameters i.e. seedling length, fresh and dry biomass of sugarcane showed the highest decline under the influence of stem extract of gram. Although gram is considered to be leguminous crop of restorative nature that exerts the least competitive interference on its neighboring crop for nutrients, water and light. Yet its interference to main crop in terms of allelopathic interaction has been proved to be of greater magnitude. Outcomes of this study are similar with the observation of Ashti et al. (2018) who documented that two types of chickpea (desi and kabuli) extracts significantly inhibited the shoot and root length of different crop species thus chickpea exhibited good phytotoxic allelochemical based potential. Chickpea comprises of different bioactive phytochemicals such as phenolic acids, phytosterols, flavonoids, saponins, isoflavones and sphingolipids (López-Cortez et al., 2016). Similarly, number of researcher noted that seedling growth of crops is more sensitive to phytotoxic compound as compared with emergence (Ayeb et al., 2013; Wu et al., 2015). The significant decrease in seedling elongation of plant species by different concentrations of plant extracts has been noted that could be caused by the presence of ethanol soluble inhibitors in variable concentrations (Yun and Kil, 1992; Shanee et al., 2011). Sharma and Dubey (1994) reported about 5.4% reduction in cane yield with chickpea intercropping. Jabeen et al. (2013) documented that inhibition in fresh biomass of seedlings in *Brassica* spp., wild oat and wheat under the effect of phytotoxic compounds of diversified weeds and crops. Uremis et al. (2005) determined that due to shoot powder extract of *Brassica* spp., reduction in seedling growth of crops was not as much as on their emergence. Correlation did not always exist between emergence inhibition and seedling growth inhibition (Brown and Morra, 1997). Yadav et al. (1987) reported cane yield reduction of 5.5 and 12.1% when intercropped with black gram and green gram. The consequences of this study are similar with conclusions of Singh et al. (2005), Jamil et al. (2009), Ullah et al. (2013), and Jabeen et al. (2013) who showed that allelopathy of various weeds and crops caused suppression in the dry biomass of seedlings in *Brassica* spp., wild oat, and wheat. Similar to this, Mahmood et al. (2010) reported that applying sorghum and sunflower water extracts to horse purslane lowered its shoot's dry weight. According to Khan et al. (2015), allelopathic compounds in sorghum and sunflower leaf water extracts dramatically reduced the fresh and dry biomass of weeds.

Conclusion

Results of this study revealed that root extract of sarsoon caused the maximum reduction in emergence of sugarcane bud while the stem extract of gram was proved to be more phytotoxic against seedling growth of sugarcane. The extracts of other crops (wheat and lentil) expressed little or no inhibitory effect on sugarcane emergence and growth. It can therefore be concluded and advised to sugarcane growers that intercropping of sarsoon and gram should be avoided in autumn planted sugarcane crop.

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