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Effects of Crop Residues of Sunflower (*Helianthus annuus*), Maize (*Zea mays* L.) and Soybean (*Glycine max*) on Growth and Seed Yields of Sunflower

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Abstract: This pot experiment was carried out at Suranaree Technology University Experimental Farm, Northeast Thailand to investigate effects of crop residues of sunflower, maize and soybean on total dry weight, top dry weight, plant height, root dry weight and seed yield of sunflower plants with the use of Korat soil series (Oxic Paleustults) during the rainy season (July-October) of the 2001. The experiment was laid in a split plot arranged in a Completely Randomized Design (CRD) with four replications where the crop residues of maize, sunflower and soybean were used as main plots. Whilst crop residues of roots, top growth and roots+top growth were used as subplots. The results showed that crop residues derived from roots of both sunflower and soybean plants had their significant inhibition effects of allelopathic substances on plant height, root dry weight, top growth dry weight and total dry weight plant^{-1} of the sunflower plants than those derived from top growth of both crops alone (sunflower and soybean). Maize plant residues had no significant inhibition effect on growth of subsequent crop of sunflower.

Key words: Allelopathic effect, crop residues, growth, maize, soybean, sunflower, toxic effect

INTRODUCTION

It has been advocated that crop residues, a by-product being produced after the harvest of each annual cash crop play its significant value in improving soil conditions when incorporated into the soils (Miller and Donahue, 1990; Ratnapratipa, 1996; Suksri, 1999). However, some crop residues when decomposed in soils may produce some toxic substances where they may exhibit its harmful toxic effect on growth to some other subsequent crops. This could cause a relative problem in producing crop yields of the subsequent crops, e.g., it inhibited germination of seeds and retarded growth of the subsequent sown crop by its allelophatic substances of mostly short-chain organic acids (Wallace and Elliott, 1979; Krogmeier and Bremner, 1986 and Miller and Donahue, 1990). Thus some aspects on know how technology with respect to cropping systems may be needed in order to produce crop yield more efficiently. A harmful toxic effect derives from allelopathic substances being produced by the initial cropping to the subsequent crops may receive less attention from growers or scientists when compared with other contributing factors on crop yields such as soil conditions, water and fertiliser requirements, pathogenic diseases, insect pests and some other physiological aspects or even photosynthetic processes in crop plants. Nevertheless, a harmful toxic effect to crop yields derives from allelopathic substances should be accounted since it has a tremendous effect on growth and yield of the subsequent crop plants (Pandey *et al*., 1993; Chang-Yeon *et al*., 1995 and Viles and Reese, 1996). A number of scientists had pointed out that sunflower crop (*Helianthus annuus*) produced some certain amounts of allelopathic substances where it affected growth and development of several weed species (Iron and Burnside, 1982; Leather, 1983 and Purvis and Jones, 1990). Other crops produce allelopathic substances include sesame, maize, wheat, rye, barley, potato, tobacco and many others (Kimber, 1973; Iron and Burnside, 1982; Sarobol, 1987; Miller and Donahue, 1990; Viles and Reese, 1996). Therefore, it is of tangible value to investigate how sunflower plants responded to crop residues of sunflower, maize and soybean when sunflower plants are grown as a subsequent crop when climatic conditions favour growth and production of sunflower seeds, particularly in the late rainy season when environmental temperatures become cool especially in the Central Plane area of Thailand where some large amounts of sunflower seeds have been produced annually. The obtained results may be useful to growers of the sunflower plants so that sunflower seed yields may be annually produced with high efficacy.

MATERIALS AND METHODS

This pot experiment was carried out at Suranaree Technology University Experimental Farm, Nakhon

Ratchasima province, Northeast Thailand during the rainy season (July-October) of the 2001 to investigate effects of crop residues of sunflower, maize and soybean on dry matter and seed yield of sunflower (*Helianthus annuus*). The experiment was laid in a split plot arranged in a Completely Randomized Design (CRD) with four replications where sunflower, maize and soybean were used as main plots whilst roots, top growth and roots plus top growth were used as subplots. A treatment without crop residue was also used as control treatment. The crop residues of sunflower, maize and soybean were separated into (1) roots, (2) top growth and (3) roots+top growth. Therefore, there were 12-treatment combinations plus a control treatment (without crop residue), i.e., altogether 13 treatments, hence 52 pots were used and each has a diameter of 26 cm. A considerable amount of an A horizon of Korat soil series (Oxic Paleustults) was collected and dried in a glasshouse for two weeks and then weighed out for a weight of 6.9 kg pot^{-1}. Soil analysis data of Korat soil series being analysed for mean values of soil pH, soil organic matter, soil available phosphorus and soil exchangeable potassium were 6.00, 3.20%, 29 ppm and 300 ppm, respectively. Crop residues were oven dried at 70°C for four days and then ground into meshes to pass through a 3 mm sieve and then weighed out with an amount of 100 g pot^{-1} of each specific parts of crop residues and then thoroughly mixed into the soil in each pot of their respective treatments where appropriate and then left all pots under the glasshouse for one week before sowing of sunflower seeds. After the mixing of crop residues into their respective pots of treatments, a certain amount of tap water was added to each pot to reach approximately a field capacity level (field capacity of this soil type is approximately 14%). Each pot was covered with a plastic film to prevent water loss through the soil surface and perhaps at the same time aided soil microbial activities. All pots were removed from the glasshouse to an open air where the sunflower plants could grow without any shading effect and the pots were arranged into their respective blocks with distances between rows and within rows of 50×50 cm, respectively. Plastic sheet covered soil surface of each pot was removed and then 4-5 seeds of sunflower were directly sown by hand to each pot where appropriate and eventually each pot was given approximately 100 mL of tap water. One week after emergence, seedlings were removed leaving only one seedling pot^{-1}. Daily watering to all pots to reach approximately field capacity was carried out in the morning when there was no rainfall within a few days period. To measure the changes in growth of the sunflower plants, the following parameters were used. They include mean values of total dry weight plant^{-1} (top growth+root dry weights); top growth plant^{-1}, plant height (measured from ground level up to the uppermost leaf), root dry weight plant^{-1} and seed yield plant^{-1} (measured at 112 days after emergence). The results on plant heights being measured at day 60 were excluded due to no statistical differences found among the treated plants. The collected data were statistically analysed where appropriate using an MSTAT-C Computer Programme (Nissen, 1989).

RESULTS

Total dry weight, top dry weight, plant height, root dry weight and seed yield: With total dry weight plant^{-1} of sunflower at day 60 after emergence, the results showed that average total dry weight of sunflower plant derived from residues of roots and top growth were 8.49, 16.33, 11.49 and 15.80 g for sunflower, maize, soybean residues and control, respectively (Table 1). The differences due to: types of crop residues of the same type of plants, sources of crop residues of the same sources of plants, average values of types of crop residues and average values of sources of crop residues were statistically significant. The highest total dry weight plant^{-1} of

Table 1: Total dry weight plant^{-1} (top growth+roots) of sunflower at days 60 (A) and 112 (B) after emergence as influenced by sources and types of plant residues, grown in pots with the use of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm, Northeast Thailand.

A. At 60 days after emergence

Sources of crop residues	Sunflower (g)	Types of (g)	Residues (g)	Average (g)	Control (No crop residue, g)
Roots	7.66	16.29	6.21	10.05	
Top growth	9.31	16.37	16.78	14.15	
Average	8.49	16.33	11.49	12.10	15.80

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = 5.34*, LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 5.17*, LSD for average values of types of crop residues (sunflower, maize and soybean) = 3.90*, LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = 2.98*

B. At 112 days after emergence

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (no crop residue, g)
Roots	41.83	43.70	45.14	43.55	
Top growth	49.05	56.05	45.13	50.07	
Roots+Top growth	50.45	53.15	50.37	51.32	
Average	47.11	50.96	46.88	48.32	50.81

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = NS LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 11.25*, LSD for average values of types of crop residues (sunflower, maize and soybean) = NS LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = 6.49* sunflower was found with residues of maize followed by soybean and the least was found with sunflower. At day 112 after emergence, the results showed that average total dry weight plant^{-1} of sunflower was highest with residue of maize followed by control treatment, sunflower and the least was found with soybean residue with mean values of 50.96, 50.81, 47.11 and 46.88 g, respectively. The differences due to: sources of crop residues of the same plant species and average values of sources of crop residues were statistically significant but there were no statistical differences found on types of crop residues and average values of types of crop residues.

For top growth dry weights of sunflower (dry weight above ground level) at day 60 after emergence, the results showed that average values due to types of crop residues were highest with maize followed by soybean and sunflower with average values of 14.72, 10.26 and 7.77 g plant^{-1}, respectively. Control treatment gave a mean value of 13.78 g plant^{-1}. The differences due to: Types of crop residues of the same type of plants, sources of crop residues of the same sources of plants, average values of types of crop residues and average values of sources of crop residues were statistically significant (Table 2). At day 112 after emergence, the results showed that average values of total dry weight plant^{-1} of sunflower due to types of crop residues were highest with maize followed by sunflower and soybean with values of 50.96, 47.21 and 46.88 g plant^{-1}, respectively. The control treatment gave a mean value of 50.81 g plant^{-1}. The differences due to: Sources of crop residues of the same source of plants and average values of sources of crop residues were statistical significant. On the other hand, the differences due to types of crop residues of the same types of plants and average values of types of crop residues were not statistically significant.

Table 2: Top growth dry weight plant^{-1} (dry matter above ground level) of sunflower at days 60 (A) and 112 (B) after emergence as influenced by sources and types of plant residues, grown in pots with the use of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm, Northeast Thailand

A. At 60 days after emergence

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (No crop residue, g)
Roots	7.03	14.54	5.69	9.09	
Top growth	8.51	14.90	14.83	12.74	
Average	7.77	14.72	10.26	10.92	13.78

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = 2.35*, LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 4.56*, LSD for average values of types of crop residues (sunflower, maize and soybean) = 3.31*, LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = 2.63*

B. At 112 days after emergence

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (No crop residue, g)
Roots	39.05	40.90	42.09	40.68	
Top growth	45.84	52.18	42.03	46.68	
Roots+Top growth	47.44	48.57	45.90	47.30	
Average	44.11	47.21	43.34	44.89	46.57

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = NS LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 10.57*, LSD for average values of types of crop residues (sunflower, maize and soybean) = NS LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = 6.10*

For top growth dry weight plant^{-2} at day 60 after emergence, the results showed that average values of maize residue was highest followed by soybean and sunflower residues with values of 14.72, 10.26 and 7.77 g plant^{-1}, respectively and the control treatment gave a value of 13.78 g plant^{-1} (Table 2). The effects due to: types of crop residues of the same type of plants, sources of crop residues of the same source of plants, average values of types of crop residues and average values of sources of crop residues were statistically significant. At day 112 after emergence, the results showed that average values of top growth of sunflower plants were highest with maize followed by sunflower and soybean with values of 47.21, 44.11 and 43.34 g plant^{-1}, respectively and the control treatment gave a value of 46.57 g plant^{-1}. The effects due to sources of crop residues and average values of sources of crop residues were statistically significant whereas the effects due to types of residues and average values of types of residues were not statistically significant.

With plant height at day 112 after emergence, the results showed that average values of sunflower plant heights as affected by types of crop residues were lowest with both sunflower and soybean and the highest was with maize residue with average values of 90.20, 90.20 and 100 cm, respectively where the control treatment gave an average value of 98.50 cm (Table 3). The differences due to: types of crop residues of the same plants and average values of types of crop residues were statistically significant whereas the differences due to sources of crop residues of the same sources of plants and average values of sources of crop residues were not statistically significant.

For root dry weights of sunflower at day 60 after emergence, the results showed that average values of root dry weights of sunflower plants due to crop residues of sunflower, maize and soybean were 0.72, 1.61 and 1.23 g, respectively (Table 4). The control treatment gave a mean value of 2.03 g plant^{-1}. The differences due to: Type of crop residues, types of crop residues of the same plants and sources of residues (roots and top growth) were

Table 3: Sunflower plant height (cm plant^{-1}) at days 112 after emergence as influenced by crop residues of sunflower, maize and soybean, grown in pots with the use of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm, Northeast Thailand

Sources of residues	Sunflower (cm)	Types of crop maize (cm)	Residues soybean (cm)	Average (cm)	Control (No crop crop residue, cm)
Roots	85.30	96.00	91.00	90.80	
Top growth	94.00	103.80	90.50	96.10	
Roots+Top growth	91.31	100.30	89.00	93.50	
Average	90.20	100.00	90.20	93.40	98.50

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = 11.90*, LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = NS, LSD for average values of types of crop residues (sunflower, maize and soybean) = 6.50*, LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = NS

Table 4: Root dry weights (gm plant^{-1}) of sunflower at days 60 (A) and 112 (B) after emergence as influenced by sources and types of plant residues, grown in pots with the use of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm, Northeast Thailand

A. At 60 days after emergence

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (No crop residue, g)
Roots	0.63	1.75	0.52	0.97	
Top growth	0.81	1.47	1.95	1.41	
Average	0.72	1.61	1.23	1.19	2.03

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = 0.90*, LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 0.78* LSD for average values of types of crop residues (sunflower, maize and soybean) = 0.71*, LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = NS

B. At 112 days after emergence

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (No crop residue, g)
Roots	2.78	2.80	3.04	2.87	
Top growth	3.21	3.87	3.11	3.39	
Roots+Top growth	3.00	4.58	4.47	4.02	
Average	3.00	3.75	3.54	3.43	4.47

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same types of plants = NS LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = 1.19*, LSD for average values of types of crop residues (sunflower, maize and soybean) = NS, LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = 0.69*

statistically significant. At day 112 after emergence, the results indicated that average values of root dry weights of sunflower plants were highest with crop residue of maize followed by soybean and sunflower with values of 3.75, 3.54 and 3.00 g plant^{-1}, respectively where control treatment gave a mean value of 4.47 g plant^{-1}. The effects due to sources of crop residues and average values of sources of crop residues were statistically significant

Table 5: Sunflower seed yields (gm plant^{-1}) as influenced by crop residues of sunflower, maize and soybean, grown in pots with the use of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm, Northeast Thailand

Sources of crop residues	Sunflower (g)	Types of crop maize (g)	Residues soybean (g)	Average (g)	Control (No crop residue, g)
Roots	15.96	14.25	16.60	15.60	
Top growth	17.48	19.58	16.91	17.99	
Roots+Top growth	18.12	17.76	20.42	18.77	
Average	17.19	17.20	17.98	17.45	19.83

Least significant differences (LSD, p = 0.05), LSD for types of crop residues (sunflower, maize and soybean) of the same type of plants = NS LSD for sources of crop residues (roots, top growth and roots+top growth) of the same sources of crop residues = NS, LSD for average values of types of crop residues (sunflower, maize and soybean) = NS LSD for average values of sources of crop residues (roots, top growth, roots+top growth) = NS

whereas the effects due to types of crop residues of the same types of plants and average values of types of crop residues were not statistically significant.

For seed yield plant^{-1} of sunflower, the results showed that average seed yields were highest with soybean followed by maize and sunflower with average values of 17.98, 17.20 and 17.19 g plant^{-1}, respectively and the control treatment gave a mean value of 19.83 g plant^{-1} (Table 5). There were no statistical differences due to treatments found on seed yields of sunflower plants.

DISCUSSION

With the three sources of crop residues derived from sunflower, maize and soybean, the results indicated that residues derived from roots of both sunflower and soybean had its significant inhibition effects on plant height, root dry weight and total dry weight of the sunflower plants than that of crop residues derived from top growth of both sources (sunflower and soybean). The results suggested that plant residues derived from maize plants was only a source of crop residues that had no inhibition effect on growth of the sunflower plants. Iron and Burnside (1982) reported that root of sunflower plants had its allelopathic substances, which inhibited growth of the subsequent crops apart from inhibited germination of seeds of other crops. The results of the present work clearly confirmed toxic effect derived from sunflower. Similarly, Schon and Einhellig (1982) carried out experiments with the used of sunflower residues (0.5-2.0 g in g of soil) showed that total dry weight per plant of sunflower significantly decreased with an increase in the amount of sunflower residues. They further added that when crop residues of sunflower decomposed in soil, the residues released allelopathic substances where it inhibited germination and growth of the subsequent crops, particularly roots of the sunflower plants where it contained the utmost amounts of allelopathic substances greater than other parts of the sunflower plants. These findings also confirm the works reported by Nielson *et al.* (1960) and Lawrence and Kilcher (1962) with sunflower experiments. It was also found that crop residues of soybean inhibited growth of sunflower plants where the results confirm the work reported by a number of workers such as Newman and Rovira (1975), Nicollier and Thomposon (1982). These workers stated that leguminous crops release toxic substances in soils when decomposed and it had a significant effect on growth and yields of the subsequent crops. Thus soybean residues contained allelopathic substances where it affected plant height, root dry weight and total dry weight of the sunflower plants. Tsuzuki and Kawagoe (1984) reported that roots of soybean when decomposed in soils release toxic substances to vegetable crops of radish plants (*Raphanus sutivus* L.) and turnip (*Brassica rapa* L.). Nevertheless, the differences due to seed yields of sunflower of the present work were not found. This may be attributable to the small amounts of crop residue being added to the soil in each pot where the amount may not be adequate enough to show its severe effect on seed yields of the sunflower plants although it showed significant effects on height, root dry weight and total dry weight of the sunflower plants. Another reason for this may be attributable to perhaps the leaching out of soil nutrients under heavy rainfall conditions and also the depletion of soil nutrients in each plot where the supply may not plentiful enough for roots of sunflower plants to absorb, particularly at their filling stage of seeds. Thus seed yield plant^{-1} was much lower than those reported by Suksri *et al.,* (1989). Therefore, growers of cash crops should bear in minds that some allelopathic effects derive from initial crops could possibly cause a severe reduction in yields of the subsequent crops. It may be of interest to carry out further experiments with the use of other indicator plants in order to find out how other cash crops responded to toxic substances of both sunflower and soybean so that the attained results could possibly provide adequate information for growers of most cash crops, since growers in most regions grow sunflower, soybean and maize annually. The outcome of the experiments may help growers to choose which cash crop should be sown after both sunflower and soybean crops.

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REFERENCES

Chang-Ycon, Y., E.H. Kim and J.H. Hur, 1995. *In vivo* and *in vitro* system for bioassay of allelopathic substance in rye (*Secale cereale* L.) pp. 321-325. In: Proc. (A) 15th Asian Pacific Weed Science Society Conference, Tsukuba, Japan.

Iron, S.M. and O.C. Burnside, 1982. Competitive and allelopathic effects of sunflower (*Helianthus annuus*) Weed Sci. J., 30: 372-377.

Kimbler, R.W., 1973. Phytotoxicity from plant residues. III. The relative effect of toxins and nitrogen immobilization on the germination and growth of wheat. Plant and Soil, 38: 543-555.

Krogmeier, M.J. and J.M. Bremner, 1986. Effects of water-soluble constituents of plant residues on water uptake by seeds. Agron. Abst., pp: 181.

Lawrence, T. and M.R. Kilcher, 1962. The effect of fourteen root extracts upon germination and seedling length of fifteen plant species. Can. J. Plant Sci., 42: 308-313.

Leather, G.R., 1983. Sunflowers (*Helianthus annuus*) are allelopathic to weeds. Weed Sci., 31: 37-42.

Miller, R.W. and R.L. Donahue, 1990. Soils. An introduction to soils and plant growth. 6th Edn. Prentice Hall, Englewood Cliffs, NJ 07632. USA.

Newman, E.I. and A.D. Rovira, 1975. Allelopathic effect of common weeds on soybean growth and soybean-bradyrhizobium symbiosis. Plant and Soil., 122: 177-182.

Nicollier, G.F. and A.C. Thompson, 1982. Phytotoxic compounds from *Melilotus alba* (white sweet clover) and isolation and identification of two new flavoids. J. Agric. Foodchem., 80: 760-764.

Nielson, K.F., T.F. Cuddy and W.B. Woods, 1960. The influence of the extract of some crops and soil residue on germination and growth. Can. J. Plant Sci., 40: 188-193.

Nissen, O., 1989. MSTAT-C: A microcomputer program for the design, management and analysis of agronomic research experiment, Michigan State University. USA. (1-1)-(f-l).

Pandey, D.K., L.P. Kauraw and V.M. Bhan, 1993. Inhibitory effect of Parthenium (*Parthenium hysterophorus* L.) residue on growth of water hyacinth (*Eichhornia crassipes*) I. Effect of leaf residue. J. Chem. Ecol., 19: 2651-2662.

Purvis, C.E. and G.P.D. Jones, 1990. Differential response of wheat to retain crop stubbles. II Other factors influencing allelopathic potential; intraspecific variation, soil type and stubble quantity. Aust. J. Agric. Res., 41: 243-251.

Ratnapradipa, P., 1996. Effects of organic amendments in combination with commercial fertilizer on soil properties, growth and kernel yield of maize (*Zea mays* L.) grown on Stuk loamy sand. A Ph.D Thesis, Central Luzon State University, the Philippines.

Sarobol, E., 1987. Allelopathic effect of corn and soybean on subsequent corn crop. A Ph.D Thesis, Iowa State University, Ames, Iowa. USA.

Schon, M.K. and F.A. Einhellig, 1982. Allelopathic effect of cultivated sunflower on grain sorghum. Bot. Gaz., 143: 505-510.

Suksri, A., S. Seripong and S. Teerapongtanakorn, 1989. Effects of cattle manure, city arbage compost and chemical fertilizer on growth, yield and nutrient uptake of sunflower (*Helianthus annuus* var. Hysun 33) grown on an acid soil. European Economic Commission Project, an annual report of 1990.

Suksri, A. 1999. Some Agronomic and Physiological Aspects in Growing Crops in Northeast Thailand. 1st Edn., Department of Agronomy, Faculty of Agriculture, Khon Kaen, University Press, Khon Kaen, Thailand. pp: 212.

Tsuzuki, E. and M. Kawagoe, 1984. Studies on allelopathy among higher plants. IV. On allelopathy in leguminous crops. Bulletin of the Faculty of Agriculture, Miyazaki University, 31: 39-43.

Viles, A.L. and R.N. Reese, 1996. Allelopathic potential of *Echinacea angustiforia* D. C. Env. Exp. Bot., 36: 39-43.

Wallace, J.M. and L.F. Elliott, 1979. Phytotoxins from anaerobically decomposing wheat straw. Soil Biol. and Biochem., 11: 325-330.