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Full Length Research Paper

Allelopathic effects of decomposing garlic stalk on some vegetable crops

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This study was carried out to examine the allelopathic effects of decomposed stalk of three garlic cultivars on the growth of the receiver vegetable crops: namely tomato, Chinese cabbage, lettuce, carrot, cucumber and hot pepper in a pot trial. The results showed that all three garlic cultivars have different allelopathic effects and each cultivar showed different allelopathic effects upon different vegetable crops or the same vegetable crop at different concentrations of decomposed garlic stalk. The activities of protective enzyme SOD in receiver vegetable crops appeared first, increased and then decreased with the increasing content of decomposed garlic stalk. The MDA contents in the receiver vegetable crops showed an increasing trend; however, there was no apparent regularity on POD and CAT contents. In general, the decomposed stalk of three garlic cultivars showed allelopathic inhibitory effects on all the index of carrot and lettuce but promotion effects on Chinese cabbage. Therefore, among all the receiver vegetable crops in this study, Chinese cabbage was concluded to be optimal successive crop for garlic.

Key words: Decomposing stalk, allelopathic effects, garlic.

INTRODUCTION

Allelopathy is a phenomenon in which the plant through leaching, volatility, the remnant body decomposition and the root system secretion releases the chemical substance to the environment that has harmful or advantageous function to own or periphery plants including microorganism indirectly (Lv and Duan, 2005; Chai and Hang, 2003; Peng and Shao, 2001; Wang and Tang, 2003). The research on allelopathy is propitious to guide about the scheme of plantation, system of cultivation, measure of cultivation in the economy of complex growth and it is also a way to use the advantageous effects and avoid the disadvantageous effects among plants. This aids in keeping the diversity of biology and the sustainable agricultural development (Kong and Hu, 2001; Zhou et al., 2007; Yan et al., 2001). Therefore, the study of the allelopathic relation between different crops reveals important significance to the aspects such as building the harmonious countryside ecological environment, preventing plant diseases and insect pests, increasing output and enhancing quality.

Garlic (*Allium sativum* L.) belongs to the lily family. It is a perennial root herb, a traditional vegetable and popular gardening crop of China. Some studies are available on the allelopathic effects of root exudates of garlic, decomposed stalk of walnut, processing of tomato and the hot pepper (Khan and Cheng, 2010; Ma et al., 2008; Hou et al., 2006 and Li et al., 2008) but the allelopathic effects of decomposed garlic stalk has not yet been reported. This study researched the seedling growth and physiological index effects of decomposed stalk of three garlic cultivars on different receiver vegetables through pot experiment. The objective of this study was to provide theoretical rationalization and technical guidance for the cultivation of garlic and other vegetable crops.

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Abbreviations: MDA, Malondialdehyde; **SOD,** Superoxide dismutase; **POD,** Peroxidase; **CAT,** Catalase etc.

MATERIALS AND METHODS

Plant materials

The stalks of three garlic cultivars G57, G89 and G09 as donor

Table 1. Effect of decomposing stalk of three garlic cultivars on seedling length of different vegetable crops.

Garlic variety	Treatment (%)	Seedling length (cm)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		3.51 a	0.86 cd	1.40 a	4.31 a	5.27 a	2.75 bc
G57	1	3.36 ab	0.78 cd	1.38 ab	4.24 ab	3.82 bc	3.58 a
	3	2.90 c	0.91 bcd	1.22 abc	3.81 abc	3.07 c	2.05 de
	5	2.97 bc	0.94 bc	1.06 c	3.20 d	3.20 c	1.94 e
G89	1	3.06 bc	0.84 cd	1.30 abc	4.03 abc	3.47 bc	3.06 b
	3	3.20 abc	0.74 d	1.22 abc	3.65 bcd	4.65 ab	2.51 cd
	5	3.38 ab	0.90 cd	1.22 abc	3.63 cd	3.91 bc	2.62 bc
G09	1	3.30 abc	0.87 cd	1.29 abc	4.05 abc	3.58 bc	3.7 a
	3	3.48 a	1.11 a	1.12 abc	4.01 abc	4.22 abc	2.84 bc
	5	3.22 abc	1.06 ab	1.08 c	3.96 abc	4.15 abc	2.84 bc

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

material, were taken from genetic resources of garlic in Northwest A and F University. The seeds of receiver vegetable that is, tomato, hot pepper, Chinese cabbage, lettuce, cucumber and radish, were bought from Nongcheng Seeds Center of Northwest A and F University.

Methods

The donor materials were planted in the vegetable research station of Northwest A and F University and harvested on attaining the full growth. The garlic stalk were washed, aired, and treated with 105°C for half an hour and then dried at 80°C.The material was finally preserved after smashing.

Mixtures were prepared by adding dry powder of garlic stalks and perlite with different proportions. Three different treatments of each garlic cultivar were prepared as follows: 1% (1.0 g garlic stalk + 99.0 g perlite), 3% (3.0 g garlic stalk + 97.0 g perlite) and 5% (5.0 g garlic stalk + 95.0 g perlite). The perlite with no garlic stalk added was regarded as control. The mixture were put in plastic pots, watered and kept for decomposition for 10 days at 25°C.

Sprouted seeds of receiver vegetable crops were planted in pots (12.5 cm diameter × 10 cm height). There were three seeds in each pot, 5 pots of each treatment and 3 replications of the experiment. After 45 days of planting, the leaves of seedlings were collected to test the indices. The data regarding seedling length, top fresh weight, root fresh weight, SOD (11), POD (11), CAT (11), MDA (11) and the soluble protein were recorded by the methods described by Sun and Hu (2006).

Statistical analysis

The allelopathic effect index was measured as described by Williamson and Richardson (1988), when $T \geq C$, $RI = 1 - C / T$; when $T < C$, $RI = T / C - 1$ (T was the treatment data, while C was the control data). The $RI > 0$ showed enhanced effect, $RI < 0$ showed inhibitory effect. Absolute value size and the effect intensity were consistent. The experimental data were subjected to analysis of variance. The means were compared using the Duncan's test at 5% level of significance.

RESULTS

Seedling length

The decomposed stalk of three garlic cultivars had minor allelopathic effects on the receiver crops except hot pepper. The effects of G57 decomposed stalk on the seedling length of Chinese cabbage and cucumber did not show significant difference among the treatments. The decomposed stalk of G89 reflected certain effects on the seedling length of hot pepper, but there had been no significant difference as compared to the control with other treatments. Moreover the decomposed stalk of G89 had no significant difference on seedling length of other vegetables. Only the decomposed stalk of G09 showed the positive effects on the seedling length of Chinese cabbage and hot pepper (Table 1).

Top fresh weight

The decomposed stalk of G57 and G09 had enhanced effects on the top fresh weight of hot pepper at the treatment of 1%, and attained significant difference with control. With the decomposition of stalk the contents of treatment increased, the enhancement role diminished and even inverted into inhibition. The decomposed stalk

Table 2. Effect of decomposing stalk of three garlic cultivars on top fresh weight of different vegetable crops.

Garlic variety	Treatment (%)	Top fresh weight (mg)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		3.51 a	0.86 cd	1.40 a	4.31 a	5.27 a	2.75 bc
G57	1	3.36 ab	0.78 cd	1.38 ab	4.24 ab	3.82 bc	3.58 a
	3	2.90 c	0.91 bcd	1.22 abc	3.81 abc	3.07 c	2.05 de
	5	2.97 bc	0.94 bc	1.06 c	3.20 d	3.20 c	1.94 e
G89	1	3.06 bc	0.84 cd	1.30 abc	4.03 abc	3.47 bc	3.06 b
	3	3.20 abc	0.74 d	1.22 abc	3.65 bcd	4.65 ab	2.51 cd
	5	3.38 ab	0.90 cd	1.22 abc	3.63 cd	3.91 bc	2.62 bc
G09	1	3.30 abc	0.87 cd	1.29 abc	4.05 abc	3.58 bc	3.70 a
	3	3.48 a	1.11 a	1.12 abc	4.01 abc	4.22 abc	2.84 bc
	5	3.22 abc	1.06 ab	1.08 c	3.96 abc	4.15 abc	2.84 bc

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3. Effect of decomposing stalk of three garlic cultivars on root fresh weight of different vegetable crops.

Garlic variety	Treatment (%)	Root fresh weight (mg)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		0.20 d	0.06 a	0.10 c	1.00 a	0.56 d	0.44 b
G57	1	0.25 cd	0.04 c	0.11 bc	0.09 abc	0.64 bcd	0.40 bc
	3	0.22 d	0.04 bc	0.12 abc	0.07 bcd	0.67 bc	0.17 d
	5	0.24 cd	0.03 c	0.15 ab	0.07 cd	0.71 b	0.16 d
G89	1	0.55 a	0.04 c	0.12 abc	0.09 ab	0.60 cd	0.48 ab
	3	0.37 b	0.06 ab	0.10 c	0.06 d	0.64 bcd	0.39 bc
	5	0.32 bc	0.05 abc	0.11 bc	0.06 d	0.56 d	0.31 c
G09	1	0.36 b	0.04 c	0.15 a	0.08 abcd	0.71 b	0.56 a
	3	0.25 cd	0.05 abc	0.12 abc	0.07 bcd	0.85 a	0.57 a
	5	0.20 d	0.03 c	0.13 abc	0.06 d	0.71 b	0.31 c

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

of G57 and G09 had minor allelopathic effects on the top fresh weight of Chinese cabbage, but the treatments did not demonstrate significant effects as compared to the control (Table 2).

Root fresh weight

The decomposed stalk of three garlic cultivars had enhanced allelopathic effects on root fresh weight of tomato, lettuce and cucumber but had inhibitory effects on radish and Chinese cabbage. With the increasing contents of decomposed stalk, the inhibitory effect on the root fresh weight of radish was increased. The decomposed stalk of G57 and G09 showed promotion effects on the root fresh weight of cucumber. The treatment at 5% achieved the significant difference level when statistically compared with control and its allelopathic effect index was recorded 0.211. The decomposed stalk of all tested garlic cultivars had inhibitory effects on the root fresh weight of hot pepper as shown in Table 3.

Soluble protein

The soluble proteins are set of enzymes, majority of which play a role in various metabolisms. The soluble

Table 4. Effect of decomposing stalk of three garlic cultivars on soluble protein content of different vegetable crops.

Garlic variety	Treatment (%)	Soluble protein content (mg·g^{-1} FW)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		13.96 bcde	10.33 cde	9.80 de	7.08 c	4.22 c	4.96 cd
G57	1	12.40 de	10.35 cde	11.09 b	4.96 e	4.59 c	4.39 d
	3	13.67 cde	9.41 e	12.17 a	4.97 e	6.05 a	4.43 d
	5	14.26 bcde	10.80 cde	10.64 bcd	4.68 e	5.26 b	4.61 cd
G89	1	15.16 bc	10.23 de	9.72 e	6.05 d	4.71 c	5.22 bc
	3	14.55 bcd	11.85 bc	10.69 bc	5.73 d	6.14 a	4.34 d
	5	19.03 a	14.07 a	10.35 bcde	6.12 d	4.71 c	4.62 cd
G09	1	13.13 cde	11.13 cd	9.95 cde	6.08 d	5.44 b	4.31 d
	3	16.25 b	12.90 ab	10.60 bcd	8.80 a	4.42 c	5.73 ab
	5	12.12 e	13.34 a	9.84 cde	7.89 b	5.39 b	6.21 a

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 5. Effect of decomposing stalk of three garlic cultivars on SOD activity of different vegetable crops.

Garlic variety	Treatment (%)	SOD activity (U·g^{-1} FW·h^{-1})					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		252.2 a	149.4 a	75.5 abc	443.7 a	221.2 a	332.5 cd
G57	1	197.7 abc	93.2 abc	82.2 ab	409.7 abc	139.6 cd	302.9 d
	3	198.8 abc	94.6 abc	98.3 a	415.2 ab	156.9 bc	391.9 bc
	5	108.0 d	119.9 abc	71.2 abc	400.7 abc	180.7 b	446.7 ab
G89	1	189.0 bc	53.7 c	15.2 d	336.6 e	112.8 d	468.6 a
	3	121.9 d	74.0 bc	28.0 cd	349.2 de	110.5 d	304.0 d
	5	205.2 ab	96.9 abc	89.7 a	387.5 bcd	150.1 bcd	464.7 ab
G09	1	187.6 bc	129.4 ab	46.7 abcd	402.7 abc	139.6 cd	411.5 ab
	3	148.6 cd	76.1 bc	33.1 bcd	369.1 cde	120.9 cd	281.6 d
	5	212.4 ab	136.7 ab	58.8 bcd	442.9 a	135.5 cd	316.3 cd

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

protein content of plant was an important index of plant population suppression. In total, the soluble protein content mostly increased with the increasing decomposed stalk of three garlic cultivars. The decomposed stalk of G57 and G89 reduced all the soluble protein content and reached significant differences with the control. The soluble protein content of G09 treatments appeared first, increasing and then decreasing; it reached maximum at the treatment of 3% and there was a notable difference as compared with control (Table 4).

Superoxide dismutase (SOD) activity

Plant response to hurting adverse circumstances is closely related with its inner SOD activity (Liang et al., 2003). In total, with the increasing content of decomposed garlic stalk, the activities of protective enzyme SOD in receiver vegetable crops showed upward and later downward trend. The decomposed stalk of G57 did not attain the significant difference to the enzyme SOD of hot pepper at the treatment of 1%, but it rose at the treatment of 5%, and reached significant difference with the control (Table 5).

Catalase (CAT) activity

The CAT of plant body is an important oxidoreductase. The different garlic cultivars exhibited different effects on

Table 6. Effect of decomposing stalk of three garlic cultivars on CAT activity of different vegetable crops.

Garlic variety	Treatment (%)	CAT activity ($U \cdot g^{-1} FW \cdot min^{-1}$)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		28.0 bc	5.9 abc	123.7 ab	28.3 a	24.3 b	29.9 c
G57	1	24.0 c	5.3 bc	99.2 e	14.1 cde	22.1 b	30.4 c
	3	25.9 c	4.0 c	113.1 bcd	12.0 e	28.5 ab	32.0 bc
	5	21.9 c	4.0 c	133.9 a	13.1 de	30.9 ab	35.2 ab
G89	1	28.8 bc	3.5 c	119.7 bc	18.4 bc	27.2 ab	32.3 abc
	3	22.9 c	5.9 abc	108.5 cde	19.2 b	29.1 ab	29.9 c
	5	50.7 a	7.2 ab	104.8 de	15.2 bcde	29.3 ab	36.3 a
G09	1	30.1 bc	8.5 a	103.2 de	25.9 a	34.4 a	30.1 c
	3	36.0 b	4.0 c	114.7 bcd	17.6 bcd	24.0 b	29.9 c
	5	27.7 bc	3.5 c	116.8 bc	14.4 cde	25.1 b	33.6 abc

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

the CAT activities of different receiver vegetable crops. The decomposed stalk of G89 had enhanced the CAT activities of tomato and hot pepper at the treatment of 5%, attained the significant difference with control, and the allelopathic effect index were recorded as 0.488 and 0.176 respectively. The decomposed stalk of G89 reduced the CAT activities of radish, reached significant difference with control and the allelopathic effects index was -0.463. The decomposed stalk of three garlic cultivars had very minor allelopathic effects on the CAT activities of Chinese cabbage and the treatments did not show significant difference with the control. The decomposed stalk of G57 reduced the CAT activities of lettuce at the treatment of 1% but promoted the CAT activities at the treatment of 5%. Distinguished with lettuce, the decomposed stalk of G57 had no obvious effects on cucumber (Table 6).

Peroxidase (POD) activity

POD could restrain the peroxidation effect of cell membrane under adverse stressed conditions and reduce the injury that cell membrane suffered. The decomposed stalk of the three garlic treatments had different allelopathic effects on the POD activities of different receiver vegetables. Each treatment of three garlic cultivars showed inhibitory effects on the POD activities of tomato, lettuce and radish; however each treatment of lettuce and radish reflected the significant difference with the control. Each treatment of three garlic cultivars promoted the POD activities of Chinese cabbage but had no significant difference on the POD activities of cucumber as compared to the control. The decomposed stalk of G09 treatment showed very little effects on the POD activities of tomato, but it showed an increasing trend on the POD activities of hot pepper with the increasing content of treatment (Table 7).

Malondialdehyde (MDA) content

MDA is a membraneceous peroxidation end product whose content was an important index to determine the degree of membrane lipid peroxidation and plant response to adverse conditions (Zhang et al., 2001; Zhang and Pan, 2006; Chen et al., 1991). The decomposed stalk of the three garlic treatments had different allelopathic effects on the MDA contents of various receiver vegetables. The decomposed stalk of the three garlic cultivars showed an increasing trend to the MDA contents of tomato with the increasing contents of treatment, but reflected very minor effects on the contents of tomato except the 1% treatment of G89. The decomposed stalk of G57 and G89 treatment had no obvious allelopathic effects and did not attain significant difference with the control (Table 8).

DISCUSSION

Some plants have allelopathic potential by releasing allelochemicals to their surroundings that have either deleterious or beneficial effects on other plants growing in the vicinity (Singh et al., 1999; Yu, 1999). Some plant residues stimulate the growth of crops (Narwal, 2010). The allelopathic ability of plant was co-related with their varieties. The results in this study showed that the decomposing stalk of the three garlic cultivars has different allelopathic effects on the same receiver

Table 7. Effect of decomposing stalk of three garlic cultivars on root fresh weight of different vegetable crops.

Garlic variety	Treatment (%)	POD activity ($ug \cdot g^{-1} FW \cdot min^{-1}$)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		16.69 a	6.73 d	276.05 a	38.08 a	6.20 abc	2.39 bc
G57	1	11.09 bcd	8.28 bcd	56.75 fg	22.80 bc	6.38 abc	2.23 c
	3	8.13 cd	9.04 bcd	48.96 g	23.28 bc	7.11 a	2.60 b
	5	12.69 ab	9.76 abc	98.83 c	19.60 c	5.61 c	2.39 bc
G89	1	14.64 ab	11.96 a	197.60 b	21.57 bc	6.12 abc	2.51 b
	3	7.36 d	10.95 ab	92.53 cd	23.44 bc	6.74 abc	2.49 b
	5	12.80 ab	8.44 bcd	81.01 e	18.37 c	5.94 abc	2.52 b
G09	1	11.15 bcd	7.01 cd	67.41 f	20.00 c	6.67 abc	2.42 bc
	3	11.23 bcd	10.72 ab	84.00 de	28.11 b	6.94 ab	2.58 b
	5	11.73 bc	9.36 abcd	50.83 g	21.12 bc	5.82 bc	2.81 a

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 8. Effect of decomposing stalk of three garlic cultivars on MDA content of different vegetable crops.

Garlic variety	Treatment (%)	MDA content ($mmol \cdot g^{-1} FW$)					
		Tomato	Chinese cabbage	Lettuce	Radish	Cucumber	Hot pepper
CK		0.41 c	2.69 b	4.69 a	1.48 ab	2.02 abc	0.55 abc
G57	1	0.42 c	2.37 b	4.31 ab	1.08 cd	2.10 abc	0.48 bcd
	3	1.56 b	2.39 b	3.91 b	1.31 bcd	1.91 abcd	0.50 bcd
	5	1.60 b	2.36 b	4.57 a	1.66 a	2.43 a	0.54 abc
G89	1	1.59 b	3.53 a	3.93 b	1.52 ab	2.31 a	0.62 a
	3	1.99 ab	2.33 b	3.82 b	1.39 abc	2.26 ab	0.37 e
	5	2.47 a	2.30 b	4.26 ab	1.22 bcd	1.65 bcd	0.56 ab
G09	1	2.15 a	2.26 b	4.05 b	1.23 bcd	1.34 d	0.42 de
	3	2.18 a	2.77 b	3.89 b	1.02 d	1.57 cd	0.46 bcde
	5	2.40 a	2.44 b	3.14 c	1.06 cd	1.81 abcd	0.49 cde

Means followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

vegetables under the same treatment. For example, the decomposed stalk of G57 and G89 had restrained the soluble protein content of radish at the treatment of 5%, but G09 had enhanced effect. In addition, the decomposed stalk of same cultivar had different allelopathic effects on the same receiver vegetable crops under different percentages and the effect was also intensity different.

Allelochemicals as the metabolites released from the organisms into the environment may repel or poison, inhibit, attract, nourish other organism by sharing the same habit (Chou and Waller, 1989).The results demonstrated that the decomposed stalk of three garlic cultivars reflected very minor allelopathic effects on seedling length and the top fresh weight of receiver vegetable crops but had different effects on the root fresh weight. For example, the decomposed stalk of the three garlic cultivars showed enhanced effects on root fresh weight of tomato, cucumber and lettuce but had inhibitory effects on Chinese cabbage and radish. So the roots of the receiver vegetable crops were more sensitive than the upper part. Roots probably were in direct contact with the allelochemicals, hence it had major effects on crops. Hou (2006) had similar findings while studying allelopathic effects of hot pepper. Djurdjevic et al. (2003) found that aqueous extract and volatile compounds bulbs

were stronger inhibitors of seed germination and seedling growth compared to those of of leaves.

Protecting enzyme system plays part to defense active oxygen or other peroxide free radical to damage the cell membrane system (Zeng and Jiang, 2000). The results showed that with increasing the contents of decomposed garlic stalk, the activities of protective enzyme SOD in receiver vegetable crops appeared first, increasing and then decreasing. There was no regularity or sequence among the dynamics of POD and CAT contents.

MDA is a product of membranaceous peroxidation, the higher its content, the stronger its ability to encounter adverse circumstances and their conclusive effects (Rizvi, 1992). The results showed that with the increasing content of treatment, the MDA content of the receiver vegetable crops had an increasing trend because the decomposition allelochemicals had stress on the seedlings. The soluble protein content showed an important index of plant population suppression. Results showed that with the increasing content of decomposed garlic stalk, the soluble protein content also increased, which indicates that the plant resistance increases with the raising of soluble protein contents.

Nowadays, the allelopathy has been extensively applied in agricultural ecosystem, especially in the establishment of vegetable cultivation system. Therefore, it is of great importance to take advantage of allelopathy in the efforts for maintaining biodiversity and sustainable agricultural development. Cabbage and onions, potato and peas intercropping or crop rotation can increase production while potato and cucumber intercropping will reduce the output. Results showed that the decomposed stalk of three garlic cultivars had different allelopathic effects on the different receiver vegetable crops. There were allelopathic inhibitory effects on all the indices of radish and lettuce, but enhanced effects on Chinese cabbage. Therefore, among all the receiver vegetable crops in this study, the optimal successive crops for garlic are Chinese cabbage and hot pepper.

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