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The effects of crop rotation systems on maize agronomic traits under no-tillage in optimal and dry cropping seasons

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The purpose of this research was to evaluate the crop rotations effects on agronomic traits of maize cultivated in spring-summer in optimal (OCS) and dry cropping seasons (DCS). The experimental design was set up in a randomized complete block and the treatments were arranged in a factorial (8 x 2), consisting of 8 crop rotation systems and two cropping seasons (OCS and DCS), with four replications. The following variables were determined; plant height, height of the first ear insertion, number of kernels per ear, ear diameter and length, number of kernel per ear, 1000-kernel weight and grain yield. In OCS, 1000-kernel weight and grain yield were 20.30 and 60.80% respectively, which means higher than DCS. The crop rotation systems affected the agronomic traits of maize only in OCS. The crop rotation with soybean/niger/maize, soybean/crambe/maize, soybean/rapeseed/maize and soybean/sunflower/maize resulted in higher grain yield. The effects of drought on agronomic traits of maize resulted in higher impact than the crop rotations systems assessed in this research. The amount of 752 mm of rainfall in maize cropping season was not enough for maize development and yield. This study guided alternatives of new cover crops to insert in crop rotation system.

Key words: *Glycine max* L., maize kernel yield, cover crops, soil conservation.

INTRODUCTION

The maize crop shows great economic and social importance, due to its multiple utilization as, animal feeding like grain or silage, until its use as income in high technology industry. In Brazil, the area cultivated with

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Abbreviations: NTS, No-tillage system; **OCS,** optimal cropping season; **DCS,** dry cropping season.

Table 1. Soil chemical properties from samples collected in 0-20 and 20-40 cm depth in the experimental site.

Chemical properties	Depth (cm)	
	0-20	20-40
pH ($CaCl_2$)	5.2	4.9
CEC	11.4	5.8
P (mg dm^{-3})	12.4	1.9
Al^{3+} ($mmol_c$ dm^{-3})	0.9	4.1
K^+ ($mmol_c$ dm^{-3})	2.5	0.7
Ca^{2+} ($mmol_c$ dm^{-3})	5.5	2.4
Mg^{2+} ($mmol_c$ dm^{-3})	1.6	0.9
H+Al ($mmol_c$ dm_{-3})	1.7	1.9
BS (%)	9.6	3.9

CEC: Cation exchange capacity; total acidity pH 7.0 (H^+ +Al^{3+}); exchangeable (KCl 1 mol L^{-1}) Ca^{2+}, Mg^{2+} and Al^{3+}; BS: Base Saturation = (∑cations/CEC)x100.

maize is 15,596.6 millions hectares, and the grain yield average is 5,200 kg ha^{-1} (Conab, 2015). Nevertheless, the potential maize grain yield in Brazil may achieve values above 10,000 kg ha^{-1} (Sanghoi et al., 2001; Souza et al., 2003). However, the average grain yield in Brazil is under the maize potential that may be associated with low technology applied by farmers, which in many cases do not use conservation cropping systems. The use of cover crops to increase aboveground dry matter is an important step to implement a conservation system as no-tillage associate with crop rotation (Congreves et al., 2015). Nevertheless, in the Cerrado region, there are little options of species of cover crops (Freitas et al., 2016), which results in the intensive plantation of soybean in spring-summer and maize in fall-winter season (Rosa et al., 2015; Ensinas et al., 2015). This cultivation is limited in the Cerrado region where the weather conditions are adequate for good plant development, especially in terms of enough rainfall in fall-winter season. When the rainfall is not enough in some Cerrado regions, the area remains the fall-winter season without any crops; in this situation, eventually the sorghum or millet is used as cover crops in preceding months before sowing the spring-summer crop. In the period with absence of cover crops, the soil remains exposed to raindrop impact, which results to damage in physical (Liu et al., 2011), chemical (Ensinas et al., 2016) and biologic soil properties (Balota et al., 2014; Lourente et al., 2016). The implementation of cropping rotation system with maize in spring-summer season is an opportunity to use the oleaginous species in fall-winter season that may result in economic benefits, besides the possibility in improving the yield of succession crop (Freitas et al., 2016). Researches with oleaginous in crop rotation systems in fall-winter season in Brazilian Cerrado are scarce, which is necessary to find more cover crops species to insert in crop rotation with maize. The challenge is to find the adequate proportion and frequency of each species in rotation to maximize the biomass production, carbon sequestration and nutrients recycled in soil. Nevertheless, the climate changes specially the rainfall in some cropping seasons have worried the farmers. With decrease in rainfall amount, the consequence is the seasonality of crop yield because of the drought stress faced in Brazilian Cerrado in some cropping seasons. The deforestation in Cerrado biome occupy more than 65% in Mato Grosso do Sul State (Casella and Filho, 2013), probably, this alteration in forest can modify the rainfall in this region. Spracklen et al. (2012) reported the negative effects of forests replacement to crop or pasture, which can cause decrease in rainfall, due to reduction of evapotranspiration of moisture from soil and vegetation in comparison with forest. The purpose of this research was to measure the cropping systems effects on maize agronomic traits cultivated in spring-summer in optimal (OCS) and dry cropping seasons (DCS).

MATERIALS AND METHODS

Site and soil description

This research was carried out in 2010/2011 and 2011/2012 cropping seasons in a Rhodic Hapludox, clayey texture, clay mineralogy constituted mainly by Al/Fe oxy-hydroxides classified according to Santos et al. (2013). Located in the municipality of Dourados, State of Mato Grosso do Sul, Brazil (approximately 22°13'16" S latitude, 54°48'2" W longitude, average altitude 430 m above sea level). The soil chemical properties analyzed before the establishment of the experiment in October 2009 are in Table 1. The textural analysis showed the following results: 531, 249 and 220 g kg^{-1} of clay, silt and sand respectively, according to Claessen (1997).

Weather condition in the experimental site in optimal and dry cropping seasons

The data of rainfall and temperature in the experimental site are

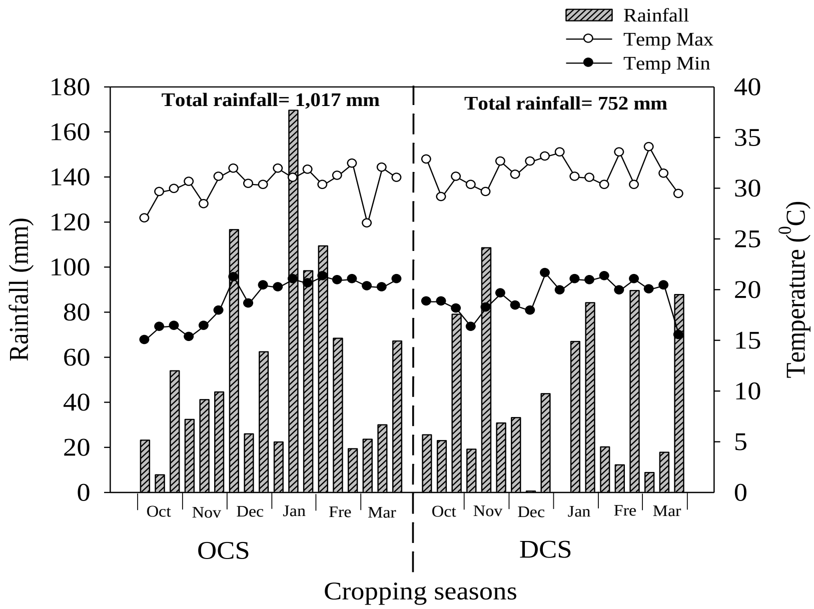

Figure 1. Rainfall, maximum and minimum temperature by each 10 days, in the period of October to March in optimal cropping season (OCS) and dry cropping season (DCS). Data from meteorological station of Universidade Federal da Grande Dourados (UFGD), Dourados city, in Brazil.

shown in Figure 1. The period of these data collection initiated in October, 2010 and ended in March, 2011 for the optimal cropping season (OCS), and initiated in October, 2011 and ended in March, 2012 for the dry cropping season (DCS). The definition of optimal and dry cropping season was based on the results of historic rainfall and the drought occurrence in the region of the study published by Arai et al. (2010). According to Köppen (1948), the region is classified as tropical climate of type Cwa, with rainy summer and dry winter.

Historic of the experimental area

Before the implementation of the experiment, the site was cultivated with soybean in spring-summer and maize crop in fall-winter seasons under no-till. Before the implementation of the experiment, the correction of soil acidity was performed in September, 2009. The recommendation of liming dose was based on the results of soil chemical analysis (Table 1), which was necessary to apply 4,000 kg ha^{-1} of liming. The dolomitic lime showed calcium carbonate equivalent (CCE) of 80% (33% calcium oxide and 15% magnesium oxide). The incorporation of the liming occurred with disk harrow of 32 inches. Right after the lime incorporation, 2,000 kg ha^{-1} gypsum was applied and incorporated with leveling disk harrow of 22 inches.

Experimental design and treatments

The experimental design was set up in a randomized complete block design and the treatments were arranged in a factorial arrangement (8 x 2), consisting of 8 crop rotation systems (Table 2) and two cropping seasons (OCS and DCS), with four replications. The experimental units had dimensions of 15 m length by 35 m width (525 m^2). All operations were executed with a tractor wheel of 112 HP (Horsepower). For the seeding procedure, the grain drill was used with the rows spaced 90 cm apart for planting maize. The cover crops are fall-winter crops species, sowed in the fall-winter season, right after the maize harvest. Despite the treatment with maize/fallow/maize, the other treatments of crop rotation systems were maize in spring-summer and fall-winter crop rotations were compiled by gramineaes and oilseed, S-S-M, S-R-M, S-W-M, S-T-M, S-C-M, S-N-M, S-M-M, M-S-S-W, M-R-S-S, M-W-S-R, M-C-S-T, M-N-S-C, M-N-S-C, and M-W-S-N (Table 2).

Plant material and measurement

The maize (*Zea mays* Hybrid DKB 390 YG) was established in crop rotation to be feasible the implementation of sustainable no-till system. The maize was sowed on October, 20th 2010 and October, 10th 2011 right after the fall-winter cover crops desiccation. The maize sowing was performed 20 days after the cover crops desiccation with glyphosate herbicide (1,296 kg a.i. ha^{-1}). The seed density of maize was 6 seeds per meter, resulting in 66,667 plants per hectare, and the dose of fertilizer was N=16, P_2O_5=60, K_2O=60, Zn=0.9 and B=0.9 kg ha^{-1}. The fertilizer application was in seeding row, with 8 cm depth that was allocated under and beside the seed to avoid contact with the seed. The topdressing nitrogen (60 kg N ha^{-1}) was applied in the development stage of V5 (maize plant with five leaves). In order to increase the N use efficiency, the fertilizer was incorporated deeper in soil with appropriate device. To control the weeds, herbicide nicosulfuron (0.7 L ha^{-1}) and atrazine (3.0 L ha^{-1}) were sprayed in the vegetative growth of maize plant, and the weed stage was in the beginning of vegetative stage. The maize was harvested and sampled on March, 5th 2011 and March, 1st 2012, cropping seasons 2010/2011 and 2011/2012, respectively. The following variables were determined: plant height (PH), the height of the first ear insertion (HFEI), number of kernels per ear (NKE), ear diameter (ED) and length (EL), 1000-kernel weight (1000 KW) and maize grain yield (MGY). The measurement of PH consisted of the distance in centimeters from the soil surface to the

Table 2. The treatments[1] of crop rotation systems evaluated in two cropping seasons.

Crop rotation systems (Abbreviation)	Cropping seasons				
	2009/2010	2010	2010/2011	2011	2011/2012
	Spring-Summer	Fall-winter	Spring-summer	Fall-winter	Spring-summer
M-F-M	**Maize**	**Fallow**	**Maize**	**Fallow**	**Maize**
S-R-M	**Soybean**	**Rapeseed**	**Maize**	Sunflower	Soybean
S-W-M	**Soybean**	**Wheat**	**Maize**	Rapeseed	Soybean
S-T-M	**Soybean**	**Forage turnip**	**Maize**	Wheat	Soybean
S-C-M	**Soybean**	**Crambe**	**Maize**	Wheat	Soybean
S-N-M	**Soybean**	**Níger**	**Maize**	Crambe	Soybean
S-M-M	**Soybean**	**Maize**	**Maize**	Níger	Soybean
S-W-M	Maize	Sunflower	**Soybean**	**Wheat**	**Maize**
S-S-M	Maize	Rapeseed	**Soybean**	**Sunflower**	**Maize**
S-R-M	Maize	Wheat	**Soybean**	**Rapeseed**	**Maize**
S-T-M	Maize	*Carthamus tinctorius* L.	**Soybean**	**Forage turnip**	**Maize**
S-M-M	Maize	Crambe	**Soybean**	**Maize**	**Maize**
S-C-M	Maize	Níger	**Soybean**	**Crambe**	**Maize**
S-N-M	Maize	Wheat	**Soybean**	**Níger**	**Maize**

[1]In bold font indicates the crop rotation systems studied in this research. Maize (*Zea mays*); soybean (*Glycine max*); Rapeseed (*Brassica napus* L.); Sunflower (*Heliathus annuus*); níger (*Guizotia abyssinica*); wheat (*Triticum durum*); crambe (*Crambe abyssinica);* (*Carthamus tinctorius* L.); forage turnip (*Brassica rapa*).

basis of flag leaf at reproductive stage. Similarly, the HFEI scored as the distance from the soil surface to the primary ear node at the same development stage. The measurement of maize grain yield was comprised by the manual harvest in the center of experimental unit in a dimension of 5 by 0.9 m. The grains were weighed and the yield was determined in kg ha^{-1}.

Statistical analysis

The variables evaluated in the experiment were submitted to the analysis of variance (ANOVA) by the *F*-test. The joint analysis was accomplished by OCS and DCS, and in the case of significant effects of the treatments in ANOVA, the mean were compared by the Scott-Knott test of mean at 0.05 levels. The correlation matrix of dependent variable was performed to obtain the degree of relationship between them. To define the strength of correlation, the following criteria were adopted: weak (r^2=0.10 to 0.30), moderate (r^2=0.31 to 0.70) and strong (r^2=0.71 to 100), and positive or negative correlation. These statistical analyses were carried out with the assistance of ASSISTAT software.

RESULTS AND DISCUSSION

Statistical analysis of all variables assessed

The variables were measured in optimal cropping season (OCS) in 2010/2011 and dry cropping season (DCS) in 2011/2012. In order to assess and compare the results in two cropping seasons, the same maize agronomic traits in both cropping seasons (OCS and DCS) was measured, then the crop rotation systems and cropping seasons were studied in a joint analysis. Based on the results in ANOVA, the crop rotation systems did not affect ($p>0.05$) the plant height, height of the first ear insertion, number of kernels per ear and stem diameter. However, the ear diameter, ear length, 1000-kernel weight and grain yield showed significant difference ($p \leq 0.01$) among the crop rotation systems evaluated (Table 3). With the exceptions of stem diameter, the other maize agronomic traits showed significant difference ($p \leq 0.01$) between the OCS and DCS. The crop rotation systems and cropping seasons showed interactive effects for the most variables evaluated (Table 3).

Crop rotation and cropping seasons changed the agronomic performance of maize

The cultivation of maize after sunflower, rapeseed, crambe and niger, respectively, S-S-M, S-P-M, S-C-M, and S-N-M crop rotation systems showed higher plant height of maize in OCS, on the other hand, the crop rotations evaluated did not show any resulting in plant height in dry cropping season (DCS) (Figure 2A). Despite the cropping rotation systems effects, the OCS showed the highest plant height on average (2.313 m) in all treatments in comparison with the DCS (1.592 m). In both cropping seasons, the plant height showed positive and moderate Person's correlation with stem diameter, 1000-kernel weight and grain yield (Table 4). Nevertheless, in DCS, the plant height showed positive and strong correlation with first ear insertion and moderate with ear diameter and number of kernel per ear. Even with significant correlation between these variables, most correlations showed moderate and positive, which is in

Table 3. Summary of analysis of variance (ANOVA).

Source of variation	*df*	PH	HFPI	NKE	ED	SD	EL	1000KW	MGY
		***F*-value**							
Block	3	2.37	1.28	0.03	0.86	0.72	0.93	3.98	4.52
CR†	7	1.43^{ns}	1.06^{ns}	0.72^{ns}	3.27^{**}	1.29^{ns}	2.46**	2.91**	6.73**
CS††	1	527.08**	13.81**	8.47**	152.36**	1.32^{ns}	2126.64**	302.16**	482.79**
CRxGS	7	3.25^{**}	1.02^{ns}	1.22^{ns}	3.82**	1.25^{ns}	2.54**	3.78**	6.81**

Df: Degree of freedom. ^{ns}non-significant; *significant at 0.05 probability level; **significant at 0.01 probability level by *F*-value; ^{NS}no significant at 0.05 probability level by *F*-value; †CR=crop rotation; ††CS=cropping seasons (OCS and DCS). PH: plant height; HFEI: height of the first ear insertion; NKE: number of kernels per ear; ED: ear diameter; SD: stem diameter; EL: ear length; 1000KW: 1000-kernel weight; MGY: maize grain yield.

accordance with the field conditions, because other variables influence the maize agronomic traits. In order to obtain great development for this hybrid (DKB-390 YG), in a regular cropping season, the plant height of 2.2-2.4 m for DKB is expected, which is indicated by hybrid producing company. However, Mendonça et al. (2014) obtained values higher than 2.4 m for DKB-390 YG hybrid, which observed on average 2.65 m. The height of the first ear insertion (HFEI) did not change with the crop rotations systems (Figure 2B), otherwise the OCS and DCS showed significant difference in this agronomic trait, in the DCS the HFEI decreased 39.10% in relation to OCS. In DCS, the HFEI was positive and strongly correlated (r=0.901) with plant height (Table 4).

For the number of kernel per ear (NKE), no effects were observed in relation to the crop rotation systems, however in relation to the cropping seasons, the OCS was 10.74% higher than DCS for NKE (Figure 2C). In crop rotations with S-N-M, S-C-M, S-S-M and S-P-M observed higher ear length, the crop rotations remaining was equal to the M-F-M. The ear length in OCS and DCS did not differ in the crop rotations M-F-M and S-M-M, these two cropping systems placed negative effects on grain yield due to the positive correlation of ear length with grain yield. The ear diameter showed higher values in S-N-M, S-C-M, S-S-M and S-P-M crop rotations in OCS, but no effect of crop rotation system was observed in DCS (Figure 2D). The ear diameter was sensitive to the drought stress, which showed 17.78% reduction in DCS.

Optimal and dry cropping seasons and crop rotation systems affected 1000-kernel weight and grain yield

In OCS, the crop rotation system S-N-M showed the highest value of 1000-kernel yield, followed by S-C-M, S-S-M and S-P-M, on the other hand, the crop rotations did not affect the 1000-kernel weight in DCS (Figure 3A). On average, in OCS the 1000-kernel weight was 20.30% higher than DCS. The crop rotations in OCS affected the maize grain yield, which showed higher grain yield in S-S-M, S-C-M and S-N-M crop rotations (Figure 3B). In DCS, the crop rotation systems did not influence the grain yield, but the drought stress decreased on average (60.80%), the maize grain yield. As reported by Sabiel et al. (2014), the drought stress in vegetative and reproductive stages of maize may affect drastically the maize grain yield, because of alterations in the period of pre-flowering and post-flowering that imply negatively in the agronomic traits of maize.

The Person's correlation between 1000-kernel weight and grain yield was positive in both cropping seasons (Table 4), which infers that 1000-kernel weight was the most effective variable that influenced maize grain yield. Furthermore, 1000-kernel weight was moderate and positively correlated with maize stem diameter, ear length and ear diameter in OCS (Table 4). This way, the effects of drought and crop rotations on these variables mentioned above may influence indirectly on maize grain yield. In DCS, the occurrence of unfavorable weather conditions, mainly in grain filling stage contributes to decrease the biomass accumulation in grain and consequently reduction on grain yield.

The production potential of maize in DCS was decreased, and no response of the crop rotation systems was observed. Despite the cover crops evaluated, the cropping seasons on average showed 9,486 and 3,718 kg ha^{-1}, OCS and DCS, respectively. As reported by Conab (2011), the average of the maize grain yield in Mato Grosso do Sul State was 6,700 kg ha^{-1} in 2010/2011 cropping season and 6,850 kg ha^{-1} in 2011/2012 cropping season. The most crop rotation systems in OCS was average above the region, with exception of M-F-M (Figure 3B). On the other hand, in DCS, all crop rotation systems showed average yield below the region of the experiment. The drought and high air temperature influenced hardly maize yield in the local of the experiment, with the absence of cover crops effecting maize grain yield. As reported by Bassu et al. (2014), the air temperature may be one of the most limited factors in maize yield; their results showed that increasing 1°C might reduce 500 kg ha^{-1} of maize grain yield. This can imply that decreasing liquid photosynthesis

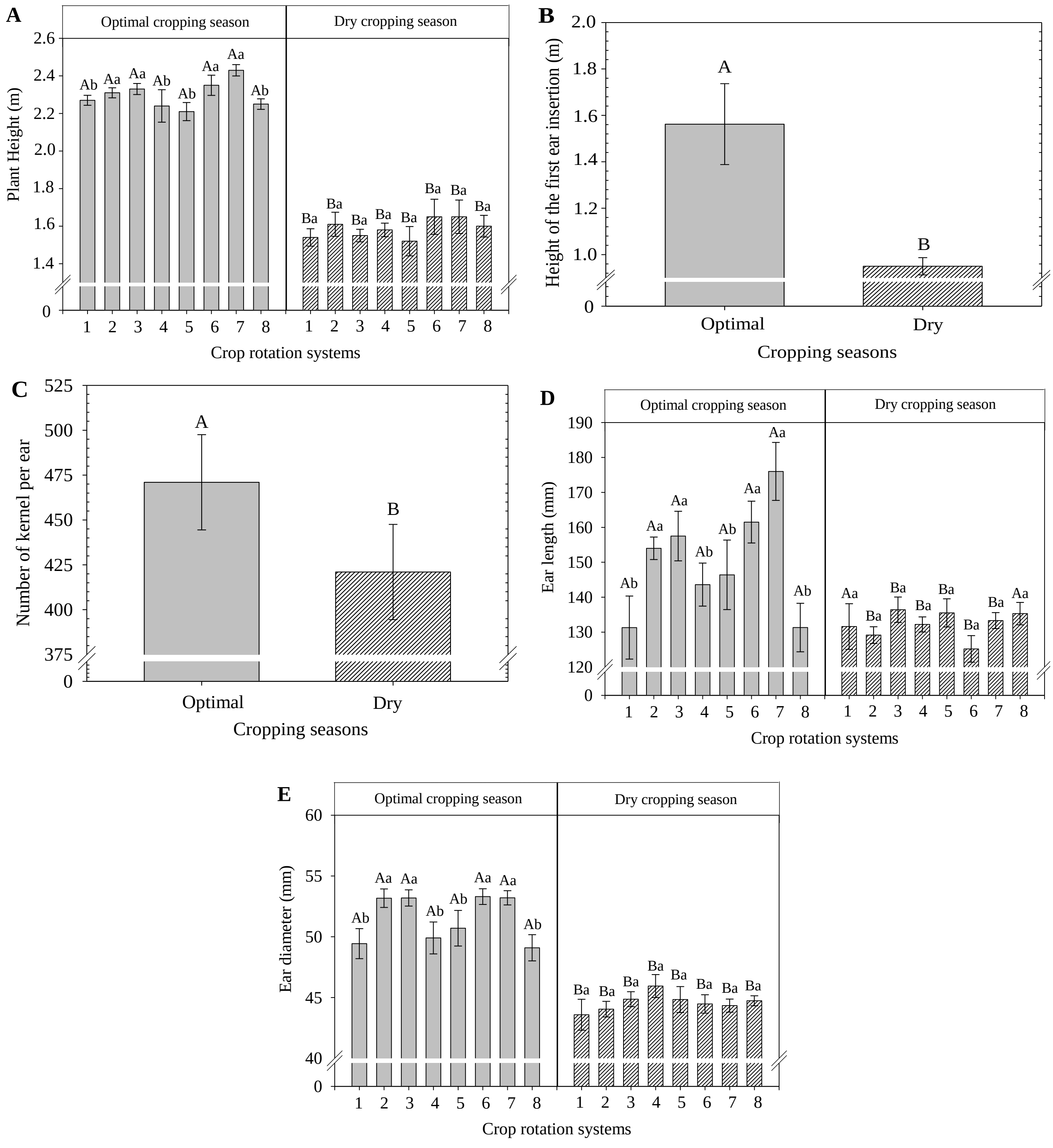

Figure 2. Agronomic traits of maize under optimal and dry cropping seasons and crop rotation systems. (A) Plant height; (B) Height of the first ear insertion; (C) Number of kernel per ear; (D) Ear length; (E) Ear diameter. 1: maize/Fallow/maize; 2_soybean/sunflower/maize; 3: soybean/rapeseed/maize; 4: Soybean/wheat/maize; 5: soybean/forage turnip/maize; 6: soybean/crambe/maize; 7: soybean/niger/maize; 8: soybean/maize/maize. Mean in each bar followed by the same capital letter are not significantly different between the cropping seasons by Scott-Knott test of means (p<0.05). Mean in each bar followed by the same lower case are not significantly different among the crop rotation systems by Scott-Knott test of means (p<0.05).

in the function of increasing breath rate, affect the biomass accumulation, and the number of eggs per ear. These negative effects of high air temperature ought to decrease 1000-kernel weight and consequently the grain yield, due to the positive and moderate correlation among these variables observed in this research (Table 4). The

Table 4. Correlation matrix of dependent variable.

	MGY	PH	SD	HFEI	EL	ED	NKE	1000-KW
				Optimal cropping season				
MGY	1.000	0.405**	0.512**	-0.132^{ns}	0.583**	0.643**	0.486**	0.716**
PH		1.000	0.560**	-0.115^{ns}	0.277*	0.282*	0.284*	0.348*
SD			1.000	-0.074^{ns}	0.333*	0.417*	0.239*	0.586**
HFEI				1.000	-0.344*	-0.295*	-0.352**	-0.062^{ns}
EL					1.000	0.782**	0.848**	0.580**
ED						1.000	0.804**	0.595**
NKE							1.000	0.424*
1000-KW								1.000
Dry cropping season								
	MGY	**PH**	**SD**	**HFEI**	**EL**	**ED**	**NKE**	**1000-KW**
MGY	1.000	0.595**	0.090^{ns}	0.441**	0.448**	0.519**	0.294*	0.630**
PH		1.000	0.310**	0.901**	0.258*	0.346*	0.343*	0.508**
SD			1.000	0.277*	0.492**	0.091^{ns}	0.412**	0.295*
HFEI				1.000	0.195^{ns}	0.252*	0.262*	0.406**
EL					1.000	0.445*	0.570**	0.226*
ED						1.000	0.648**	0.275**
NKE							1.000	0.312*
1000-KW								1.000

PH: plant height; HFEI: height of the first ear insertion; NKE: number of kernels per ear; ED: ear diameter; SD: stem diameter; EL: ear length; 1000KW: 1000-kernel weight; MGY: maize grain yield. Significance effects are at P<0.05 (*), and <0.01 (**).

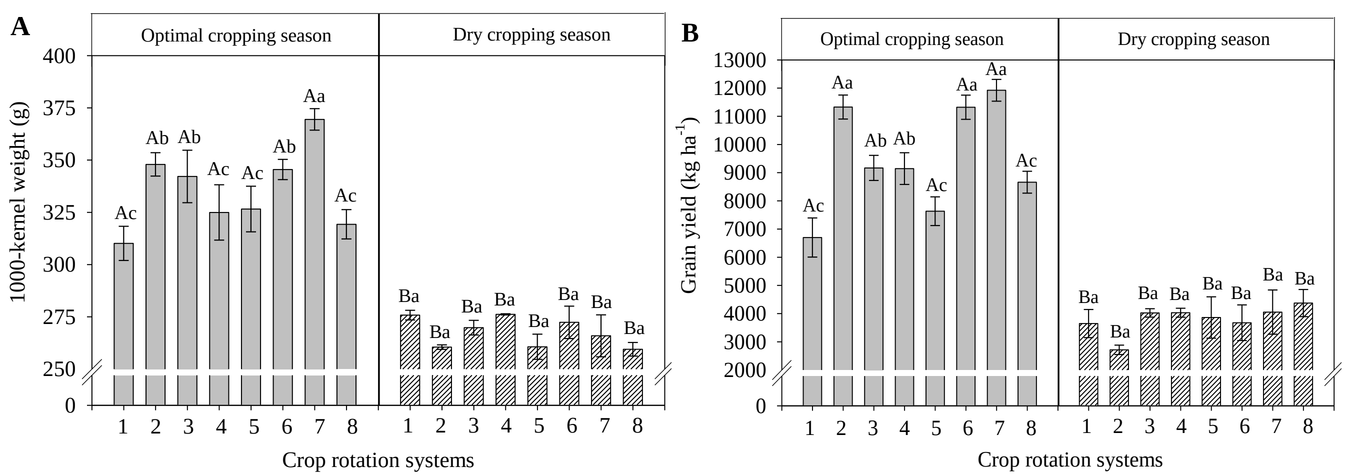

Figure 3. 1000-Kernel weight and kernel yield under optimal and dry cropping seasons and crop rotation system. (A) 1000-kernel weight; (B) maize grain yield. 1: maize/Fallow/maize (M-F-M); 2: soybean/sunflower/maize (S-S-M); 3: soybean/rapeseed/maize; 4: Soybean/wheat/maize; 5: soybean/forage turnip/maize; 6: soybean/crambe/maize; 7: soybean/niger/maize; 8: soybean/maize/maize. Mean in each bar followed by the same capital letter are not significantly different between the cropping seasons by Scott-Knott test of means (p<0.05). Mean in each bar followed by the same lower case are not significantly different among the crop rotation systems by Scott-Knott test of means (p<0.05).

adequate rain distribution on maize cycle is quite important, because reproductive stage is the most required stage for maize. Bergamaschi et al. (2006) observed that maize needs 7 mm day^{-1} in this stage. In OCS, the well-distributed rainfall, contributes to obtain higher grain yield and response of crop rotation systems on the variables evaluated. It is possible to infer that the crops in rotation contribute to increase chemical and physical soil properties, as the case of the sunflower, crambe and niger as preceding crop in rotation. As reported by Lima et al. (2007), the root development of sunflower may break the layer compacted in deeper soil that increases the root volume and higher water uptake. With time, the root decomposition increases the bio-pores and may contribute to aggregate stability (Vezzani and Mielniczuk, 2011). In preview research developed by Bergamin et al. (2015) in the same experimental area of this research, resulting in decreasing soil bulk density in 0-10 cm in the plots cultivated with niger as preceding crop of soybean or maize. This author observed the benefits of this cover crop in soil physical properties. In crop rotation with niger and maize, Zerihun et al. (2013) observed higher grain yield (8,500 kg ha^{-1}). The effects of niger on maize grain yield may be attributed to better chemical and physical soil properties, as the case of increasing residual phosphorus content and nitrogen (Tolera et al., 2005; Lourente et al., 2007). It is possible to infer that the greater benefits from monoculture to crop rotation with these species evaluated were the improvement of maize grain yield and decreasing risk that monoculture offer.

Conclusions

In optimal cropping season (OCS), the crop rotation systems affected the agronomic traits of maize. This indicate that the crop rotation with soybean/niger/maize (S-N-M), soybean/crambe/maize (S-C-M), soybean/ rapeseed/maize (S-R-M) and soybean/sunflower/maize (S-S-M) resulted in higher kernel yield in comparison with fallow and crop rotations with preceding crops as wheat, maize and forage turnip. The effects of drought in dry cropping season (DCS) on agronomic traits of maize were highly pronounced than the crop rotations systems evaluated. In DCS, the drought reduced the plant height, height of the first ear insertion, ear diameter, 1000-kernel weight and kernel yield. The drought in reproductive stage of maize is a constraint that decreased the kernel yield in 60.80% from optimal cropping season. The amount of 752 mm of rainfall in maize cropping season is not enough for well growth and economic maize grain yield, majorly when the drought occurs in reproductive stage of maize. This research shows options for cover crops system to be viable under no-till system with maize in spring-summer season.

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Conflict of Interests

The authors have not declared any conflict of interests.

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