Nitrogen application on maize cultivated under no-tillage system in a year with normal precipitation and with “el-niño”

Dolores Wolschick, Reimar Carlesso, MirtaTerezinha Petry e Sidnei Osmar Jadoski

Abstract

In this study the split application of nitrogen and the maize crop pre-sowing nitrogen application under a no-tillage system followed by black oat, with two rainfall regimes were evaluated. Treatments were: 1. application of 150 kg N ha^{-1} in pre-sowing and 30 kg N ha^{-1} at sowing with 1997/98 “El-Niño” rainfall simulation; 2. nitrogen application (CFS RS/SC, 1994), being 30 kg N ha^{-1} at sowing, and 30 kg N ha^{-1} at 31 and 57 days after emergency (DAE), with “El-Niño” rainfall simulation; 3. without N application and “El-Niño” rainfall simulation and; 4. nitrogen application (CFS RS/SC, 1994), with normal rainfall simulation. The experiment was conducted during 1998/99 growing season, at the Federal University of Santa Maria, in a completely randomized design, with two replications. A set of eight drainage lysimeters was used, protected from natural rainfall through an arch rain shelter. Leaf area index, plant height, above ground dry matter, grain yield and percent of N in maize grain and dry matter were evaluated. Nitrogen application on both water regimes had no effect on plant leaf area index, plant height, grain yield, percent of N in grains and N translocated to grains. Above ground dry matter and the amount of N carried out to shoot were smaller for the treatments submitted to normal rainfalls, compared to the ones that received N applications and “El-Niño” rainfalls.

Key words: nitrogen fertilization; soil cover; climate anomalies.

Introduction

The type of vegetable residue in decomposition on the soil surface, under a no-tillage system, can affect the follow tillage nitrogen application efficiency. A great part of the tilled areas under a no-tillage system in Rio Grande do Sul State make use of black oat as soil cover plant, in the winter (PÖTTKER e ROMAN, 1994). Nevertheless, because of the relationship between carbon/nitrogen (C/N) of its residue, the N balance in the soil can be affected, when maize crop is followed, since the soil N immobilization, decreasing the availability for maize initials stages of development.

In the beginning of the maize growing, a small quantity of N is necessary. But, according to Ritchie et al. (1993), since the root is not so developed, just a small area of the soil is explored: thus, a great concentration of N is necessary close to the small root, whereas, is in this period that the parts of the plant are distinguished. The leaves and cobs size and other parts of the plant are defined.

So, the lack of N in this period can decrease the grain yield.

The grains formation in the maize crop is related to the translocation of sugar (CRAWFORD et al., 1982) and of N (KARLEN et al., 1988) of vegetative organ, manly the leaves, for the grains.

So, the grain yield is related to the leaf photosynthetic active area of the plant. Leaves well nourished in N have greater capacity to assimilate CO2 and synthesize carbohydrates during photosynthesis, resulting in greater accumulation of dry mass and increased grain yield.

Thus, when using black oat as soil cover plant, in the winter, and maize crop, in the summer, nitrogen application that provides N to the plant during the initials stages of development should be chosen. An alternative is the maize crop pre-sowing nitrogen application, counterbalancing the initial immobilization caused by microorganisms of the soil, discharging more rapidly the nutrients in the soil and satisfying both, the decomposer microorganisms’ necessity of N and the maize plants.

The maize grains yield with the nitrogen application under a no-tillage system, with black oat as soil cover plant, was higher in relation to the traditional management (splitting of N) in years with normal distribution of the rainfall simulation (SÁ, 1996; CERETTA et al., 1997; BASSO, 1999). In the occurrence of intense rainfall simulation, as observed during the phenomenon called "El Niño", in the 1997/98 growing season, the grains yield was inferior in relation to the traditional management of nitrogen application (DIEKOW et al., 1998; BASSO, 1999). The authors relate this fact to the losses of N through the leaching of nitrate, because of the intense and frequent rainfall simulation that mainly occurred during management period (drying and incorporation of the residue) of the soil cover plants to the initials stages of the maize development.

In the south part of the American South Continent, the influence period of the hot phase of the "El Niño" about the rainfall simulation is from November of the phenomenon occurrence to February of the next year (ROPELEWISKI e JONES, 1987). In Rio Grande do Sul, the influence is bigger in the western part of the State where the agriculture has increased expression. The October and November months are more affected, with medium rainfall simulation for the hot phase ("El Niño), cold ("La Niña") and for the climatic average of 300, 172 and 256 mm, respectively. Besides making difficult the management of the N in the region, the "El Niño" phenomenon also causes the sowing period delay, reduction of the luminosity (solar radiation) for the tillage, harvest time difficulties, the grains quality and quantity reduction and it also causes the soil aeration.

The relationship between the intense and frequent rainfall simulation and the production can help the decision process, with the meaning of minimize the weather impact, especially during the grains production and the rainfall resources protection. The maize plants behavior in relation to the climatic changes and the nitrogen application can help the right nitrogen application management under a no-tillage system. The objectives of this research were to verify the morphologic changes and the maize grains yield and determine the quantity of N translocated to the aerial part of the maize plant submitted to the split application of nitrogen and the maize crop pre-sowing nitrogen application with two rainfall regimes.

Material and methods

The experiment was conducted during 1998/99 growing season, with a set of eight drainage lysimeters with dimension of 1,40 x 0, 95 m depth of 1,40 m, in the experimental area of the Rural Engineering Department at the Federal University of Santa Maria, Santa Maria-RS, with the geographic coordinates: latitude 29°41'24"S; longitude 53°48'42"W; and average altitude of 95 m. The weather in the region is moist subtropical, type Cfa 2, according to the Köppen (MORENO, 1961) classification, the coldest month temperature oscillates between -3°C and 18°C; the hottest month temperature is superior to 22°C and the annual average precipitation is 1769 mm.

The lysimeters soil is classified as Argissolo Vermelho-Amarelo distrófico arênico (EMBRAPA, 1999), and has been managed under a no-tillage system since 1994. In the winter of the previous year of the experiment installation (1997) the lysimeters were cultivated with black oat (*Avena strigosa*) and vetch (*Vicia sativa* L.); from October of 1997 to February of 1998, the lysimeters were put with maize and, from February to May (little harvest), with bean and next black oat was used as the winter soil cover plant. When natural rainfall precipitation occurred the dry lysimeres were protect through an arch rain shelter.

The experimental design was a completely randomized design, with four treatments and two repetitions. The tested treatment were: 1. application of 150 kg N ha^{-1} in pre-sowing and 30 kg N ha^{-1} at sowing with 1997/98 "El-Niño" rainfall simulation; 2. nitrogen application according to the Soil Fertility Commission (CFS RS/SC, 1995), being 30 kg N ha^{-1} at sowing, and 30 kg N ha^{-1} at 31 and 57 days after emergency (DAE), with "El-Niño" rainfall simulation; 3. without N application and with "El-Niño" rainfall simulation and; 4. nitrogen application according to the Soil Fertility Commission (CFS RS/SC, 1995), with normal rainfall simulation like the applications that occurred in the year of 1996/97 (October of 1996 to February of 1997). The treatments two and four correspond to the traditional management of maize nitrogen application and the treatment three was considered as the control treatment.

Normal rainfall simulation like the applications that occurred in 1996/97 were utilized, because the monthly precipitated volume was similar to the mensal average of the last 30 years (1961 to 1990) in the region (Figure 1), and for the impossibility to utilize the average of various years to simulate daily rainfall precipitations, due to the variability of distribution and intensity.

The type of N utilized was urea, with throwing applications followed by irrigation. The application of 150 kg N ha^{-1} in the treatment with pre-application of N was realized seven days before the maize sowing (November 20th 1998). This date corresponds to October 1st 1997 for the treatment with application of precipitations like the "El Niño" and October 1st 1996 for the treatment with application of precipitations like the growing season of 1996/97. From this date, all the daily rainfall precipitations that occurred from October to February of each growing season selected were applied.

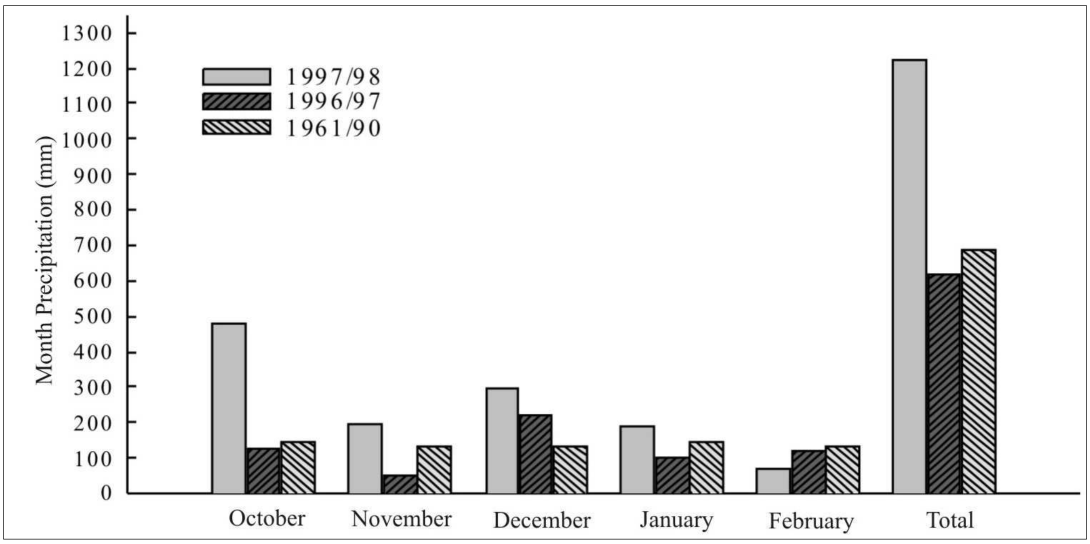
The total precipitated every day was applied all together through a dripping system.

The cultivar Pioneer 3069 maize sowing was realized manually on November 27th 1998, under a no-tillage system, in lines, with a population of 60.000 plants ha^{-1}, with distance between rows of 1.0 m. The fertilizer with phosphorus and potassium was carried out according to the analysis of soil and following recommendations of the Commission for Soil Fertility – CFS RS/SC (1995), for maize crop.

December 03rd 1998, was considered the plants emergence date, when 50% of them had emerged. The tillage development stages were identified in relation to the days after emergence, according to the scale offered by Ritchie et al. (1993). After the emergence, three plants per lysimeters were selected for determinations not destructive of the leaf area, plants height and leaf senescence. The determinations were realized twice a week, during the tillage development cycle.

The leaf area of the plants was carried out since the emergence of the leaves of the cartridge until the emergence of the sheath and was determined from the measurement of the length and width maximum, multiplied by the factor 0.75 (STICKLER et al., 1961). The senescence observations were visually realized, in each leaf, establishing a scale of 0 to 100% that corresponds to the leaves totally green and totally senescent, respectively. Discounting the senesced percentage in each leaf, the photosyntheticvely active area of the plant (leaf area) was gotten. The leaf area index was determined by the plant leaf area and the soil superficial area uses by the plant. The plants height was measured from the soil surface up to the highest sheath of the plant.

Figure 1. Monthly values of the rainfall precipitations in the growing season of 1997/98 ("El Niño"), in the growing season of 1996/97 (year considered as normal) and the average of thirty years, from 1961 to 1990.



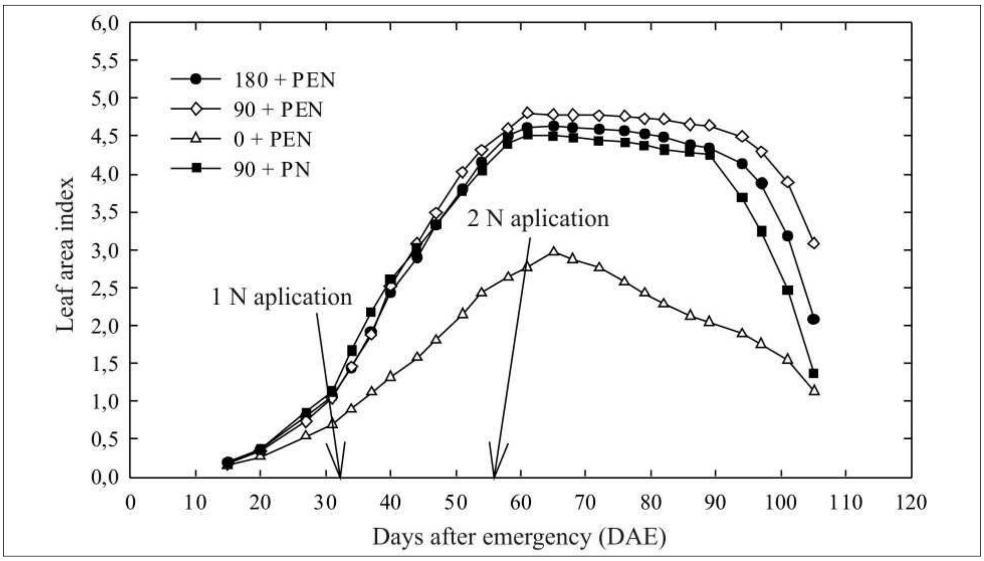
The harvest of the selected plants in each lysimeter was realized manually on the 127th DAE, separated in leaves, stems and corncobs, they were put in the oven with a temperature of 65°C, until constant weight. The pulp of the ear was determined individually, and afterwards divided in husk, corncob and kernels. After the drying and weighting, the N percentage of each plant component was determined. The samples were ground into a small crusher feed and then on Willey mill fitted with 40-mesh sieve. The N percentage was determined joining 0,2 grams of vegetal tissue with H_2SO_4 and joining mixture (Na_2SO_4 and $CuSO_45H_2O$)) and then boiling with NaOH in drag steam distiller of semi-micro Kjeldahl (TEDESCO et al., 1985). The total N absorbed and translocated to the shoot was gotten through the multiplication of the shoot dry weight by the N percentage in the plant tissue.

The results of the leaf area index, plants height, dry weight, N percentage and total N were submitted to analyses of the variance e averages comparison through the Duncan test, probability of 5%.

Results and discussion

In the figure 2 are represented the leaf area indexes of the maize plants during the tillage development. In the period from 34 to 37 DAE, just the plants of the treatment with normal rainfall precipitation showed leaf area index values superior to the plants without nitrogen application (Table 1). The delay in the plants development of the treatments with nitrogen application and "El Niño" rainfall precipitation, compared to those plants of the treatment with normal rainfall precipitation, probably was due to elevated rainfall precipitation in the beginning of the development cycle. The excess of water causes aeration in the distribution region of the root system of the plant, making difficult the gasses exchange in the soil. These problems result in difficulties for the plant to absorb the water and nutrients, as a consequence, the reduction of the productive potential. From the 40th DAE to the end of the tillage system, it was not observed statistic difference between the plants of the treatment with nitrogen application, just the plants that did not receive nitrogen application leaf area index values statistically inferior to the others treatments (Figure 2 and Table 1)

Figure 2. Variation of leaf area index during the maize development cycle. [150 kg de N ha-1 pre-sowing and 30 kg of N ha-1 in the sowing plus "El Niño" (180 + PEN); 30 kg of N ha-1 in the sowing and 30 kg of N ha-1 on the 31 and 57 DAE plus "El Niño" (90 + PEN); N application plus "El Niño" (0 + PEN) and; 30 kg of N ha-1 in the sowing, 30 kg of N ha-1 on the 31 and 57 DAE plus normal precipitation (90 + PN)].



It was observed accelerated leaf senescence from the 90 DAE in the plants that received nitrogen application, when the plants were in the farinaceous grain stage. In this stage, the kernels have about 70% of water; they have already accumulated half of the dry weight, the leaf senescence is a natural process from this stage. On the control treatment (without N), accelerated senescence was observed right after the plants had gotten the maximum leaf area index, showing reduced leaf area index values during the grain filling stage. In this stage the maintenance of the maximum leaf area index, with elevated photosynthetic capacity, is essential for achieving high yields of grains (ALESSI and POWER, 1975; FANCELLI e DOURADO NETO, 1996).

Figure 3 shows the maize plants height values during the vegetative growing. Until 31 DAE, just the plants of the treatment with normal rainfall precipitation showed plants height values statistically superior to the plants of the control treatment (Table 1). The determinations realized on the 34, 37 and 40 DAE, the plants with N split application and "El Niño" showed inferior plants height values to those of the treatment with N split application and normal rainfall precipitations and N pre-application and "El Niño". This behavior shows that the application of 30 kg of N ha^{-1} in the sowing, followed by intense and frequent rainfall precipitations, was not enough to attend the maize plants N necessity in the initial stage of the vegetative growing.

From the 44 DAE to the end of the plants vegetative stage, it was not observed differences in the plants height between the treatments that received nitrogen application, just the plants of the treatment without N showed plants height statistically inferior to the other treatments (Table 1 and Figure 3). Evaluating the different methods of nitrogen application with maize and followed by black oat, Fleck et al. (1997) verified the plants height increment at the beginning of the cycle to the measure that the N application in the sowing was increased. During the vegetative development, occurred compensation in the plants height on the treatments with split application of N, the differences verified at the beginning of the vegetative development stage vanished. This behavior can be explained by the N competition among the soil microorganisms and the plants in the initial stage of vegetative development.

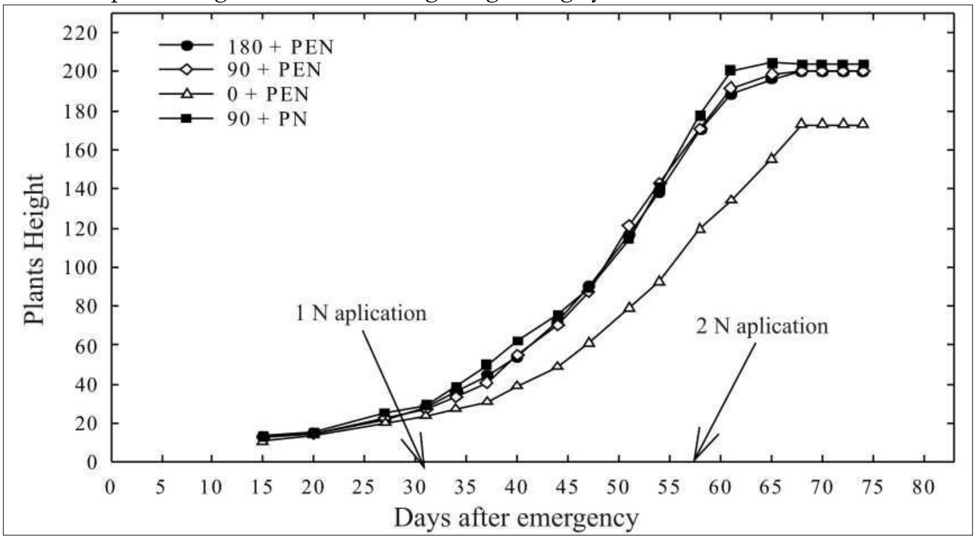
The production of leaf dry pulp, stem and kernels was meaningfully smaller in the plants of the control treatment than the plants of the other treatments (Table 2). The smallest leaf area index values observed in the maize plants of this treatment probably decreased interception of the solar radiation and the production of carbohydrates, affecting the production of leaf dry pulp, stem and kernels.

Table 1. Treatment mean square (QMT), error mean square (QME) and coefficient of variation (CV) variance analyses of the variable, leaf area index and the plants height.

DAE(1)	leaf area index			Plants Height		
	QMT	QME	CV (%)	QMT	QME	CV (%)
15	0.00063	0.00077	15.47	4.29491*	0.86736	7.28
20	0.00544	0.00309	16.77	0.56001*	0.06931	1.78
27	0.04168	0.01477	16.71	9.60283*	1.84042	5.97
31	0.07617	0.02812	17.20	15.65298*	2.75486	6.06
34	0.22644*	0.04764	16.03	61.67944*	1.42071	3.44
37	0.43417*	0.11572	19.22	152.92694*	5.27376	5.38
40	0.75735*	0.16302	18.21	197.48158*	1.80931	2.52
44	1.04800*	0.20725	17.24	357.69288*	7.99931	4.14
47	1.28871*	0.24401	16.55	524.25418*	21.30115	5.49

(1) Days after the plants emergence. ** Significant to 5%, by the Duncan test .*

Figure 3. Maize plants height variations during the growing cycle.



Comparing different N application periods in the maize tillage followed by black oat, during the growing season in 1997/98 (El Niño), Basso (1999) observed a smaller grain yield on the treatments that received N pre-application compared to the treatments with N split application. The result showed by Basso is different from the one found on this research, where it was not observed difference in the grain yield of the plants submitted to N application in pre-sowing and the split application with rainfall precipitations in 1997/98. It probably happened because of the quantity of N used in the pre-sowing by Basso was inferior to the quantity used on this present research, and the larger interval of time between the N applications and the sowing too.

Applying 175 Kg of N ha^{-1} in pre-sowing and 125 Kg of N ha^{-1} split in three times, Varshney et al. (1993) did not observe difference in the grain yield either. These results and the one achieved by this research indicate that the split application of smaller quantities of N during the tillage development cycle does not reduce the grain yield in relation to N pre-application; in the split application can occur the decrease of the nitrate leaching potential for the groundwater, mainly in years with excess of rainfall precipitations.

The percentage of N in the corncobs, corn husk of the ear and kernels do not change during the treatment (Table 3). The highest percentage of N in the leaves + stems submitted to N split application and "El Niño" precipitation probably occurred due to the addition of N in the soil through the split of the total quantity in relation to the treatment with pre-application and "El Niño", and for better rainfall conditions of the soil in relation to the treatment with N split application and normal rainfall precipitations.

The amount of N extracted and translocated to the shoot was 152, 157, 36, 6 and 128 Kg ha^{-1} of N with anticipated application and "El Niño", split application and "El Niño", control and split application and normal rainfall precipitation, respectively. Considering that the N extracted by the control plants correspond to the soil capacity in giving N to the plants and, adding this value to the quantity of N given on the other treatments, from the 180 Kg of N ha^{-1} of the treatments with anticipated application, 63.7 Kg of N ha^{-1} keep in the soil or percolated, while the treatments with N split application and "El Niño" rainfall precipitations are normal, the plants extracted soil quantities of N exceed the amount used. The plants of the treatment with split application and "El Niño" extracted a higher quantity of N from the soil in relation to the plants of the treatment with N split application and normal rainfall simulation, even though the quantity of N was the same (90 Kg of N ha^{-1}). It probably occurred because of the smaller humidity of the soil during the vegetative

Table 2. Leaf dry pulp values, stems and maize kernels (during the harvest) submitted to different managements of nitrogen application and rainfall regimes.

Variabless	Treatments[(2)]				CV
	180 + PEN	90 + PEN	0 + PEN	90 + PN	
	...................................g plants^{-1}...................................				%
Leaves	36.34 a [(1)]	35.72 ab	23.01 c	31.63 b	4.87
Stems	94.06 a	96.21 a	43.10 c	74.20 b	7.11
Kernels	139.90 a	132.20 a	27.25 b	122.31 a	21.20

[(1)] Averages followed by the same letter, in line, are not different between them, according to the Duncan test there is 5% of probability.
[(2)] Treatments: (i) 180 + PEN = 150 kg of N ha^{-1} pre-sowing and 30 kg of N ha^{-1} during sowing, with "El Niño"; (ii) 90 + PEN = 30 kg of N ha^{-1} during sowing, 30 kg of N ha^{-1} on the 31 and 57 DAE, with "El Niño"; (iii) 0 + PEN = witness, with nitrogen application and El Niño precipitation and; (iv) 90 + PN = 30 kg of N ha^{-1} during sowing, 30 kg of N ha^{-1} on the 31 and 57 DAE, normal precipitation .

Table 3. Percentage of N and total N in the maize components in the harvest, submitted to different managements of nitrogen application and rainfall regimes.

Treatment	Leaves + Stems		Kernels		Husk		Corncobs	
	N	N total	N	N total	N	N total	N	N total
	%	g/planta	%	g/planta	%	g/planta	%	g/planta
180 + PEN	0.39 b [(1)]	0.50 ab	1.39 a	1.93 a	0.22 a	0.029 ab	0.31 a	0.078 a
90 + PEN	0.48 a	0.63 a	1.45 a	1.88 a	0.23 a	0.034 a	0.28 a	0.069 a
0 + PEN	0.33 b	0.22 c	1.23 a	0.34 b	0.28 a	0.018 c	0.34 a	0.035 a
90 + PN	0.36 b	0.38 b	1.36 a	1.66 a	0.20 a	0.024 bc	0.29 a	0.075 a
CV (%)	5.03	7.85	11.01	15.22	11.98	9.02	11.47	19.97

development and in the grain filling stage, caused by the deficient rainfall precipitations of the growing season in 1996/97, considered as normal. As a result, the plant absorbed less quantity of water and consequently less N was absorbed, since the principal mechanism of N supply from the soil to the root is the mass flow, which is affected by the quantity of water in the soil.

The extraction of N from the soil by the plants submitted to N slip and "El Niño" rainfall precipitations also was superior to the plants that received the double N application and the same rainfall precipitations, showing that the N split application during the development cycle with "El Niño" helps the plants absorb the N in relation to the anticipated application, decreasing the loss of N and, consequently, the farmers will save money since they will use less fertilizer.

Conclusion

1. The leaves dry pulp, stems and the total N translocated to the leaves and stems were smaller with the application of the rainfall precipitations considered normal than the plants submitted to "El Niño" rainfall precipitations and received N application.

2.The rainfall regime, as well as the split or anticipated application of N did not cause the reduction of the leaf area index, plants height, grain yield and the total N translocated to the kernels.

3.It is not economic the N anticipated application, in high proportion, since the yield achieved with 90 Kg of N ha^{-1} slip in three times in both rainfall regimes, does not differ with 180 Kg of N ha^{-1}, applied during the sowing and with anticipated application.

References

ALESSI, J. e POWER, J.F. Effect of plant spacing on phenological development of early and midseason corn hybrids in a semiarid region. **Crop Sci**., n.15, p. 179-182, 1975.

BASSO, C.J. **Épocas de aplicação de nitrogênio para milho cultivado em sucessão a plantas de cobertura de solo, no sistema plantio direto.**1999, 76 f. Dissertação (Mestrado em Agronomia) , Universidade Federal de Santa Maria, UFSM, 1999.

CERETTA, C.A.; BASSO, C.J.; DIEKOW, J.; MARCOLAN, A.L e TISSOT, A.R. Possibilidades de manejo do nitrogênio na cultura do milho em sucessão à aveia preta, sob plantio direto. In: SEMINÁRIO INTERNACIONAL DO SISTEMA PLANTIO DIRETO, Passo Fundo, 1997. Anais... p.235-237.

COMISSÃO DE FERTILIDADE DO SOLO (CFSRS/SC). **Recomendações de adubação e de calagem para os estados do Rio Grande do Sul e Santa Catarina**. 3.ed. Passo Fundo: Sociedade Brasileira de Ciência do Solo – Núcleo Regional Sul, 1995. 224p.

CRAWFORD, T.W.; RENDIG, V.V. e BROADBENT, F.E. Sources, fluxes, and sinks of nitrogen during early reproductive growth of maize (*Zea mays* L.). **Plant Physiol**., n.70, p.654-660, 1982.

CUNHA, G.R. El Nino – Oscilação do Sul e suas aplicações na agricultura do Sul do Brasil. **Lavoura Arrozeira**, n.50, p.3-12, 1997.

DIEKOW, J.; CERETTA, C.A. e PAVINATTO, P. É possível antecipar a adubação nitrogenada do milho no sistema plantio direto? In: REUNIÃO SUL-BRASILEIRA DE CIÊNCIA DO SOLO, 2., 1998, Santa Maria. 1998. **Anais...** p.163-166.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). Centro Nacional de Pesquisa de Solos. **Sistema Brasileiro de Classificação de Solos**. Brasília, Rio de Janeiro, 1999. 412p.

FANCELLI, A.L. e DOURADO NETO, D. Milho: Fisiologia da produção. In: SEMINÁRIO SOBRE FISIOLOGIA DA PRODUÇÃO E MANEJO DE ÁGUA E DE NUTRIENTES NA CULTURA DO MILHO DE ALTA PRODUTIVIDADE, Piracicaba, 1996. **Anais...** Potafos, 1996. 29p.

FLECK, N.G.; NEVES, R. e SILVEIRA, C.A. Avaliação do crescimento inicial de milho semeado em restevas de aveia-preta e ervilhaca manejadas com e sem herbicida. **Pesq. Agropec. Gaúcha**, n.3, p. 35-40, 1997.

KARLEN, D.L.; FLANNERY, R.L. e SADLER, E.J. Aerial accumulation and partitioning of nutrients by corn. **Agron. Journal**., n.80, p.232-242, 1988.

MORENO, J.A. **Clima do Rio Grande do Sul.** Porto Alegre: Secretaria da Agricultura, Diretoria de Terras e Colonização, Seção de Geografia, 1961. 46 p.

PÖTTKER, D. e ROMAN, E.S. Efeito de resíduos de culturas e do pousio de inverno sobre a resposta do milho ao nitrogênio**. Pesq. Agropec. Bras.**, n.29, p.763-770, 1994.

RITCHIE, S.W.; HANWAY, J. e BENSON, G.O. **How a corn plant develops**. Ames, Iowa State University of Science and Technology, Cooperative Extension Service, 1993. 21p. (Special Report, 48).

ROPELEWISKY, C.F. e JONES, P.D. An extension of the Tahiti-Darwin southerns ocillation index. **Mon. Wea. Rev**., n.115, p.2161- 2165, 1987.

SÁ, J. C. M. Manejo de nitrogênio na cultura de milho no sistema plantio direto. Passo Fundo, **Aldeia Norte**, 1996, 23p.

STICKLER, F.C.; WEARDEN, S. e PAULI, A.W. Leaf area determination in grain sorghum. **Agron. Journal.,** 53:187-188, 1961.

TEDESCO, M.J.; VOLKWEISS, S.J. e BOHNEM, H. **Análises de solo, plantas e outros materiais.** Porto Alegre: Universidade Federal do Rio Grande do Sul, 1985. 118p. Boletim Técnico 5.

VARSHNEY, P.; KANWAR, R.S.; BAKER, J.L. e ANDERSON, C.E. Tillage and nitrogen management effects on nitrate-nitrogen in the soil profile. **Trans. Am. Soc. Agric. Engineer**., n.36, p. 783-789, 1993.