IPNI PROJECT BRAZIL-62

Source, rate, and locality of nitrogen fertilization for sugarcane

REPORT #3

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Introduction

The requirement for worldwide abundant food, feed, fiber, and more recently biofuel, leads to higher amounts of fertilizer utilized in agriculture in diverse parts of the globe. Nitrogen (N) is, most generally, the first nutrient in terms of plant demand. Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development. Because nitrogen is a constituent of amino acids, which are required to

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synthesize proteins and other related compounds, it plays a role in almost all plant metabolic processes. Nitrogen is an integral part of chlorophyll manufacture through photosynthesis. Carbohydrates (sugars) provide energy required for growth and development Nitrogen application may be interfered by chemical reactions generating losses by leaching or volatilization, therefore the use of distinct sources is strategic to overcome such problems. In many areas farmers are testing different sources to increase N use efficiency.

Objectives

The main objective of the study is to evaluate the agronomic effectiveness of different N sources for sugar cane. Also, other important factors, which affect the N fertilizer effectiveness in tropical soils, are under evaluation as rate and locality of application.

Materials & Methods

Location

Project is located at the São Pedro farm in Iracemápolis, São Paulo, Brazil: 22º31'25"S and 47º29'65"W.

Soil conditions

Trial was carried out on an Oxisol which test results of the experimental area are presented at Table 1.

Table 1. Soil conditions of the experimental area.

Soil parameters	Deapth (cm)		
	0-20	20-40	80-100
Organic Matter. (g/dm^3)	23	18	11
Soil pH ($CaCl_2$)	5,4	5,1	5,1
Available P-resin (mg/md$^{3)}$	6	4	4
Available K (mmolc/dm^3)	1,8	1,20	0,5
Available Ca (mmolc/dm^3)	34	33	20
Available Mg (mmolc/dm^3)	15	15	8
Al concentration (mmolc/dm^3)	1	0	0
H + Al (mmolc/dm^3)	25	34	28
Available S (mg/md$^{3)}$	26	67	67
Sum of bases (mmolc/dm^3)	51	49	29
CEC (mmolc/dm^3)	76	83	57
Base saturation (%)	67	59	50
Al saturation (%)	2	0	0
Clay (%)	49	45	52
Silt (%)	9	11	9
Sand (%)	42	44	39

Experimental design

Trial was installed using a complete randomized block design with 4 replicates in a factorial 3x3x2 and 4 controls, as such: 3 N sources (UAN, Urea, and Ammonium Nitrate), 3 N rates (60, 120, and 180 kg/ha), and 2 localities of application (in furrow and surface). Controls are: no N application (in furrow and surface) and 120 kg N/ha via Ammonium Sulphate (in

furrow and surface). Plots were composed by 9 meters width (6 sugarcane rows) by 14 meters long. Treatments are presented at Table 2 below and field trial layout at the appendix along with recent images of the trial.

Table 2. Treatments under evaluation on this project.

#	Source	Rate (kg N/ha)	Locality
1	UAN	60	In furrow
2	UAN	120	In furrow
3	UAN	180	In furrow
4	UAN	60	Surface
5	UAN	120	Surface
6	UAN	180	Surface
7	Ammonium Nitrate (AN)	60	In furrow
8	Ammonium Nitrate	120	In furrow
9	Ammonium Nitrate	180	In furrow
10	Ammonium Nitrate	60	Surface
11	Ammonium Nitrate	120	Surface
12	Ammonium Nitrate	180	Surface
13	Urea	60	In furrow
14	Urea	120	In furrow
15	Urea	180	In furrow
16	Urea	60	Surface
17	Urea	120	Surface
18	Urea	180	Surface
19	Control	0	In furrow
20	Control	0	Surface
21	Ammonium Sulphate (AS)	120	In furrow
22	Ammonium Sulphate	120	Surface

Rainfall conditions

Figure 1 shows the monthly rainfall precipitation in Piracicaba, SP, Brazil from January 2014 through June 2015, the period that the trial was carried out. The total amount of rainfall during the period of the trial was 1,425 mm, which is considered adequate for sugarcane good development that is more than 1,200 mm per year, according to Landell (2014).

Set up information

The experimental area used was a three-year-old sugarcane field (variety RB96 6928) that was harvested early May 2014. The field where the trial was set presented a gross yield of 140 t/ha in 2013, 95 t/ha in 2014, and 71 t/ha in 2015. Treatments were initially applied on May 22nd, 27th, and 28th, 2014, in accordance to Table 2, when seedlings were 20 cm in height. Plots were composed of six rows (1.5 row spacing) by 14 meters long each. UAN was applied using proper equipment that sprayed on surface or in furrow aside the plant row. Urea, ammonium nitrate, and ammonium sulphate were applied manually on surface or using a seed planter in furrow aside the plant row. Figure 2 presents images of the trial during treatments application, and Figure 3 shows the equipment used for UAN application. Potassium as KCl was applied to all plots at the rate of 140 kg K_2O/ha on the soil surface.

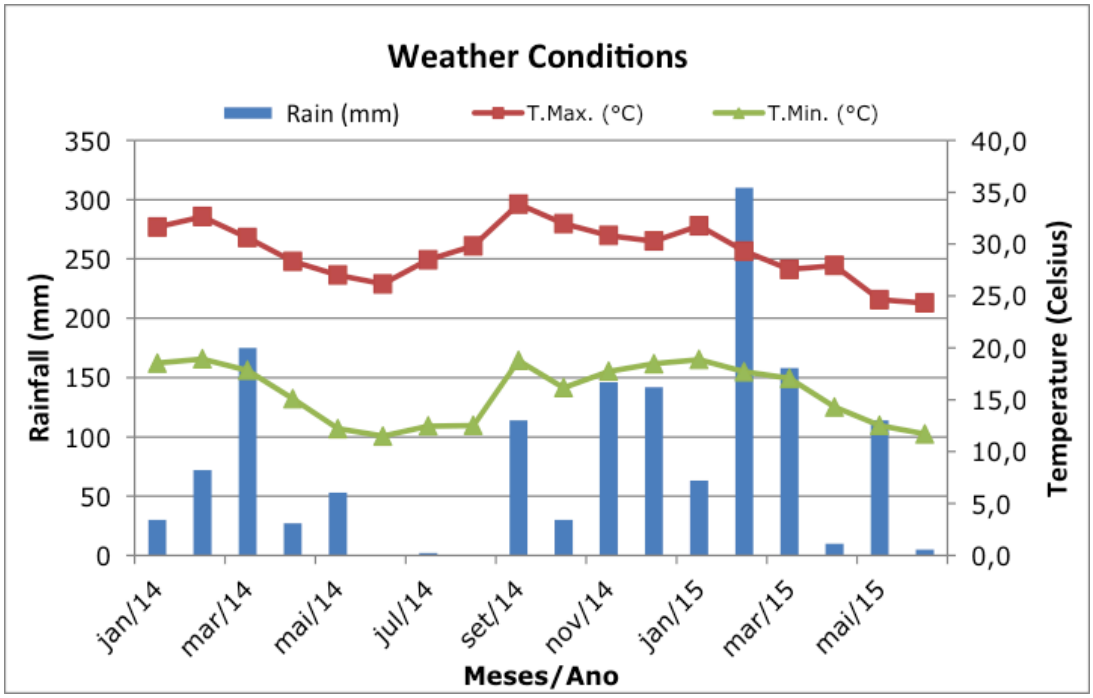


Figure 1. Monthly rainfall precipitation and temperature in Piracicaba, SP, Brazil, from January 2014 through June 2015.

Evaluated parameters

Germination and plant stand

Germination and plant stand were evaluated according to Stolf (1986) initially in two dates: Jul 28th and Oct 21st, 2014. Afterwards, final evaluation was taken on Jan 14th, 2015. In all moments, the number of tillers and empty spaces larger than 0.5 m were counted using two central rows of each plot.

Gross yield and industrial characteristics

For the evaluation of industrial characteristics, 10 stalks were collected randomly from the two central rows of each plot, defoliated, and ground. A 0.5 kg sample was pressed at 250 kgf/cm^2 for 1 minute and soup taken to lab for BRIX and Pol measurements. This information was used to calculate TRS – total recoverable sugar, TPH – total pol by hectare, and TSH, total sugar by hectare. For gross yield, each plot was entirely harvested and weighted using a dynamometer. This sampling occurred on May 13 th, 2015.

Leaf analysis

For the evaluation of nutritional status of plants, five leaves (middle third of blades with visible dewlap and midribs removed) were taken from the two center rows of each plot and sent to lab analysis of macronutrients, according to Malavolta et al. (1977).

Statistical analysis

Results were submitted to Duncan test (P>0.05), contrasts and regression analysis using SAS software.

Figure 2. Field trial images during treatments application.

Figure 3. Tractor mounted sprayer used to apply UAN.

Results

Germination and plant stand

Table 3 presents the results and ANOVA for plant stand and stand loss of sugarcane in response to source, rate, and locality of N application.

Table 3. Analysis of variance regarding source, rate, and locality of N application for plant stand and stand loss in two initial stages and near harvest. Control treatments were disregarded for this analysis (complete factorial design).

Source of variation	Plant stand			Stand loss		
	tiller/m		stalk/m	frequency of plant loss, %	size of empty space, m	frequency of empty space, m
	Jul 28th, 2014	Oct 21st, 2014	Jan 14th, 2014			
Source (S)						
UAN	3.65	11.35	13.12	25.10	0.86	3.23
AN	3.63	11.48	13.76	21.79	0.86	3.87
Urea	4.23	10.56	13.00	29.30	0.88	2.90
Rate (R)						
60	3.62	11.24	13.23	24.32	0.90	3.33
120	3.87	11.02	13.17	25.41	0.86	3.57
180	4.01	11.14	13.48	26.46	0.85	3.10
Locality (L)						
In furrow	3.91	11.22	13.33	22.05b	0.82	3.55
Surface	3.76	11.04	13.25	28.74a	0.91	3.11
F Value						
S	1.80	0.41	0.80	2.30	0.08	1.23
R	0.60	0.02	0.13	0.18	0.33	0.29
L	0.26	0.04	0.03	5.44*	2.74	0.75
S x R	1.09	1.00	0.12	0.68	0.33	1.66
S x L	0.03	0.00	0.85	0.67	0.11	0.71
R x L	0.93	0.94	0.68	0.81	0.09	0.61
S x R x L	2.19	0.78	0.46	0.58	0.67	0.43
Rep	13.04	5.51	3.60*	5.22**	2.76	2.02
CV(%)	32.36	34.59	16.89	47.91	26.82	64.78
SD	1.24	3.85	2.24	12.16	23.27	216.01
Mean	3.84	11.13	13.29	25.40	0.87	3.33
MSD (S)	0.87	2.68	1.56	8.48	0.16	1.50
MSD (R)	0.87	2.68	1.56	8.48	0.16	1.50
MSD (L)	0.59	1.82	1.06	5.75	0.11	1.02

Figures 4 e 5 present the results for plant stand of sugarcane in response to source and locality of N application and to the presence of N application, respectively.

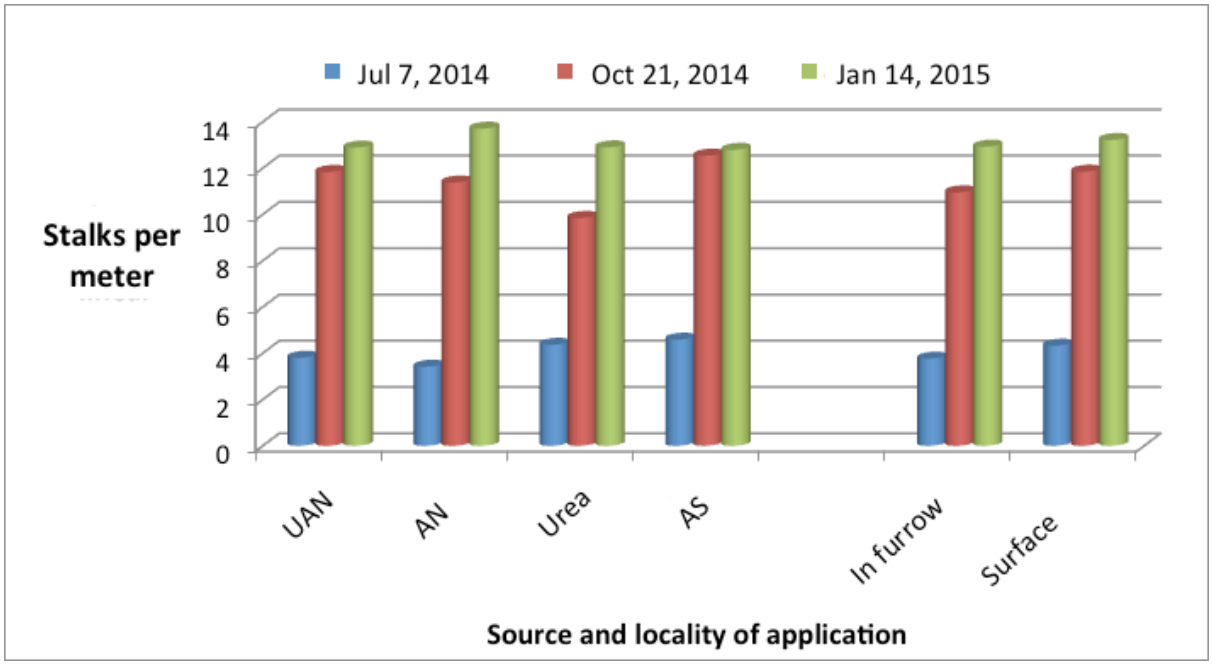


Figure 4. Plant stand of sugarcane in two initial stages and near harvest as a function of source and locality of application at N rate of 120 kg/ha.

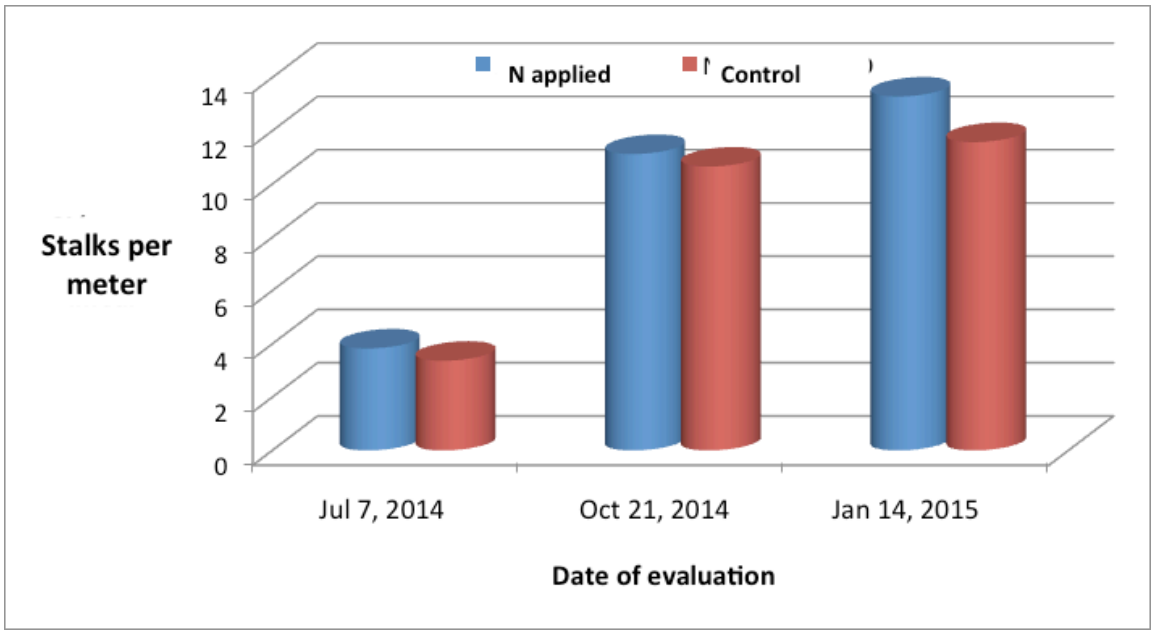


Figure 5. Plant stand of sugarcane in two initial stages and near harvest as a function of N application (all treatments with N *versus* control).

Nutritional status

Table 4 presents the results and ANOVA for macronutrients leaf content of sugarcane in response to source, rate, and locality of N application, while Table 5 presents the results and ANOVA for macronutrients leaf content of sugarcane in response to source and locality of N application at the rate of 120 Kg N/ha.

Table 4. Analysis of variance regarding source, rate, and locality of application of N for macronutrients leaf content. Control treatments were disregarded in this analysis.

Source of variation	N	P	K	Ca	Mg	S
Source (S)			g/kg			
UAN	17.58	2.14	10.90	3.81 ab	1.41 ab	2.23
AN	17.67	2.13	10.80	3.66 b	1.35 b	2.27
Urea	17.55	2.11	10.78	3.97 a	1.46 a	2.18
Rate (R)						
60	17.55	2.13	11.06	3.81	1.43 a	2.31
120	17.67	2.14	11.02	3.78	1.41 a	2.15
180	17.58	2.11	10.39	3.85	1.38 a	2.22
Locality (L)						
In furrow	17.55	2.11	10.78	3.77	1.39	2.21
Surface	17.65	2.14	10.87	3.85	1.42	2.23
F Value						
S	0.03	0.24	0.09	5.43**	6.03**	0.30
R	0.03	0.30	3.36*	0.22	1.56	0.82
L	0.07	0.66	0.12	1.16	1.04	0.06
S x R	2.07	0.69	0.23	2.02	4.04**	1.73
S x L	0.37	0.54	0.44	0.14	0.08	0.61
R x L	0.03	0.72	0.40	1.30	0.22	0.26
S x R x L	0.38	0.91	0.40	0.59	0.94	0.76
Rep	2.46	3.49*	13.19**	43.07**	16.76**	25.30**
CV(%)	9.06	6.59	9.29	8.60	8.10	19.31
SD	1.59	0.14	1.00	0.32	0.11	0.43
Mean	17.60	2.13	10.83	3.81	1.41	2.23
MSD (S)	1.11	0.09	0.70	0.22	0.07	0.30
MSD (R)	1.11	0.09	0.70	0.22	0.07	0.30
MSD (L)	0.75	0.06	0.47	0.15	0.05	0.20

Table 5. Analysis of variance regarding source and locality of N application at rate of 120 kg N/ha for macronutrients leaf content. Control treatment ammonium sulphate (AS) was considered in this analysis.

Source of variation	N	P	K	Ca	Mg	S
Source (S)			g/kg			
UAN	16.88	2.11	10.95	3.65	1.34	2.09
AN	18.72	2.19	11.18	3.71	1.38	2.28
Urea	17.41	2.13	10.95	4.00	1.51	2.09
AS	17.32	2.13	11.02	3.75	1.38	2.08
Locality (L)						
In furrow	17.50	2.12	11.06	3.68	1.39	2.08
Surface	17.67	2.16	10.98	3.86	1.42	2.18
F Value						
S	2.33	0.73	0.09	1.12	2.50	0.64
L	0.11	0.74	0.05	1.57	0.37	0.69
S x L	0.13	1.22	0.18	0.30	0.33	0.65
Rep	2.12	2.40	2.82	9.91**	5.86**	20.90**
CV(%)	8.35	5.18	9.44	10.84	9.30	15.97
SD	1.46	0.11	1.04	0.40	0.13	0.34
Mean	17.58	2.14	11.02	3.77	1.40	2.13
MSD (S)	2.04	0.15	1.45	0.57	0.18	0.47
MSD (L)	1.08	0.08	0.76	0.30	0.09	0.25

Figure 6 presents the results for macronutrients leaf content of sugarcane in response to the presence of N application.

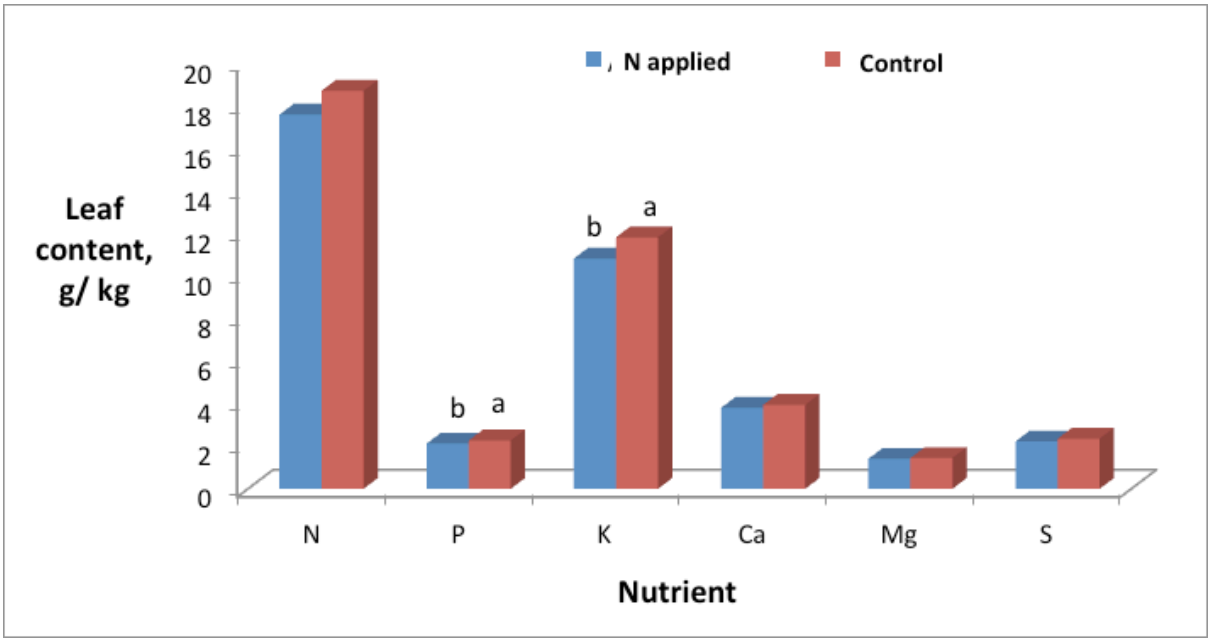


Figure 6. Macronutrients leaf content of sugarcane as a function of N application (all treatments with N *versus* control).

Gross yield and industrial characteristics

Table 6 presents the results and ANOVA of gross yield, percentage of brix, percentage of fiber, POL, total recoverable sugar, total POL per hectare, and total sugar per hectare in response to source, rate, and locality of N application, while Table 7 presents the results and ANOVA for the same parameters in response to source and locality of N application at the rate of 120 Kg N/ha.

Table 6. Analysis of variance regarding source, rate, and locality of application of N for gross yield (GY) and industrial characteristics[1]. Control treatments were disregarded in this analysis.

Source of variation	Brix %	Fiber %	POL %	GY ton/ha	TRS kg/ton	TPH ton/ha	TSH ton/ha
Source (S)							
UAN	17.76	13.24	12,65a	81.72a	126.74a	10.34a	10.36a
AN	17.64	13.21	12,53ab	81.14a	125.71ab	10.14a	10.17a
Urea	17.30	14.06	11,79b	74.38b	119.30b	8.81b	8.91b
Rate (R)							
60	17.56	13.42	12,30	78.35	123.80	9.68	9.74
120	17.46	13.41	12,31	80.50	123.72	9.92	9.97
180	17.67	13.68	12,35	78.39	124.23	9.68	9.73
Locality (L)							
In furrow	17.46	13.60	12,24	79.24	123.03	9.71	9.76
Surface	17.67	13.41	12,40	78.92	124.81	9.82	9.87
F Value							
S	2.09	2.22	4,59*	4.58*	4.44*	7.41**	7.12**
R	0.39	0.22	0,02	0.42	0.02	0.20	0.20
L	1.15	0.27	0,45	0.02	0.65	0.09	0.10
S x R	1.01	0.59	0,62	0.67	0.61	0.24	0.27
S x L	0.40	0.53	0,37	0.19	0.40	0.29	0.30
R x L	1.22	0.00	0,92	0.11	0.90	0.58	0.52
S x R x L	0.27	0.55	0,50	0.17	0.42	0.26	0.24
Rep	0.82	1.06	0,80	3.16*	0.83	1.46	1.49
CV(%)	4.67	11.72	8,65	11.79	7.56	15.35	14.76
SD	0.82	1.58	10,6	9.32	9.37	1.49	1.44
Mean	17.57	13.50	12,32	79.08	123.92	9.76	9.81
MSD (S)	0.57	1.10	0,74	6.50	6.53	1.04	1.01
MSD (R)	0.57	1.10	0,74	6.50	6.53	1.04	1.01
MSD (L)	0.38	0.74	0,50	4.41	4.43	0.70	0.68

[1] Industrial characteristics: total recoverable sugar (TRS), total POL per hectare (TPH), and total sugar per hectare (TSH).

Figure 7 shows the results of gross yield of sugarcane, total POL per hectare, and total sugar per hectare as a function of N application.

Table 7. Analysis of variance regarding source and locality of N application at rate of 120 kg N/ha for gross yield (GY) and industrial characteristics[1]. Control treatment ammonium sulphate (AS) was considered in this analysis.

Source of variation	Brix %	Fiber %	POL %	GY ton/ha	TRS kg/ton	TPH ton/ha	TSH ton/ha
Source (S)							
UAN	17.61	12.99	12,76	82.64	127.35	10.53	10.50
AN	17.24	12.99	12,24	84.16	123.02	10.28	10.34
Urea	17.54	14.24	11,93	74.68	120.81	8.96	9.06
AS	17.29	13.61	11,93	80.73	120.59	9.67	9.77
Locality (L)							
In furrow	17.45	13.52	12,26	80.00	123.32	9.84	9.89
Surface	17.39	13.39	12,17	81.11	122.56	9.88	9.98
F Value							
S	0.50	0.76	0,96	1.25	0.80	1.49	1.37
L	0.05	0.04	0,06	0.09	0.05	0.00	0.01
S x L	0.39	0.14	0,46	0.28	0.44	0.38	0.34
Rep	2.01	0.25	0,47	0.86	0.54	0.97	1.04
CV(%)	4.16	14.28	9,21	13.07	8.07	16.48	15.88
SD	0.72	1.92	1,12	10.53	9.93	1.62	1.57
Mean	17.42	13.46	12,22	80.55	122.94	9.86	9.92
MSD (S)	1.01	2.67	1,56	14.67	13.84	2.26	2.19
MSD (L)	0.53	1.41	0,82	7.74	7.30	1.19	1.15

[1] Industrial characteristics: total recoverable sugar (TRS), total POL per hectare (TPH), and total sugar per hectare (TSH).

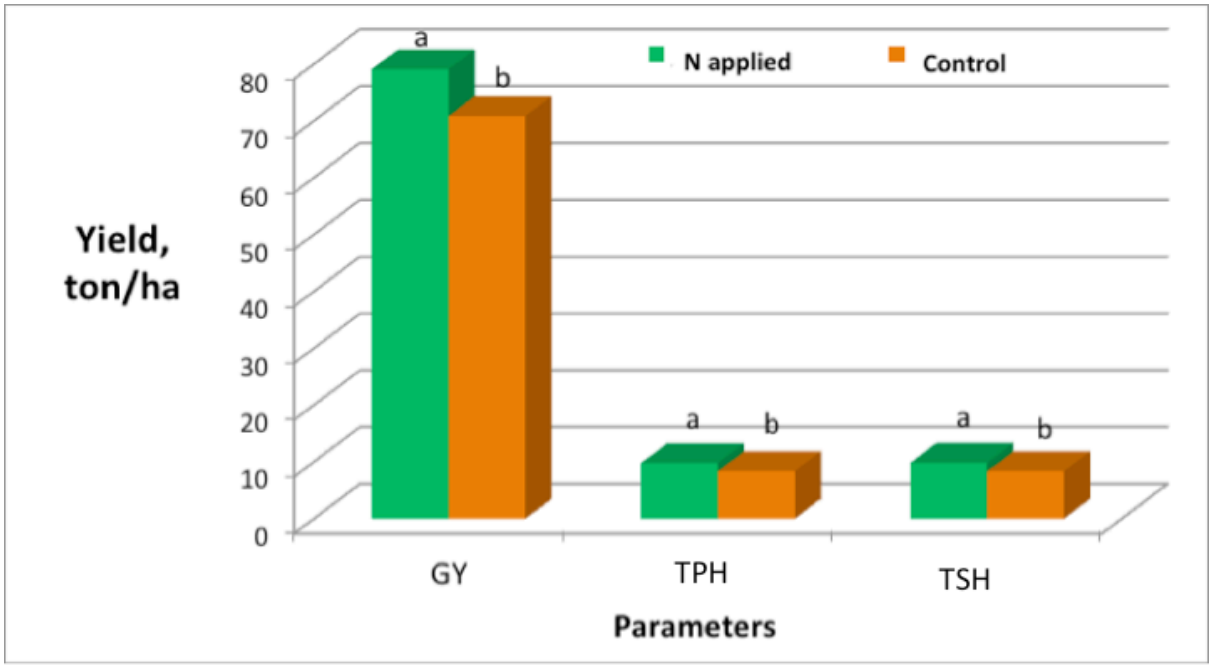


Figure 7. Gross yield of sugarcane (GY), total POL per hectare (TPH), and total sugar per hectare (TSH) as a function of N application (all treatments with N *versus* control).

Figures 8 e 9 present the regression analysis for gross yield of sugarcane in response to source and rate of N as a function of the locality of N application, respectively, in furrow or on the surface.

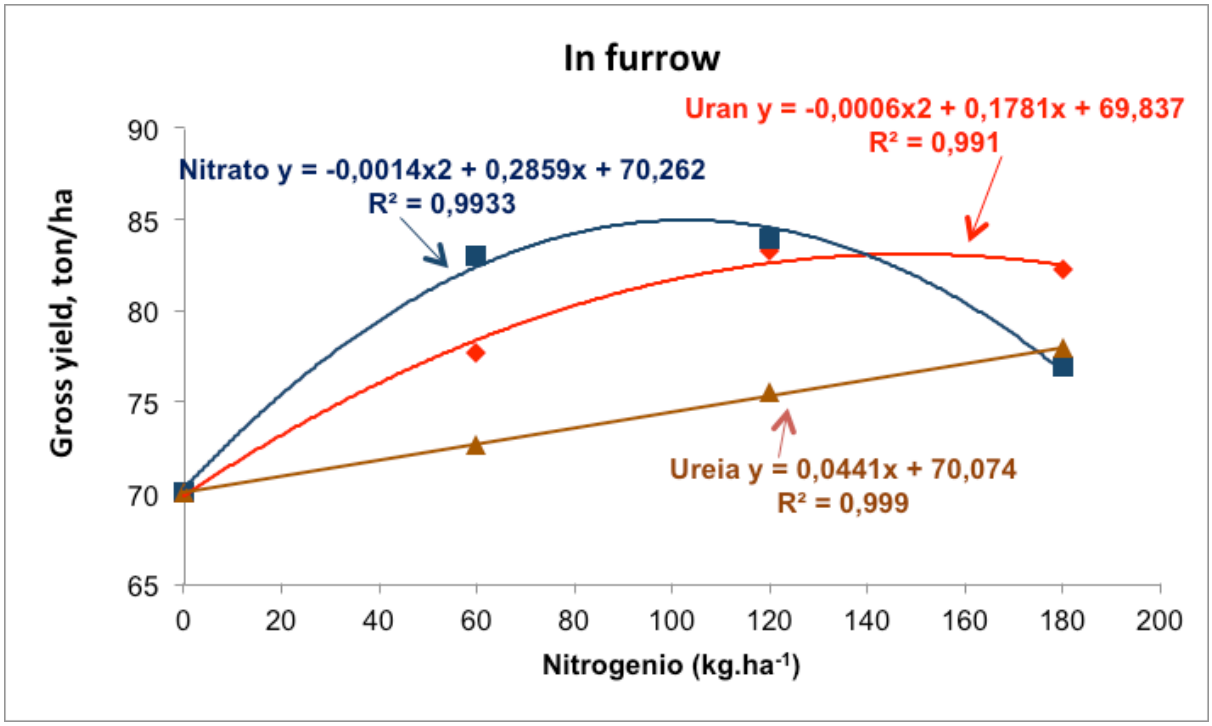


Figure 8. Gross yield of sugarcane as a function of source and rate of N applied in furrow.

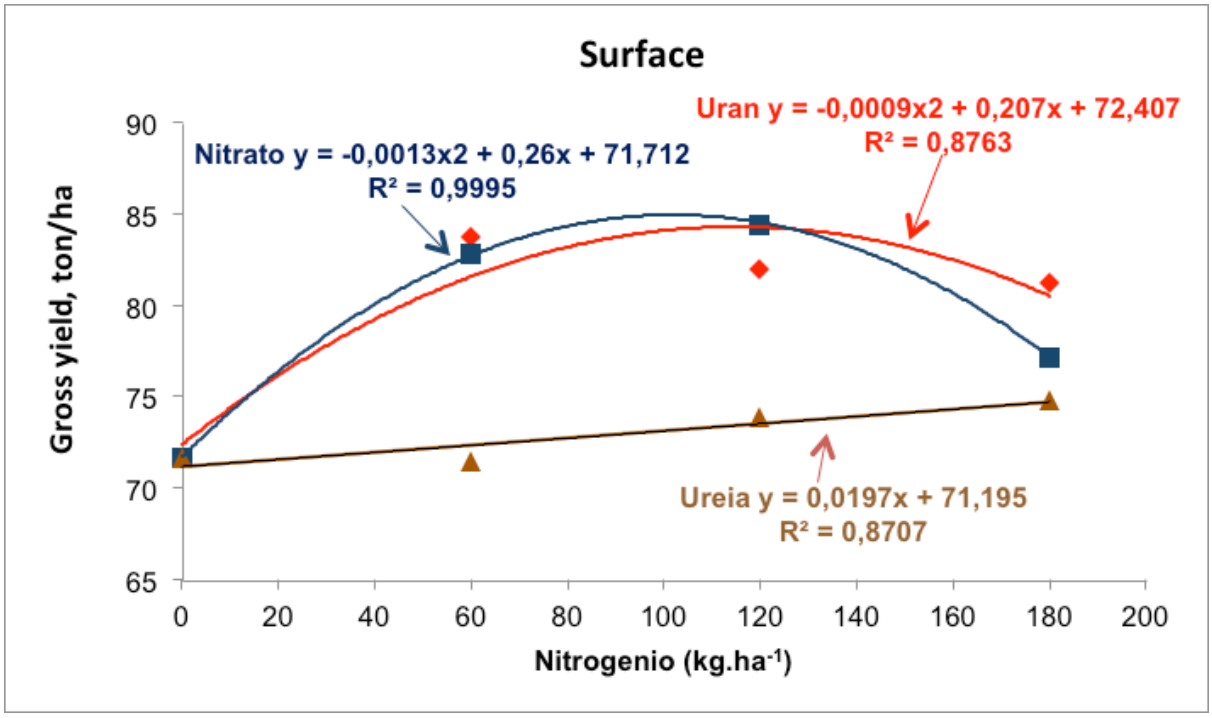


Figure 9. Gross yield of sugarcane as a function of source and rate of N applied on the surface.

Conclusions

Under the agronomic conditions of this study:

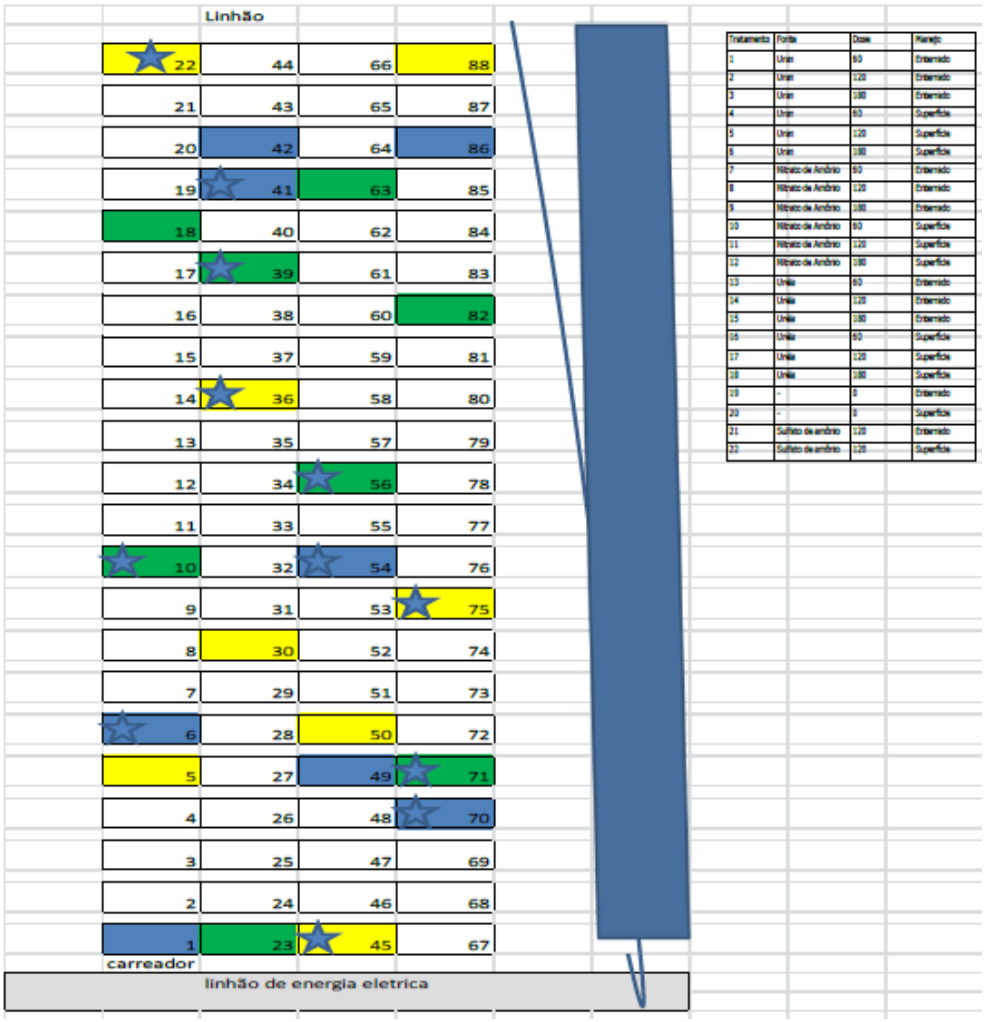
a) Nitrogen fertilization may be placed on the soil surface with no damage to sugarcane yield and, therefore, speed the process of fertilizer application.

b) Nitrogen rate for best agronomic performance of sugarcane is in the range of 60 to 120 kg N/ha.

c) Fertilizers UAN and AN represent better sources of N for sugarcane production, as compared to Urea.

Appendix

Appendix 1. Images of trial taken on June 09th, 2014, during Dr. Prochnow's visit to the site.



Appendix 2. Field trial layout of the project.

Appendix 3. Raw data of Brazil-62 project, season 2014-2015.

T#	Source	N Rate	Time	Rep	Plant stand			FSL	SES	FES
					Jul/14	Oct/14	Jan/15			
		kg/ha			tiller/m			%	m	%
1	UAN	60	In furrow	1	2.07	8.46	12.96	27.14	1.09	2.91
1	UAN	60	In furrow	2	5.68	12.32	11.21	10.71	0.75	6.25
1	UAN	60	In furrow	3	3.39	11.68	11.18	18.57	0.65	2.85
1	UAN	60	In furrow	4	2.43	11.29	12.29	29.46	0.92	2.19
2	UAN	120	In furrow	1	2.79	7.07	14.5	19.29	1.08	4.52
2	UAN	120	In furrow	2	5.50	17.14	15.5	13.75	0.64	4.03
2	UAN	120	In furrow	3	3.54	13.00	13.32	32.50	1.30	2.70
2	UAN	120	In furrow	4	4.89	17.07	15.39	8.75	0.82	8.52
3	UAN	180	In furrow	1	2.96	10.82	12.83	23.04	1.08	3.59
3	UAN	180	In furrow	2	4.07	11.21	10.64	31.96	0.69	1.47
3	UAN	180	In furrow	3	6.61	17.82	13.61	18.21	0.73	3.27
3	UAN	180	In furrow	4	3.43	13.11	14.25	7.86	0.55	6.45
4	UAN	60	Surface	1	1.61	6.39	14.75	40.39	1.13	1.67
4	UAN	60	Surface	2	5.07	17.21	12.95	11.43	0.64	4.96
4	UAN	60	Surface	3	3.36	10.14	11.96	37.14	1.16	1.96
4	UAN	60	Surface	4	3.39	8.04	12.14	29.89	0.84	1.96
5	UAN	120	Surface	1	2.64	10.18	16.64	25.36	0.89	2.61
5	UAN	120	Surface	2	2.71	6.46	13.68	43.93	0.82	1.05
5	UAN	120	Surface	3	4.39	10.50	10.5	14.29	0.67	4.00
5	UAN	120	Surface	4	3.75	13.21	14.07	22.11	0.77	2.73
6	UAN	180	Surface	1	1.32	2.79	12.64	63.32	1.27	0.73
6	UAN	180	Surface	2	5.11	10.79	11.21	30.71	0.72	1.62
6	UAN	180	Surface	3	3.89	14.93	13.39	21.61	0.86	3.14
6	UAN	180	Surface	4	2.89	10.93	13.32	21.14	0.66	2.45
7	AN	60	In furrow	1	1.25	6.46	13.49	25.64	0.72	2.08
7	AN	60	In furrow	2	4.93	11.64	13.29	17.86	1.00	4.60
7	AN	60	In furrow	3	6.75	18.39	13.43	15.18	0.61	3.39
7	AN	60	In furrow	4	3.89	10.71	13.75	20.18	0.81	3.19
8	AN	120	In furrow	1	3.07	12.79	16.18	14.11	0.79	4.81
8	AN	120	In furrow	2	1.79	9.86	12.89	31.61	0.80	1.74
8	AN	120	In furrow	3	4.14	8.96	11.86	33.57	1.04	2.07
8	AN	120	In furrow	4	2.54	16.14	15.32	22.86	0.91	3.09
9	AN	180	In furrow	1	1.50	4.29	13.54	38.21	0.76	1.24
9	AN	180	In furrow	2	3.46	13.32	16.68	16.07	0.64	3.36
9	AN	180	In furrow	3	1.96	5.89	8.71	16.43	1.15	5.85
9	AN	180	In furrow	4	3.21	17.14	15.96	7.39	0.69	8.64
10	AN	60	Surface	1	3.36	11.04	14.5	26.96	0.76	2.05
10	AN	60	Surface	2	5.82	14.18	17.04	5.89	0.83	13.18
10	AN	60	Surface	3	4.54	11.29	10.68	18.93	0.76	3.24
10	AN	60	Surface	4	3.57	13.86	12.64	43.89	1.54	1.96
11	AN	120	Surface	1	3.86	10.71	15.5	19.64	1.10	4.50
11	AN	120	Surface	2	5.36	19.36	15.5	13.93	0.56	3.44
11	AN	120	Surface	3	4.93	13.21	11.75	20.71	0.73	2.78
11	AN	120	Surface	4	3.29	7.89	12.54	26.61	1.06	2.94
12	AN	180	Surface	1	2.29	7.82	18.18	16.43	0.92	4.68
12	AN	180	Surface	2	2.25	4.11	8.82	29.29	0.82	1.98
12	AN	180	Surface	3	5.71	19.21	14.75	11.79	0.83	6.18
12	AN	180	Surface	4	3.71	7.25	13.36	29.82	0.76	1.79

Continuing …

T#	Source	N Rate	Time	Rep	Plant stand			FSL	SES	FES
					Jul/14	Oct/14	Jan/15			
		kg/ha			tiller/m			%	m	%
13	Urea	60	In furrow	1	1.57	7.14	14.86	42.86	0.80	1.07
13	Urea	60	In furrow	2	4.57	14.11	16.64	18.04	0.84	3.83
13	Urea	60	In furrow	3	2.21	6.07	8.36	33.75	1.58	3.09
13	Urea	60	In furrow	4	5.14	10.11	12.96	22.32	0.69	2.42
14	Urea	120	In furrow	1	2.32	6.71	13.68	35.50	0.90	1.64
14	Urea	120	In furrow	2	4.04	15.50	15.11	20.36	0.81	3.19
14	Urea	120	In furrow	3	4.36	10.07	11.54	15.00	0.84	4.76
14	Urea	120	In furrow	4	4.11	6.96	7.89	54.82	1.18	0.97
15	Urea	180	In furrow	1	1.14	5.57	11.04	41.79	1.06	1.48
15	Urea	180	In furrow	2	3.93	9.11	16.18	16.25	0.76	3.91
15	Urea	180	In furrow	3	6.82	14.57	13.93	11.07	0.78	6.23
15	Urea	180	In furrow	4	5.61	7.93	12.04	28.68	0.73	1.82
16	Urea	60	Surface	1	2.14	6.82	10.82	60.89	1.00	0.64
16	Urea	60	Surface	2	4.25	12.21	14.18	20.89	0.65	2.46
16	Urea	60	Surface	3	4.46	13.86	13.93	20.54	0.72	2.78
16	Urea	60	Surface	4	6.64	8.71	11.14	36.07	0.92	1.63
17	Urea	120	Surface	1	3.64	14.96	15.64	27.57	0.77	2.03
17	Urea	120	Surface	2	5.14	16.11	15.21	10.89	0.61	4.99
17	Urea	120	Surface	3	6.25	16.43	14.71	6.61	0.62	8.72
17	Urea	120	Surface	4	6.21	5.86	10.64	23.71	0.95	3.05
18	Urea	180	Surface	1	1.54	8.71	14.29	60.21	0.89	0.59
18	Urea	180	Surface	2	7.89	17.50	16.57	12.32	0.69	4.91
18	Urea	180	Surface	3	3.07	10.75	12.04	25.61	0.80	2.31
18	Urea	180	Surface	4	4.43	7.61	8.71	57.50	1.61	1.19
19	Control	0	In furrow	1	2.25	6.75	10.11	56.43	1.76	1.36
19	Control	0	In furrow	2	2.75	10.93	13.46	19.11	0.67	2.83
19	Control	0	In furrow	3	3.71	14.54	12.89	16.71	0.78	3.89
19	Control	0	In furrow	4	3.07	5.18	9.04	37.46	0.87	1.46
20	Control	0	Surface	1	1.14	8.93	9.29	48.93	0.91	0.95
20	Control	0	Surface	2	5.18	12.14	15.96	11.96	0.67	4.93
20	Control	0	Surface	3	4.43	17.36	13.32	14.64	0.82	4.78
20	Control	0	Surface	4	4.43	9.43	8.57	43.93	0.77	0.98
21	AS	120	In furrow	1	2.75	8.68	13.71	30.54	0.78	1.77
21	AS	120	In furrow	2	4.25	10.18	9.5	30.36	0.77	1.77
21	AS	120	In furrow	3	6.14	13.71	10.79	8.93	0.63	6.38
21	AS	120	In furrow	4	2.54	11.96	13.5	30.79	0.78	1.76
22	AS	120	Surface	1	3.11	12.64	16.89	25.89	0.91	2.59
22	AS	120	Surface	2	6.32	12.64	14.25	8.21	1.15	12.85
22	AS	120	Surface	3	7.29	23.36	15.39	0.00	0.00	0.00
22	AS	120	Surface	4	4.36	7.14	8.29	33.04	1.03	2.08

Appendix 3. Raw data of Brazil-62 project, season 2014-2015.

T#	Source	N Rate	Time	Rep	Leaf content					
					N	P	K	Ca	Mg	S
		kg/ha			g/kg					
1	UAN	60	In furrow	1	18.90	2.12	11.70	3.90	1.36	1.4
1	UAN	60	In furrow	2	16.10	2.04	10.40	3.00	1.24	2.1
1	UAN	60	In furrow	3	18.20	2.17	10.40	3.20	1.38	2.3
1	UAN	60	In furrow	4	17.50	2.25	11.00	4.60	1.55	3.3
2	UAN	120	In furrow	1	16.80	2.32	13.70	3.80	1.38	3.6
2	UAN	120	In furrow	2	18.20	2.13	10.40	3.20	1.34	2.1
2	UAN	120	In furrow	3	17.50	2.01	10.40	3.60	1.53	2.1
2	UAN	120	In furrow	4	18.90	2.20	11.00	4.80	1.45	3.3
3	UAN	180	In furrow	1	17.50	2.22	11.00	3.70	1.32	1.7
3	UAN	180	In furrow	2	18.20	2.33	10.40	3.50	1.31	2.1
3	UAN	180	In furrow	3	14.70	1.95	11.70	2.80	1.08	1.7
3	UAN	180	In furrow	4	17.50	2.12	11.00	4.00	1.49	2.3
4	UAN	60	Surface	1	21.00	2.10	13.70	3.70	1.35	2
4	UAN	60	Surface	2	14.70	1.93	10.40	3.30	1.21	1.9
4	UAN	60	Surface	3	16.80	2.20	10.40	3.60	1.37	2
4	UAN	60	Surface	4	14.70	2.10	9.00	4.60	1.64	3
5	UAN	120	Surface	1	17.50	1.96	11.00	4.30	1.64	2
5	UAN	120	Surface	2	18.20	2.21	11.70	4.10	1.50	1.6
5	UAN	120	Surface	3	18.20	2.35	10.40	3.20	1.29	1.9
5	UAN	120	Surface	4	16.10	2.07	9.00	4.80	1.69	3.3
6	UAN	180	Surface	1	22.40	2.51	11.70	4.20	1.44	1.9
6	UAN	180	Surface	2	17.50	1.86	10.40	3.70	1.54	1.6
6	UAN	180	Surface	3	17.50	2.16	10.40	4.00	1.40	2
6	UAN	180	Surface	4	17.50	2.21	10.40	3.90	1.40	2.4
7	AN	60	In furrow	1	16.80	2.32	12.30	3.70	1.42	1.9
7	AN	60	In furrow	2	18.90	2.22	10.40	3.40	1.36	2
7	AN	60	In furrow	3	16.80	2.00	10.40	3.20	1.25	1.9
7	AN	60	In furrow	4	16.80	2.20	11.70	4.40	1.64	3.1
8	AN	120	In furrow	1	21.00	2.04	10.40	3.80	1.51	1.3
8	AN	120	In furrow	2	14.70	2.01	11.70	3.60	1.47	2.3
8	AN	120	In furrow	3	17.50	2.06	9.00	2.80	1.16	2.1
8	AN	120	In furrow	4	16.80	2.01	11.70	3.80	1.36	2.3
9	AN	180	In furrow	1	20.30	2.04	13.00	3.40	1.40	1.4
9	AN	180	In furrow	2	16.80	2.16	10.40	3.20	1.40	2
9	AN	180	In furrow	3	18.90	2.08	10.40	3.60	1.30	2.1
9	AN	180	In furrow	4	17.50	2.29	11.00	4.10	1.40	3.6
10	AN	60	Surface	1	19.60	2.30	12.30	3.80	1.43	2.4
10	AN	60	Surface	2	17.50	2.24	11.70	3.70	1.32	1.9
10	AN	60	Surface	3	18.90	2.18	9.00	3.40	1.33	2.1
10	AN	60	Surface	4	20.30	2.27	11.70	4.50	1.50	2.7
11	AN	120	Surface	1	19.60	2.35	13.00	3.50	0.95	2.7
11	AN	120	Surface	2	15.40	1.95	9.70	3.60	1.32	1.6
11	AN	120	Surface	3	14.70	1.91	9.00	3.20	1.15	1.7
11	AN	120	Surface	4	18.20	2.02	9.70	4.50	1.50	3.6
12	AN	180	Surface	1	16.80	2.31	11.70	3.30	1.32	2.4
12	AN	180	Surface	2	18.20	2.17	9.70	3.90	1.39	2.3
12	AN	180	Surface	3	16.80	1.88	8.40	3.40	1.17	2.1
12	AN	180	Surface	4	15.40	2.20	11.00	4.10	1.42	3

Continuing …

T#	Source	N Rate	Time	Rep	Leaf content					
					N	P	K	Ca	Mg	S
		kg/ha			g/kg					
13	Urea	60	In furrow	1	17.50	2.08	11.70	4.20	1.50	1.4
13	Urea	60	In furrow	2	14.70	2.05	11.70	3.20	1.30	2.4
13	Urea	60	In furrow	3	21.00	2.12	9.70	3.90	1.48	2.4
13	Urea	60	In furrow	4	17.50	2.19	10.40	5.20	1.74	2.9
14	Urea	120	In furrow	1	17.50	2.17	13.00	3.80	1.51	1.6
14	Urea	120	In furrow	2	16.10	2.01	10.40	3.70	1.56	2.3
14	Urea	120	In furrow	3	17.50	2.09	11.70	3.50	1.39	1.9
14	Urea	120	In furrow	4	18.20	2.37	10.40	5.20	1.63	3.4
15	Urea	180	In furrow	1	16.10	2.05	12.30	3.90	1.66	1.9
15	Urea	180	In furrow	2	17.50	1.99	11.00	3.80	1.28	2
15	Urea	180	In furrow	3	18.20	2.03	11.00	3.20	1.30	1.4
15	Urea	180	In furrow	4	17.50	2.25	10.40	4.70	1.74	3.3
16	Urea	60	Surface	1	18.20	2.13	10.40	4.30	1.61	1.3
16	Urea	60	Surface	2	16.80	2.05	10.40	3.80	1.51	1.9
16	Urea	60	Surface	3	17.50	2.28	11.70	3.60	1.34	1.6
16	Urea	60	Surface	4	17.50	2.28	10.40	4.70	1.67	3.3
17	Urea	120	Surface	1	18.20	1.78	10.40	3.80	1.26	2
17	Urea	120	Surface	2	19.60	2.13	11.00	3.90	1.28	2.1
17	Urea	120	Surface	3	16.80	1.98	7.70	2.50	1.14	1.9
17	Urea	120	Surface	4	18.20	2.32	10.40	4.70	1.68	2.7
18	Urea	180	Surface	1	16.10	2.14	13.70	4.30	1.48	1.6
18	Urea	180	Surface	2	17.50	1.95	10.40	3.40	1.33	1.7
18	Urea	180	Surface	3	17.50	2.05	9.00	3.50	1.28	2.9
18	Urea	180	Surface	4	18.20	2.35	9.70	4.60	1.55	2.3
19	Control	0	In furrow	1	21.70	2.58	13.00	3.60	1.16	3.7
19	Control	0	In furrow	2	16.10	2.12	11.00	3.50	1.46	1.7
19	Control	0	In furrow	3	17.50	2.18	11.70	3.20	1.32	2
19	Control	0	In furrow	4	19.60	2.25	11.00	4.60	1.75	3.4
20	Control	0	Surface	1	20.30	2.34	12.30	4.10	1.51	1.9
20	Control	0	Surface	2	17.50	2.24	12.30	4.00	1.44	1.6
20	Control	0	Surface	3	16.80	2.34	11.70	4.10	1.50	1.9
20	Control	0	Surface	4	20.30	2.22	11.70	4.50	1.47	2.7
21	AS	120	In furrow	1	18.20	2.24	11.70	5.30	1.76	1.7
21	AS	120	In furrow	2	15.40	1.98	9.70	3.20	1.30	2
21	AS	120	In furrow	3	17.50	2.10	10.40	2.90	1.24	1.7
21	AS	120	In furrow	4	18.20	2.24	11.70	3.70	1.31	2.4
22	AS	120	Surface	1	18.20	2.30	11.00	3.80	1.22	1.6
22	AS	120	Surface	2	18.20	2.06	10.40	3.50	1.43	2.4
22	AS	120	Surface	3	15.40	1.98	11.00	3.40	1.32	1.9
22	AS	120	Surface	4	17.50	2.21	12.30	4.20	1.49	2.9

Appendix 3. Raw data of Brazil-62 project, season 2014-2015.

T#	Source	N Rate	Time	Rep	Brix	Fiber	POL	TRS	GY	TPH	TSH
		kg/ha				%		kg/ton		ton/ha	
1	UAN	60	In furrow	1	17.97	14.2	12.21	123.46	63.34	7.73	7.82
1	UAN	60	In furrow	2	16.49	14.78	10.90	111.08	87.86	9.58	9.76
1	UAN	60	In furrow	3	19.15	13.89	13.36	134.09	85.29	11.39	11.44
1	UAN	60	In furrow	4	16.60	13.24	12.37	122.04	74.31	9.19	9.07
2	UAN	120	In furrow	1	16.59	13.68	11.16	113.76	66.86	7.46	7.61
2	UAN	120	In furrow	2	18.22	14.8	12.33	124.35	94.89	11.70	11.80
2	UAN	120	In furrow	3	18.10	12.73	12.85	129.35	86.77	11.15	11.22
2	UAN	120	In furrow	4	18.45	10.96	13.94	139.29	86.77	12.10	12.09
3	UAN	180	In furrow	1	17.50	10.76	13.93	136.49	71.77	10.00	9.80
3	UAN	180	In furrow	2	18.25	13.92	12.75	128.15	71.72	9.14	9.19
3	UAN	180	In furrow	3	18.15	14.97	12.07	122.18	97.24	11.74	11.88
3	UAN	180	In furrow	4	17.50	11.64	13.90	135.82	92.22	12.82	12.53
4	UAN	60	Surface	1	17.93	11.51	13.23	132.72	71.48	9.46	9.49
4	UAN	60	Surface	2	16.50	10.56	13.11	128.81	92.89	12.18	11.97
4	UAN	60	Surface	3	16.88	16.08	10.77	109.96	83.58	9.00	9.19
4	UAN	60	Surface	4	18.22	14.53	12.35	124.68	80.29	9.92	10.01
5	UAN	120	Surface	1	16.56	13.15	11.10	113.51	81.62	9.06	9.26
5	UAN	120	Surface	2	18.80	12.44	14.36	140.80	74.19	10.66	10.45
5	UAN	120	Surface	3	18.48	15.4	12.26	123.83	84.38	10.34	10.45
5	UAN	120	Surface	4	17.91	13.18	12.69	127.64	88.81	11.27	11.34
6	UAN	180	Surface	1	18.05	12.84	13.01	129.98	81.26	10.57	10.56
6	UAN	180	Surface	2	17.71	13.91	11.86	120.49	72.43	8.59	8.73
6	UAN	180	Surface	3	17.40	10.88	13.70	134.53	88.96	12.19	11.97
6	UAN	180	Surface	4	19.04	13.74	13.47	134.91	82.39	11.10	11.11
7	AN	60	In furrow	1	17.25	12.96	11.89	120.65	72.00	8.56	8.69
7	AN	60	In furrow	2	17.77	14.39	11.99	121.34	83.90	10.06	10.18
7	AN	60	In furrow	3	17.52	13.27	12.09	122.41	82.53	9.98	10.10
7	AN	60	In furrow	4	17.51	14.2	12.00	121.23	93.67	11.24	11.36
8	AN	120	In furrow	1	18.39	13.57	12.95	130.10	74.00	9.58	9.63
8	AN	120	In furrow	2	17.90	12.52	13.80	135.16	93.15	12.85	12.59
8	AN	120	In furrow	3	17.97	13.43	12.45	125.67	76.53	9.53	9.62
8	AN	120	In furrow	4	18.61	12.24	13.54	135.69	81.79	11.07	11.10
9	AN	180	In furrow	1	16.94	14.23	11.45	116.20	92.77	10.62	10.78
9	AN	180	In furrow	2	16.30	10.64	12.67	125.17	70.48	8.93	8.82
9	AN	180	In furrow	3	16.76	13.18	11.56	117.36	90.34	10.44	10.60
9	AN	180	In furrow	4	18.46	15.67	12.29	123.90	82.19	10.10	10.18
10	AN	60	Surface	1	17.51	13.07	12.40	124.91	91.48	11.34	11.43
10	AN	60	Surface	2	16.40	11.88	12.56	123.83	77.12	9.69	9.55
10	AN	60	Surface	3	17.93	12.89	12.51	126.34	78.15	9.78	9.87
10	AN	60	Surface	4	17.68	12.43	12.53	126.47	90.81	11.38	11.49
11	AN	120	Surface	1	18.40	11.76	14.96	145.28	73.86	11.05	10.73
11	AN	120	Surface	2	17.63	14.88	11.81	119.54	86.53	10.22	10.34
11	AN	120	Surface	3	17.31	14.76	11.21	114.49	75.05	8.41	8.59
11	AN	120	Surface	4	17.50	11.60	13.60	133.54	72.15	9.81	9.63
12	AN	180	Surface	1	17.81	11.31	12.94	130.38	72.29	9.35	9.43
12	AN	180	Surface	2	17.16	15.45	11.30	114.71	87.10	9.84	9.99
12	AN	180	Surface	3	18.20	14.92	12.62	126.60	79.34	10.01	10.04
12	AN	180	Surface	4	18.56	11.99	13.60	136.24	70.12	9.54	9.55

Continuing …

T#	Source	N Rate	Time	Rep	Brix	Fiber	POL	TRS	GY	TPH	TSH
		kg/ha				%		kg/ton		ton/ha	
13	Urea	60	In furrow	1	18.14	14.41	12.57	126.40	78.71	9.89	9.95
13	Urea	60	In furrow	2	15.70	11.36	11.81	117.35	76.24	9.00	8.95
13	Urea	60	In furrow	3	14.87	14.64	9.21	96.18	56.81	5.23	5.46
13	Urea	60	In furrow	4	18.04	10.87	13.33	133.99	78.91	10.52	10.57
14	Urea	120	In furrow	1	17.10	12.36	12.72	125.85	66.81	8.50	8.41
14	Urea	120	In furrow	2	18.22	14.27	12.25	123.97	87.27	10.69	10.82
14	Urea	120	In furrow	3	16.91	15.88	10.92	111.25	66.55	7.27	7.40
14	Urea	120	In furrow	4	18.16	13.59	12.56	126.71	65.48	8.22	8.30
15	Urea	180	In furrow	1	16.72	16.92	10.59	107.99	75.24	7.97	8.13
15	Urea	180	In furrow	2	18.15	11.69	13.46	134.73	90.55	12.19	12.20
15	Urea	180	In furrow	3	17.76	13.63	12.23	123.61	75.24	9.20	9.30
15	Urea	180	In furrow	4	17.32	14.69	11.69	118.30	61.03	7.13	7.22
16	Urea	60	Surface	1	17.30	14.54	11.41	116.18	64.24	7.33	7.46
16	Urea	60	Surface	2	16.93	15.96	10.82	110.49	91.77	9.93	10.14
16	Urea	60	Surface	3	19.02	12.28	14.28	142.01	78.86	11.26	11.20
16	Urea	60	Surface	4	17.13	14.21	11.03	113.17	60.57	6.68	6.86
17	Urea	120	Surface	1	18.04	14.29	12.32	124.36	73.81	9.09	9.18
17	Urea	120	Surface	2	17.21	15.17	11.32	115.04	87.77	9.94	10.10
17	Urea	120	Surface	3	17.92	14.03	12.09	122.47	81.96	9.91	10.04
17	Urea	120	Surface	4	16.26	14.96	10.62	108.56	68.15	7.24	7.40
18	Urea	180	Surface	1	17.51	13.52	11.98	121.40	75.29	9.02	9.14
18	Urea	180	Surface	2	17.09	13.87	11.60	117.70	87.05	10.10	10.25
18	Urea	180	Surface	3	16.63	16.22	10.92	110.79	70.67	7.72	7.83
18	Urea	180	Surface	4	17.09	14.15	11.25	114.84	66.31	7.46	7.62
19	Control	0	In furrow	1	16.80	11.16	13.22	129.85	64.93	8.59	8.43
19	Control	0	In furrow	2	17.08	13.11	11.48	117.14	79.43	9.12	9.30
19	Control	0	In furrow	3	14.60	10.56	10.84	108.84	68.34	7.41	7.44
19	Control	0	In furrow	4	16.52	14.95	10.73	109.77	67.53	7.25	7.41
20	Control	0	Surface	1	15.74	13.90	11.93	118.36	71.66	8.55	8.48
20	Control	0	Surface	2	15.09	10.72	15.11	142.98	75.22	11.37	10.75
20	Control	0	Surface	3	16.78	13.85	11.54	116.91	71.29	8.23	8.33
20	Control	0	Surface	4	15.35	17.13	9.15	95.20	68.48	6.27	6.52
21	AS	120	In furrow	1	16.41	14.71	10.58	108.56	70.81	7.49	7.69
21	AS	120	In furrow	2	16.48	15.09	10.70	109.38	70.91	7.59	7.76
21	AS	120	In furrow	3	18.60	11.34	13.85	138.55	86.05	11.92	11.92
21	AS	120	In furrow	4	17.95	13.34	12.58	126.75	81.48	10.25	10.33
22	AS	120	Surface	1	17.00	14.83	11.07	113.03	84.10	9.31	9.51
22	AS	120	Surface	2	17.55	14.57	11.81	119.60	84.34	9.96	10.09
22	AS	120	Surface	3	17.38	12.53	12.15	123.04	92.01	11.18	11.32
22	AS	120	Surface	4	17.00	12.47	12.75	125.86	76.17	9.71	9.59