
AGRONOMIC CHARACTERISTICS OF LYPOXYGENASE-FREE SOYBEAN INTRODUCED IN LOW LATITUDES OF THE STATE OF TOCANTINS

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SUMMARY: This study aimed at evaluating physiological and agronomic components of food type soybean introduced in the State of Tocantins, as compared to common type locally adapted cultivars. The experiment was conducted at the Federal University of Tocantins, located at 11° 43' S and 49° 04' W. The experimental design was randomized complete block with four cultivars and four repetitions of food type BRSMG790A and BRS 257, and common type A7002 and M 8585. Evaluations were made on plant height (PH), number of days to flowering (NDF), number of days to maturity (NDM), number of days of the reproductive period (NDPR), number of pods per plant (NPP), dry matter yield (DMY), grain yield (GY), leaf area (LA) and growth rates: leaf area index (LAI), leaf area ratio (LAR), net assimilation rate (NAR), absolute growth rate (AGR) and relative growth rate (RGR). The BRSMG 790A and BRS 257 had lower PH, LA, LAI, LAR, NAR, AGR and RGR, reflected by NDF and maturity, reducing NPP, DMY and GY. These lipoxygenase free cultivars are not adapted to soybean commercial production at low the latitudes of Tocantins but can be employed in hybridization with long-juvenile, locally adapted cultivars, being a source of genetic diversity in breeding programs.

Keywords: Leaf area index. Net assimilation rate. Relative growth rate. Leaf area ratio. Dry matter.

RESUMO: Este trabalho objetivou avaliar os componentes fisiológicos e agrônômicos de soja tipo alimento, introduzida no Estado do Tocantins, em comparação com soja tipo comum selecionada para as baixas latitudes. O experimento foi conduzido na Universidade Federal do Tocantins, localizado a 11° 43' S e 49° 04' W. O desenho experimental foi de blocos ao acaso com quatro cultivares e quatro repetições. Os tratamentos foram BRSMG790A e BRS 257, do tipo alimento; A7002 e M 8585 do tipo comum de grão. Avaliaram-se: altura de plantas (AP), número de dias para o florescimento (NDF), número de dias para a maturação (NDM), número de dias do período reprodutivo (NDPR), número de vagens por planta (NPP), produção de matéria seca (PMS), produção de grãos (PG), área foliar (AF) e taxas de crescimento: índice de área foliar (IAF), taxa de área foliar (TAF), taxa de assimilação líquida (TAL), taxa absoluta de crescimento (TAC) e taxa relativa de crescimento (TRC). Os genótipos BRSMG 790A e BRS 257, apresentaram valores mais baixos de AP, AF, IAF, TCA, TAL, TCA e TCR, refletida pelo NDF e maturação, reduzindo o NVP, MS e RG. Estes cultivares livres de lipoxigenase mostraram-se não adaptados à produção comercial de soja no Estado do Tocantins, mas podem ser empregados em hibridações com soja adaptada localmente, possuindo período juvenil longo, constituindo-se em fonte de variabilidade genética em programas de melhoramento de soja às baixas latitudes.

Palavras-chave: Índice de área foliar. Taxa de assimilação líquida. Taxa de crescimento relativo. Razão de área foliar. Matéria seca.

INTRODUCTION

Soybeans (*Glycine max* L.) has been introduced and selected to commercial production in major producing countries, the United States of America and Brazil, where it is mostly directed to oil and animal

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feed. However, in Asian countries as China, Korea and Japan it has been cultivated since millennia as important source of proteins and other compounds as carbohydrates, fiber, minerals, vitamin A, E, B1 and B2 to humans. Soybean possesses functional properties and contributes to human health, being protein rich, source of isoflavones (SILVA *et al.*, 2012) and alternative to lactose intolerant patients.

Soybean byproducts have gained space in the market for intrinsic health conditioning properties. However, it is estimated that only 6 % of the soybean produced in Brazil is destined to food products. Even though the benefits of soybean derived products have been demonstrated, many potential consumers avoid using them in diet, mainly due to the presence of undesirable odor and flavor by lipoxygenase enzymes in common type soybean (SILVA *et al.*, 2009).

The sensorial difference make common soybean undesirable in food preparations such as tofu and other derived food. The breeding programs have developed food type cultivars as lipoxygenase free BRS 257 and BRSMG 790A, of better flavor than common type soybean (SILVA *et al.*, 2012). Food type cultivars have been selected to a narrow latitude zone, lacking alleles conditioning long juvenile trait that extend vegetative period and present in tropical adapted genotypes (SPEHAR *et al.*, 2014).

Growth analysis is based on the fact that about 90% of accumulated dry matter by the plants results from photosynthetic activity alone. It allowed assessing the final plant growth and relative contribution of the plant parts in soybean development under different cropping systems (YUSUF *et al.*, 1999). In spite of its complexity, growth pattern has shown rather precise to evaluate and understand physiological processes, quantifying plant response to environmental variations (MEHMET SINCIK *et al.*, 2011). Moreover, it has been useful in crop breeding for higher photosynthetic efficiency and yield (MORRISON *et al.*, 1999).

Genotype introduction has been an approach to initiate breeding and adapt a crop into new environment, while growth analysis allows estimating the causes of variations in plant development. It has been essential to understand functional and structural differences among genotypes of same species aiming at selection for yield stability (SPEHAR *et al.*, 2014).

Applications of growth analysis have been reported to define the phases of plant development of several crops as castor bean (SANTOS *et al.*, 2011c), cowpea (SANTOS *et al.*, 2011a; FREITAS *et al.*, 2014), tomato (MARTINAZZO *et al.*, 2015), rice (ALVAREZ *et al.*, 2015) and soybean (BULEGON *et al.*, 2016; OLIVEIRA *et al.*, 2013; CRUZ *et al.*, 2010 e YUSUF *et al.*, 1999).

The potential to grow soybean in low latitudes of Brazil has been realized by selecting cultivars with extended vegetative phase, incorporating alleles for long juvenile period (SPEHAR *et al.*, 2014). These alleles induce the plant to grow and yield at levels comparable to the ones obtained in temperate regions or the world. Producing areas in the State of Tocantins are located at latitudes between 5 - 13° S and low altitude where common type soybean has been adapted competitively. However, cultivation of lipoxygenase free soybean in this region has not yet been realized, justifying studies to understand genotypic growth and reproduction phases.

This study aimed at evaluating food-type soybean cultivars introduced in the State of Tocantins and common type locally selected on the basis of growth analysis and agronomic performance. It is expected the results could be useful in breeding programs to acquire yield competitive lipoxygenase-free cultivars to low latitude, low altitude tropical areas.

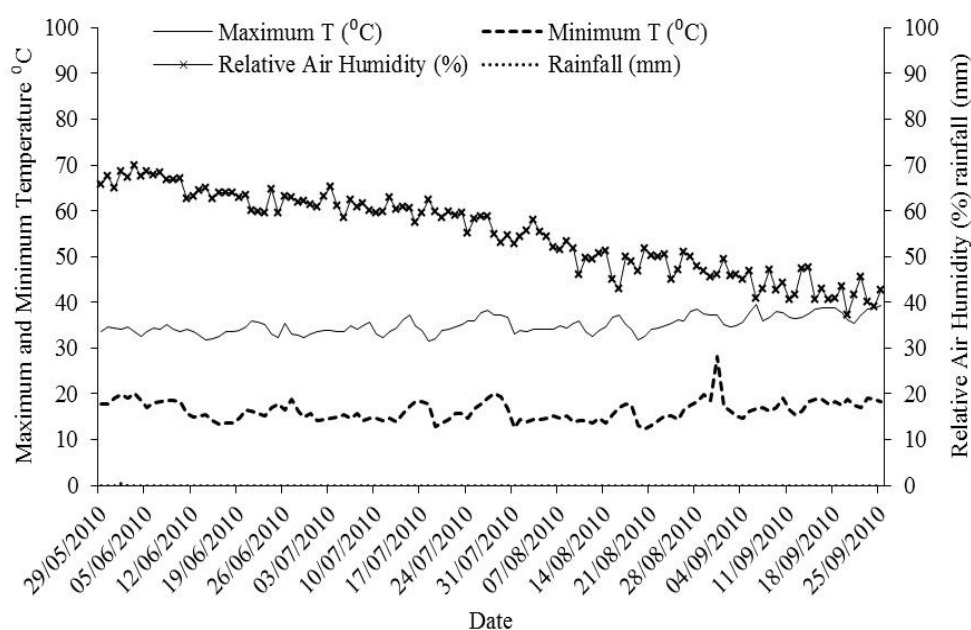
MATERIAL AND METHODS

The experiment was conducted in the Federal University of Tocantins, Campus of Gurupi, Tocantins located at 11° 43' S, 49° 04' W and altitude of 280 m, on red yellow oxisol or Ferralsol in

FAO's soil classification (IUSS Working Group WRB, 2015). The soil was previously amended with lime and the analysis presented the following chemical and physical composition: pH = 5.6; $Al^{+3} + H^{+1} = 2,6$ $cmol_c dm^{-3}$; $Ca + Mg = 2,8$ $cmol_c dm^{-3}$; $K = 72$ $mg dm^{-3}$; $P = 3,7$ $mg dm^{-3}$; base saturation (BS) = 53.5 %; cation exchange capacity (CEC) = 5.6 $cmol_c dm^{-3}$; organic matter: 2.2 $dag kg^{-1}$; sand = 71 $dag kg^{-1}$; silt = 5.0 $dag kg^{-1}$; clay = $24,0$ $dag kg^{-1}$.

The climate was classified as Aw, wet with moderate water deficit (KOTTEK *et al.*, 2006). During the plant growth the climate data were collected in the Meteorological Station at Gurupi Campus (Figure 1).

Figure 1. Maximum and minimum temperatures ($^{\circ}C$), daily rainfall pluvial (mm) and mean air relative humidity (%), between 29 May and 25 September 2010, Gurupi, Tocantins, Brazil.



Source: Elaborated by the authors from the climatic data of the Meteorological Station at Gurupi-TO, Brazil.

The experiment was sown in no-till system, on 29 May 2010. Fertilization, based on soil analysis and to supply plant requirements in phosphorus (P) and potassium (K), consisted of 60 $kg ha^{-1}$ P_2O_5 , 60 $kg ha^{-1}$ K_2O , formulated 00-16-16 NPK. Nitrogen (N) was supplied by association of plants and the bacterium strains of *Bradyrhizobium japonicum*, from inoculated seeds before sowing.

The experimental design was complete randomized blocs with four treatments and four repetitions. The treatments consisted of two food type cultivars: BRSMG 790A and BRS 257; and two common type cultivars: A7002 e M 8585. These cultivars have been recommended to a range of latitudes, belonging to different maturity groups and obtained by public and private breeding institutions (Table 1).

Table 1. Cultivars utilized in the experiment with respective recommended states of cultivation, maturity group and Institution of origin.

Cultivar	Recommended State	Maturity Group*	Institution
BRSMG 790A	MG, GO, DF e SP	7.9	Epamig-MG
BRS 257	RS, PR, SP	6.4	Embrapa soja
A 7002	MT, MG, GO, DF, TO	8.2	Nidera
M 8585	MT, MG, GO, DF, TO	8.5	Monsanto

*Maturity Group classification ranging from 4.5 (early) to 9 (late), covering Southern Brazil to Equatorial zone.

Source: Tecnologias de Produção de Soja - Região Central do Brasil 2013. <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/975595/tecnologias-de-producao-de-soja---regiao-central-do-brasil-2014>.

Each plot was made by five 6.00 m long rows, spaced by 0.45 m, and 0.08 m between plants in the row, corresponding to a population density of 278×10^3 plants ha^{-1} . The measurements for growth analysis were taken on the second row, which was subdivided into 10 subplots, for periodical sampling. The 4th row was harvested at maturity to biomass and grain yield evaluations. The experiment was kept weed free by hand hoeing and irrigated before VC until R8 (FEHR *et al*, 1971) with sprinklers using a net wet line of 6 mm, every three days, maintaining the water tension in soil at 65 - 70% field capacity.

Five plants were collected in each plot at 15, 25, 35, 45, 55, 65, 75, 85, 95 and 105 days after emergence (DAE) and utilized in growth analysis. The measurements were as follows: a) plant height (PH), from the plant base to the apex containing unopened leaves using a measuring tape to nearest mm; b) total dry matter yield (TDMY), by dividing the plants into the respective parts – leaves, stem, flowers and pods and drying up in forced ventilation muffle at 70 °C to constant weight and weighing in precision balance; c) leaf area (LA), determined from scanning the leaf limbs using Lexmark X75, Lexmark, Incorporated, Lexington, KY, USA, using the shade to calculate the area by image interpretation (PAPA, 2009); d) leaf area index (LAI): determined by the relation between mean leaf area of plants and the land surface of projected canopy in $\text{m}^2 \text{m}^{-2}$; e) leaf area ratio (LAR): defined as the ratio between LAI and TDMY, in $\text{m}^2 \text{g}^{-1}$; f) net assimilation rate (NAR): determined by the ratio between crop growth ratio (CGR) and LAI, in $\text{g m}^{-2} \text{dia}^{-1}$; g) absolute growth ratio (AGR); h) relative growth ratio (RGR): expressed in $\text{g g}^{-1} \text{dia}^{-1}$ and calculated by dividing CGR to TDMY. The crop growth measurements and their analysis were adapted from existing methodology (HOFFMANN; POORTER, 2002; PRICE; MUNNS, 2010).

In growth analysis, best fit curves for linear and quadratic polynomial models were obtained using the means for each collecting time. The best fit to the data was based on the highest determination coefficient (R^2), allowing definition of plant growth pattern (PRICE; MUNNS, 2010).

The agronomic characteristics were evaluated as follows: a) number of days to first flower (NDF) – corresponding to the period between emergence and 50% of plants with at least one flower; b) number of days for maturation (NDM) – period between emergence and 95 % of plants presenting ripe pods; c) number of days to reproductive period (NDRP) – period between NDF and NDM; d) number of pods per plant (NPP) – mean pod number of five plants; grain yield (GY) – obtained by harvesting the plants on the 4th row, threshing, cleaning, drying, weighing, and converting to kg ha^{-1} at 13% humidity. Data were subject to analysis of variance and means separated by Tukey test ($p \leq 0.05$), using the SISVAR statistical program.

RESULTS AND DISCUSSION

Plant height had a significant quadratic response, with R^2 of 0.97 and 0.98 (Table 2 and Figure 2A). Irrespective of cultivar, the initial growth was slow until 25 days after emergence (DAE). After this point, cultivars A7002 e M 8585 had outstanding growth, relative to food type BRSMG 790A and BRS 257, until 65 DAE. The plant height of BRS 257 stabilized at 45 DAE while for BRSMG790A it happened at 55 days after emergence. These cultivars had expressive difference in plant height varying from 82 cm of common type to respective 48.6 and 36.5 cm to BRSMG 790A and BRS 257 food type. The quadratic response for plant growth was also observed in soybeans grown in high northern latitudes (PEDERSEN; LAUER, 2004)

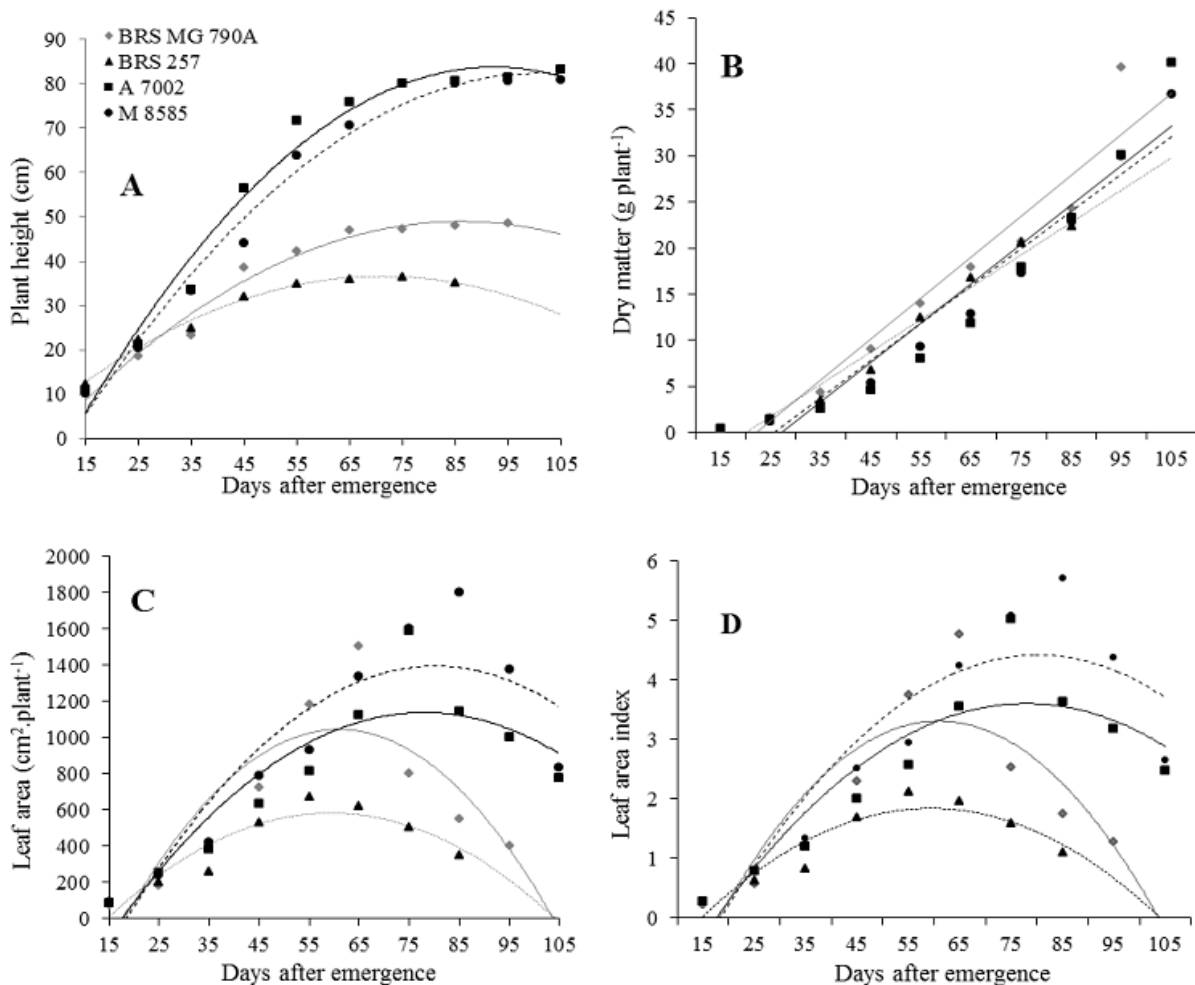
Table 2. Adjusted equations for plant height (PH), total dry matter yield (TDMY), leaf area (LA), leaf area index (LAI), leaf area ratio (LAR), net assimilation rate (NAR), absolute growth rate (AGR) and relative growth rate (RGR) of food type BRSMG 790A and BRS 257 and A7002 e M 8585 common type soybean grown in Gurupi, Tocantins, Brazil.

Cultivar	PH (cm)	R^2	TDMY (g plant ⁻¹)	R^2
BRSMG790A	$y = -0,008x^2 + 1,372x - 9,957$	0,97**	$y = 4,4473x - 7,6086$	0,93**
BRS257	$y = -0,0075x^2 + 1,072x - 1,482$	0,98**	$y = 3,5128x - 5,3048$	0,97**
A7002	$y = -0,013x^2 + 2,401x - 26,99$	0,98**	$y = 4,2745x - 9,4902$	0,91**
M8585	$y = -0,0104x^2 + 2,099x - 23,54$	0,98**	$Y = 4,0444x - 8,364$	0,94**
Cultivar	LA (cm ² plant ⁻¹)		LAF	
BRSM790A	$y = -0,569x^2 + 69,35x - 1069$	0,73*	$y = -0,18x^2 + 2,021x - 2,34$	0,73*
BRS257	$y = -0,291x^2 + 34,51x - 443,78$	0,86*	$y = -0,092x^2 + 1,003x - 0,88$	0,86*
A7002	$y = -0,312x^2 + 48,57x - 757,62$	0,82*	$y = -0,099x^2 + 1,443x - 1,66$	0,82*
M8585	$y = -0,365x^2 + 58,63x - 958,85$	0,83*	$y = -0,116x^2 + 1,745x - 2,14$	0,83*
Cultivar	LAR (cm ² g ⁻¹)		NAR (g cm ² dia ⁻¹)	
BRSM790A	$y = 1,666x^2 - 39,877x + 234,9$	0,99**	$y = 5E-06x^2 - 0,0002x + 0,0013$	0,96**
BRS257	$Y = 2,826x^2 - 51,128x + 243$	0,99**	$y = -4E-06x^2 - 6E-05x + 0,001$	0,99**
A7002	$y = 0,326x^2 - 24,66x + 229,63$	0,99**	$y = 4E-06x^2 - 8E-05x + 0,0007$	0,91**
M8585	$y = 0,935x^2 - 29,87x + 237,86$	0,98**	$y = 5E-06x^2 - 8E-05x + 0,0006$	0,95**
Cultivar	AGR (g ¹ dia ⁻¹)		RGR (g g ¹ dia ⁻¹)	
BRSM790A	$y = 0,0105x^2 + 0,001x + 0,152$	0,98**	$y = 0,0039x^2 - 0,0604x + 0,239$	0,96**
BRS257	$y = -0,0013x^2 + 0,085x + 0,013$	0,98**	$y = 0,0035x^2 - 0,0553x + 0,22$	0,97**
A7002	$y = 0,01x^2 + 0,0089x + 0,079$	0,99**	$y = 0,0019x^2 - 0,0316x + 0,150$	0,97**
M8585	$y = 0,004x^2 + 0,0511x + 0,010$	0,99**	$y = 0,0024x^2 - 0,0367x + 0,159$	0,97**

** And * significant at $P < 0.01$ and $P < 0.05$ respectively by F-test

Source: Prepared by the authors of this article

Figure 2. Plant height (A), dry matter (B), leaf area (C) and leaf area index (D) of food type BRSMG790A and BRS 257 and common type A7002 and M 8585 soybean cultivars in Gurupi, Tocantins, Brazil, 2010.



Source: Prepared by the authors of this article

Plant height is directly related to maturity groups, day length response and presence of long juvenile trait (SPEHAR *et al.*, 2014). The food type cultivars had short plants, typical response to short day conditions prevailing in Tocantins, while plants of common type soybeans were tall to suit combine harvest. Genotypes devoid of juvenile alleles have started flowering at V3 in tropical regions, where plants grow under short day length (ALMEIDA *et al.*, 1999). This early flowering resulted smaller plants with direct negative impact on biomass and grain yield (SPEHAR *et al.*, 2014).

Dry matter (DM) yield by the plants, as a function of time, showed linear response by the cultivars (Figure 2B). However, the largest increments were observed for A7002, M8585 and BRSMG790A, while the least values were shown by BRS 257 (Figure 2B). From emergence until 35 DAE differences among cultivars were not significant. Between 45 e 75 DAE, food type cultivars had accumulated high dry matter. At 85 DAE, however there were differences among cultivars when BRS 257 had already passed physiological maturity, accumulating 22 g DM per plant. At 95 DAE the plant of BRSMG 790A reached maturity with 40 g dry matter. This was expected in view of the differences in maturity group. Early maturing BRS 257 yielded less than BRSMG 790A and the difference related to extending the plant cycle for additional ten days as demonstrated to common type soybeans (SPEHAR *et al.*, 2014).

The cultivars A7002 and M 8585 behaved similarly in dry matter accumulation during the plant cycle (Figure 2B). Food type cultivars tended to accumulate biomass in a shorter period, coinciding with

their selection and recommendation to Southern higher latitude areas. The earlier cycle (NDM) of food type BRS 257 and BRSMG790A than the common type A7002 and M 8585 had negative impact on number of pods per plant and grain yield (Table 3).

Table 3. Mean values for number of days to flowering (NDF), number of days to maturity (NDM), number of days of reproductive period (NDRP), number of pods per plant (NPP), and grain yield (GY) of food and common type soybean cultivars. Gurupi Tocantins, Brazil 2010.

Cultivar	Characteristics				
	NDF	NDM	NDRP	NPP	GY (Kg ha ⁻¹)
BRSMG 790A	29 b	96 c	67 b	46 b	1033 c
BRS 257	24 c	78 d	54 c	29 c	583 d
A7002	31 b	108 b	77 a	70 a	3696 a
M 8585	39 a	126 a	81 a	77 a	3180 b
Média	31	101	70	55	1858

Means followed by same letter in the column are not statistically different (Tukey $p \leq 0.05$).

Source: Prepared by the authors of this article

Linear response to dry matter accumulation was similar to the one obtained with gerbera (LUDWIG *et al.*, 2010) while diverging results were obtained with rice (ALVAREZ *et al.*, 2015) and soybean (OLIVEIRA *et al.*, 2013). In the latter and former a sigmoid curve was the best fit to explain biomass production. However, at lower altitudes as Gurupi, where the experiment was conducted, higher temperatures contributed to accelerate plant cycle, when considered in degree days (SPEHAR *et al.*, 2014), justifying the growth response presented here.

Leaf area (LA) and leaf area index (LAI) adjusted to quadratic model (Table 2) and showed similar trend (Figure 2C and 2D). The cultivars did not show significant differences in LA and LAI for the first 25 DAE. The maximum leaf area happened at 55 DAE for BRS 257 and at 65 DAE for BRSMG 790A. After this period, there was a reduction in LA and LAI, as in reproductive phase, photo assimilate drain intensified and was associated with mineral elements translocation, causing senescence of older leaves. This was noted when comparing common type to food type soybeans that presented the least values for both LA and LAI.

Leaf area index, measures the covering area represented by the leaves in the plant (PRICE e MUNNS, 2010). The lower index values of, food type, introduced cultivars were notorious when compared with common type locally selected cultivars. It must be said that BRS 257 had the lower LA with LAI of only 2.13 when compared to M 8585 and A7002 with LAI higher than 5.0 as would be expected (NGUY-ROBERTSON *et al.*, 2010). The maximal LAI occurred at different times for the cultivars, justifying the varietal difference in maturity group conditioned by response to short day length. The maximum index values was observed at 55 DAE for BRS 257, at 65 DAE for BRSMG 790A, at 75 DAE for A7002 and at 85 DAE for M 8585 and these differences could also be associated to high temperature response (SPEHAR *et al.*, 2014).

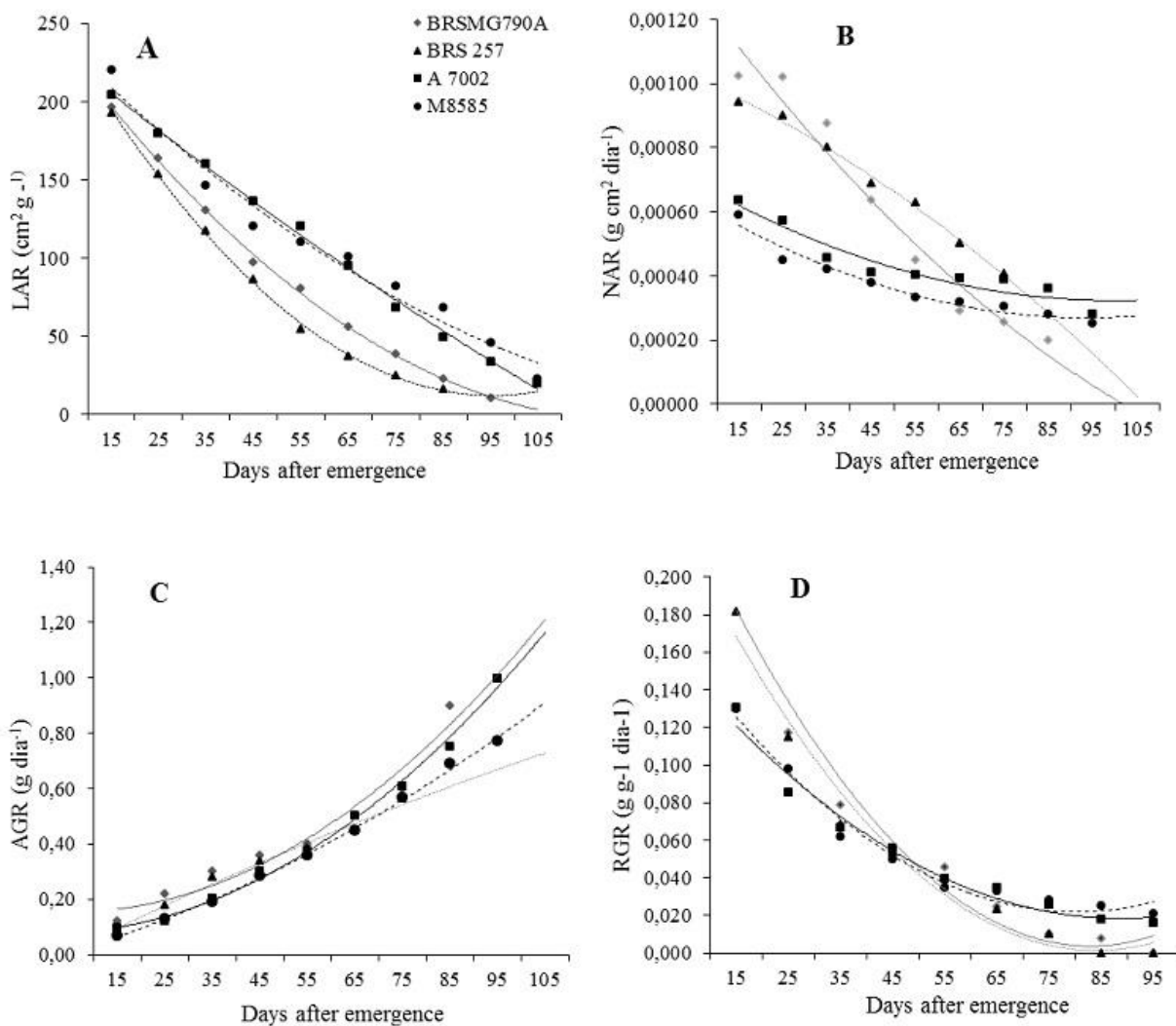
The decline in LAI after maximum leaf area verified to all cultivars could be ascribed to rapid photo assimilates drained to seed formation which increased dry matter at the time of biosynthesis of oil

and protein (HEIFFIG *et al.*, 2006). In addition, the rapid drain caused reduction in the effective leaf area, leading to senescence and loss of older leaves (CAMPOS *et al.*, 2008).

In soybeans at R₁ leaf area index has been reported to be 5.5 on high yielding commercial crop (NGUY-ROBERTSON *et al.*, 2010). The lower LAI values by BRS 257 explain significant yield reduction reported here. Environmental factors as temperature and day length have direct effect on LAI, depending on latitude, altitude, sowing date and genotypic characteristics. This experiment was conducted under short day condition, causing anticipated flowering induction in cultivars that are early maturity and do not possess long juvenile alleles (SPEHAR *et al.*, 2014). As a result of early flowering there was less plant growth, with reduced LA, implicating in lower number of pods and grains.

The leaf area ratio (LAR), corresponding to the ratio between the leaf area response to light interception, CO₂ and dry matter, declines during plant growth, as a result of shading and consequent reduction of photo synthetically active area (PRICE e MUNNS, 2010). LAR showed a quadratic response with R² varying between 0.98 and 0.99 (Table 2). It was maximal at 15 DAE for all cultivars, with a continuous decline thereafter. (Figure 3A). The cultivars divided into two distinct groups, where food type had the lowest values at maturity were: 85 DAE to BRS 257, 95 DAE to BRSMG 790A and 105 DAE to A7002 e M8585.

Figure 3. A- Leaf area ratio (LAR), B – net assimilation rate (NAR), absolute growth rate (AGR) - C and relative growth rate (RGR) - D of food type BRSMG790A and BRS 257, and common type A7002 and M 8585 soybean plants grown in Gurupi, TO.



Source: Prepared by the authors of this article

LAR has shown high value early in plant cycle as demonstrated here, as there is higher photosynthetic activity, by leaf expansion and light interception (LUDWIG *et al.*, 2010). The values decline along the plant cycle due to shading of upper leaves to lower leaves. There is an inverse relation between leaf area and leaf area ratio, the plants fixing more carbon at lower LA. Similarly, the LAR reduced as tomato plants had grown and expanded leaf area (MARTINAZZO *et al.*, 2015).

Net assimilation rate (NAR) represents the balance between the product of photosynthesis and the losses due to respiration, indicating plant efficiency in dry matter production. NAR was adjusted to quadratic model equation, where R^2 varied between 0.91 to A7002 and 0.99 to BRS 257 (Table 2). NAR gradually decreased to all cultivars in the experiment (Figure 3B).

Food type cultivars BRSMG 790A and BRS 257 had higher NAR early in plant cycle than common type ones until 45 and 65 DAE respectively. The common type cultivars A7002 e M 8585 showed a steady increase in NAR throughout the evaluation period, with no significant difference between them. This performance probably occurred due to extended vegetative period, with lower initial indexes of photosynthesis but maintained during the longer plant cycle, indicating their adaptability to growth under low latitude high temperature.

The trend found here was divergent from the ones with cowpea and tomato plants (FREITAS *et al.*, 2014; MARTINAZZO *et al.*, 2015) where NAR gradually decreased throughout the plant cycle.

Absolute growth rate values (AGR) were adjusted to quadratic model equations for R^2 between 0.98 and 0.99 (Table 2). The initial growth of plants was slow until 35DAE (Figure 3C). At 75 DAE all cultivars presented similar AGR but, thereafter, the common type cultivars had increasing values surpassing the food type cultivars.

The RGR had similar decreasing response as observed for LAR and AGR (Figure 3D). The RGR equations were significant for quadratic response with R^2 of 0.96 and 0.97 (Table 2). The cultivars had two groupings: common type and food type soybeans. Within group there was no significant difference, corroborating difference in agronomic performance. From emergence to 35 DAE, food type soybeans had higher RGR and did not differ from common type soybeans at 45 and 55 DAE. The former kept increasing RGR and were significantly higher in later phase, similar to varietal differences in coffee plant growth (SOUZA *et al.*, 2016). Increase and decline of RGR along the plant cycle are associated to fluctuations in the net assimilation rate (FREITAS, *et al.*, 2014).

The mean values of NDF, NDM, NDPR, NDRP, NPP and GY (Table 3) confirm the lack of adaptation of food type BRSMG 790A and BRS 257, as a result of earliness in number of days to first flower and number of days to maturity. BRS 257 was the earliest maturing cultivar flowering at 24 DAE and finishing reproduction at 78 DAE. As a consequence it was the least yielding, 84% and 82% inferior to A7002 and M 8585, respectively. These results confirm the tests with BRS 257 in low latitude Formoso of Araguaia, TO (SANTOS *et al.*, 2011b).

The food type BRSMG 790A had a total cycle of 96 days and did not differ statistically from A7002 for NDF. However, its reproductive period was 10 days inferior and this contributed to reduction in grain yield. Grain type cultivars yielded 2405 kg ha⁻¹ higher than BRSMG 790A. Moreover, the difference of 12 days in total plant cycle also impacted negatively plant height as BRSMG 790A was, on average, 41% less than A7002 and M 8585 (Figure 2A).

The growth analysis measurements as leaf area, leaf area index, leaf area ratio, net assimilation rate and relative growth ratio were efficient to demonstrate the lack of adaptation of BRSMG 790A and BRS 257 at latitude 11° 43' and lower. This was corroborated by the agronomic characteristics as number of days to flowering, number of days to reproduction, number of pods per plant and grain yield.

Even though the BRSMG 790A and BRS 257 food type cultivars did not show adaptability to the low latitudes of Tocantins State, they could be useful in breeding programmes to cross with long juvenile trait genotypes as A7002 and M 8585. The genetics of both characters: long juvenile trait and lack of lipoxygenase are conditioned by few alleles (CARPENTIERI-PIPOLO *et al.*, 2009; LENIS *et al.*, 2010).

The possible recombinants should include both traits and food type adapted genotypes can be acquired, enlarging the possibilities of rationalizing soybean production to suit increasing food market demand.

CONCLUSIONS

Existing lipoxygenase-free, food type, soybean cultivars are not adapted to commercial cultivation at 11° 43' and lower latitudes of Tocantins State.

Food type cultivar BRS 257 matures in 78 days, presenting reduced plant height, number of pods per plant, and grain yield while BRS790A extends the plant cycle but its agronomic performance is still inferior to the common type, long juvenile phase A7002 and M 8585 cultivars.

Growth analysis is efficient to quantify the biological response of food type soybeans when grown at low latitudes.

Food type soybeans are useful in breeding programs aiming at acquisition of long-juvenile and lipoxygenase-free soybean genotypes.

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