EFFECT OF SOIL SOLARIZATION AND CHICKEN MANURE ADDITION ON CORN YIELD AND NITROGEN UPTAKE UNDER ARID ZONE CONDITIONS

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ABSTRACT

Two field experiments were conducted at Hada Al-sham Experimental Station, King Abdulaziz University, during two sowing dates (Fall 1994 and Spring 1995) to study the effects of soil solarization (mulching wet soil with clear polyethylene during summer season for the control of soil pests) and different rates of chicken manure as a soil amendment (0, 10, 20 and 40 t/ha) on yield and ear characters and nitrogen uptake by hybrid corn (AGA seed 215 cultivar). The results indicated that values in the Fall was higher than the values in the Spring sowing date in the following parameters: total yield dry matter, weight of 1000 kernels, ear diameter, ear volume, number of kernels/row and weight of ears and its parts (kernels and cobs). However, harvest index was higher in the spring than the fall sowing date. On the other hand, weight of kernels, cobs, and ears shelling %, and protein content of kernels were not significantly affected by sowing date. However, yield and ear characters and their parts were not significantly affected by either soil solarization or chicken manure treatments. Total yield dry matter and nitrogen uptake by corn plants were increased in solarized than in non-solarized soil for both sowing dates.

INTRODUCTION

Corn (*Zea mays* L) is considered as one of the most important economical crops. It is ranked as the third important cereal crop after wheat and rice worldwide. Generally, the Arab countries, Egypt, Morocco, Somalia, Sudan, Iraq and Yemen are considered corn-importing countries. However, Egypt is the most Arab corn-producing country, where more than eighty three percent of the total corn of all the Arab countries is produced (FAO, 1984).

In the Kingdom of Saudi Arabia, corn cultivation is rather limited. It was reported that the total area of all crops, for the main regions in the Kingdom, was 1.3 million hectares, among which only 3333 hectares were reported corn-producing land with total annual production of 5843 tons of grains (Ministry of Agriculture, 1998).

For the production of high yield of grains and dry matter, corn plant requires applications of chemical fertilizers, and/or application of organic fertilizers and control of soil-borne plant pests.

Application of organic matter provides many essential nutrients needed by crop plants. The increase in crop yield by the use of animal manure have been imperative many times as resulted, mainly, from the nitrogen, phosphorus or potassium or the combination of the three elements supplemented by manure (Parker and Sommers, 1983). Animal manure also improves the physical conditions of the soil and increases soil water holding capacity (Russel et al., 1952). Nishiwaki and Inoue (1996) investigated the effect of different rates of animal manure compost. They found that manure compost reduced the leaching out of soil nutrients from vegetable upland fields. They also found that it increased the total carbon content of soil (organic matter). Another study by Maynard (1994) indicated that yield of all vegetable crops under study was increased as the rate of animal manure compost increased. Similar results were found by Jackson and Smith (1997) and Ritz et al. (1997).

Soil solarization is a new safe non-chemical technique used for the control of soilborne plant pests such as plant pathogens, weeds, and arthropods (Katan, 1981; Stapleton and DeVay, 1986 and Katan, 1987). This technique utilizes the solar energy by tarping wet field soil with transparent polyethylene sheets during the hot summer for several weeks to raise soil temperature to an extent lethal to plant soil pests. Dubey (1992) indicated a maximum increase of temperature in solarized soil up to 11 C. Another report by Chellimi et al. (1994), stated that an increase in temperature in solarized soil of 8.8, 7.8 and 4.9 C at soil depths of 5, 15 and 25 cm over non-solarized soil, respectively. Habeebrrahman and Hosmani (1996) indicated similar results. Polyethylene sheets application was reported to warm the soil beneath the sheets and conserve soil moisture by reducing water loss by evaporation from the surface soil (Adetunji, 1994).

Although this method is applied worldwide, successful application is conditioned by hot, dry, and cloudless climates (Chellimi et al., 1994). An important feature frequently observed following soil solarization is the increased plant growth response (IPGR) even in the absence of major plant pathogens. There has been a great deal of research indicating an increase in plant height, dry weight, and yield of many crops following soil solarization (Chen and Katan, 1980; Katan, 1980 and 1981; Stapleton and DeVay, 1983 and 1984, Stapleton et al. 1985; Katan, 1987 and Ahmad et al., 1996). Stapleton and DeVay (1983) observed 32 – 128 % increase in the fresh weight of peppers in solarized over non-solarized soil. In another study by Stapleton et al. (1985), they reported a greater fresh and dry weight of radish, pepper, and chinese cabbage plants were observed after solarization. Ahmad et al. (1996) observed that growth of corn crop planted in solarized plots was better and it yielded one to three times more grains than non-solarized plots.

Many researchers indicated that a combination of soil solarization and organic matter amendment gave better results concerning weed and plant disease control and higher yield than soil solarization or soil organic amendment alone (Singh and Sitarmaiah, 1970; Katan, 1981; Muller and Gooch, 1982; Vijayalakshmi et al. 1985; Keinath, 1996; Gamaliel and Stapleton, 1997 and Campiglia et al. 1998).

Keinath (1996) found that incorporating cabbage residue into mulched soil increased growth and yield of watermelon. In another study by Gamliel and Stapleton (1997), they determined that combining chicken and cruciferous residues during solarization gave better control of soil pathogens and higher yield of lettuce and tomatoes than control or each treatment alone. They suggested that solarization might increase the rate of degradation of organic matter to cause accumulation of toxic gases in the soil air that have an effect on soilborne pest population densities. Campiglia et al. (1998) found out that weed density and total biomass using the solarization method were decreased up to 91% that resulted in an increase in the growth and yield of head lettuce up to 106%.

This research has an important impact at the local level especially under the environmental conditions of the Kingdom of Saudi Arabia. The special conditions of high intensity of solar radiation and very high temperature during the summer season provide ideal conditions for solarization approach. This approach of soilborne control reduces the use of pesticide and herbicide and their pollutant effect on the crop, soil, and groundwater. Also, solarization will increase the decomposition of organic matter, which will improve the availability of nutrients for plant and increase the crop yield.

The objectives of this research is to determine the effect of soil solarization and chicken manure addition on yield and ear characters and nitrogen uptake by corn plant.

MATERIALS AND METHODS

Sowing dates and experimental design

Two experiments were conducted at the King Abdulaziz University Agricultural Research Station in Hada Al-Sham, which is located 120 km northeast of Jeddah. Soil solarization experiment was conducted during the period of July 31 to September 15, 1994. However, the two sowing dates of the experiment were as follows: fall sowing date from October 8,1994 to January 26,1995, and the spring sowing date from February 8 to June 13, 1995. Each experiment was conducted in a complete randomized block design with three replications in 2x4 factorial arrangement.

Each sowing date included eight treatments; two treatments of solarization (solarized and non-solarized soil)) and four treatments of chicken manure as a soil amendment (0, 10, 20 and 40 t/ha). The treatments were randomly distributed in three replicates.

Climatic conditions

Table (1) illustrates Air and soil temperature during solarization experiment preceded the corn experiment and Table (2) illustrates climatic conditions recorded by the Faculty of Meteorology, King Abdulaziz University. These data include temperatures (maximums, minimums and means), and mean relative humidity of each sowing date experiment.

Table 1. Average monthly recorded air and soil temperatures during soil solarization experiment.

Temp. Range	Soil depth (cm)	Soil temperature (C)				Air temperature (ºC)	
		August		September			
		Solarized*	Non-Sol.	Solarized	Non-Sol.	Aug.	Sept.
Minimum	5	28.5	27.0	29.0	33.5	18.9	20.0
	10	24.8	23.0	33.9	40.1		
	25	26.4	33.9	23.7	38.2		
Maximum	5	68.6	52.2	62.4	50.7	47.0	47.7
	10	51.6	45.2	53.5	49.0		
	25	50.4	38.7	51.5	41.8		
Mean	5	48.5	39.8	48.2	42.1	32.9	32.7
	10	38.2	34.1	43.7	44.5		
	25	38.4	36.3	37.6	40.0		

***Soil was solarized from July 31 – September 15, 1994.**

Table 2. Average monthly recorded air temperature and relative humidity of the study area during the two sowing dates of corn plant.

Sowing date	Month	Temperature (C)			Relative humidity (%)		
		Min.		Mean	Min.	Max.	Mean
First (Fall)	October	19.0	42.0	30.9	28.10	99.3	63.7
	November	16.2		27.1	39.1	92.4	65.7
	December	11.00	34.9	24.1	41.9	75.4	58.7
	January	18.2	32.6	25.4	38.5	86.9	59.4
Second(Spring)	February	15.3	30.0	20.5	36.6	86.5	55.6
	March	18.2	35.7	27.0	30.9	78.1	54.5

	April	21.7	38.5	29.1	34.0	75.3	52.9
	May	24.7	43.0	33.0	28.8	69.6	45.2
	June	25.5	46.5	34.8	28.5	68.3	46.8

First sowing date (October 8, 1994 to January 26, 1995)
Second sowing date (February 8, 1995 to June 13, 1995)

Soil conditions

Initial soil analysis was achieved by collecting four random soil samples from the open field used for the two experiments at a depth of 0 - 30 cm. Soil texture using hydrometer, was performed as described by Day (1956) at 25 C using pyrophosphate as differential factor. Data of soil texture analysis were presented in Table (3).

Table 3. Soil texture analysis of Hada Al-sham experimental field.

For the determination of pH and EC, soil was mixed with water at 1:1 (W:V) rate using pH and EC meter. Total organic matter in the soil was also determined using Walkeley and Black's method as described by Jackson (1973). Total soil nitrogen content was estimated following Bremner's method (Bremner, 1965) using Kjeletec Auto 1030 analyzer. Total quantities of phosphorous and potassium were determined after they were extracted by digestion method with perchloric and nitric acids (Shelton and Harper, 1941). Phosphorous content was determined at light wavelength 640 nanometer using Turner Spectrophotometer (model 2000). Whereas potassium concentration was measured in the extraction using flame photometer (Corning 400). Data of soil analysis are tabulated in Table (4).

Table 4. Initial soil analysis of Hada Al-sham experimental field.

Nutritional element (g/kg soil)			Organic matter %	Ec (mm os/cm)	Soil pH
K	P	N			
2.1	0.115	0.3	0.484	0.415	8.36

Texture	Composition %		
	clay	silt	sand
sandy loam	12	12	76

Chicken manure analysis

The chicken manure, used in this study, was collected from the animal section of the Agricultural Research Station at Hada Al-Sham. The manure sample was air dried and stored in tight plastic bags until used for analysis. A sub sample was ground, passed through a 20-mesh sieve and stored in tight plastic bags until used in the laboratory analysis. The N, P and K were determined by the same methods used in the soil analysis .The initial contents of chicken manure analysis obtained are given in Table (5).

Table 5. Chemical composition of chicken manure used in the experiment.

Element	content (g/kg)
N	15.7
P	3.7
K	23.8
C	254.3
C:N	16.2:1

Land preparation and planting method

The experimental land was tilled using moldboard plow at a depth of 25 to 30 cm. The land was harrowed with disk harrows, leveled, and then divided into 24 plots, at three by three meters dimension.

Data Acquisition System was applied to record continuous observations for the different experiment variables: soil temperature at three different soil depths (5, 10 and 25 cm), air temperature and relative humidity. Different variable sensors were located at the decided depths through soil layers and at two-meter height above the soil surface. A data logger was connected with all the above sensors for continuous recording during the solarization period (Table 1).

Land was directly fertilized with chicken manure at 0, 10, 20 and 40 t/ha. The field experiment started with full water saturation condition by applying enough floodwater depths. This saturation process was followed for both solarized and non-solarized areas. Good heat conductivity was achieved by these full saturation processes over more than 25 cm soil depth. A 100-µ clear polyethylene sheet was used to cover half of the experimental area, while the other half was left uncovered to serve as control.

After the solarization experiment (when the plastic sheet was removed), the land was fertilized with triple superphosphate (46% P_2O_5) and potassium sulphate (50% K_2O). Both fertilizers were applied at a rate of 400 kg/ha as a single dose. Urea (46% N) was applied as a side dressing at a rate of 400 kg/ha at four equal doses in 15 days intervals during the growth period. In this respect, the first dose was applied 15 days from sowing, whereas the last dose was applied 60 days after sowing.

The experimental land was irrigated at sowing, and then, irrigation was applied according to the crop water requirement.

Each of the 24-bordered plots was divided into four ridges in 75 cm distance. Hills within ridges were 30 cm apart. At sowing, three corn seeds (AGA seed 215 cultivar) were planted per hill and after a full emergence they were thinned to a single seedling per hill.

Weight of yield and its characters

At the end of each sowing date, the whole crop was harvested and the total weight of the residual stovers, weight of ears, weight of kernels, and total dry yield of 20 plants were measured for each plot. In addition, total dry yield and its parts (kg/ha), harvest index, and shelling % were also estimated. Five ears from each plot were collected and their mean length, diameter and volume, and number of kernels/row, number of kernels/ear, number of rows/ear, mean weight of ears, and its parts (kernels and cobs), weight of 1000 kernels (kernel index) and protein content of kernels were also measured. Statistical analysis was performed using M-STAT program.

RESULTS AND DISCUSSION

Ear characters

Average values of ear diameter, ear volume, and number of kernels/row in the second sowing date were significantly lower than those of the first sowing date. On the other hand, there was no significant difference in ear diameter, ear volume, number of kernels/ear and number of kernels/row due to soil solarization or manure treatments (Table 6).

Ear length and ear volume was significantly affected by the interaction of sowing date and soil solarization. Figure (1-A and B) shows that ear volume and ear length are higher in solarized than in non-solarized treatment in both sowing dates.

Ear parts

Average values of the weight of kernels, cobs and ears in the second sowing date were significantly lower than those of the first sowing date (Table 6).

Weight of ears was significantly affected by the interaction of sowing date and soil solarization. Figure (2) shows that the weight of five ears was higher in solarized than non-solarized soil treatment for both sowing dates.

Yield dry matter and its parts

Average values of stovers and total yield dry matter were significantly higher in the first than the second sowing date (Table 7). The difference in the stovers and yield dry matter between the first and second sowing date was possibly due to the release of nutritive elements, particularly nitrogen, phosphorus and potassium, from the decomposition of chicken manure in the soil during the solarization that preceded the first sowing date as observed by Hinesly et al. (1979), Maynard (1994), Nishiwaki and Inoue (1996), Jackson and Smith (1997) and Ritz et al. (1997). The direct exposure of soil (solarized and non-solarized) to the sunlight during the summer for pest control might

have contributed to the difference observed in dry matter production, as indicated by Grosshevoy (1939), Raghaven (1964) and Katan (1981). Also, the difference in the environmental conditions between the two sowing dates, in terms of temperature (Table 1) (Mack et al. 1966) and light intensity (Leonard and Martin, 1963) might have contributed to the difference observed in the total yield dry matter production. In addition, the nitrogen uptake by corn plant was higher in the Fall than the Spring sowing date (Table 7) that might have increased stover and total yield dry matter.

However, there was no significant difference in stovers and Total yield dry matter due to soil solarization and chicken manure treatments. Also, there was no significant difference in weight of kernels, cobs and ears due to sowing date, soil solarization and chicken manure treatments (Table 7).

Soil amendment with different rates of chicken manure revealed no significant difference concerning all studied parameters (Table 6 and 7). These observations contradict with the observations of other researchers who indicated that an improvement of plant growth and yield of crops when animal manures were applied as soil amendment (Maynard, 1994; Jackson and Smith, 1997; Gamliel and Stapleton, 1997 and Ritz et al., 1997). It is possible that the fertilization of the field soil with triple superphosphate, potassium sulphate and Urea at a rate of 400 kg\ha gave enough requirement of nutrients for the corn plant and hence masked the effect of chicken manure.

The effect of soil solarization on total yield dry matter by the two successive sowing dates are shown in Figure (3). Soil solarization had higher values of total yield dry matter than in non-solarization treatment for both sowing dates. Similar results were observed by Ahmad et al. (1996), Habeebrrahman and Hosmani (1996), Keinath (1996), and Gamliel and Stapleton (1997).

Yield characters

The average value of the weight of 1000 kernels in the second sowing date was significantly lower than those o the first sowing date. The average value of the harvest index in the first sowing date was lower than the value in the second one (Table 7). On the other hand, there was no significant difference in the weight of 1000 kernels, harvest index, shelling % and protein content of kernels due to soil solarization and chicken manure treatment (Table 7).

Nitrogen Uptake

The average value of nitrogen uptake in the second sowing date (75.2) was significantly lower than the value in the first one (174.7 kg/ha) (Table 7). The difference in nitrogen uptake between the first and second sowing date was possibly due to the release of nutrient elements particularly nitrogen from the decomposition of chicken manure. Hinesly et al. (1979), Maynard (1994), Nishiwaki and Inoue (1996), Jackson and Smith (1997) and Ritz et al. (1997) indicated similar results.

The average value of nitrogen uptake in non-solarized soil (106.59) was lower than the value in solarized soil (143.35 kg/ha) Table (7). The increase in the nitrogen uptake due to solarization treatment might be occurred as a result of the competition of soilborne microorganisms and weeds with the plant for available nutrients and water. Similar results were observed by Ghini et al. (1993) and Habeebrrahman and Hosmani (1996). Soil solarization increased the soil content of nitrogen which might have increased the nitrogen uptake by the corn plant. This resulted in the increase in the stover and total yield dry matter. Similar results were found by Stapleton et al. (1985), Adetunji (1994), Arora (1998) and Arora and Yaduraju (1998).

The effect of soil solarization treatment on nitrogen uptake by two successive sowing dates of corn plant is shown in Fig. (4). The nitrogen uptake was significantly higher in the first than the second sowing date and in solarized than in non-solarized soil.

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تـأثير تشـميس التربـة و إضـافة زرق الـدجاج إليهـا علـى إنتاجيـة محصـول الذرةالشـامية (*Zea maize* L.) و امتصاصها للنيتروجين

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أقيمت تجربتان حقليتان في محطة الأبحاث الزراعية التابعة لجامعة الملك عبد العزيز بهدى الشام خلال موعدين زراعيين (خريف ١٩٩٤ و ربيع ١٩٩٥) على نبات الذرة الشامية (صنف أجا سيد ٢١٥) لدراسة تأثير تشميس التربة (تغطية التربة الحقلية المشبعة بالماء بشرائح البولي إيثيلين الشفاف أثناء الصيف لمقاومة أفات التربة), و معدلات مختلفة من زرق الدجاج (٠, ١٠, ٢٠ و ٤٠ طن/هكتار) على الوزن الكلي للمحصول و الكيزان و صفاتهما, بالإضافة إلى امتصاص نبات الذرة الشامية للنيتروجين في موعدين زراعيين. و قد أوضحت الدراسة أن موعد الزراعة الخريفية أعطى قيم أعلى من موعد الزراعة الربيعية في الصفات التالية: الوزن الكلي الجاف, وزن ١٠٠٠ حبة, قطر الكوز و حجمه, عدد الحبوب في الصف الواحد و وزن الكيزان (جم/١,٢ م^{٢})و أجزائها (حبوب و قوالح). أما بالنسبة لدليل الحصاد فقد وجد أن موعد الزراعة الربيعية أعطى قيم أعلى من موعد الزراعة الخريفية. و في المقابل وجد أن موعد الزراعة لم يكن له أي تأثير معنوي على وزن الحبوب و القوالح و الكيزان (كج/هكتار), نسبة التصافي و محتوى الحبوب من البروتين. كذلك لم يكن هنالك تأثير لتشميس التربة و إضافة زرق الدجاج إليها على صفات المحصول و الكوز و أجزائهما. و قد لوحظ أن هناك زيادة في الوزن الكلي الجاف لنبات الذرة الشامية و امتصاصها للنيتروجين في التربة المشمسة مقارنة بالتربة الغير مشمسة لكلا الموعدين الزراعيين.

Table 6. Ear characters and its parts of the two sowing dates of corn plant and their test of significance

Factor		Ear Characters						Ear Parts (g/1.2 m²)		
		Length (cm)	Diameter (cm)	Volume (cm^3)	Number of rows/ear	No. of kernels/ ear	No. of kernels/row	Weight of kernels	Weight of cobs	Weight of ears
Sowing date	1	15.91 A	5.11 A	329.81 A	12.96 A	439.60 A	33.88 A	688.34 A	183.25 A	871.59 A
	2	16.26 A	4.77 B	219.40 B	13.31 A	413.62 A	31.03 B	485.74 B	151.58 B	637.32 B
LSD		NS	0.11	18.59	NS	NS	1.67	44.4	14.48	54.64
Soil solarization	1	16.13 A	4.96 A	314.54 A	13.16 A	428.12 A	32.37 A	592.62 A	168.60 A	761.22 A
	2	16.05 A	4.91 A	306.66 A	13.12 A	425.09 A	32.53 A	581.47 A	166.23 A	742.70 A
LSD		NS	NS	NS	NS	NS	NS	NS	NS	NS
Chicken manure	1	16.51 A	5.05 A	326.25 A	13.20 A	429.77 AB	32.58 AB	605.87 A	185.00 A	790.87 A
	2	15.32 A	4.91 A	299.75 A	13.20 A	413.88 AB	31.60 AB	576.88 A	159.33 A	736.21 A
	3	15.75 A	4.85 A	293.51 A	12.93 A	407.21 B	30.92 B	558.12 A	157.10 A	715.22 A
	4	16.77 A	4.97 A	322.91 A	13.22 A	455.57 A	34.70 A	607.32 A	168.23 A	775.55 A
LSD		NS	NS	NS	NS	NS	NS	NS	NS	NS

Sowing date 1 = Fall, 2 = Spring. Soil solarization, 1 = Solarized and 2 = Non-solarized
Chicken manure (t/ha), 1 = 0, 2 = 10, 3 = 20 and 4 = 40 NS = Not significant
LSD = Least Significant Difference at 0.05 * Values holding the same letter are significantly at 0.05 not different

Table 7. Yield characters and its parts of the two sowing dates of corn plant and their test of significance.

Factor		Yield dry matter (kg/ha)					Nitrogen uptake	Protein content of	1000 Kernels weight	Harvest index	Shelling %
		Kernels	Cobs	Ears	Stovers	Total	(kg/ha)	kernels %	(kernel index)		
Sowing date	1	368.67 A	2055.56 A	11990.74 A	18129.63 A	32544.60 A	174.69 A	10.72 A	368.67 A	19.05 B	2 A
	2	257.75 A	1694.45 A	11402.78 A	8837.963 B	20240.74 B	75.23 B	10.19 A	257.75 B	27.40 A	48.09 A
LSD		NS	NS	NS	1033.7	1516.38	18.6	NS	0.89	3.03	NS
Soil solarization	1	315.55 A	1842.59 A	11935.19 A	13599.07 A	25534.26 A	143.34 A	10.82 A	315.55 A	22.59 A	46.84 A
	2	310.87 A	1907.41 A	11458.33 A	13368.52 A	24826.85 A	106.58 B	10.09 A	310.88 A	23.86 A	49.38 A
LSD		NS	NS	NS	NS	NS	18.63	NS	NS	NS	NS
Manure	1	8166.67 A	2027.78 A	11314.8 A	13564.82 A	24879.63 A	119.68 A	11.81 A	310.94 A	24.30 A	50.15 A
	2	5592.59 A	1870.37 A	11296.3 A	13759.26 A	25055.56 A	118.6 A	10.12 AB	320.13 A	24.10 A	50.51 A
	3	5666.67 A	1787.04 A	12148.12 A	13446.30 A	25594.45 A	133.03 A	10.08 AB	312.12 A	21.80 A	45.53 A
	4	5505.56 A	1814.82 A	12027.18 A	13164.81 A	25192.59 A	128.33 A	9.82 B	308.67 A	22.67 A	46.80 A
LSD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Sowing date 1 = Fall, 2 = Spring. Soil solarization, 1 = Solarized and 2 = Non-solarized Chicken manure (t/ha), 1 = 0, 2 = 10, 3 = 20 and 4 = 40 NS = Not significant, LSD = Least Significant Difference at 0.05

*** Values holding the same letter are significantly at 0.05 not different**