Nativa, Sinop, v.4, n.5, p.296-302, set./out. 2016.
Pesquisas Agrárias e Ambientais
DOI: 10.14583/2318-7670.v04n05a05
http://www.ufmt.br/nativa

ISSN: 2318-7670

Subdivision of nitrogen fertilization in irrigated bean culture in the Middle-North of Mato Grosso, Brazil

Edilson CAVALLI[1*], Anderson LANGE[1], Antonio Carlos BUCHELT[1], Cassiano CAVALLI[2], Flávio Jesus WRUCK[3]

[1] Instituto de Ciências Agrárias e Ambientais, Universidade Federal de Mato Grosso, Sinop, Mato Grosso, Brasil.
[2] Instituto Agronômico de Campinas, Campinas, Brasil.
[3] Embrapa Agrossilvipastoril, Sinop, Mato Grosso, Brasil.
*E-mail: edilso_c@hotmail.com

Recebido em fevereiro/2016; Aceito em julho/2016.

ABSTRACT: This study aimed to evaluate the effect of subdividing nitrogen fertilization on irrigated beans into two moments. The study was developed in Vera, MT, Brazil, from August to November 2012, under central pivot in direct sowing system. The experimental design consisted in randomized blocks with 10 treatments and four replications. Treatments consisted in dividing nitrogen application in two moments (sowing and coverage) with the final dose of 120 kg ha^{-1} except for the control treatment which received only 30 kg ha^{-1} at sowing. The following characteristics were evaluated: plant dry weight at flowering and at harvest, plant height and insertion of the first pod, nitrogen content in leaf and in grain, chlorophyll analysis (nitrogen sufficiency index and SPAD), nitrogen export, number of grains per pod and pods per plant, weight of one hundred grains and productivity. Pearson correlation was carried out for all factors. There was a significant difference between treatments only for productivity and nitrogen export, and the best results were observed in treatments that received fertilization equally divided between sowing and coverage. Production components that correlated with productivity were weight of one hundred grains and number of pods per plant.

Keywords: *Phaseolus vulgaris*, winter cultivation, direct sowing system.

Parcelamento da adubação nitrogenada na cultura do feijoeiro irrigado no Médio Norte do Mato Grosso

RESUMO: O presente estudo objetivou avaliar a influência do parcelamento da adubação nitrogenada em duas épocas no feijoeiro irrigado. O estudo foi desenvolvido em Vera, MT, Brasil, no período de agosto a novembro de 2012, sob pivô central em sistema de semeadura direta. O delineamento experimental utilizado foi o de blocos ao acaso, com 10 tratamentos e quatro repetições. Os tratamentos consistiram na divisão da aplicação de nitrogênio em duas épocas (semeadura e cobertura) sendo a dose final de 120 kg ha^{-1} exceto em um tratamento controle que recebeu apenas 30 kg ha^{-1} na semeadura. Foram avaliadas as seguintes características: massa seca de plantas no florescimento e na colheita, altura de plantas e inserção da primeira vagem, teor de nitrogênio na folha e no grão, análise de clorofila (índice de suficiência de nitrogênio e SPAD), exportação de nitrogênio, números de grãos por vagem e vagens por planta, massa de cem grãos e produtividade, realizando-se correlação de Pearson para todos os fatores. Em relação aos tratamentos houve diferença significativa, apenas para a produtividade e exportação de Nitrogênio, sendo observado os melhores resultados nos tratamentos que receberam adubação dividida de forma igual na semeadura e em cobertura. Os componentes de produção que apresentaram correlação com a produtividade foram a massa de cem grãos e o número de vagens por planta.

Palavras-chave: *Phaseolus vulgaris*, cultivo de inverno, sistema de semeadura direta.

1. INTRODUCTION

The main crops cultivated in the Middle-North of Mato Grosso are soybeans and corn. Soybean is sown in the first harvest and maize in the second harvest, up to February 15, preferably. Beans appear as an option for crop rotation. This is grown in the second harvest or in the winter under pivot, from May onwards. It is an economic alternative because the prices in recent years have turned beans into a profitable crop.

Cerrado soils with built fertility, which are usually found at pivot areas in the state of Mato Grosso, favor bean crops because this has root system concentrated mainly in the soil surface layer. Most of the roots (62-87%) spread through the 10 cm of the surface and nearly the entire root system is restricted to the first 20 cm of depth (SANTOS; GAVILANES, 2006). In this situation, and with the control of irrigation, nitrogen (N) is the nutrient that has generated more questions on which is the best source, dose and right time to carry out fertilization, since the nutritional deficiency most frequently observed in bean crops happens due to N (BARBOSA FILHO; SILVA, 2001), because much of the nutrient is absorbed and exported along with the grain (MEIRA et al., 2005). This situation is further worsened in the region because, in some cases, corn was the previous crop, and this leaves residues with high C/N ratio in the soil. The N is present in the DNA, RNA, chlorophyll, coenzymes, amino acids, proteins, enzymes, and it is necessary for many other functions. Thus, N deficiency makes the plant less resistant to pests and diseases (MALAVOLTA, 2008).

There are three ways through which N can be provided for the plants: mineralization of crop residues through the microbial action, but in this case only a fraction becomes available to the subsequent culture (MALAVOLTA, 2006); biological nitrogen fixation (SILVA et al., 2007), but this is often insufficient when high productivity is sought (KANECO et al., 2010; SILVA et al. 2009), Berthold et al. (2015) observed that the inoculation, by itself, is not enough to achieve grain yield at similar levels obtained with application of urea (70 kg ha^{-1} of N); and nitrogen fertilization, which has its efficiency affected by factors such as source, dose and application method (BARBOSA FILHO; SILVA, 2001).

For this, the management strategy monitored with the aid of portable chlorophyll meters has been used. This is a promising strategy, since some studies have shown high agronomic efficiency of nitrogen fertilization (BARBOSA FILHO et al., 2008; BARBOSA FILHO et al., 2009).

As mentioned, the response to N may vary depending on the type of residue left by the previous crop. In terms of residues with higher C/N ratio, more N is spent in its decomposition (BARBOSA FILHO; SILVA, 2001) and in this context, with sowing in succession to grasses with high C/N ratio, it is recommended increasing the amount N in the order of 20 to 30 kg ha^{-1} at sowing, to compensate for the immobilization of the nitrogen fertilizer (RIBEIRO et al., 1999).

Although bean gets part of its demand of N from the association with bacteria of the genus *Rhizobium*, the amount of the nutrient provided by this process is usually insufficient and needs to be supplemented, which is done by means of mineral fertilization (SILVA et al., 2007). Lago et al. (2009) evaluated the bean yield with and without the use of N and they observed a productivity that was 63% higher when N was provided. This corroborates Binotti et al. (2007), where a 62% higher productivity was obtained with the use of N, with increase in the total N in leaves and grains. Barbosa Filho; Silva, (2001) found an increase in productivity of about 100 kg ha^{-1} when the application of N was released in different moments. In turn, Binotti et al. (2009) found no difference in productivity between provision of N in a single moment, at sowing, or dividing fertilization in different moments, and still, nitrogen content in the leaf was higher when dividing fertilization.

The present study aimed to evaluate the effect of subdividing nitrogen fertilization in two seasons on irrigated beans.

2. MATERIAL AND METHODS

The experiment was conducted during the growing season of 2012, in the commercial area of Celeste farm, located in the municipality of Vera, Middle-North Mato Grosso, Brazil. The climate is classified as Aw according to Köppen classification, with well-defined dry season, which is typically a rigorous dry season (September/October to March/April), and very intense rainy season. The average temperature ranges from 20 to 38°C, with a mean of 26 °C.

The soil of the experimental area was sampled before sowing with the help of auger tube and 20 subsamples were collected in the experimental area in the depths of 0-0.10 and 0.10-0.20 m, generating a composite sample at each depth (Table 1).

The cultivar evaluated was the BRS Style cultivar, which has an average weight of 26.0 g per 100 grains and normal cycle (85-90 days from emergence up to physiological maturity). The plants are shrubby, with habit of indeterminate growth, type II. The beans are of the "carioca" type (beige with brown stripes). With regard to plant architecture, the BRS style is straight and has good tolerance to lodging, it is adapted to mechanical harvesting, with potential production of 4,011 kg ha^{-1}.

The experimental design used was a randomized block design, consisting of ten treatments (types of subdivision of N fertilization) (Table 2) with four replications, totaling 40 plots. The plots were composed of six 4-meters-long lines, 0.45 m distant from each other, and the floor area of the plot was made up of the four central lines, discounting one meter at both ends of the plot, and totaling eight linear meters per plot.

The preparation of the area, sowing, control of pests and weeds as well as the basic fertilization followed the management

Table 2. Treatments used in the field where: treatment (TRT.), nitrogen applied at sowing (N. SO.), nitrogen applied on coverage (N. COV.), total nitrogen applied (N. TOTAL).

Tabela 2. Tratamentos empregados no campo, em que: tratamento (TRT.), nitrogênio aplicado na semeadura (N. SO.), nitrogênio aplicado em cobertura (N. COV.), Nitrogênio total aplicado (N. TOTAL).

Treatment	N. SO.	N. COV.	N. TOTAL
		kg ha^{-1}	
T1	30	0	30
T2	30	90^{L}	120
T3	40	80	120
T4	50	70	120
T5	60	60	120
T6	60	60^{L}	120
T7	70	50	120
T8	80	40	120
T9	90	30	120
T10*	100	20	120

^{L} nitrogen applied based on chlorophyll readings, applied when the reading reached 90% of the reading of a standard plot.
* Standard plot.

Table 1. Chemical characteristics of the soil according to the analysis performed prior to implementation of the experiment, at depths of 0.0-0.10 and 0.10-0.20 m.

Tabela 1. Características químicas do solo conforme análise realizada antes da implantação do experimento, nas profundidades de 0,0-0,10 e 0,10-0,20 m.

Depth	pH(H_2O)	K*	P*	Ca	Mg	Al	Al+H	CTC_{pH7}	V	O.M.
m		mg dm^{-3}				cmol$_c$ dm^{-3}			%	g kg^{-1}
0.0-0.10	5.60	49.70	8.50	4.00	2.70	0.00	2.00	8.83	77.34	28.60
0.10-0.20	5.54	45.70	13.30	2.70	2.30	0.00	2.50	7.60	67.17	27.60

* Extraction by Mehlich 1.

of the farm. Sowing was done in direct sowing system on corn stover on August 4 and it was carried out mechanically, planting 13 seeds per linear meter, resulting in a population of about 290,000 seeds ha^{-1}.

The basic fertilization was mechanically performed at sowing, applying 270 kg ha^{-1} of MAP, totaling 119 kg ha^{-1} of P_2O_5 and 24,3 kg ha^{-1} of N. Potassium (K) was applied by throwing in two moments using KCl (60% of K_2O) as source, with 106 kg ha^{-1} KCl two days before sowing and 104 kg ha^{-1} KCl five days after emergence (DAE), totaling 126 kg ha^{-1} of K_2O. All treatments were inoculated with peaty inoculant (Masterfix®), 24 h before sowing, by seeds, at a dose of 200 g per 50 kg of seed.

In the basic nitrogen fertilization, urea was thrown to complement the dose of the farm (24.3 kg ha^{-1} of N); for coverage fertilization, urea was also thrown (45% N) at 20 DAE. In the treatments T2 and T6, fertilization was carried out based on the nitrogen sufficiency index (NSI) applied when this was at 90% of the maximum control dose, which occurred at 22 DAE. The standard treatment was T10. The NSI is obtained through chlorophyll analysis with the use of chlorophyll meter (CFL1030-FALKER®) which compares a given plot with a standard plot without N deficiency. After nitrogen fertilization, 20 mm of water was applied to prevent loss of fertilization.

Cultural practices such as pesticide application were all performed by the farmer using a self-propelled sprayer, applying a volume of 100 L ha^{-1}. Control with fungicides was carried out at 28, 43 and 61 DAE. The irrigation experiment was carried out with central pivot, and it followed the management of the farm, which was based on planed application with 72 h irrigation schedule and fixed layer of 20 mm.

When the beans were in full bloom, plants were collected to obtain the dry weight of the plant at flowering, and of leaves for analysis of nitrogen content. When physiological maturity was reached, a manual harvest was carried out, picking up ten plants in the two center lines for carrying out evaluations of the following parameters: plant height, height at insertion of the first pod, number of pods per plant, number of grains per pod, weight of one hundred grains, nitrogen content in the grain and nitrogen export, and plant dry weight at harvest. In order to determine grain productivity, plants were collected from the eight linear meters of the floor area, thrashing them with the aid of a mechanical threshing, weighing the grains and correcting to 13% of moisture, and converting the data to kg ha^{-1}. Nitrogen content analyses were performed using the Kjeldahl method (EMBRAPA, 2009).

At 45 DAE, readings were taken at three points of the plot using the chlorophyll meter (CFL1030-FALKER®), two plants per point and five readings per leaf (penultimate fully developed trifoliate leaf), throughout the leaf limb, except for the ribs, totaling 30 readings per plot and 120 per treatment, according to the adapted methodology of Barbosa Filho et al. (2008). Readings were taken from 10h in the morning onwards, always by the same operator in the absence of clouds.

Data were evaluated through simple analysis of variance (F test). Means were compared with Tukey test at 5% probability in the program SISVAR® (FERREIRA, 2011). Pearson's correlation coefficient (r) was also used, in excel, to verify if data is correlated to 1 or 5% in the F test, according to the methodology proposed by Garlaça et al. (2010).

3. RESULTS AND DISCUSSION

3.1. Agronomic characteristics

Plant dry weight at flowering (DWF) and at harvesting (DWH) did not differ between treatments (Table 3), which may have occurred due to the fact that all received nitrogen fertilizer and were inoculated with rhizobia. The average was 41.42 g $plant^{-1}$ at flowering and 42.94 g $plant^{-1}$ at harvesting. Soratto et al. (2001) had higher shoot dry weight at flowering with early application of N in relation to late application in direct sowing system, indicating the need for N in initial moments in the system. Increases in dry mass are more related to the total amount of N applied than to the subdivision of fertilization.

Table 3. Plant dry weight at flowering (DMF); dry weight at harvest (DWH); number of pods per plant (PPP); number of grains per pod (GPP); weight of 100 grains (M100) and productivity (PRO), which is presented in kg ha^{-1}; gain in percentage compared to the control treatment (T1). Vera, MT, Brazil, 2013.
Tabela 3. Massa seca de plantas no florescimento (MSF); massa seca de plantas na colheita (MSC); número de vagens por planta (VPP); número de grãos por vagens (GPV); massa de 100 grãos (M100) e produtividade (PRO) sendo esta apresentada em kg ha^{-1} e ganho em porcentagem em relação ao tratamento testemunha (T1). Vera, MT, Brasil, 2013.

Treatment	DMF^{ns}	DWH^{ns}	PPP^{ns}	GPP^{ns}	$M100^{ns}$	PRO^{*}	
	(g PL^{-1})				G	kg ha^{-1}	(%)
T1	37.73	34.65	16.55	4.41	26.49	2500.3 c	100
T2	43.38	46.69	21.83	4.72	25.95	2740.8 bc	110
T3	36.81	37.54	17.78	4.44	25.44	2881.2 ab	115
T4	33.68	45.33	19.03	4.72	25.99	2924.4 ab	117
T5	44.64	47.55	25.15	4.39	26.60	3099.0 a	124
T6	52.03	50.58	24.62	4.43	26.79	2910.0 ab	116
T7	43.84	42.72	21.15	4.20	25.88	2487.6 c	99
T8	36.48	44.49	21.85	4.65	24.94	2818.8 abc	113
T9	43.71	44.89	21.25	4.66	25.83	2790.6 abc	112
T10	41.89	35.00	16.73	4.49	26.25	2793.6 abc	112
CV (%)	31.52	20.38	21.68	6.94	6.64	5.25	
DMS	31.75	21.28	10.86	0.76	4.20	355.96	
Mean	41.42	42.94	20.59	4.51	26.02	2794.6	

ns not significant,*significant according to Tukey test at 5% probability of error.

Treatments: T1 (30[1] S2); T2 (30 S + 90 C3)*; T3 (40 S + 80 C); T4 (50 S + 70 C);T5 (60 S + 60 C); T6 (60 S + 60 C)*; T7 (70 S + 50 C); T8 (80 S + 40 C); T9 (90 S + 30 C); T10(100 S + 20 C), wherein: 1-Dose applied kg ha^{-1}; 2-Applied at sowing (S); 3-Applied on coverage (C); * -treatments where fertilization of coverage was performed according to the reading of chlorophyll.

Studies with N doses have shown to exert a positive effect on mass accumulation in plants at flowering (BINOTTI et al., 2010). No differences between treatments were observed for plant height and height at insertion of the first pod. These parameters averaged 101.0 and 27.7 cm, respectively.

Number of grains per pod was not affected by nitrogen fertilization and the average of treatments was 4.51 grains pod $^{-1}$ (Table 3). The data reported by Meira et al. (2005), who evaluated doses and times of nitrogen fertilization, did not find difference for this variable. This feature may be intrinsic to genotypes and may not be influenced by the environment. However, Salgado et al. (2012) evaluated 12 cultivars and found that four of them responded to nitrogen fertilization by increasing the number of grains per pod.

Salgado et al. (2012) found that higher N doses result in highest average of pods per plant, as Soratto et al. (2001) found an increase in the number of pods proportional to the increase of the dose, but without interference of the season.

The weight of 100 grains (M100) did not differ between treatments. Overall, the mean was 26.02 g, which is nearly equal to the average indicated to the BRS style, which is 26 g (CARGNIM; ALBRECHT, 2010), demonstrating that decrease of M100-induced by lack of N did not happen in any of the treatments.

Nascimento et al. (2009) found no relationship between nitrogen fertilization and M100, a result that can be explained by the work done by Salgado et al. (2012), who studied the effect of nitrogen levels in 12 cultivars and found different responses to N doses, although only three responded to nitrogen fertilization. Fernandes et al. (2005), while evaluating fertilization in the planting furrow (0 and 20 kg ha^{-1}) and on coverage (0 and 70 kg ha^{-1}), showed a negative effect of nitrogen fertilization on the weight of 100 grains. This may have occurred because nitrogen fertilization result in a greater number of pods, generating less mass per grain.

The highest yields were observed in the treatments T4, T5 and T6 (Table 3), management in which the nitrogen fertilization was divided equally between the base and the coverage [T4 (50 S + 70 C); T5 (60 S + 60 C); T6 (60 S + 60 C)], with T6 corresponding to the application according to chlorophyll meter (90% of the standard), while more concentrated doses in the base or in the coverage led to lower yield. The control with only 30 kg ha $^{-1}$ of N at sowing, and T7 (70 S + 50 C) were the least productive (~ 2500 kg ha^{-1}), while T5, the more productive, produced 51.65 bags ha $^{-1}$ (3,099 kg), what means an increase of 24%. In general, the average productivity of 2794.6 kg ha^{-1} was 95% higher than that of the state of Mato Grosso (1433 kg ha^{-1}). Soratto et al. (2001) found significant differences between times of N application; the most efficient time was 15 DAE. Salgado et al. (2012) found responses to N in seven out of 12 cultivars studied.

It can be observed among the treatments where applications were not equally divided, those receiving the lowest doses at sowing had also the lower productivity. This is due to the fact that the efficiency and the dose of N in direct sowing system depend on the amount and the C/N ratio of the straw, which changes the dynamics of the nutrient. In the present case, sowing occurred on corn straw. It is also observed that the treatment T10, which received almost all the fertilizer at sowing, also obtained a low average. This shows the need for fertilization of coverage with N to meet the demands of the culture and also that the possible N immobilization occurred without mineralization in time to meet the bean.

Carvalho et al. (2003) tested doses of N (0; 35; 70; 105 and 140 kg ha^{-1}) and application times (total at 15 DAE, total at 30 DAE and divided between 15 and 30 DAE) and they obtained a linear increase in productivity with increasing dose, regardless of the time. As for the time of application and the interaction time x dose, there was no difference, noting that the responses to high doses can be the result of high C/N ratio of the preceding crops, which in that case was corn.

For all parameters analyzed, we must take into account that there was general inoculation, and that the area has built fertility and that controlled irrigation was employed. All these factors may have influenced the parameters and promoted adequate conditions for the crop. This was observed in the control treatment, which despite having presented a lower productivity when compared to other treatments, it had an average 74% superior to the average of the MT state.

3.2. Reading of the nitrogen sufficiency index (NSI), SPAD and N concentration

Nitrogen concentrations on leaf in full bloom did no differ between treatments (Table 4). The lowest value of 39.06 g kg-1 of^{-1} was observed in the treatment T1 (lower dose of N), but this value is not below the critical level of N in leaf, which is, according to Ambrosano et al. (1996), 30 g kg^{-1}. This ensured a productivity that was greater than 2,500 kg ha $^{-1}$.

According to Valderrama et al. (2009), the content of N in the leaf is directly influenced by the increase of N doses. When testing doses on coverage, they obtained values of 31.50 g kg^{-1} in the control and up to 39.25 g kg^{-1} in the treatment that received 120 kg ha^{-1} of N. Fernandes et al. (2005) found higher N levels in treatments that received lower doses of N, and they point out

Table 4. Nitrogen concentration in the leaf at flowering (NCF), nitrogen concentration in the grain (NCG); chlorophyll reading (CR); nitrogen export (EX) in relation to the treatments. Vera, MT, Brazil, 2013.

Tabela 4. Concentração de nitrogênio na folha da planta em florescimento (CNF), concentração de nitrogênio no grão (CNG); leitura de clorofila (LC); exportação de nitrogênio (EX) em relação aos tratamentos utilizados. Vera, MT, Brasil, 2013.

Treatments	NCF^{ns}	NCG^{ns}	CR^{ns}	ISN	EX*
	(g kg^{-1})		(unit)	%	(kg ha^{-1})
T1	39.06	29.65	47.56	98	64.50 c
T2	41.72	31.85	47.81	99	75.91 abc
T3	40.95	31.50	46.79	96	78.91 ab
T4	40.92	32.03	47.89	99	81.53 ab
T5	41.79	31.85	48.49	100	85.88 a
T6	42.70	31.68	47.68	98	80.17 ab
T7	43.09	32.03	46.70	96	69.33 bc
T8	42.28	32.38	47.52	98	79.47 ab
T9	41.06	32.55	48.28	100	79.06 ab
T10	41.58	31.15	47.94	99	75.73 abc
CV (%)	8.05	4.48	4.05	-	7.30
DMS	8.13	3.45	4.69	-	13.69
Mean	41.51	31.67	47.66	-	77.05

^{ns} not significant,*significant according to Tukey test at 5% probability of error.

Treatments: T1 (301 S2); T2 (30 S + 90 C3)*; T3 (40 S + 80 C); T4 (50 S + 70 C);T5 (60 S + 60 C); T6 (60 S + 60 C)*; T7 (70 S + 50 C); T8 (80 S + 40 C); T9 (90 S + 30 C); T10(100 S + 20 C), wherein: 1-Dose applied kg ha^{-1}; 2-Applied at sowing (S); 3-Applied on coverage (C); * -treatments where fertilization of coverage was performed according to chlorophyll reading.

that this may be due to a dilution effect of N content. This effect happens because when the dose of N is increased, this creates conditions for the plant to produce more dry mass, resulting in a lower N content in the plant tissue.

The application of 120 kg ha^{-1} of N kept the nutrient concentrations in the grain close to 31.67 g kg^{-1} (Table 4), regardless the application time.

Chlorophyll reading were similar in all treatments. This is possibly because readings were conducted at 45 DAE, and 24 days after the last application of N. Except for the control (lower dose of N), all other treatments received the same final dose (120 kg ha^{-1} of N). Barbosa Filho et al. (2009) analyzed the chlorophyll content during the the development of the culture and they found increasing content up to the moment of flowering, when this content stabilizes.

According to Cate; Nelson (1971), critical values of nitrogen sufficiency index (NSI) were equal to 90% of the maximum, when values are lower than this, there is no indication that response to supplemental N application may happen. According to this methodology, it is observed that none of the treatments presented deficiency at the reading.

The treatment T5 (60S + 60C) was the one that most exported N, with ~ 86 kg ha^{-1}, While the overall average of the study was ~77 kg ha^{-1}. The control treatment, with lower productivity, lower concentration of N in leaf and grain and lower NSI, also had the lowest N export rate, with 64.5 kg ha^{-1} of N, a result of the addition of only 30 kg ha^{-1} of N. This treatment exported 34.5 kg ha^{-1} over the amount received at fertilization. One of the likely sources of this N was fixation, as beans were inoculated, and the MO of the soil. In a study conducted by Perez et al. (2013) the average nitrogen export was 28.7 kg to 1000 kg of grains produced, which is consistent with the value observed in the present work. Taking into account the average export of N with grains and the average productivity, we would have 27.6 kg to 1000 kg of grains produced.

Lago et al. (2009) conducted two experiments, one with application of N (30 kg ha^{-1} at sowing and 40 kg ha^{-1} on coverage) and another without N application. Both experiments had six cultivars, and greater accumulation of N was obtained in the experiment that received nitrogen fertilizer.

3.2. Pearson correlation coefficients

Among the positive correlations, content of N on leaf (NCL) and the dry mass of the plant at harvest (DMH) were significantly correlated, making clear that N is important for vegetative growth of bean, and that the increase in NCL causes increase in DMH (Table 5). It was found that the DMH was negatively correlated with the height of insertion of the first pod (IFP). This is justified by the fact that plants that had the first highest pod were more etiolated and had fewer side branches, and this led to lower DMH. A correlation with N doses applied on coverage (N. COV.) was also observed. This means that increasing the dose of N on coverage promotes an increase in the DMH.

The IFP had a direct correlation with plant height (PH), because the plants that had greater increases in height had also the tallest first pod. There was also a correlation with the number of pods per plant (PPP). However, in this case, this correlation was negative, which can possibly be explained by the fact that plants with tallest IFP produced fewer pods.

Among the evaluated parameters, those that correlated with the number of pods per plant (PPP) were nitrogen concentration in the leaf (NCL), dry weight at harvest (DWH), productivity (PD), N export (EX) and insertion of the first pod (IFP), all with positive correlations except for IPV, which had negative correlation. Possibly, the NCL led the plant to higher DWH. The plant with higher dry weight represents a larger plant with greater number of leaves, which result in a higher rate of photosynthesis generating greater amount of photo-assimilated compounds, providing better conditions for flowering and greater fertilization of these flowers. In turn, plants that had the tallest first obtained smaller numbers of pods per plant.

The W100 had a positive correlation with plant dry weight at flowering (DWF), productivity (PR) and height at insertion of

Table 5. Pearson correlation coefficients estimated between evaluated parameters [productivity (PD), nitrogen export (EX), chlorophyll reading (CR), nitrogen concentration in grains (NCG), nitrogen concentration in the leaf (NCL), weight of 100 grains (W100), number of pods per plant (PPP), grains per pod (GPP), height at insertion of the first pod (IFP), plant height (PH), plant dry weight at harvest (DWH), plant dry weight at flowering (DWF), nitrogen applied at sowing (NS) and nitrogen applied on coverage (NC)].
Tabela 5: Coeficientes de correlação de Pearson estimados entre parâmetros avaliados (produtividade (PD), exportação de Nitrogênio (EX), leitura de clorofila (LC), concentração de nitrogênio no grão (TNG), concentração de nitrogênio na folha (TNF), massa de 100 grãos (M100), vagens por planta (VPP), grãos por vagem (GPV), altura de inserção de primeira vagem (IPV), altura de planta (AL), massa seca de planta na colheita (MSC), massa seca de planta no florescimento (MSF), nitrogênio aplicado na semeadura (NS) e nitrogênio aplicado em cobertura (NC)).

	PD	EX	CR	NCG	NCL	W100	PPP	GPP	IFP	PH	DWH	DWF
EX	**0.90****	-										
CR	0.22	-0.31	-									
NCG	0.03	**0.63***	-0.26	-								
NCL	0.19	**0.89***	-0.23	0.21	-							
W100	**0.53***	-0.20	0.21	-0.15	-0.16	-						
PPP	**0.38****	**0.32****	-0.17	0.06	**0.37****	0.13	-					
GPP	0.25	-0.11	0.09	0.07	-0.18	0.09	0.12	-				
IFP	0.11	-0.26	**0.38****	-0.12	-0.25	**0.35****	**-0.53***	-0.03	-			
PH	**0.33****	-0.16	0.16	0.11	-0.26	0.26	0.03	**0.58***	**0.33****	-		
DWH	**0.42***	0.30	-0.13	0.12	**0.31****	0.17	**0.82***	**0.40****	**-0.37****	0.26	-	
DWF	0.29	0.02	0.08	0.18	-0.08	**0.38****	0.19	-0.14	0.00	0.07	0.27	-
NS	0.06	0.22	0.08	0.24	0.15	-0.06	0.05	0.00	-0.05	0.09	0.00	0.08
NC	0.19	0.23	-0.05	0.27	0.14	-0.06	0.24	0.12	-0.08	0.23	**0.32****	0.03

* F test sifnificant at 1% ($p < 0.01$)

** F test sifnificant at 5% ($p < 0.05$)

the first pod (IFP). Plants with higher DWF resulted in greater W100, and this happens because plants with higher DWF generate greater amount of photo-assimilated compounds and, therefore, these grains are drained for increasing their weight. With respect to IFP, plants higher IFPE had fewer pods and that led to a smaller grain yield per plant and, consequently, heavier grains.

The production components that influenced directly the productivity were the W100 grains and the number of pods per plant (PPP), with a positive correlation. There was also positive correlation between productivity and plant height (PH) and plant dry weight at harvest (DWH). It is possible that the tallest plants (PH) propitiated better development of lateral branches, causing higher dry weight at harvest (DWH), which has provided conditions for the plant to attain a greater number of PPP and of W100.

Export of N (EX) was influenced by the concentration of N in the grain (NCG), concentration in the leaf (NCL) and number of pods per plant (PPP) and productivity (PD). This is demonstrated in the Pearson correlation diagram (Table 5), in which the number of PPP directly influences the productivity, a higher NCL enables greater translocation of N to the grain, resulting in higher NCG.

4. CONCLUSIONS

Nitrogen fertilization in high productivity bean crop has better results when equally divided between the base and the coverage.

The production of components that directly influenced productivity were weight of 100 grains and number of pods per plant.

The number of pods per plant correlates positively with the nitrogen concentration in the leaf at full flowering.

5. ACKNOWLEDGEMENTS

To the FAPEMAT (Universal Notice, process Nº 300111/2010) for providing financial support to the project, to the Soils Laboratory of the UFMT/Sinop, MT and all academic collaborators who participated in the work.

6. REFERENCES

AMBROSANO, E. J.; WUTKE, E. B.; AMBROSANO, G. M. B.; BULISANI, E. A.; BORTOLETTO, N.; MARTINS, A. L. M.; PEREIRA, J. C. V. N. A.; SORDI, G. Resposta da aplicação de micronutrientes no cultivo de feijão irrigado no inverno. **Scientia Agricola**, Jaboticabal, v. 53, n. 2-3, p. 273-279, 1996.

BARBOSA FILHO, M. P.; COBUCCI, T.; FAGERIA, N. K.; MENDES, P. N. Época de aplicação de nitrogênio no feijoeiro irrigado monitorado com auxilio de monitor portátil. **Ciência e Agrotecnologia**, Lavras, v. 33, n. 2, p. 425-431, 2009.

BARBOSA FILHO, M. P.; COBUCCI, T.; FAGERIA, N. K.; MENDES, P. N. Determinação da necessidade de adubação nitrogenada de cobertura no feijoeiro irrigado com auxílio do clorofilômetro portátil. **Ciência Rural**, Santa Maria. v. 38, n. 7, p.1843-1848, 2008. http://dx.doi.org/10.1590/S0103-84782008000700007

BARBOSA FILHO, M. P.; SILVA, O. F. **Adubação de cobertura do feijoeiro irrigado com uréia fertilizante em plantio direto.** Informações Agronômicas nº 93 – março/2001

BERTOLDO, J. G.; PELISSER, A.; SILVA, R. P.; FAVRETO, R.; OLIVEIRA, L. A. D. Alternativas na fertilização de feijão visando a reduzir a aplicação de N-ureia. **Revista Pesquisa Agropecuária Tropical**, Goiânia, v. 45, n. 3, p. 348-355, 2015. http://dx.doi.org/10.1590/1983-40632015v4534885

BINOTTI, F. F. S.; ARF, O.; CARDOSO, E. D.; SÁ, M. E.; BUZETTI, S.; NASCIMENTO, V. Fontes e doses de nitrogênio em cobertura no feijoeiro de inverno irrigado no sistema plantio direto. **Bioscience Journal**, Uberlândia, v. 26, n. 5, p. 770-778, 2010.

BINOTTI, F. F. S.; ARF, O.; ROMANINI JUNIOR, A.; FERNANDES,F. A.; SÁ, M. E.; BUZETTI, S. Manejo do solo e da adubação nitrogenada na cultura de feijão de inverno e irrigado. **Bragantia**, Campinas, v. 66, n. 1, p. 121-129, 2007. http://dx.doi.org/10.1590/S0006-87052007000100015

BINOTTI, F. F. S.; ARF, O.; SÁ, M. E.; BUZETTI, S.; ALVAREZ, A. C. C.; KAMIMURA, K. M. Fontes, doses e modo de aplicação de nitrogênio em feijoeiro no sistema plantio direto. **Bragantia**, Campinas, v. 68, n. 2, p. 473-481, 2009. http://dx.doi.org/10.1590/S0006-87052009000200022

CARGNIM, A.; ALBRECHT, J. C. **BRS Estilo: nova cultivar de feijoeiro comum do grupo comercial carioca para o Distrito Federal**. Comunicado Técnico 169, Planaltina, Distrito Federal, 2010.

CARVALHO, M. A. C.; JUNIOR, E. F.; ARF, O.; SÁ, M. E.; PAULINO, H. B.; BUZETTI, S. Doses e épocas de aplicação de nitrogênio e teores foliares deste nutriente e de clorofila em feijoeiro. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 27, p. 445-450, 2003.

CATE, R. B. J. R.; NELSON, L. A. A simple statistical procedure for partitioning soil correlation data intoclasses. **Soil Science Society of America Proceedings**, Madison, v. 35, p. 658-660, 1971.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). **Manual de análises químicas dos solos, plantas e fertilizantes**. Brasília, DF. 2. ed. rev. ampl. Embrapa Informação Tecnológica, 2009, 627p.

FERNANDES, F. A.; ARF, O.; BINOTTI, F. F. S.; ROMANINI JUNIOR, A.; SÁ, M. E.; BUZETTI, S.; RODRIGUES, R. A. F. Molibdênio foliar e nitrogênio em feijoeiro cultivado no sistema plantio direto. **Acta Scientiarum Agronomy,** Maringá. v. 27, n. 1, p. 7-15, 2005.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

GALARÇA, S. P.; LIMA, C. S. M.; SILVEIRA, G.; RUFATO, A. R. Correlação de Pearson e análise de trilha identificando variáveis para caracterizar porta-enxerto de Pyrus communis L. **Ciência e Agrotecnologia**, Lavras, v. 34, p. 860-869, 2010.

LAGO, F. J.; FURTINI NETO, A. E.; FURTINI, I. V.; RAMALHO, M. A. P.; HORTA, I. M. F. Frações nitrogenadas e eficiência nutricional em linhagens de feijoeiro (*Phaseolus vulgaris* L.). **Ciência Agrotecnologia,** Lavras, v. 33, n. 2, p. 440-447, 2009.

MALAVOLTA, E. **Manual de nutrição mineral de plantas.** São Paulo: Editora Agronômica CERES, 2006. 638p.

MALAVOLTA, E. O **futuro da nutrição de plantas tendo em vista aspectos agronômicos, econômicos e ambientais.** Informações Agronômicas nº 121 – março/2008.

MEIRA; F. A.; SÁ; M. E.; BUZETTI; S.; ARF, O.: Doses e épocas de aplicação de nitrogênio no feijoeiro irrigado cultivado em plantio direto. **Pesquisa Agropecuária Brasileira**, Brasília, v. 40, n. 4, p. 383-388, 2005. http://dx.doi.org/10.1590/S0100-204X2005000400010

NASCIMENTO, M. S.; ARF, O.; BARBOSA, G. F.; BUZETTI, S.; NASCIMENTO, R. S.; CASTRO, R. M. Nitrogênio em cobertura e molibdênio via foliar em feijoeiro de inverno no sistema plantio direto. **Scientia Agraria**, Curitiba, v. 10, n. 5, p. 351-358, 2009. http://dx.doi.org/10.5380/rsa.v10i5.15187

PEREZ, A. A. G.; SORATTO, R. P.; MANZATTO, N. P.; SOUZA, E. F. C. Extração e exportação de nutrientes pelo feijoeiro adubado com nitrogênio, em diferentes tempos de implantação do sistema plantio direto. **Revista Brasileira de Ciências do Solo**, Viçosa, v. 37, p. 1276-1287, 2013.

RIBEIRO, A. C.; GUIMARÃES P. T. G.; ALVAREZ V., V. H. **Recomendações para o uso de corretivos e fertilizantes em Minas Gerais. 5ª Aproximação.** Viçosa 1999.

SALGADO, F. H. M.; SILVA, J.; OLIVEIRA, T. C.; TONELLO, L. P.; PASSOS, N. G.; FIDELIS, R. R. Efeito do nitrogênio em feijão cultivado em terras altas no sul do estado de Tocantins**. Ambiência Guarapuava**, Guarapuava, v. 8, n. 1, p. 125-136, 2012.

SANTOS, J. B.; GAVILANES, M. L. Botânica In: VIEIRA, C.; PAULA JUNIOR, T. J.; BORÉM, A. **Feijão.** Viçosa: UFV, 2006. p.41-65.

SILVA, E. F.; MARCHETTI, M. E.;SOUZA, L. C. F.; F. M. M.; RODRIGUES, E. T.; VITORINO; A. C. T. Inoculação do feijoeiro com *Rhizobium tropici* associada à exsudato de *Mimosa flocculosa* com diferentes doses de nitrogênio. **Bragantia,** Campinas. v. 68, n. 2, p. 443-451, 2009. http://dx.doi.org/10.1590/S0006-87052009000200019

SILVA, R. G.; CALDAS, I. J. G; ARAÚJO, A. L. S.; FIGUEIREDO, C. C.; SOUZA, C. H. E.; SILVA, D. G. Adubação com micronutrientes na produtividade e qualidade fisiológica de sementes de cultivares de feijão comum. **Revista Trópica: ciências agrárias e biológicas,** Chapadinha, v. 1, n. 1, p. 48, 2007.

SORATTO, R. P.; SILVA, T. R. B.; ARF, O.; CARVALHO, M. A. C. Níveis e épocas de aplicação de nitrogênio em cobertura no feijoeiro irrigado em plantio direto. **Cultura Agronômica**, Ilha Solteira, v. 10, n. 1, p. 89-99, 2001.

VALDERRAMA, M.; BUZETTI, S.; BENETT, C. G. S.; ANDREOTTI, M.; ARF, O.; SÁ, M. E. Fontes e doses de nitrogênio e fósforo em feijoeiro no sistema plantio direto. **Pesquisa Agropecuária Tropical**, Goiânia, v. 39, n. 3, p. 191-196, 2009.