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Effects of corn residues on the subsequent soybean crops

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Abstract. Field study was conducted on a silt loam soil (fine-loamy, mixed, nonacid, hyperthermic, Fluvaquentic Dystroochrept) at the experimental farm of Taiwan Agricultural Research Intstitute to compare the growth and yield of soybean [*Glycine max* (L.) Merr. var. Nung-Yu No. 7] grown with or without corn residues in the summer crop of 1991 and the spring crop of 1992. Four levels of corn residue treatments were made, i.e., 0 (control), 1/2 x (half), x (full), and 2 x (double). The changes of soil properties were also investigated. The results showed that effects of corn residues varied in growing seasons and the amount incorporated. Corn residues stimulated seedling emergence in both crops, a 6% and 9% increase was observed by double residues treatment in Summer and Spring, respectively. Full amount of residues elevated leaf area and plant dry weight only in the summer crop. The pH of soil was not changed by the incorporation of corn residues, whereas the measured nutrient elements (N and K) were gained by full amount of residues incorporated into the soil in Summer crop. No significant differeces were revealed in nodule number, nodule dry weight, and the effective plant percentage calculated at harvest by corn residue treatments. However, generally less weeds were collected in soils treated with corn residues in Summer and in Spring since April. Seed yield was significantly increased, from 50 to 79%, in Summer crop but not in Spring crop. The results suggested that soybean may be benefited from corn residues in the summer growing season.

Key words: Corn, Plant residues, Soil nutrients, Soybean, Growth, Yield, Rotation.

玉米植株殘留物對大豆 [*Glycine max* (L.) Merr.] 生長與產量之影響

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摘要：本文以大豆農育七號為試驗材料，分別於1991年夏作及1992年春作

在臺灣省農業試驗所農場進行，以比較土壤混入玉米植株殘留物對大豆生育與產量之影響，同時調查土壤酸鹼值、有機質、及營養元素（土壤全氮、有效性磷及有效性鉀）之變化，以瞭解玉米植株殘留物對土壤之效應。根據試驗結果，玉米植株殘留物可提高大豆幼苗出土百分比，在兩倍量玉米殘留物下夏、秋作分別增加6%及9%。除了在生育早期之外，大豆生長似亦受到玉米殘留物促進，即在玉米植株殘留物處理土壤生長之大豆其株高、葉數與葉面積均略增加，而累積較多乾物質。此一差異在夏作更為明顯。土壤酸鹼值、有機質及有效性磷雖未明顯改變，混入玉米植株殘留物之夏作區土壤則有較高氮素及有效性鉀含量。而且經殘留物處理之夏作大豆田區雜草量遠較對照土壤區為低，但是根瘤數與重量無差異。收穫時，處理間有效大豆植株百分比雖無顯著差別，但生長在以玉米植株殘留物處理區之夏作大豆獲得較高產量，增產50至79%。

關鍵語：玉米、植株殘留物、土壤營養元素、大豆、生長、產量、輪作

INTRODUCTION

Many plants when incorporated into the soil were found to affect growth and yield of the succeeding crops (Bhowmik and Doll 1982, Bonner 1950, Borner 1960, Johnson III and Coble 1986, Menges 1987, Patrick 1971, Rice 1984, Weston and Putnam 1986). Such effect is influenced by soil temperature (Bhowmik and Doll 1983, Einhelling and Eckrich 1984, Toai and Linscott 1979), moisture (Wilhelm et al. 1986), salinity (Del Moral 1972, Fowler 1960, Patrick et al. 1963), irradiation (Koeppe et al. 1969, Lott 1960, Wedner 1970) and microbial reactions (Kimber 1973, Lynch et al. 1981) that affecting the decomposition of plant residues, and determines the advantage of a rotation system. A preferred crop rotation is recommended because of the amelioration of soil fertility and physical properties, the reduction of disease and pest occurrence, and/or the improvement of weed control. Understanding the effects caused by plant residues of the preceding crop is therefore essential for determining a proper rotation sequence.

Shrader et al. (1966) and Baldock and Musgrave (1980) reported that corn was benefited from proper rotations to increased availability of nitrogen. Since soybean is a legume and would not be expected to be improved from the increase of nitrogen supply following rotation to cereal crops, whether soybean is a suitable crop following corn harvest needs to be further studied.

The objective of this research was conducted to compare the difference of growth and yield of soybean grown in soil with or without corn residues from the previous season. The changes of soil properties were analyzed and their importance to yield was determined.

MATERIALS AND METHODS

Field study was conducted at the experimental farm of Taiwan Agricultural Research Institute (TARI, 24° 02′ N, 120° 40′ E, elevation 85 m) in the summer crop season of 1991 and the spring crop season of 1992 in a silt loam soil (fine-loamy, mixed, nonacid, hyperthermic, Fluvaquentic Dystroochrept). The soil contained 23.3% sand, 53.3% silt, and 23.4% clay with 1.60% (summer) and 1.30% (spring) organic matter and with pH 6.0 (summer) and 6.9 (spring). The determinate growth habit of soybean 'Nung-Yu No. 7', received from Soybean Research Laboratory of TARI as a gift, and corn (*Zea mays* L.) 'Tainung No. 1', purchased from Taiwan Seed Service (Ta-nan village, Shinshieh, Taichung, Taiwan, ROC), were used. The preceding corn crop was planted at a rate of 57140 plants ha^{-1} in both years. After ear removal, plant residues (whole plant) of corn were harvested, chopped and returned back onto the soil surface of the experimental plots. The experimental area was then rotary plowed twice and seedbed prepared seven days prior to cultivation. Three levels of corn residues were made, i.e., half (1/2 x), full (x, 57140 plants ha^{-1}) and double (2x). A bare soil control was used to compare the effects of corn residues on the growth and yield of soybean. Separate experimental plots, which were not cropped with corn in at least a year, were employed in different seasons to avoid the influence of the accumulated corn residues.

The weather data were collected from the weather station at TARI experimental farm. The accumulated data of irradiance, air temperature and precipitation were the sum of the daily accumulated irradiance (MJ m^{-2} d^{-1}), the daily air mean temperature (°C) and the daily accumulated precipitation (mm d^{-1}), respectively.

The 7-row plots were 8 m long and 0.55 m row spacings and the seeds were planted at a rate of 25 seeds m^{-1} of each row on 12 July 1991 and 22 January 1992. Fertilizer (20-90-60, $N/P_2O/K_2O$) was applied onto soil surface at planting. All plots were sprayed with methomyl (90% WP, 0.5 kg ha^{-1}), S-methyl-N-[(methyl carbamoyl)-oxy]-thioacetimidate, and mancozeb (80% WP, 2.5 kg ha^{-1}), Mn^{2+} 16%/Zn^{2+} 2%/Ethylene-bisdithiocarbamate ion 62%, for pest control applied between Growth Stage R6 and R7.

Changes of the soil pH value, organic matter percentage, and soil nutrient contents (i.e., the total nitrogen, the available phosphorus, and the available potassium) during the growing seasons of summer crop of 1991 and spring crop of 1992 were analyzed periodically. Soil total nitrogen was measured by Kjeldahl method. Organic matter was determined by wet digestion using colorimetric method and the available phosphorus and potassium were analyzed by Bray No.1 and Mehlich No.1 extractions, respectively (Handbook on Reference Methods for Soil Testing 1980). Soybean seedling emergence percentage (seedlings emerged/seeds planted) was recorded for sixteen and twenty days after planting for the summer crop of 1991 and the spring crop of 1992, respectively. During the growing seasons, plant height, leaf number, leaf area, nodule number, and dry weight (oven-dried at 80°C for 72 hrs) of the different plant parts were measured at regular intervals. Dry weight (80°C for 72 hrs) of weeds collected from soybean fields during the two growing seasons was also determined. Two rows were hand harvested from the middle rows of each plot to estimate seed yield (50°C for 72 hrs) on 21 October 1991 and 18 May 1992 . Yield components such as pod number, seed number, seed dry weight (50°C for 72 hrs) and 100-seed dry weight were determined at harvest by sampling 10 plants from the near rows. The effective plant percentage (EPP) was calculated by counting the number of matured plants and the emerged plants (matured plants/emerged plants). Leaf area was measured by an area meter (LI-3000, Li-Cor, Inc., Nebraska, USA).

The experiment was arranged in a randomized complete block design with three replicates. Data were subjected to analysis of variance and means were compared with Fisher's Least Significant Difference (LSD) test at the 5% probability level. The standard errors were also computed.

RESULTS AND DISCUSSION

Reports in the literature showed that many plants, including crop plants (Dabney et al. 1988, Guenzi et al. 1967, Parker 1962, Rice 1984) and weeds (Bhowmik and Doll 1982, Caussanel 1979, Chang and Yang 1992, Stachon and Zimdahl 1978), can affect growth and yield of crop in the next season when incorporated into soil. However, limited information is available on the effects of corn residues on soybean growth and yield and the soil properties under field conditions.

Fig. 1 shows a distinct climate environment during the growing seasons of summer

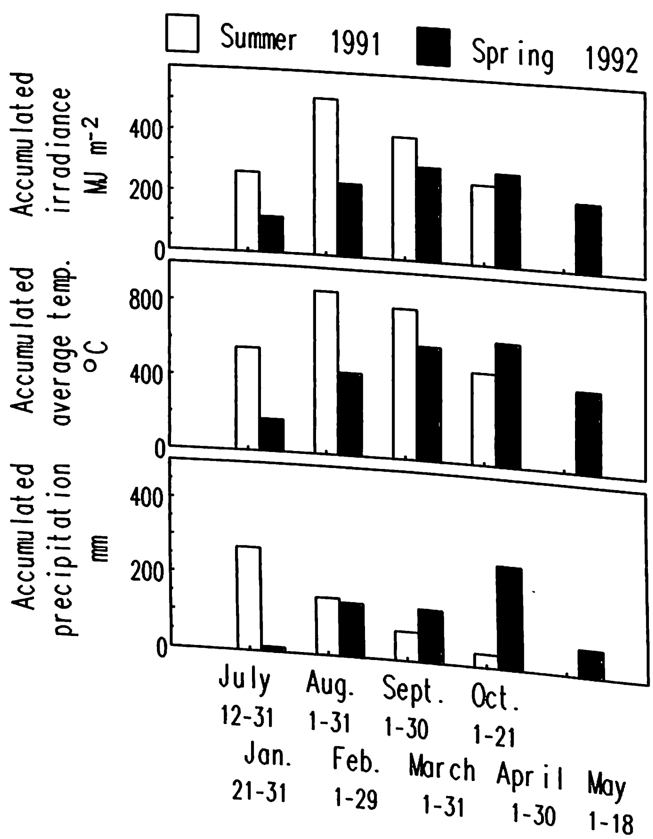

Fig. 1. The weather data during the growing seasons of summer crop of 1991 and spring crop of 1992.

crop of 1991 and spring crop of 1992, which not only affected soybean growth and weed infestations but the impact of the incorporated corn residues. As indicated, corn residue stimulated seedling emergence in both crops (Fig. 2), a 6 % and 9% increase was found by 2 x treatment in Summer and Spring, respectively. Plant weight and leaf area (in Summer only) were slightly elevated by 2 x corn residues incorporated into the soil (Fig. 3 and Table 1). However, nodule number and nodule dry weight as well as plant height, leaf number and the effective plant percentage were not varied by corn residues (data not shown).

As for soil properties, corn residue incorporation did not result in significant changes in pH, organic matter and phosphorus content (data not shown). Slight increase in N and K contents was found in Summer but not in Spring crop (Table 2).

Of particular interest of the present study is the finding that corn residue incorporation reduced the amount of weeds at all sampling dates in Summer crop (Table 3). Less weeds induced by corn residue incorporation only observed at the time after April in Spring crop (Table 3). The cause(s) was unknown, yet this may reduce crop-weed competition on natural resources and/or the allelopathy induced by weeds, which in turn improves soybean growth environment. It seems that the weather condition favors weed growth in Summer as judged by the data in Fig. 1. Horn and Burnside (1985) pointed out that optimal soybean growth

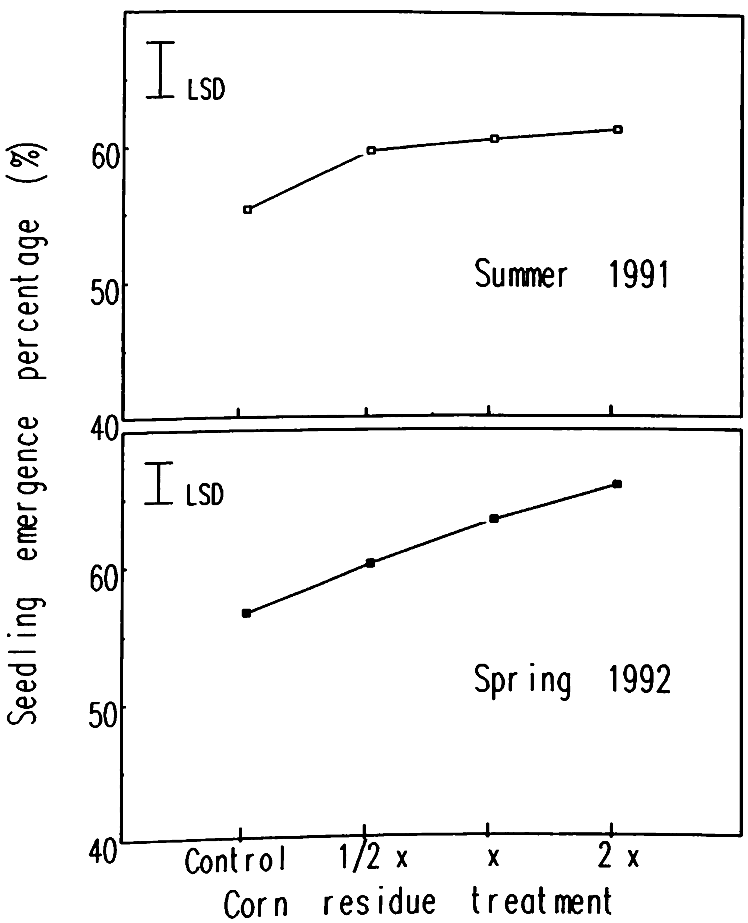

Fig. 2. The seedling emergence percentage of soybean grown in soil with or without corn residue treatments in the summer crop of 1991 and the spring crop of 1992.

Table 1. The differences of plant dry weight and its components of soybean grown in soil with or without corn residue treatments at two weeks before harvest.

Crop season	Amount of residues	Dry weight (g pl^{-1})			
		leaf	stem	root	sum
Summer 1991	Control	4.857	10.129	2.130	17.116
	1/2 x	5.087	10.537	2.156	17.780
	x	5.107	10.612	2.162	17.881
	2 x	5.184	10.768	2.201	18.153
LSD*(0.05)					0.343
Spring 1992	Control	4.045	5.495	1.291	10.831
	1/2 x	4.141	5.645	1.330	11.116
	x	4.171	5.698	1.351	11.220
	2 x	4.254	5.825	1.415	11.494
LSD (0.05)					0.367

*Fisher's Least Significant Difference Test at p=0.05.

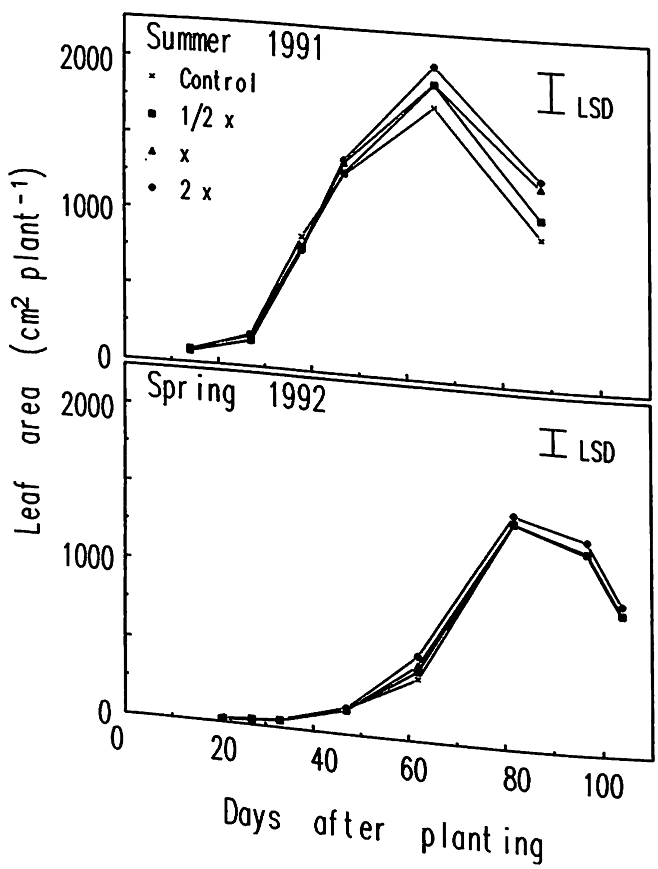

Fig. 3. Changes of leaf area of soybean grown in soil with or without corn residues treatment during the growing seasons of summer crop of 1991 and spring crop of 1992.

Table 2. Changes of soil nutrient contents (the total N and the available K) during Summer 1991 and Spring 1992.

Crop season	Sampling date	Amount of residues	Soil nutrient (ppm)	
			N	K
Summer 1991	July 26	Control	982.3	55.1
		1/2 x	1,014.3	71.7
		x	1,027.7	76.4
		2 x	1,041.5	80.9
	Aug. 8	Control	940.0	57.4
		1/2 x	1,003.0	71.5
		x	1,025.5	81.9
		2 x	1,040.1	83.5
	Aug. 31	Control	956.7	63.1
		1/2 x	990.1	70.7
		x	1,010.0	83.7
		2 x	1,023.7	86.1
	Sept. 19	Control	952.0	48.3
		1/2 x	970.7	64.9
		x	1,016.0	78.9
		2 x	1,024.8	80.7
	Oct. 21	Control	945.0	46.9
		1/2 x	1,027.5	55.7
		x	1,045.7	70.5
		2 x	1,053.2	73.4
LSD*(0.05)			9.8	4.9
Spring 1992	Jan. 22	Control	945.0	84.6
		1/2 x	948.2	91.5
		x	950.4	97.2
		2 x	961.7	105.3
	Feb. 14	Control	925.3	78.7
		1/2 x	929.1	82.5
		x	933.5	85.6
		2 x	948.7	91.6
	March 6	Control	1,005.3	81.6
		1/2 x	1,007.1	84.7
		x	1,008.9	88.8
		2 x	1,017.5	97.9
	March 23	Control	962.0	79.0
		1/2 x	967.6	82.2
		x	973.2	85.2
		2 x	979.7	91.5
	April 29	Control	983.7	65.8
		1/2 x	988.9	68.6
		x	994.7	71.7
		2 x	1,001.7	77.5
	May 21	Control	1,012.2	78.8
		1/2 x	1,024.4	81.5
		x	1,037.5	84.9
		2 x	1,051.2	91.0
LSD (0.05)			10.4	5.7

*Fisher's Least Significant Difference Test at $p = 0.05$.

Table 3. Means and standard errors of dry weight of weeds collected from soybean fields with and without corn residues treatments.

Corp season	Sampling date	Amount of residues	Weed dry wt (g m^{-2})
Summer 1991	Aug. 8	Control	129.18 ± 36.11*
		1/2 x	108.72 ± 43.32
		x	81.11 ± 13.42
		2 x	75.43 ± 15.96
	Sept. 19	Control	142.65 ± 35.36
		1/2 x	125.11 ± 30.12
		x	85.65 ± 10.65
		2 x	78.23 ± 13.02
	Oct. 21	Control	107.51 ± 21.64
		1/2 x	88.56 ± 15.69
		x	55.68 ± 11.07
		2 x	48.39 ± 9.64
Spring 1992	March 5	Control	16.35 ± 5.93
		1/2 x	16.54 ± 3.79
		x	17.10 ± 4.16
		2 x	16.10 ± 2.82
	March 18	Control	86.05 ± 6.04
		1/2 x	84.28 ± 5.83
		x	83.25 ± 6.70
		2 x	79.67 ± 6.57
	April 29	Control	22.84 ± 4.33
		1/2 x	19.63 ± ·4.07
		x	17.39 ± 5.62
		2 x	11.32 ± 1.48
	May 18	Control	24.56 ± 4.25
		1/2 x	19.33 ± 3.78
		x	15.26 ± 4.78
		2 x	12.65 ± 1.57

*Standard error.

Table 4. Difference in yield components of soybean, Nung-Yu No. 7, as affected by corn residue treatments.

Crop season	Amount of residues	Pod No. (No. P1^{-1})	Pod dry wt (kg ha^{-1})	Seed No. (No. P1^{-1})	Seed yield (kg ha^{-1})	100-seed dry wt (g)
Summer 1991	Control	45 ± 7*	3,610 ± 240	81 ± 13	1,870 ± 70	15.44 ± 1.28
	1/2 x	47 ± 5	4,610 ± 220	87 ± 10	2,810 ± 150	15.87 ± 1.32
	x	50 ± 6	5,220 ± 400	90 ± 10	3,140 ± 130	16.53 ± 1.46
	2 x	51 ± 6	6,060 ± 350	92 ± 11	3,350 ± 160	17.55 ± 1.38
Spring 1992	Control	29 ± 4	3,540 ± 400	59 ± 8	2,200 ± 180	16.68 ± 1.82
	1/2 x	29 ± 2	3,600 ± 360	60 ± 5	2,290 ± 190	16.62 ± 1.24
	x	30 ± 4	3,660 ± 340	60 ± 4	2,330 ± 200	16.70 ± 1.63
	2 x	30 ± 2	3,730 ± 330	61 ± 4	2,420 ± 170	16.84 ± 1.33

*Standard error.

was obtained by weed control practices. Many scientists have also indicated that soybean growth and yield was greatly reduced by weed interference (Burnside 1979, Coble and Ritter 1978, Eaton et al. 1976, Jackson et al. 1985, Shurtleff and Coble 1985).

Table 4 shows that corn residue incorporation, especially in 2 x treatment, significantly increased the seed yield of soybean in Summer, but not in Spring crop. The increase of seed yield by corn residues in Summer was due mainly to the rise of pod weight (Table 4). Similar results were reported by Bhowmik and Doll (1982) that soybean yielded 10 to 15% better when rotated with corn rather than with sunflower or grown continuously.

In summary, the results suggested that soybean may be benefited from corn residues in the summer season through the improvement of weed control and perhaps, soil N and K availability.

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REFERENCES

Baldock, J. O. and Musgrave, R. B. (1980) Manure and mineral fertilizer effects in continuous and rotational crop sequences in central New York. *Agron. J.* 72:511-518.

Bhowmik, P. C. and Doll, J. D. (1982) Corn and soybean response to allelopathic effects of weed and crop residues. *Agron. J.* 74:601-606.

Bhowmik, P. C. and Doll, J. D. (1983) Growth analysis of corn and sorghum response to allelopathic effect of weed residues at various temperatures and photosynthetic photon flux densities. *J. Chem. Ecol.* 9:1263-1280.

Bonner, J. (1950) The role of toxic substances in the interactions of higher plants. *Bot. Rev.* 16:51-65.

Borner, H. (1960) Liberation of organic substances from higher plants and their role in the soil sickness problem. *Bot. Rev.* 26:393-424.

Burnside, O. C. (1979) Soybean (*Glycine max*) growth as affected by weed removal, cultivar, and row spacing. *Weed Sci.* 27:562-565.

Caussanel, J. P. (1979) Non-competitive effects between lambsquarters (*Chenopodium album* L.) and maize (INRA 258). *Weed Res.* 19:123-135.

Chang, F. C. and Yang, C.-M. (1992) Allelopathic potential of purple nutsedge (*Cyperus rotundus* L.) and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] on corn (*Zea mays* L. cv. Tainung No. 1). II. Weed residue effects on corn emergence and seedling growth. *J. Agric. Res. China* 41:9-23.

Coble, H. D. and Ritter, R. L. (1978) Pennsylvania smartweed (*Polygonum pennsylvanicum*) interference in soybeans (*Glycine max*). *Weed Sci.* 26:556-559.

Dabney, S. M., McGawley, E. C., Boethel, D. J. and Berger, D. A. (1988) Short-term crop rotation systems for soybean production. *Agron. J.* 80:197-204.

Del Moral, R. (1972) On the variability of chlorogenic acid 25 concentration. *Oecologia* 9:289-300.

Eaton, B. J., Russ, O. G. and Filtner, K. C. (1976) Competition of velvetleaf, prickly sida, and venice mallow in soybeans. *Weed Sci.* 24:224-228.

Einhellig, F. A. and Eckrich, P. C. (1984) Interactions of temperature and ferulic acid stress on grain sorghum and soybeans. *J. Chem. Ecol.* 10:161-170.

Fowler, H. D. (1960) Variations of scopoletin in leaves in relation to chloride treatment of tobacco. *Nature* 188:1044.

Guenzi, W. D., McCalla, T. M. and Norstadt, F. A. (1967) Presence and persistence of phytotoxic substances in wheat, oat, corn and sorghum residues. *Agron. J.* 59:163-165.

Handbook on Reference Methods for Soil Testing (1980) (revised edition). p.42-46, p.52-57, p.126-130. Univ. of Georgia, Athens, GA., USA.

Horn, P. W. and Burnside, O. C. (1985) Soybean growth as influenced by planting date, cultivation, and weed removal. *Agron. J.* 77:793-795.

Jackson, L. A., Kapusta, G. and Mason, D. J. S. (1985) Effect of duration and type of natural weed infestations on soybean yield. *Agron. J.* 77:725-729.

Johnson III, W. C. and Coble, H. D. (1986) Effects of three weed residues on weed and crop growth. *Weed Sci.* 34:403-408.

Kimber, R. W. L. (1973) Phytotoxicity from plant residues. III. The relative effect of toxin and nitrogen immobilization on the germination and growth of wheat. *Plant Soil* 38:543-555.

Koeppe, P. E., Rohrbaugh, L. M. and Wender, S. H. (1969) The effect of varying UV intensities on the concentration of scopolin and caffeoylquinic acids in tobacco and sunflower. *Phytochemistry* 8:889-896.

Lott, H. V. (1960) Uber den einfluss der kurzwelligen strahlung auf die biosnthese der pflanzlichen polyphenole. *Planta* 55:480-495.

Lynch, J. M., Penn, D. J. and Gussin, E. J. (1981) Microbiological problems from the decomposition of grass and weed residues following herbicide application. *J. Sci. Food Agric.* 32:628-629.

Menges, R. M. (1987) Allelopathic effects of palmer amaranth (*Amaranthus oalmeri*) and other plant residues in soil. *Weed Sci.* 35:339-347.

Parker, D. T. (1962) Decomposition in the field of buried and surface-applied corn-stalk residue. *Soil Sci. Soc. Am. Proc.* 26:559-562.

Patrick, Z. A. (1971) Phytotoxic substances associated with the decomposition of plant residues in soil. *Soil Sci.* 111:13-18.

Patrick, Z. A., Toussoun, T. A. and Snyder, W. C. (1963) Phytotoxic substances in arable soils associated with decomposition of plant residues. *Phytopathology* 53:152-161.

Rice, E. L. (1984) Allelopathy. 2nd ed. p.1-422. Academic Press, Orlando, Fl. USA.

Shrader, W. D., Fuller, W. A. and Cady, F. B. (1966) Estimation of a common nitrogen response function for corn in different crop rotations. *Agron. J.* 58:397-401.

Shurtleff, J. L. and Coble, H. D. (1985) Interference of certain broadleaf weed species in soybean (*Glycine max*). *Weed Sci.* 33:654-657.

Stachon, W. J. and Zimdahl, R. L. (1978) Allelopathic activity of Canada thistle (*Cirsium arvense*) in Colorado. *Weed Sci.* 26:83-86.

Toai, T. V. and Linscott, D. L. (1979) Phytotoxic effect of decaying quackgrass (*Agropyron repens*) residues. *Weed Sci.* 27:595-598.

Wender, S. H. (1970) Effects of some environmental stress factors on certain phenolic compounds in tobacco. *Recent Adv. Phytochem.* 3:1-29.

Weston, L. A. and Putnam, A. R. (1986) Inhibition of legume seedling growth by residues and extracts of quackgrass (*Agropyron repens*). *Weed Sci.* 34:366-372.

Wilhelm, W. W., Doran, J. W. and Power, J. F. (1986) Corn and soybean yield response to corn residue management under no-tillage production systems. *Agron. J.* 78:184-189.

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