GREEN EAR YIELD IN CORN GROWN AFTER COWPEA INCORPORATION

PAULO SÉRGIO LIMA E SILVA[1], MANOEL XAVIER DOS SANTOS[2], PAULO IGOR BARBOSA E SILVA[3], RANOEL JOSÉ DE SOUSA GONÇALVES[4], HUDSON RAMALHO DA COSTA[3].

[1] *Professor adjunto. Esc. Sup. Agric. Mossoró (ESAM) – Departamento de Ciências Vegetais C. Postal 137, CEP 59625-900 Mossoró-RN. Bolsista do CNPq. E-mail: paulosergio@esam.br (autor para correspondência).*

[2] *Pesquisador da Embrapa Milho e Sorgo. C. Postal 151, CEP 35701 – 970 Sete Lagoas-MG. Bolsista do CNPq. E-mail: xavier@cnpms.embrapa.br*

[3] *Acadêmico de graduação do curso de Agronomia. ESAM. Departamento de Ciências Vegetais C. Postal 137, CEP 59625-900 Mossoró-RN. E-mail: paulosergio@esam.br*

[4] *Acadêmico de graduação do curso de Agronomia. ESAM. Departamento de Ciências Vegetais C. Postal 137, CEP 59625-900 Mossoró-RN. Bolsista de Iniciação Científica do CNPq E-mail: paulosergio@esam.br*

Revista Brasileira de Milho e Sorgo, v.4, n.2, p.215-223, 2005

ABSTRACT - Under irrigation, maize (*Zea mays* L.) can be grown throughout the year in Northeastern Brazil, which in many areas results in soil degradation. The renewed interest in the study of crop rotations with legumes is targeted at reducing this degradation. The objective of our work was to evaluate the green ear yields of three maize cultivars (AG 8080, AG 9010 and DKB 333B), after growing the Sempre-verde cowpea cultivar (*Vigna unguiculata* (L.) Walp.), incorporated at three different moments. Two sprinkler-irrigated experiments (one involving cowpea and the other with maize) were conducted. The following treatments were applied to the cowpea experiment, in a random block design with ten replicates: no cowpea cultivation; cowpea cultivation and incorporation into the soil at bloom time; or after four green bean harvests; or after three mature bean harvests (dry grains). The maize cultivars were grown in each of the four areas of each block in the cowpea experiment. Therefore, the maize experiment followed a split-plot design with treatments arranged as random blocks with ten replicates. In spite of the differences between the amounts of cowpea matter incorporated to the soil, there were no differences between the chemical characteristics of the soil at maize planting. The incorporation of cowpea at any time, or not, did not have an influence on the total number and weight of green ears and on the number and weight of marketable maize ears, both unhusked and husked. Cultivar AG 8080 presented the highest green ear yields.

Key words: *Zea mays, Vigna unguiculata*, green corn, green bean, crop rotation, organic fertilization.

RENDIMENTOS DE ESPIGAS VERDES DE MILHO CULTIVADO APÓS CAUPI

RESUMO - Com irrigação, o milho pode ser cultivado durante praticamente todo o ano, na região Nordeste do Brasil, o que, em muitas áreas, resulta em degradação do solo. O renovado interesse no estudo de rotações culturais com leguminosas tem como objetivo reduzir essa degradação. O objetivo do trabalho foi avaliar os rendimentos de espigas verdes de cultivares de milho (AG 8080, AG 9010 e DKB 333B) após o cultivo da cultivar de caupi Sempre Verde, incorporada ao solo em três épocas. Dois experimentos irrigados (um envolvendo caupi e o outro milho) foram realizados. Os seguintes tratamentos foram aplicados, no delineamento de blocos ao acaso, com dez repetições: sem cultivo de caupi e incorporação do caupi por ocasião do florescimento, ou após quatro colheitas do feijão verde, ou após três colheitas do feijão maduro. As cultivares de milho foram cultivadas em cada uma das áreas do experimento com caupi. Portanto, o experimento com milho seguiu o delineamento de parcelas subdivididas em blocos ao acaso, com dez repetições. A despeito das diferenças entre as quantidades de matéria seca de caupi incorporadas ao solo, não existiram diferenças entre as características químicas do solo, por ocasião do plantio do milho. A não-incorporação do caupi ou sua incorporação, em qualquer época, não teve influência sobre o número e o peso totais de espigas e o número e peso de espigas comercializáveis, empalhadas e despalhadas. A cultivar AG 8080 apresentou os maiores rendimentos.

Palavras-chave: *Zea mays, Vigna unguiculata,* feijão verde, milho verde, rotação cultural, adubação orgânica.

Maize (*Zea mays* L) and cowpea (*Vigna unguiculata* (L) Walp.) are grown in the State of Rio Grande do Norte for green or dry grain yield. The green maize grains show a moisture content ranging between 70% and 80%, while cowpea grains have a moisture content from 60% to 80%. Green and dry grains of both crops are very popular products in the diet of Brazilian northeasterners.

Repeated maize cultivation , which is made possible under irrigation and with the intensive use of chemical products, result in physical, chemical, and biological soil degradation (Lal and Stewart, 1990) in several areas. Physical degradation results in deterioration of soil properties that influence water infiltration and plant growth. Chemical degradation implies a rapid decline in soil quality. Nutrient depletion, acidification, and salinization are processes that reduce crop yields. Biological degradation includes reductions in organic matter content, decreases in the amount of carbon in the biomass, and decreased soil fauna activity and diversity. Biological degradation is perhaps the most serious form of soil degradation because it affects soil life and because organic matter affects the physical and chemical properties of the soil. It is usually more serious in semiarid regions because of high soil and air temperatures (Stewart & Robinson, 1997).

Soil degradation maintains a close relationship with the agro-ecosystem sustainability, i.e., the ability an agro-ecosystem has to maintain productivity when subject to salinity, toxicity, erosion, etc. (Squires, 1991). Soil organic matter conservation in semiarid regions is one of the most important limiting factors for sustainability development (Stewart & Robinson, 1997).

Crop rotations involving legumes-maize or legumes-other crops were common in the past in several regions. Studies have shown that maize rotation or intercropping with legumes provided positive effects on yield (Hesterman et al., 1986a), with economical benefits as well (Hesterman *et al*., 1986b). Such positive effects were due to improvement in the physical (Cintra & Mielnickzuk, 1983) and chemical (Ceretta *et al*., 1994) properties of the soil. Those results indicated that the effect of legumes is excellent in repeatedly cultivated soils and that the practice of green fertilization is highly viable (De-Polli and Chada, 1989). The renewed interest (Ceretta *et al*., 1994; Teixeira *et al*., 1994) in the study of crop rotation with legumes is a result of factors related to agriculture sustainability (MacRae et al., 1990): degradation of agricultural resources, costs reduction, interest in obtaining better quality foods, and preventing quality of life deterioration in rural communities.

Because of the adaptation and importance of cowpea to northeastern Brazil, we considered growing this crop in rotation with corn, in order to reduce soil problems caused by the intensive exploitation of this grass. The use of this legume is recommended (Oliveira & Carvalho, 1988) for the recovery of soils with poor natural fertility, or that have been depleted by intensive use, a common occurrence in the region. Since cowpea is explored in the area for the production of green and dry grain, this work was planned to study cowpea incorporation at different seasons. In other words, we planned to make incorporations at flowering, as usually done with legumes (Alcântara *et al*., 2000), or after harvesting the kernels, either green or dry. In the two latter cases, the farmer would obviously count on extra income from selling the grain.

This work had the objective of evaluating the green ear yields of three maize cultivars after cultivation of cowpea incorporated at three different moments.

Material and Methods

Two sprinkler-irrigated experiments (one involving cowpea and the other with maize) were conducted at Fazenda Experimental “Rafael Fernandes”, of Escola Superior de Agricultura de Mossoró (ESAM), located 20 km from the municipal seat of Mossoró-RN, Brazil. Information on the region climate were summarized by Carmo Filho & Oliveira (1989). Table 1 presents the data for some weather factors that occurred during the experimental period.

The physical analysis of a soil sample from the experiment area, a Red-Yellow Argisol, cultivated for over ten years with maize, indicated moisture retention of 12.48 (at 0.01 Mpa) and 3.59 (at 1.5 Mpa) and an apparent density of 1.32 Mg m^{-3}, and the following granulometric fractions (g kg^{-1}): 522 coarse sand, 338 fine sand, 84 silt, and 56 clay. The chemical analysis of the same sample showed: pH, in water = 6.9; P = 37 mg kg^{-1} soil; $K^{+} = 0.42\ {}_{c}mol_{c}dm^{-3}$; $Ca^{2+} = 3.9\ {}_{c}mol_{c}dm^{-3}$; $Mg^{2+} = 2.1$ $cmolcdm^{-3}$; $Al^{3+} = 0.0$ $cmolcdm^{-3}$; Na+ = 0.27 $cmolcdm^{-3}$ and 9.4 g kg^{-1} organic matter.

The following treatments were applied to the cowpea experiment, in a random block design with ten replicates: no cowpea cultivation; cowpea cultivation and incorporation into the soil at bloom time; or after four green bean harvests; or after three mature bean harvests (dry grains). The cowpea cultivar utilized was Sempre-verde, which has indeterminate growth, and incorporation was made with a hoe. The treatments were evaluated in 12 m × 7 m plots. The soil was tilled by means of two harrowings and was not fertilized. Planting was done on 8/15/01, with four seeds/pit, at a 1 m × 1 m row spacing. Thinning was performed 30 days after planting, leaving the two more vigorous plants in each pit. The crop was hoed for weeds at 25 and 45 days after planting. The green and dry kernel harvests were done manually as the grain reached the “ideal harvest time”. Before incorporation, eight plants were cut even with the ground and weighed for fresh and dry matter yield evaluation. Dry matter evaluation was performed by the oven method, utilizing a 500 g sample of crushed material. After evaluation, the material was returned to the experiment area where it had been removed from. A soil sample from each plot cultivated with cowpea was removed one day after the soil had been tilled to be planted with maize.

Soil tillage for maize consisted of two harrowings, and was performed one month after incorporation of the cowpea plants that yielded green or dry kernels. Fertilization at planting consisted of the application of 30 kg N, 60 kg P_2O_5 and 30 kg K_2O, per hectare, in furrows located beside and below the seeding furrows. The sources of nitrogen, phosphorus and potassium were ammonium sulfate, single superphosphate and potassium chloride, respectively. Planting was performed with four seeds per pit, at a 1.0 m × 0.4 m row spacing, on 1/4/02. Therefore, 90, 65, and 60 days had elapsed from cowpea incorporation at flowering, or after the green kernels were harvested, or after the dry grain were harvested until the corn was planted, respectively. The corn cultivars (AG 8080, AG 9010, and DKB 333B) used are simple hybrids that yield semiflint, orangish-yellow grain. In the region where these experiments were conducted, the three cultivars showed grain yields higher than 6,000 kg ha^{-1} and plant heights around 170 cm, 140 cm, and 175 cm, respectively. The corresponding ear heights are 100 cm, 80 cm, and 115 cm.

The cultivars were grown in each one of the four areas in each block in the cowpea experiment. Therefore, the maize experiment followed a split-plot design with treatments arranged as random blocks with ten replicates. Each plot consisted of three 6.0 m long rows. The usable area was the one occupied by the central row, with the elimination of one pit at each end. A thinning operation was performed 28 days after planting, leaving two plants/pit. Pest control was achieved with two deltamethrin sprays (250 ml/ha), at 25 and 30 days after planting. Weeds were controlled by hoeing 20 and 45 days after planting. Sidedressing with 30 kg N/ha was done after the first hoeing. Green maize yield was evaluated by the number and total weight of unhusked green ears, and by the number and weight of both marketable unhusked and husked ears. Marketable unhusked ears were considered as those with a length equal to or above 22 cm and that showed an appearance suitable for commercialization. Marketable husked ears were considered as those that displayed grain set and health suitable for commercialization, and with a length equal to or above 17 cm.

The statistical analysis of the data was done according to recommendations by Zar (1999).

Results and Discussion

The green beans were harvested from 60 to 69 days after planting. The dry grains were harvested from 69 to 76 days after planting. The mean cowpea green pod, green kernel (immature grain) and dry grain (mature grain) yields (mean ± standard deviation of the mean) were, respectively: 2632 ± 281, 1621 ± 174, and 1262 ± 136 kg ha^{-1}. The pod and green kernel yields were lower than those obtained by other authors; however, dry grain yield was comparable (Oliveira *et al*., 2002).

The mean fresh matter mass values in the above-ground part of the cowpea plants incorporated at flowering, after green bean harvesting, and after mature bean harvesting, were 11,800 kg ha^{-1}, 19,600 kg ha^{-1} and 20,160 kg ha^{-1}, respectively. There were no differences between fresh matter mass values after green bean or mature bean harvesting, but both surpassed fresh matter mass at flowering. Similar behavior occurred with regard to dry matter mass. The mean dry matter mass yield values for the above-ground part of incorporated cowpea plants at flowering and after green bean, or mature bean harvesting were, respectively, 1,557 kg ha^{-1}, 3,529 kg ha^{-1} and 3,786 kg ha^{-1}. Since the cowpea cultivar utilized has indeterminate growth, after flowering the plants continue to grow, even more so because they were irrigated, which explains the greater fresh and dry matter yields in the above-ground part of the plants, after green bean or dry bean harvesting. The analysis of a sample from the above-ground part of the cowpea plants at flowering indicated, in percentages: 0.76 P, 2.31 K, 0.06 Na, 3.92 Ca, and 0.37 Mg. The corresponding values for plants after green bean harvesting were: 0.80, 2.41, 0.04, 1.44, and 1.95. In plants harvested after mature bean harvesting, values were 0.76, 2.03, 0.03, 4.08, and 0.34, respectively. These values are higher than those determined by Calegari (1995) and by Ferreira (1996) in several legumes.

In spite of the differences between the amounts of cowpea matter incorporated to the soil, there were no differences between the chemical characteristics of the soil at maize planting (Table 1). Probably the differences in time at which cowpea incorporation was performed contributed to explain this observation. Alcântara *et al*. (2000) made evaluations of soil samples at three different times (90, 120 and 150 days after management) to determine the performance of pigeon pea (*Cajanus cajan* (L.) Millsp.) and sunn hemp (*Crotalaria juncea* L.) for soil recovery. They verified that pigeon pea had a better performance on the first evaluation and sunn hemp performed better on the second. On the third evaluation no beneficial green fertilizer effects were found in the chemical properties of the soil. The chemical compositions of most crops are subject to great alterations during their growth period. When the plant

TABLE 1. Soil chemical analysis results without or with cowpea incorporation at three different moments[1].

Cowpea incorporation	pH (1:2.5)			Ca	Mg	K	Na	Al	P	Sorptive	Org. Matt.
	Water	KCl	$CaCl_2$	------------------		cmol$_c$ dm^{-3}		------------	(mg dm^{-3})	Compl. (S)	(%)
Without	7.8	6.6	7.1	5.4	2.2	0.61	0.40	0.0	104	8.60	20.1
After flowering	7.7	6.5	7.0	5.5	2.3	0.64	0.38	0.0	110	8.78	21.2
After green bean production	7.7	6.5	7.0	5.7	2.3	0.62	0.34	0.0	117	8.90	17.1
After mature bean production	7.7	6.5	7.0	5.4	2.3	0.58	0.36	0.0	112	8.63	25.5
Means	7.7	6.5	7.0	5.5	2.3	0.61	0.37	0.0	111	8.73	21.0
Coefficient of variation, %.	2	3	2	15	20	17	21	-	20	13	35

[1]There were no differences between treatments, at 5% probability, by Tukey test.

matures, its protein contents and water-soluble constituents decrease, while its amounts of hemicellulose, cellulose and lignin increase. In general, the water-soluble fractions are degraded first, followed by structural polysaccharides, and then by lignin. The residues from immature plants are more rapidly decomposed than residues from older plants, releasing more nutrients (Kumar and Goh, 2000). From this point of view, cowpea incorporation at flowering would be more advantageous, but the continued irrigation might have contributed, at least in part, to leach the released nutrients. In addition, plants incorporated at a later time grew more, thus accumulating more organic matter. Results from experiments that study the effects of plant residue management on crop yields are many times conflicting, since many factors related to residue quality, cropping, soil practices and climatic factors (Table 2) are involved (Magdoff *et al*., 1997).

Again, no differences were observed between green ear yields of maize grown without or after cowpea incorporation at different times (Table 3). It is important to note that the crops

TABLE 2. Values for some climatic factors in pertinent months of 2001/02 in Mossoró, RN, Brazil.

Month	Max. air temperature (°C)	Min. air temperature (°C)	Relative humidity (%)	Precipitation (mm)	Piche evaporation (mm)	Mean wind speed (m/s)	Insolation (h month^{-1})
August	34.8	21.2	58.2	2.2	7.7	4.6	97
September	35.4	22.6	62.2	0.0	8.6	7.7	10.1
October	35.0	23.7	63.4	0.0	8.3	5.9	9.3
November	34.8	24.2	65.7	0.0	8.1	5.5	9.5
December	35.6	23.4	67.1	7.8	8.1	5.7	8.3
January	31.1	25.6	83.3	328.6	3.3	2.1	6.4
February	33.6	22.5	76.6	41.7	5.8	2.8	8.3
March	32.7	23.7	82.6	282.5	4.6	2.6	8.6

TABLE 3. Green ear yield means in three maize cultivars grown without or with cowpea incorporation at three different moments[1].

Cowpea incorporation	Total no. of green ears ha^{-1}	Total green ear weight (kg ha^{-1})	No. marketable unhusked ears ha^{-1}	Marketable unhusked ear weight (kg ha^{-1})	No. marketable husked ears ha^{-1}	Marketable husked ear weight (kg ha^{-1})
Without	48,859	13,021	45,597	12,485	42,678	7,441
After flowering	49,851	13,054	45,928	12,610	43,016	7,441
After green bean production	49,882	13,249	46,379	12,590	42,338	7,271
After mature bean production	49,735	13,386	44,192	12,526	41,408	7,376
Means	49,582	13,178	45,524	12,553	42,360	7,382
Coeff. variation, % (plots)	6	9	12	13	13	14

[1]There were no differences between treatments, at 5% probability, by Tukey test.

were irrigated. Therefore, in plots where cowpea was not cultivated, the weeds must have grown bigger than in plots containing cowpea plants. Hoeing obviously represents a way of incorporating diversified plant material to the soil. According to Magdoff *et al* (1997), when several sources of plant residues are incorporated to the soil, they promote greater biodiversity in terms of soil organisms, which could be beneficial to the crop. In addition, Vasquez *et al*. (2003) verified that weed decomposition was slower than crop residue decomposition. Similarly as in this work, Ferreira (1996) also did not find grain yield differences in maize grown without or after incorporation of several legumes. Santos and Lhamby (2001) also did not observe any effects of crop rotation on maize grain yield.

There were significant differences between cultivars only with regard to total weight and marketable unhusked ear weight (Table 4). Cultivar AG 8080 was superior with respect to both traits.

There has been great interest in cowpea consumption in the region where this work was carried out. Although no differences between cowpea incorporation seasons were observed, incorporation after the green or dry kernels are harvested would allow an extra source of income for the farmer in relation to incorporation after flowering. It must also be highlighted that the work was carried out considering a single crop rotation cycle. It is possible that repeated rotation cycles provide greater benefits to corn when grown after cowpea. Data obtained by other authors (Mascarenhas *et al*., 1998) support this possibility.

Conclusions

Cowpea incorporation does not change the concentrations of the main nutrients in the soil, and does not interfere with green corn yield. Cultivar AG 8080 presented the highest green ear yields.

TABLE 4. Green ear yield means in three maize cultivars grown without or with cowpea incorporation at three different moments[1].

Cultivars	Total no. of green ears ha^{-1}	Total green ear weight ($kg\ ha^{-1}$)	No. marketable unhusked ears. ha^{-1}	Marketable unhusked ear weight. ($kg\ ha^{-1}$)	No. marketable husked ears. ha^{-1}	Marketable husked ear weight ($kg\ ha^{-1}$)
AG 9010	49,979 a	12,454 b	44,747 a	11,844 b	41,881 a	7,317 a
AG 8080	49,601 a	13,967 a	46,708 a	13,396 a	42,146 a	7,351 a
DKB 333B	49,165 a	13,112 ab	45,117 a	12,419 b	43,303 a	7,387 a
Means	49,582	-	45,524	-	42,360	7,382
Coeff. variation, % (subplots)	6	9	10	10	12	13

[1]Means followed by a common letter are not different among themselves at 5% probability by Tukey test.

Literature Cited

ALCÂNTARA, F. A. de; FURTINI NETO, A. E.; PAULA, M. B. de; MESQUITA, H. A. de; MUNIZ, J. A. Adubação verde na recuperação da fertilidade de um Latossolo Vermelho-Escuro degradado. **Pesquisa Agropecuária Brasileira**, Brasília, v. 35, n. 2, p. 277-287, 2000.

CALEGARI, A. **Leguminosas para adubação verde de verão no Paraná**. Londrina: IAPAR, 1995. 118 p. (IAPAR.Circular, 80).

CARMO FILHO, F. do; OLIVEIRA, O. F. de. **Mossoró**: um município do semi-árido nordestino. Mossoró: ESAM, 1989. (ESAM.Coleção Mossoroense B, 672).

CERETTA, C. A.; AITA, C.; BRAIDA, J. A.; PAVINATO, A.; SALET, R. L. Fornecimento de nitrogênio por leguminosas na primavera para o milho em sucessão nos sistemas de cultivo mínimo e convencional. **Revista Brasileira de Ciência do Solo**, Campinas, v. 18, p. 215-220, 1994.

CINTRA, F. L. D.; MIELNICZUK, J. Potencial de algumas espécies vegetais para a recuperação de solos com propriedades físicas degradadas. **Revista Brasileira de Ciência do Solo**, Campinas, v. 7, p. 197-201, 1983.

DE-POLLI, H.; CHADA, S. de S. Adubação verde incorporada ou em cobertura na produção de milho em solo de baixo potencial de produtividade. **Revista Brasileira de Ciência do Solo**, Campinas, v. 13, p. 287-293, 1989.

FERREIRA, A. M. **Efeitos de adubos verdes nos componentes da produção de diferentes cultivares de milho**. 1996. 70 F. Dissertação (Mestrado) – Universidade Federal de Lavras, Lavras.

HESTERMAN, O. B.; SHEAFFER, C. C.; BARNES, D. K.; LUESCHEN, W. E, & FORD, J. H. Alfafa dry matter and nitrogen production, and fertilizer nitrogen response in legume corn rotations. **Agronomy Journal**, Madison, v. 78, p. 19-23, 1986a.

HESTERMAN, O. B.; SHEAFFER, C. C.; FULLER, E. I. Economic comparisons of crop rotations including alfafa, soybean and corn. **Agronomy Journal**, Madison, v. 78, p. 24-28, 1986b.

KUMAR, K.; GOH, K. M. Crop residues and management practices: effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. **Advances in agronomy**, San Diego, v. 68, p. 197-319, 2000.

LAL, R.; STEWART, B. A. Soil degradation: a global threat. **Advances in Soil Science**, San Diego, v. 11, p. 13-17, 1990.

MacRAE, R. J.; HILL. S. B.; MEHUYS, G. R.; HENNING, J. Farm-scale agronomic and economic conversion from conventional to sustainable agriculture. **Advances in Agronomy**, San Diego, v. 43, p. 155-198, 1990.

MAGDOFF, F.; LANYON, L.; LIEBHARDT, B. Nutrient cycling, transformations and flows: implications for a more sustainable agriculture. **Advances in Agronomy**, San Diego, v. 60, p. 1-73, 1997.

MASCARENHAS, H. A. A.; NOGUEIRA, S. S. S.; TANAKA, R. T.; MARTINS, A. L. M.; CARMELLO, Q. A. C. Efeito na produtividade da rotação de culturas de verão e crotalária no inverno. **Scientia Agrícola**, Piracicaba, v. 55, n. 3, p. 534-537, 1998.

OLIVEIRA, I. P.; CARVALHO, A. M. A cultura do caupi nas condições de clima e solo dos trópicos úmidos do semi-árido do Brasil. In: ARAÚ-

JO, J. P. P.; WATT, E. E. (Org.). **O caupi no Brasil**. Brasília, DF: IITA: EMBRAPA, 1988. p. 63-96.

OLIVEIRA, A. P. de, TAVARES SOBRINHO, J.; NASCIMENTO, J. T.; ALVES, A.U.; ALBUQUERQUE, I. C. de; BRUNO, G. B. Avaliação de linhagens e cultivares de feijão-caupi, em Areia, PB. **Horticultura Brasileira**, Brasília, v. 20, n. 2, p. 180-182, 2002.

SANTOS, H. P. dos; LHAMBY, J. C. B. Rendimento de grãos de milho e sorgo em sistemas de rotação de culturas. **Pesquisa Agropecuária Gaúcha**, Santa Maria, v. 7, n. 1, p. 49-58, 2001.

SQUIRES, V. R. A systems approach to agriculture. In: SQUIRES, V. R.; TOW, P. (Ed.). **Dryland farming**: a systems approach. SouthMelbourne: Sidney University Press, 1991. 591 p.

STEWART, B. A.; ROBINSON, C. R. Are agroecosystemns sustainable in semiarid regions? **Advances in Agronomy**, San Diego, v. 60, p. 191-228, 1997.

TEIXEIRA, L. A. J.; TESTA, V. M.; MIELNICZUK, J. Nitrogênio do solo, nutrição e rendimentos de milho afetados por sistemas de cultura. **Revista Brasileira de Ciência do Solo**, Campinas, v. 18, p. 207-214, 1994.

VASQUEZ, R. I.; STINNER, B. R.; McCARTNEY, D. A. Corn and weed residue decomposition in northeast Ohio organic and conventional farming. **Agriculture, Ecosystems and Environment**, Amsterdam, v. 95, n. 2-3, p. 559-565, 2003.

ZAR, J. H. **Biostatistical analysis**. 4. ed. Englewood Cliffs: Prentice Hall, 1999. 663 p. (Prentice-Hall Biological Sciences Series).