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Geographical zoning of soybean yield adaptation according to relative maturity in Brazil

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Abstract: Brazil is the largest soybean producer, representing about 40% of world production. Soybean fields span all country regions, resulting in high environmental diversity for cultivation. The wide adoption of early-maturity cultivars and intensified cropping systems has recently introduced significant challenges in selecting the most well-adapted cultivars. In this study, we aimed to map soybean yield adaptation geographically, according to relative maturity (RM) groups, to increase assertiveness in cultivar development and recommendation. Data from yield trials of 175 locations were used, covering latitudes from 7ºS to 33ºS. The trials were conducted from 2014/2015 to 2017/2018 crop seasons. Altogether, 159 cultivars with different RM were evaluated in each location. The grain yield was adjusted using the linear mixed model to identify the most adapted RM range in each location. Subsequently, the regression kriging method was performed to spatialize this optimized RM, considering the latitude, longitude and elevation as predictors. We concluded that under Brazilian soybean growing conditions, cultivars with RM from 5.5 to 6.4 are best adapted in the subtropical region, and, in the subtropical/tropical transition, are those with RM from 6.5 to 6.9. In the tropical region, predominantly, cultivars with RM from 7.5 to 8.4 are best adapted. The adaptation of late-maturity cultivars with RM from 8.5 to 9.4 has been restricted to the northernmost regions. Latitude and elevation are key factors in defining soybean yield adaptation, with elevation promoting slight deflections in adaptation zones, favoring earlier cultivars. In contrast, longitude does not show significant effect on adaptation to these conditions.

Keywords: agronomic mapping, soybean adaptation, yield prediction, cultivar recommendation, geospatial analysis.

Introduction

It is no surprise to know that Brazil is the largest soybean producer globally, representing around 40% of world production. The cultivated area in the country totals approximately 47 million hectares, increasing by more than twenty million hectares from 2010 to 2025 (Conab, 2025; USDA, 2025). The continuous increase in cultivated area, with higher yield levels, is mainly due to the advances in crop management and genetic improvement targeting low-latitude regions (Araújo et al., 2019). Currently, soybean fields cover practically all Brazilian regions, which results in high environmental diversity for cultivation, reaching territorial extensions wider than 30º of latitude across uneven edaphoclimatic conditions.

Soybean is a photo-thermal sensitive species, so the adaptation of cultivars is restricted to specific latitude ranges and edaphoclimatic regions (Bu et al., 2021). Cultivars adapted to subtropical regions when submitted to low latitudes tends to present early flowering, low plant height, short internodes length and, commonly, considerable yield and cycle reduction. However, over the last years, the adoption of earlier and adapted soybean cultivars has been preferred, despite their limited adaptation to low latitude regions. The main purpose of reducing the soybean cycle is the possibility of growing a second crop successfully, within the same season. In this context, efforts have been made in breeding programs to select earlier, stable and high-yield cultivars (Umburanas et al., 2022). Therefore, it is essential for the development of new cultivars to consider not only the yield but also maturity or, especially, the combination of these traits.

The introgression of the indeterminate growth type into soybean cultivars was initially targeted at subtropical regions but has progressively expanded to tropical areas of Brazil, enhancing stability across latitudes and sowing periods (Milioli et al., 2022). This genetic improvement has allowed for the development of cultivars with lower relative maturity while maintaining high yield potential under tropical conditions. Indeterminate cultivars exhibit greater plasticity in response to environmental variations, which has contributed to their widespread adoption in regions with diverse climatic conditions. In contrast, earlier determinate cultivars, when grown at lower latitudes, frequently experience reductions in plant height, leading to shorter internodes, lower biomass accumulation, and ultimately, yield reductions. These changes underscore the importance of breeding programs in selecting genotypes that balance phenological development with agronomic performance, ensuring adaptability and productivity across Brazil's distinct soybean-producing environments (Medeiros et al., 2024).

The Brazilian seed market has increasingly favored earlier indeterminate soybean cultivars with branched architecture, primarily due to their phenotypic plasticity across diverse environmental conditions (Balbinot et al., 2018). These cultivars exhibit greater adaptability in response to plant density and environmental variability, contributing to stable yield performance. Concurrently, breeding programs have optimized agronomic traits to meet the demands of intensive production systems, reducing the crop cycle while maintaining or even increasing yields (Umburanas et al., 2022). Over the past decades, the transition to cultivars with improved lodging resistance, higher harvest index, and enhanced resource use efficiency has reshaped soybean production in Brazil. These modifications in cultivar profiles likely influence the adaptation of different relative maturity groups, as environmental interactions with phenological traits continue to shape regional yield potential and cultivar recommendations.

The soybean response to temperature and photoperiod comprises one of the most important aspects to be considered for selecting adapted cultivars for target regions, because it implies directly on the synchrony of the phenological stages with environmental conditions (Camara et al., 1997; Setiyono et al., 2007). Assuming that temperature and photoperiod can be substantially influenced by latitude and elevation (Basnet et al., 1974; Sinclair et al., 2005), the effects of their interactions need to be better understood across the wide diversity of environments where soybean is cultivated, in order to guide the cultivar recommendation geographically.

In this study we aimed to understand, from a geographical perspective, the yield adaptation levels of soybean cultivars according to their relative maturity (RM) across growing regions of Brazil, and with this to improve accuracy in cultivar development and recommendation, as well as to support breeding program strategies in these regions.

Materials and Methods

Experimental data

The grain yield (GY) data from trials conducted in 175 locations, covering the south, southeast, midwest, north, and northeast of Brazilian regions were used. These trials were allocated predominantly in the most relevant regions for soybean production (Figure 1). The trials were conducted from 2014/15 to 2017/18 growing seasons, covering all soybean macro-regions of Brazil, with latitudes ranging from 7ºS to 33ºS and elevations from 9,000 m to 1,188 m (Supplementary Table 1).

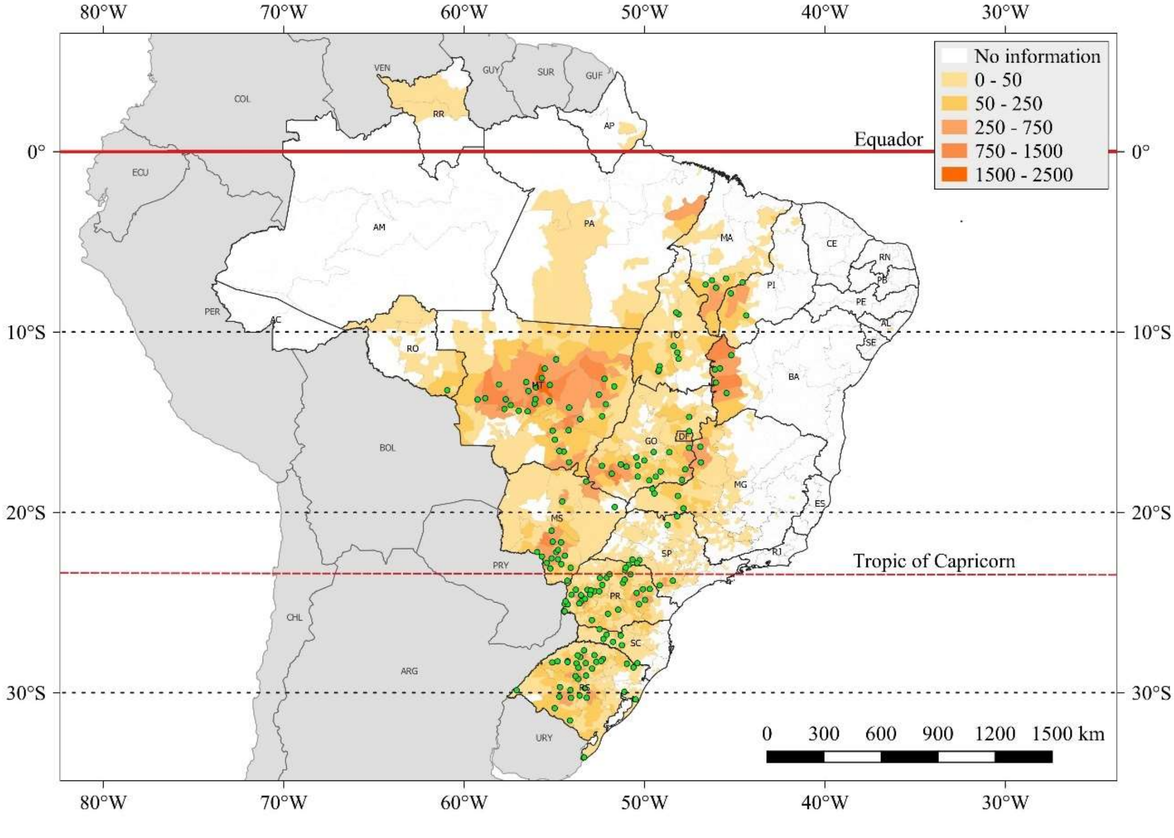

Figure 1 – Yield trials locations (green dots) from 2014/2015 to 2017/2018 seasons. The background color (orange) indicates the total production of soybean (kton) throughout the Brazilian territory (IBGE, 2022).

The experimental design was randomized complete block, with three replications, and each plot was composed of four rows of 5.0 m each, spaced 0.5 m apart. On average, sixty soybean cultivars (commercial and pre-commercial inbred lines), with different RM were evaluated in each trial (Supplementary Table 2). In all, 160 cultivars were evaluated, which were distributed in the entrylists of each location. GY data were the measurements of grain weights, corrected to 13% (w.b.) moisture, from two central rows of each plot. The maturity date was considered at the R8 stage of plants, with 95% of the pods mature (Fehr et al., 1971). The crop management was conducted according to technical recommendations for soybean crop (Seixas et al., 2020). In general, the sowing was carried out at proper seasons for each region, as recommended in the Agricultural Zoning of Climate Risk (MAPA, 2018).

Yield data analysis: relative maturity x location $(\mathrm{RM} \times \mathrm{L})$

Initially, the cultivars were grouped into RM ranges, then the groups were named from G1 to G10 (Table 1). Cultivars earlier than 4.5 and later than 9.4 were not evaluated in the trials, due to adaptation restrictions in the main soybean-producing regions of Brazil. The complete distribution of these groups by location is also available in Supplementary Table 1. The GY data taking account each RM group and location was adjusted using the following linear mixed model (1):

$$y = X\beta + Z_1u_1 + Z_2u_2 + Z_3u_3 + Z_4u_4 + Z_5u_5 + Z_6u_6 + Z_7u_7 + e \qquad (1)$$

where: y is the vector of experimental observations; X and Z_i $(i = 1\ to\ 7)$ are incidence matrices; β is the vector of fixed effects (β'=[β_0 ⋮ β_1], in which β_0 is the intercept, and β_1 is the vector of RM group effects); u_i $(i = 1\ to\ 7)$ are the vectors of random effects, with $u_i \sim N(0, \sigma^2_{ui})$, associated to the effects of year, location, block within location, cultivar within RM group, interaction between RM group and year, interaction between RM group and location, and interaction between RM group, location, and year, respectively; and e is the vector of experimental errors, with $e \sim N(0, \sigma^2_e)$.

Table 1 – Relative maturity (RM) groups of soybean cultivars assessed in Brazilian growing conditions from 2014 to 2018, and respective class midpoints and number of entries for each group.

Group	RM	Midpoint	Entries	Group	RM	Midpoint	Entries
G1	4.5-4.9	4.7	04	G6	7.0-7.4	7.2	20
G2	5.0-5.4	5.2	08	G7	7.5-7.9	7.7	20
G3	5.5-5.9	5.7	25	G8	8.0-8.4	8.2	24
G4	6.0-6.4	6.2	21	G9	8.5-8.9	8.7	19
G5	6.5-6.9	6.7	17	G10	9.0-9.4	9.2	02

The fitting of this model was performed with *lme4* package (Bates et al., 2015) of the R software (R Core Team, 2024). After, the corresponding deviance analysis was performed to verify the significance of model effects (α = 0.05). The predictor of $X\beta + u_6$ (adjusted means for each combination of RM group and location), denoted as $\hat{y}_{\mathrm{RM}\times\mathrm{L}}$, was then adopted to define the best RM group adapted to each location ($\mathrm{RM_B}$). This final result was defined as in equation (2):

$$\mathrm{RM_B} = \arg\max_{\mathrm{RM}}(\hat{y}_{\mathrm{RM}\times\mathrm{L}}) \quad (2)$$

The results for $\mathrm{RM_B}$ represent the RM group for each location with maximized grain yield. The midpoints of these groups were then considered the optimal RM values ($\mathrm{RM_{op}}$) of the different locations, and were subsequently used for spatialization by regression-kriging.

Geographic zoning of yield adaptation

The regression-kriging method (Hengl et al., 2004) was used to delineate the geographic yield adaptation zones of the soybean cultivars, based on their relative maturity. In this method, initially, multiple linear regression (MLR) is performed between the regionalized variable and predictors, using data from sampled locations, in order to extrapolate the RM predictions to unsampled locations. Additionally, the variation not explained by predictors through regression is interpolated using ordinary kriging, according to the following model (3):

$$\boldsymbol{\hat{z}(s_0) = \sum_{k=0}^{p} \hat{\beta}_k \cdot \hat{q}_k\,(s_0) + \sum_{i=1}^{n} \hat{\lambda}_i \cdot e(s_i)} \quad (3)$$

where: $\hat{z}(s_0)$ is the best RM in an unsampled location; $\hat{\beta}_k$ are the estimated regression coefficients associated to the predictors ($k = 0, 1, 2, \dots\ p$); $\hat{q}_k(s_0)$ is the k$^{\mathrm{th}}$ predictor value at an unsampled location, with $\hat{q}_0(s_0) = 1$, $\hat{\lambda}_i$ are weights determined by covariance function, and $e(s_i)$ corresponds to regression residuals.

For MLR fitting the predictors latitude, longitude and elevation were considered, with elevation obtained from “Digital Elevation Model” – SRTM (Farr et al., 2007). Then, a “backward” procedure was applied to select the most appropriate model, based on the values of adjusted coefficients of determination ($\mathrm{R^2_{adj}}$). An isotropic distribution of effects along the map was predefined.

Then, the exponential variogram model was considered as the best adjusted to the $\mathrm{RM_{op}}$ spatial distribution. The minimum residual sum of squares was adopted as the model selection criterion. The regression-kriging procedure was performed using the *rsaga* (Brenning, 2024) and *gstat* (Gräler et al., 2016) packages of the R software (R Core Team, 2024). Map creation was implemented using the Quantum GIS software (2023). A flowchart summarizing all the methodological steps for this study is shown in Figure 2.

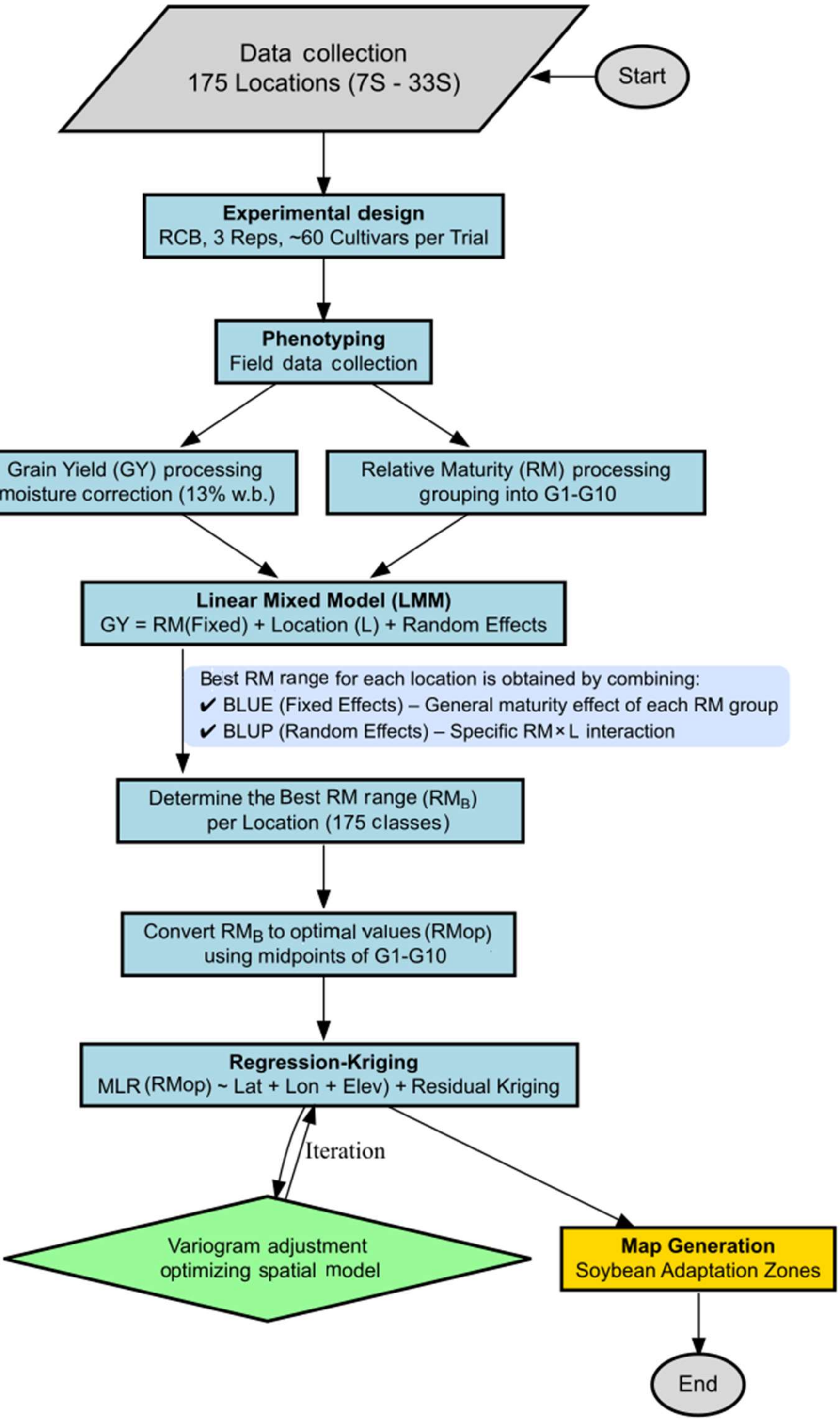

Figure 2 – Flowchart summarizing the methodological steps to determine the yield adaptation zones for soybean cultivars in Brazil, according their relative maturity (RM). Trial data from 175 locations, designed in randomized complete block (RCB) with ~60 cultivars per trial, and field phenotyping for grain yield (GY) and RM were used. A linear mixed model (LMM) was used to estimate the best RM group for each location ($\mathrm{RM_B}$), incorporating both fixed (BLUE) and random (BLUP) effects. The $\mathrm{RM_B}$ ranges were then converted into so-called optimum values ($\mathrm{RM_{op}}$) per location taking the ranges midpoints, which were modeled using multiple linear regression-kriging. Spatial interpolation was refined through variogram adjustment, generating the soybean adaptation zones based on the relative maturity groups.

Results

Deviance analysis for grain yield

The observed differences ($p<0.05$) among RM levels are due to the differential response of the cultivars, with different RM, across all the sampled environments (Table 2). This component explains 31.72% of the total variation. The interaction between the RM groups and assessed locations (RM x Location) was significant ($p<0.05$), explaining 25.91% of the total variation. This interaction corresponds directly to the specific adaptation of the cultivars, grouped by RM_r, across sampled locations.

Table 2 – Analysis of deviance results, variance components and coefficients of determination (R^2) of the multi-location trials for grain yield, considering 159 cultivars and 175 Brazilian locations, over four subsequent growing seasons (from 2014/2015 to 2017/2018).

Source of variation[1]	Deviance	LRT (χ^2)	AIC	Variance	Standard deviation	R^2(%)
Relative Maturity (RM)	618355	1334.49*	618383	634244	796.39	31.73
RM/Cultivar	615142	953.36*	615776	100309	316.72	12.62
RM x Location	616695	1660.14*	616727	422829	650.25	25.91
RM x Year	614839	693.55*	614685	47943	218.96	2.94
RM x Location x Year	614645	102.90*	614663	39125	197.80	2.40
Residual		-	-	388079	622.96	24.42
Model	619690	-	-	-	-	100.00

* Significant values by the χ^2 test at 5% of significance.

The interaction between RM groups and growing seasons (RM x Year), that also was significant ($p<0.05$), is due environmental variations as crop management, sowing time, non-permanent soil and weather conditions. This component can be used as an indicator of stability once it measures the repeatability of results over seasons. Similarly, the interaction "RM x Location x Year" ($p<0.05$) suggests that the levels of specific adaptation of each RM groups in each location varied slightly over time (only 2.40% of total variation). Therefore, it is necessary to investigate this temporal variation to understand and identify adaptive trends of the soybean germplasm in each region.

Zoning the soybean adaptation according to RM

The highest optimal RM values ($\mathrm{RM_{op}}$) was estimated for lower latitude regions, with a maximum value of 9.3 in northernmost locations, such as in the Brazilian states Roraima and Amapá.

Conversely, the lowest $\mathrm{RM_{op}}$ were estimated for higher latitude regions, presenting a minimum value of 5.3 in the states Rio Grande do Sul and Santa Catarina. This indicates that in the different regions and cropping systems in Brazil, there is a current demand for cultivars with different RM levels, whose amplitude reaches 4.0 points on the soybean relative maturity scale.

The results confirmed that the soybean yield adaptation according to the RM groups was significantly ($p<0.05$) influenced by latitude and elevation (Table 3). However, the longitude did not influence ($p>0.05$) the adaptation levels. There was a negative correlation between the optimal RM values and latitude ($r=0.82$; $p<0.05$). Thus, for each latitude degree upward, we have an increase of around 0.14 points in the RM level at a given position. There is also a negative correlation ($r=-0.16$; $p<0.05$) between elevation and RM values. Similarly, taking as an example an increase of 500 m in elevation, we have an approximate reduction of 0.2 points (-0.0004×500) in the relative maturity level (Table 3).

Table 3 – Predictors and coefficients from linear multiple regression (LMR) analysis for relative maturity optimized ($\mathrm{RM_{op}}$).

Predictors	Coefficients	R	R^2	R^2 (adjusted)	Standard-error	t-test	p-value
Latitude[1]	0.1407*	-0.8203	0.6729	0.6691	0.0075	18.8612	<0.0001
Elevation[2]	-0.0004*	-0.1608	0.0258	0.0145	0.0002	-2.1466	0.0408
Longitude	0.0298	-0.0356	0.0013	0.0000	0.0232	-1.2927	0.1739
Intercept	9.956923	-	-	-	1.9321	51.8432	<0.0001

[1] Digital Elevation Model-SRTM. [2] The latitude values must be considered negatives for the correct use of the model.

* Significant values by the t-test (Student) at 5% of significance.

The adaptation zones indicate that RM levels from 5.5 to 5.9 (G3 group) are the best adapted to the southernmost locations, specifically covering the Brazilian states of Rio Grande do Sul, Santa Catarina and the southwest, southeast and south of Paraná mesoregions (Figure 3). Whereas G4 group (with RM levels from 6.0 to 6.4) was the best adapted to Paraná state, covering its center, north, northwest and west, as well as southwest of Mato Grosso do Sul and São Paulo states. This group also shown to be the best adapted to the north of Santa Catarina and central east of Rio Grande do Sul, mainly in the low-elevation locations of these states, close to Atlantic Ocean coast.

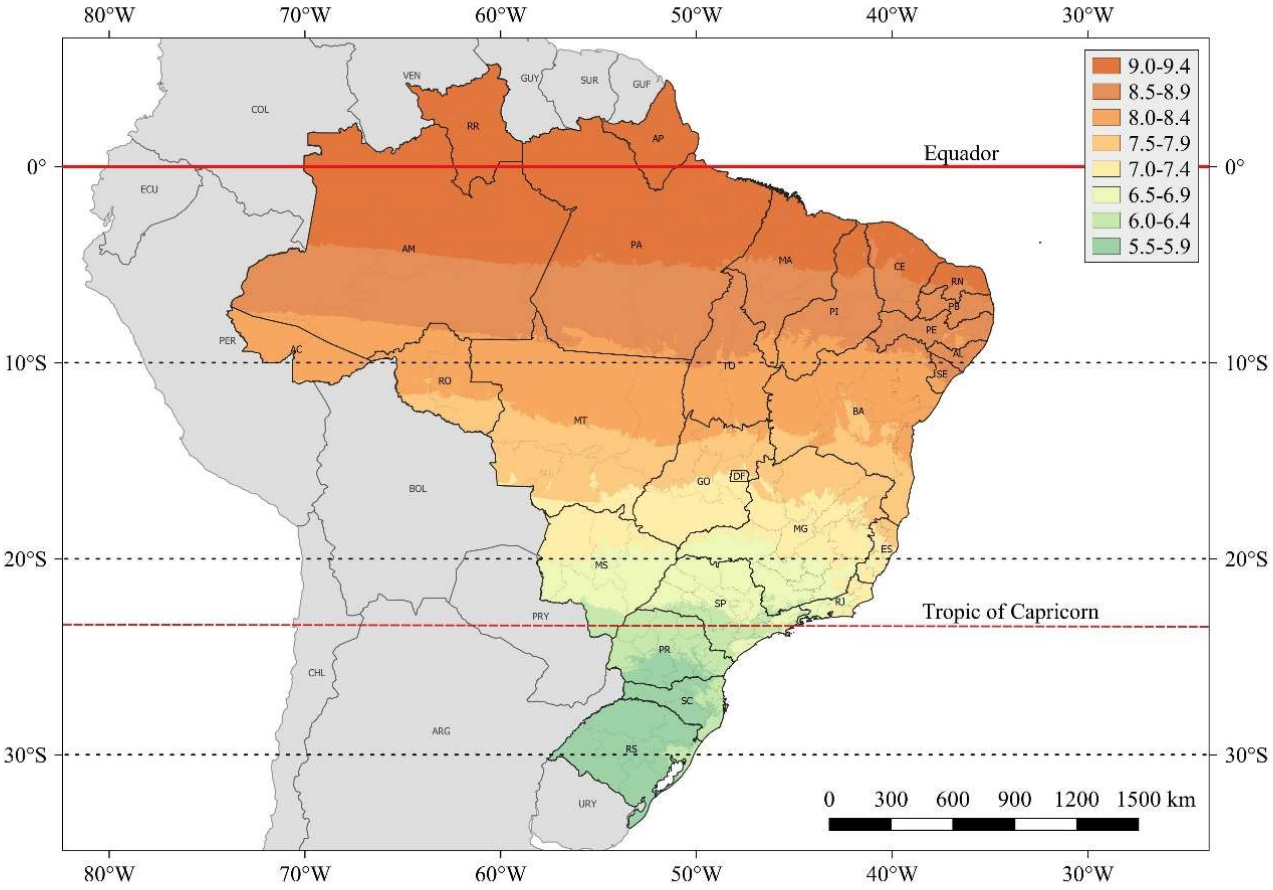

Figure 3 – Soybean geographic adaptation according to Relative Maturity (RM) in Brazil, considering as predictors the latitude and elevation.

In the transition zones between the Brazilian subtropical and tropical regions (23º27'S), the G5 group (RM from 6.5 to 6.9) was the one that adapted best. This transition covers the central north and east of Mato Grosso do Sul, north and northwest of São Paulo, south and southwest of Minas Gerais states, including its Triângulo Mineiro and Alto Paranaíba regions (Figure 3).

In the central north of Mato Grosso do Sul, south and central south of Goi In the transition zones between the Brazilian subtropical and tropical regions (23º27'S), the G5 group (RM from 6.5 to 6.9) was the one that adapted best. This transition covers the central north and east of Mato Grosso do Sul, north and northwest of São Paulo, south and southwest of Minas Gerais states, including its Triângulo Mineiro and Alto Paranaíba regions (Figure 3).ás states, in the Federal District, and in the central and northwest of Minas Gerais, as well as in areas around latitude 18º, the G6 group (RM from 7.0 to 7.4) was the best adapted. This group also shown to be the best adapted to the boundary regions between the states of Goiás, Mato Grosso do Sul, and the southeast of Mato

Grosso. The G7 group (RM from 7.5 to 7.9) was the best adapted to the north, northwest and east of Goiás state, including the transition between Goiás and Mato Grosso, as well as to the southeast and northeast of Mato Grosso. This RM group also was the best adapted to the central south and southwest of Mato Grosso and sub-regions around latitude 14° to the north of this state. Furthermore, cultivars of this group were also most adapted to the eastern region of Rondônia state, and to the central south of Bahia, as well as to other northern and northwestern Brazilian areas.

In the mid-north and northwest of Mato Grosso state, where are the Brazilian regions of highest concentration of soybean areas, also in other regions of lower relevance such as oriental do Tocantins state, west and central north of Bahia, including Vale do São Francisco region and southeast of Piauí state, G8 group (RM from 8.0 to 8.4) was the best adapted. This group was also the best to agricultural frontier regions, covering the largest extensions of Madeira-Guaporé region and part of east of Rondônia, further to the transition region between Mato Grosso and Pará states (Figure 3).

The G9 group (RM from 8.5 to 8.9) showed to be the best adapted to regions positioned around latitude 6ºS, including mainly the southeast and southwest of Pará, as well as to the west of Toc3ntins, east and south of Maranhão, central north and part of southwest of Piauí state, known as "MAPITO" region (referring to the acronyms of Maranhão, Piauí and Tocantins states). At latitudes around 5ºS, extending northward to the northernmost Brazilian regions, including the mesoregions of Marajó Island and northeast of Pará, east, west and areas of center and north of Maranhão, in addition to the whole states of Amapá and Roraima, G10 (RM from 9.0 to 9.4) was the best adapted (Figure 3). Cultivars with relative maturity from 9.5 to 10 were not considered because they do not compose the database used in this research (Supplementary Table 1).

The regression-kriging procedure provided predictions with good quality, resulting in a maximum standard error of 0.5 points on the soybean relative maturity scale. However, standard errors were noticeably higher in regions with a lower density of sampled locations, suggesting the need to geographically expand test locations to provide more accurate estimates, especially in Brazilian agricultural frontiers, such as in the states of Pará, Amapá, and Roraima.

Discussion

Soybean cultivars with higher RM levels are more adapted to lower latitudes. In general, these cultivars have a longer juvenile period and higher thermal demand, therefore, even under critical photoperiod and higher temperature conditions, their cycle tends to be longer due to delay in flowering and, consequently, longer reproductive stages. Cultivars with lower RM levels, adapted mainly to subtropical regions, generally have shorter juvenile periods and, consequently, flower earlier under short day conditions. When submitted to low latitudes, these cultivars present reduced height, low number of productive nodes, and, consequently, low adaptation (Dong et al., 2021). Therefore, according to the RM groups, the cultivars tend to present different adaptations, restricted to each latitude range (Figure 3).

Latitude shown to be crucial to define the soybean yield adaptation and, consequently, to support the recommendation and use of cultivars in the Brazilian growing conditions, once it can intensely affect the dynamics of growth, especially through correlated variations in photoperiod and temperature. As the growing location approaches latitude 0º (Equator), the cultivars with higher RM tend to show better adaptation. Other studies also observed similar behavior when investigating the adaptation of cultivars with different RM at low latitudes (Alliprandini et al., 2009; Penariol, 2000; Zdziarski et al., 2018). However, cultivars with different RM do not present regular adaptation within the latitude ranges, as suggested in these studies, mainly due to elevation effects and edaphoclimatic variations (Figure 3).

In general, lower elevations present higher temperatures, which favor higher RM cultivars due to their higher thermal demand, whereas lower RM cultivars are favored by higher elevations. Cultivars of the different RM groups present shorter cycle as the temperature rises in the growing environment (Battisti et al., 2018), which indirectly favors higher RM cultivars due to the long grain-filling period compared to those with lower RM. Kumagai and Sameshima (2014) also support that higher temperatures favor late cultivars, increasing the number of pods, grain weight and yield. This pattern can be easily noticed in Brazilian coastal regions (e.g., state of Rio Grande do Sul), where the elevation tends to be lower (Figure 3).

Overall, the results in this study are partially convergent with the recommendations of other similar researches (Alliprandini et al., 2009; Penariol, 2000; Zdziarski et al., 2018), although with relevant differences in some regions. Where the latitude is higher than 30°S, Zdziarski et al. (2018) noted that cultivars with RM 5.3 and 5.4 are the best adapted, differently, Penariol (2000) also indicates cultivars with RM lower than 5.0. Although cultivars with RM from 4.5 to 4.9 and 5.0 to 5.4 were evaluated in this study, which were the best to specific locations, these groups were not the best adapted.

Between latitudes 20°S and 30°S, already covering part of tropical zone, the recommendations by Zdziarski et al. (2018) are similar to the results of the present study. Correspondingly, Gesteira et al. (2015) based on a regional study, highlighted the importance of adopting early-maturing soybean cultivars in the southern region of Minas Gerais, recommending cultivars whose RM is around 6.2 for this region. However, Penariol (2000) and Alliprandini et al. (2009) also recommend RM 7.0 cultivars to the transition region, from subtropical for the tropical, in northern of Paraná and even RM 8.0 for Mato Grosso do Sul, São Paulo, and Minas Gerais states. From 10°S to 20°S, the differences between studies are more significant. Zdziarski et al. (2018) point out that cultivars with RM from 7.7 to 7.9 are the most adapted to the southwest of Goiás and north and northeast of Mato Grosso, but cultivars with RM from 8.0 to 8.4 was not evaluated, in this case. Penariol (2000) and Alliprandini et al. (2009) also include RM 8.0 cultivars for the southwest of Goiás and RM 9.0 for the north of Mato Grosso. From 0°S to 10°S, the same authors recommend cultivars with RM of 9.0 and 10 for the southern of Pará and “MAPITO”. Zdziarski et al. (2018) did not make recommendations to these regions.

Considering that cultivars in the studies of Penariol (2000) and Alliprandini et al. (2009) were released approximately 20 years ago, the differences between the results in relation to the current study may be due to the variations that soybean production systems have undergone in the last two decades in Brazil. Changes in the agronomic profile of soybean cultivars have been reported in several studies, mainly associated with yield level, grain composition, growth type, and lodging level (Kaster and Farias, 2012; Specht et al., 2014; Umburanas et al., 2022). In general, especially in tropical regions, still considering the results of Penariol (2000) and Alliprandini et al. (2009) in comparison to the current study, it was observed optimal RM reducing trend for each region over the years. It may result from efforts in genetic breeding, aiming to obtain earlier cultivars adapted to lower latitudes, and environmental improvements, such as soil correction in agricultural frontiers, and crop management, as well as optimizing sowing time and plant density adjustment. Although the effect of different sowing seasons was not considered in this study due to the limitations imposed by the climatic conditions of each region. Differently, the cultivars evaluated by Zdziarski et al. (2018) are contemporary, so the divergencies between the results may be due to the germplasm evaluated, representativeness of the dataset, or even from the analytical approach used.

The widespread adoption of the second cropping ("safrinha", in Portuguese), in large areas of the Cerrado region (Brazilian savannah) over the last few years has demanded the use of earlier cultivars (Cattelan and Dall'Agnol, 2018). Thus, the objective is to reduce the crop exposure to weather deteriorating factors and mitigate risks to the subsequent crop by sowing at a proper time, which may reduce the demand for fungicide and insecticide spraying. The adoption of the no-tillage system, with a consequent increase in soil fertility level, adjustment in plant density, and planting season also favored the northward adaptation of earlier cultivars, mainly those with indeterminate growth.

All these improvements in the soybean production system, especially in relation to the appropriate of maturity groups, sowing season, and plant density, have made the soybean production more intensive. Thus, significant changes have occurred in the commercial cultivar profile developed for the Brazilian soybean seed market in recent years.

New cultivars, with wider geographic adaptation and flexibility to different sowing seasons, which suggests a lower environmental interaction, have become preferred. In this context, cultivars with RM from 7.3 to 8.1, branched, with indeterminate growth, low-lodging, short internodes, erect growth habit and leaf insertion are currently predominant in the market. These cultivars have shown high yield potential, earliness, stability and wider adaptation, especially in low-latitude regions. Cultivars with these traits are part of a genetic base recently exploited in Brazil, whose adoption has resulted in high yield levels in the Cerrado region (Specht et al., 2014). Therefore, in Brazil, the genetic progress in soybean may be different among maturity groups, considering the priority given to this new cultivar profile over the last years. In addition, the dynamic of cropping systems has favored cultivars of specific RM, which indirectly promotes differential genetic gains between maturity groups. Rincker et al. (2014), analyzing the changes resulting from the genetic breeding of soybean over eighty years in North America, considering different maturity groups, found that generally contemporary cultivars have lower height and lodging rates, and, mainly, lower groups of maturity. The adaptation of a soybean subtropical genetic basis northward led to a gradual loss of photoperiod sensitivity, what has contributed to the development of earlier high-yield cultivars, with wider geographic adaptation.

The introduction and development of indeterminate growth cultivars began in the Brazilian South region, with cultivars from Argentina and North America, in the early 1990s (Alliprandini, 2018). Since then, indeterminate growth cultivars were quickly adapted to the Brazilian Central region and adopted in uneven cropping systems, what correspond now to more than 70% of the cultivars released in the last ten years (MAPA, 2024).

Soybean production in low-latitude regions is around half of the total production worldwide (Dong et al., 2021). Therefore, understanding the genetic and genomic basis, as well as the complexity behind environmental factors, which imply primarily on soybean adaptation is essential to continue developing new adapted cultivars and improving yield levels especially in agricultural frontiers. Hence, the results of this study can help to guide soybean breeding programs, not only about the selection strategy aimed at obtaining commercial cultivars adapted to each zone, but also guiding the positioning of multi-environment trials in order to optimize the experimentation.

Conclusion

Soybean cultivars, according to relative maturity (RM) groups, show different levels of geographic adaptation through cropping regions in Brazil. Thus, cultivars with lower RM are best adapted to regions with higher latitudes, while those with higher RM are best adapted to lower latitudes. However, regardless of this, over the last years early-maturity cultivars have been developed targeting lower latitude regions.

In the subtropical Brazilian regions, there was a slight trend for RM to reduce, and cultivars with RM from 5.5 to 6.4 are generally the most adapted. Whereas cultivars with RM from 6.5 to 6.9 are the best adapted in the subtropical/tropical transition region. Moving northward, in the tropical Brazilian region, especially along the Cerrado extension, the cultivars with RM from 7.0 to 8.4 are predominantly the best adapted.

The adaptation of later cultivars, with RM from 8.5 to 9.4, has retracted to the northernmost Brazilian regions, wherein there is lower relevance in soybean production thus far. Latitude and elevation are preponderant factors for defining the yield adaptation of soybean cultivars. The influence of elevation promotes discrete deflections in the adaptation zones, favoring earlier cultivars in higher elevations. Differently, longitude does not have a significant effect on the soybean adaptation.

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Authors' Contributions

Conceptualization: Ferreira LU, Duarte JB. **Data curation**: Ferreira LU. **Formal analysis**: Ferreira LU. **Funding acquisition**: Ferreira LU, Muniz FRS, Steckling C. **Investigation**: Ferreira LU, Muniz FRS, Steckling C. **Methodology**: Ferreira LU, Resende RT, Trevisan BA, Duarte JB. **Project administration**: Ferreira LU, Muniz FRS, Steckling C. **Resources**: Ferreira LU, Muniz FRS **Supervision**: Ferreira LU, Muniz FRS, Steckling C, Duarte JB. **Writing-original draft**: Ferreira LU, Muniz FRS, Steckling C, Resende RT, Trevisan BA, Duarte JB. **Writing-review & editing**: Ferreira LU, Duarte JB.

Conflict of interest

The authors have no conflicts of interest to declare.

Data availability statement

Data will be made available on request.

Declaration of use of AI technologies

AI technologies were not used in the present study.

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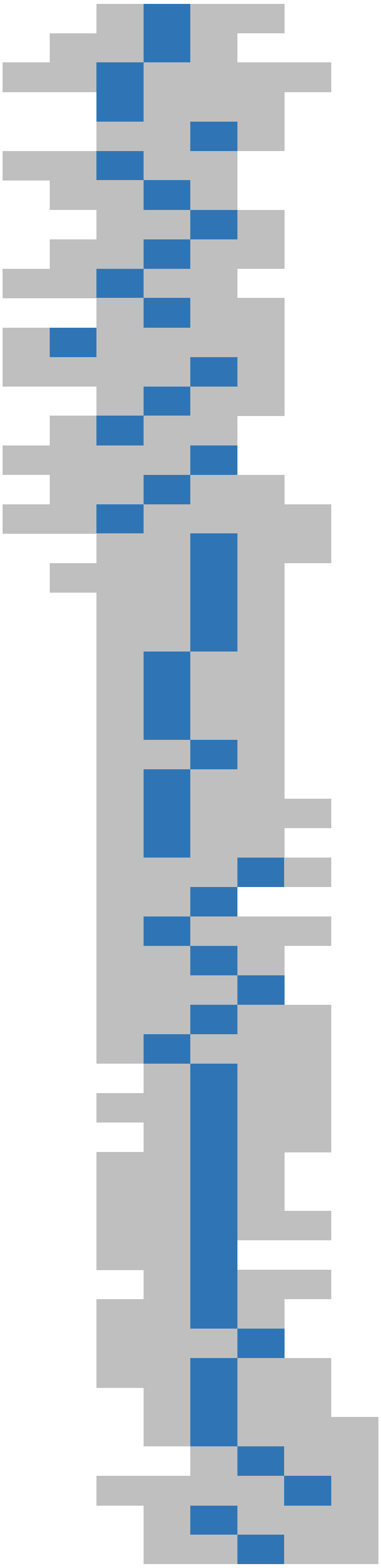
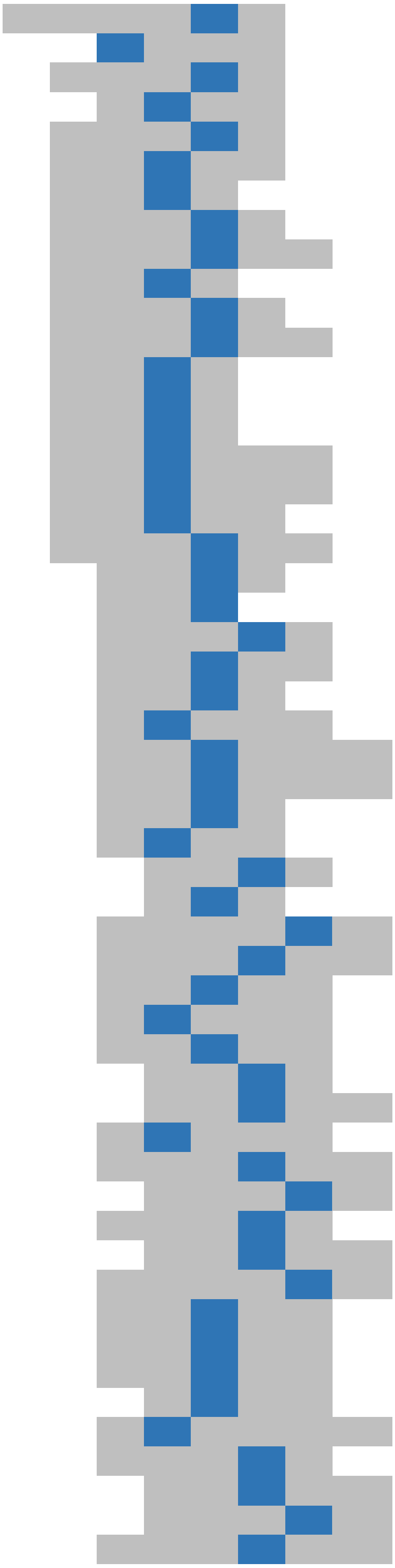
Supplementary Table 1 – Relative maturity (RM) groups of soybean cultivars by Brazilian test locations, with the respective decimal geographical coordinates to latitude (Lat) and longitude (Lon), and elevation (Alt), in meters above sea level (the gray cells denote RM of evaluated cultivars, and those blue denote RM of those best adaptaded).

Location	RM group[1]										Lat	Lon	Alt
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10			
Santa Vitória do Palmar-RS		▨	▨	🟦	▨						-33.584	-53.343	23
Bagé-RS	▨	🟦	▨	▨	▨						-31.539	-54.131	154
Dom Pedrito-RS	▨	▨	▨	🟦	▨						-30.853	-54.979	157
Palmares do Sul-RS		▨	▨	🟦	▨						-30.367	-50.492	9
São Gabriel-RS	▨	▨	▨	🟦	▨						-30.281	-54.078	152
Cachoeira do Sul -RS	▨	▨	▨	🟦	▨						-30.279	-53.212	144
Rosário do Sul-RS	▨	▨	▨	🟦	▨						-30.214	-54.722	171
São Sepé-RS		▨	🟦	▨	▨						-30.145	-53.590	72
Cachoeirinha-RS	▨	▨	▨	🟦	▨						-29.949	-51.117	17
Santa Maria-RS	▨	▨	🟦	▨	▨						-29.854	-54.125	105
Uruguaiana-RS	▨	▨	▨	🟦	▨						-29.854	-57.089	66
São Vicente do Sul-RS	🟦	▨	▨	▨	▨						-29.689	-54.683	129
Júlio de Castilhos-RS		▨	🟦	▨	▨						-29.230	-53.678	513
Santa Bárbara-RS	▨	▨	🟦	▨	▨						-29.089	-51.737	467
Salto do Jacuí-RS	▨	🟦	▨	▨	▨						-29.088	-53.213	389
Tupanciretã-RS	▨	▨	🟦	▨	▨						-29.082	-53.836	466
Tapera-RS	▨	▨	🟦	▨	▨						-28.659	-52.908	400
Cruz Alta-RS	▨	▨	🟦	▨	▨						-28.639	-53.606	433
Vacaria-RS	🟦	▨	▨	▨							-28.508	-50.942	861
São Luiz Gonzaga-RS	▨	▨	🟦	▨	▨						-28.413	-54.956	300
Bozano-RS	▨	▨	▨	🟦	▨						-28.368	-53.771	429
Santo Ângelo-RS	▨	▨	🟦	▨	▨						-28.300	-54.264	277
Carazinho-RS	▨	▨	🟦	▨	▨						-28.284	-52.669	591
Rolador-RS	▨	▨	🟦	▨	▨						-28.259	-54.818	300
Passo Fundo-RS	▨	▨	🟦	▨	▨						-28.258	-52.410	569
Entre-Ijuís-RS	▨	▨	🟦	▨	▨						-28.251	-54.257	286
Restinga Seca-RS	▨	🟦	▨	▨	▨						-28.220	-54.339	272
Coxilha-RS	🟦	▨	▨	▨	▨						-28.128	-52.303	721
Palmeira das Missões-RS	▨	▨	🟦	▨	▨						-28.019	-53.562	600
Sarandi-RS		▨	🟦	▨	▨						-27.916	-52.774	647
Santo Augusto-RS	▨	🟦	▨	▨	▨						-27.851	-53.777	504
Boa Vista das Missões-RS	🟦	▨	▨	▨	▨						-27.668	-53.311	568
Campos Novos-SC	▨	▨	🟦	▨	▨						-27.401	-51.228	890
Abelardo Luz-SC	▨	▨	▨	🟦	▨						-26.572	-52.323	826
Mariópolis-PR		🟦	▨	▨	▨	▨					-26.470	-52.491	846
Clevelandia-PR	▨	▨	▨	🟦	▨	▨					-26.405	-52.351	950
Pato Branco -PR	▨	▨	▨	🟦	▨						-26.230	-52.672	765
Francisco Beltrão-PR	▨	▨	▨	🟦	▨	▨					-26.082	-53.054	610
Itapejara Do Oeste-PR		🟦	▨	▨	▨	▨					-25.972	-52.913	492
Manguerinha-PR	▨	🟦	▨	▨	▨	▨					-25.938	-52.174	924
Realeza-PR	🟦	▨	▨	▨	▨						-25.767	-53.527	445
Candói-PR		▨	🟦	▨	▨	▨					-25.624	-52.024	904
Santa Terezinha-PR		▨	🟦	▨	▨						-25.478	-54.428	291
Guarapuava-PR	▨	▨	🟦	▨	▨	▨	▨				-25.391	-51.463	1000
Missal-PR			▨	🟦	▨	▨					-25.095	-54.254	250
Ponta Grossa-PR	▨	▨	🟦	▨	▨	▨					-25.092	-50.167	850



Itaipulândia-PR			▨	■	▨	▨			-25.077	-54.422	240
Santa Tereza do Oeste-PR		▨	▨	■	▨				-25.049	-53.613	550
Cascavel-PR	▨	▨	■	▨	▨	▨	▨		-24.958	-53.460	700
Santa Helena-PR			■	▨	▨	▨			-24.926	-54.380	255
Corbélia-PR			▨	▨	■	▨			-24.798	-53.291	600
Castro-PR	▨	▨	■	▨	▨				-24.790	-50.011	985
Tupassi-PR		▨	▨	■	▨				-24.586	-53.523	550
Marechal Cândido Rondon-PR			▨	▨	■	▨			-24.558	-54.049	380
Ubiratã-PR		▨	▨	■	▨	▨			-24.556	-53.014	460
Tibagi-PR	▨	▨	■	▨	▨				-24.502	-50.442	793
Mamborê-PR			▨	■	▨	▨			-24.377	-52.505	721
Juranda-PR	▨	■	▨	▨	▨	▨			-24.364	-52.756	630
Rancho Alegre-PR	▨	▨	▨	▨	■	▨			-24.323	-52.974	495
Quarto Centenário-PR			▨	■	▨	▨			-24.292	-53.163	462
Palotina -PR		▨	■	▨	▨				-24.287	-53.841	356
Arapoti-PR	▨	▨	▨	▨	■				-24.269	-50.087	915
Jaguariaiva-PR		▨	▨	■	▨	▨			-24.244	-49.707	840
Campo Mourão-PR	▨	▨	■	▨	▨	▨	▨		-24.047	-52.379	630
Itaberá-SP			▨	▨	■	▨	▨		-24.045	-49.159	680
Mauá da Serra-PR		▨	▨	▨	■	▨			-23.907	-51.191	1080
Eldorado-MS			▨	▨	■	▨			-23.787	-54.276	370
Buri -SP			▨	▨	■	▨			-23.785	-48.424	650
Tamarana-PR			▨	■	▨	▨			-23.727	-51.102	880
Jussara-PR			▨	■	▨	▨			-23.626	-52.471	370
Floresta-PR			▨	■	▨	▨			-23.620	-52.088	389
Cornélio Procópio-PR			▨	▨	■	▨			-23.448	-50.780	661
Maringá-PR			▨	■	▨	▨			-23.425	-51.939	551
Londrina-PR			▨	■	▨	▨	▨		-23.196	-51.072	430
Amambaí-MS			▨	■	▨	▨			-23.106	-55.226	480
Naviraí-MS			▨	▨	▨	■	▨		-23.062	-54.200	364
Sertanópolis-PR			▨	▨	■				-23.058	-51.040	320
Sertaneja-PR			▨	■	▨	▨	▨		-23.028	-50.844	411
Aral Moreira-MS			▨	▨	■	▨			-22.924	-55.521	532
Juti-MS			▨	▨	▨	■			-22.868	-54.606	370
Cândido Mota-SP			▨	▨	■	▨	▨		-22.806	-50.417	486
Assis-SP			▨	■	▨	▨	▨		-22.642	-50.275	470
Caarapó-MS				▨	■	▨	▨		-22.637	-54.821	408
Maracaí-SP			▨	▨	■	▨	▨		-22.611	-50.667	379
Laguna Carapã-MS				▨	■	▨	▨		-22.545	-55.151	478
Ponta Porã-MS			▨	▨	■	▨			-22.445	-55.690	630
Vicentina-MS			▨	▨	■	▨			-22.397	-54.407	355
Dourados-MS			▨	▨	■	▨	▨		-22.224	-54.813	453
Antônio João-MS			▨	▨	■				-22.193	-55.952	512
Itaporã-MS				▨	■	▨	▨		-22.081	-54.794	390
Rio Brilhante-MS			▨	▨	■	▨			-21.804	-54.543	360
Maracaju-MS			▨	▨	▨	■			-21.611	-55.168	594
Sidrolândia-MS			▨	▨	■	▨	▨		-20.931	-54.970	483
Barretos-SP				▨	■	▨	▨		-20.699	-48.724	573
Guaíra-SP				▨	■	▨	▨	▨	-20.216	-48.188	510
Uberaba-MG					▨	■	▨	▨	-19.748	-47.939	863
São Gabriel do Oeste-MS			▨	▨	▨	▨	■	▨	-19.389	-54.551	382
Ituiutaba-MG				▨	■	▨	▨	▨	-18.978	-49.464	583
Uberlândia-MG				▨	▨	■	▨	▨	-18.915	-48.275	909



Chapadão do Sul-MS	-18.788	-52.627	786
Capinópolis-MG	-18.680	-49.572	530
Costa Rica-MS	-18.281	-53.229	851
Bom Jesus-GO	-18.217	-49.734	619
Catalão,GO	-18.166	-47.944	775
Maurilândia-GO	-18.013	-50.371	488
Goiatuba-GO	-18.011	-49.366	580
Jataí-GO	-17.879	-51.721	731
Rio Verde-GO	-17.793	-50.920	842
Morrinhos-GO	-17.734	-49.106	771
Campo Alegre-GO	-17.611	-47.743	892
Montividiu-GO	-17.444	-51.173	857
Mineiros-GO	-17.414	-52.359	940
Acreúna,GO	-17.396	-50.375	650
Paracatu-MG	-17.226	-46.872	688
Itiquira-MT	-17.215	-54.143	522
Indiara-GO	-17.116	-50.009	570
Paraúna-GO	-16.947	-50.449	710
Cristalina-GO	-16.768	-47.614	982
Silvânia-GO	-16.66	-48.609	877
Trindade-GO	-16.649	-49.489	756
Pedra Preta-MT	-16.625	-54.473	248
Rondonópolis-MT	-16.589	-54.721	449
Unaí-MG	-16.360	-46.903	565
Jaciara-MT	-15.965	-54.968	367
Primavera do Leste-MT	-15.561	-54.295	636
Campo Verde-MT	-15.545	-55.163	736
Padre Bernardo-GO	-15.500	-47.523	1187
Formosa-GO	-15.499	-47.523	1188
Santo Antônio do Leste-MT	-14.829	-53.569	638
São João da Aliança-GO	-14.709	-47.521	986
Nova Xavantina-MT	-14.678	-52.351	446
Diamantino-MT	-14.404	-56.437	620
Nova Marilândia-MT	-14.357	-56.970	489
Tangará da Serra-MT	-14.260	-57.762	661
Deciolândia-MT	-14.260	-57.411	568
Paranatinga-MT	-14.187	-54.176	550
Água Boa-MT	-14.051	-52.161	446
Campo Novo do Parecis-MT	-13.894	-57.411	568
Nova Mutum-MT	-13.838	-56.075	380
Santa Rita do Trivelato-MT	-13.823	-55.268	490
Campos de Júlio-MT	-13.805	-59.333	655
Canarana-MT	-13.552	-52.271	366
Correntina-BA	-13.348	-44.634	925
Sao José do Rio Claro-MT	-13.265	-56.432	350
Cerejeiras-RO	-13.226	-60.932	216
Lucas do Rio Verde-MT	-13.059	-55.905	385
Ribeirão Cascalheira-MT	-13.013	-51.678	382
Sapezal-MT	-12.990	-58.765	622
Nova Ubiratã-MT	-12.984	-55.256	400
Tapurah-MT	-12.772	-56.554	446
Querência-MT	-12.610	-52.183	336
Sorriso-MT	-12.543	-55.722	385

São Desidério-BA	▨	▨	▨	▨	■	▨	-12.358	-44.977	318
Figueirópolis-TO		▨	■	▨	▨	▨	-12.178	-49.230	318
Brasnorte-MT		▨	▨	■	▨		-12.148	-57.984	473
Barreiras-BA	▨	▨	▨	■	▨	▨	-12.144	-44.997	831
Ipiranga do Norte-MT	▨	▨	■	▨	▨		-12.098	-56.090	259
Luiz Eduardo Magalhães-BA	▨	▨	▨	■	▨	▨	-12.074	-46.132	851
Cariri do Tocantins-TO		▨	▨	▨	▨	■	-11.889	-49.161	295
Sinop-MT	▨	▨	▨	■	▨	▨	-11.861	-55.510	387
Gurupi-TO		▨	▨	▨	■	▨	-11.728	-49.068	318
Cláudia-MT		■	▨	▨	▨		-11.516	-54.898	541
Santa Rosa-TO		▨	▨	■	▨	▨	-11.390	-48.106	277
Silvanópolis-TO		▨	▨	▨	■	▨	-11.148	-48.170	269
Formosa do Rio Preto -BA			■	▨	▨	▨	-11.033	-45.193	776
Porto Nacional-TO		▨	▨	■	▨	▨	-10.703	-48.408	238
Bom Jesus do Piauí-PI			▨	▨	■		-9.0751	-44.357	273
Pedro Afonso-TO		▨	▨	▨	■	▨	-9.035	-48.074	217
Tupirama-TO			▨	■	▨	▨	-8.9168	-48.243	254
Baixa Grande do Ribeiro-PI			▨	▨	■	▨	-7.8494	-45.219	325
Balsas-MA			▨	▨	▨	■	-7.5325	-46.038	283
Riachão-MA			▨	▨	■	▨	-7.3601	-46.615	362
Urucuí-PI			▨	▨	▨	■	-7.2398	-44.558	167
Nova Colinas-MA			▨	▨	▨	■	-7.1230	-46.261	385
São R. das Mangabeiras-MA			▨	▨	■	▨	-7.0222	-45.481	225

[1] RM ranges by group: G1 (4.5 to 4.9); G2 (5.0 to 5.4); G3 (5.5 to 5.9); G4 (6.0 to 6.4); G5 (6.5 to 6.9); G6 (7.0 to 7.4); G7 (7.5 to 7.9); G8 (8.0 to 8.4); G9 (8.5 to 8.9); and G10 (9.0 to 9.4).

Supplementary Table 2 – Soybean cultivars assessed in locations of Brazilian growing conditions, with respective values of relative maturity (RM).

Cultivar	RM	Cultivar	RM
DM 4612	4.6	NA 7255 RR	7.2
NS 4823 RG	4.8	NS 7209 IPRO	7.2
NS 4901 RG	4.9	NS 7237 IPRO	7.2
NS 4955RG	4.9	CD 2720IPRO	7.2
AMS Tibagi RR	5.0	NA 7337 RR	7.3
FPS Iguaçu RR	5.0	NS 7338 IPRO	7.3
BMX Energia RR	5.0	W 731 RR	7.3
NS 5000 IPRO	5.0	TEC 7022 IPRO	7.3
NS 5106 IPRO	5.1	AS 3730 IPRO	7.3
SYN 1152 RR	5.2	BRS 7380 RR	7.3
BS 1543 IPRO	5.4	CD 2737RR	7.3
NS 5445 IPRO	5.4	Anta 82 RR	7.4
BMX Apolo RR	5.5	ST 740 RR	7.4
95R51 RR	5.5	TMG 1174 RR	7.4
FPS Paranapanema RR	5.6	TMG 123 RR	7.4
BMX Ativa RR	5.6	CZ 47B51 IPRO	7.5
CZ 15B64 IPRO	5.6	INC353	7.5
FPS Solimões RR	5.7	TEC 7548 IPRO	7.5
TEC 6029 IPRO	5.7	PP 7500 IPRO	7.5
AS 3570 IPRO	5.7	TMG 1175 RR	7.5
M 5705 IPRO	5.7	BMX DESAFIO RR	7.6
M 5730IPRO	5.7	TMG 1176 RR	7.6
NS 6006 IPRO	5.7	NS 7670 RR	7.6
BMX Turbo RR	5.8	M 7639 RR	7.6
DM 5958 RSF IPRO	5.8	M 7739 IPRO	7.7
DM 6458 RSF IPRO	5.8	ST 777 IPRO	7.7
BS 1580IPRO	5.8	W 787 RR	7.8
M 5892 IPRO	5.8	ST 780 RR	7.8
TMG 2158IPRO	5.8	M 7908 RR	7.8
VMax RR	5.9	W 791 RR	7.9
NS 5959 IPRO	5.9	W 799 RR	7.9
VTop RR	5.9	TMG 1179 RR	7.9
CZ 15B92 IPRO	5.9	ST 797 IPRO	7.9
BS 2590 IPRO	5.9	BS 4790 IPRO	7.9
M 5947 IPRO	5.9	BMX Bônus IPRO	7.9
M 5917 IPRO	5.9	W 805 RR	8.0
SYN 1059	5.9	SYN 1080 RR	8.0
TEC 5833 IPRO	6.0	TMG 1180 RR	8.0
BS 2601 RR	6.0	TECMT 8024 RR	8.0
BS 2606 IPRO	6.0	SYN 1281 RR	8.1
CZ 26B05 IPRO	6.0	NS 7901 RR	8.1
BMX Vanguarda	6.0	P98Y11 RR	8.1
TMG 7060 IPRO	6.0	P98Y12 RR	8.1
TEC 5936 IPRO	6.1	W 811 RR	8.1
AS 3610 IPRO	6.1	W 815 RR	8.1
NA 5909 RR	6.2	M 8133 IPRO	8.1
TMG 7262 RR	6.2	AS 3810 IPRO	8.1
ST 620 IPRO	6.2	ST 815 RR	8.1
FPS Urano RR	6.2	TMG 2181 Ipro	8.1

M 6210 IPRO	6.2	ST 820 RR	8.2
TMG 7062 IPRO	6.2	M 8210 IPRO	8.2
CZ 6205 B	6.2	P98Y30 RR	8.3
CZ 36B31 IPRO	6.3	M 8349 IPRO	8.3
DM 6563 RSF IPRO	6.3	TMG 2183 Ipro	8.3
TECIRGA 6070RR	6.3	CZ 48B32 IPRO	8.3
M 6410 IPRO	6.4	W 842 RR	8.4
CZ 26B42 IPRO	6.4	CZ 48B41 RR	8.4
BS IRGA 1642 IPRO	6.4	CZ 58B40 RR	8.4
FTS Campo Mourão RR	6.6	BG 4184 RR	8.4
DM 7166 RSF IPRO	6.6	P98Y51 RR	8.5
BMX Flecha IPRO	6.6	TMG 132 RR	8.5
BMX Potência RR	6.7	TMG 133 RR	8.5
TEC 6702 IPRO	6.7	W 866 RR	8.6
BMX Valente RR	6.7	ST 900 RR	8.6
CZ 36B80 RR	6.8	ST 860 RR	8.6
TMG 1168 RR	6.8	M 8644 IPRO	8.6
M 7110 IPRO	6.8	BMX Opus IPRO	8.6
ST 690 RR	6.9	GB 874 RR	8.7
TEC 7849 IPRO	6.9	W 875 RR	8.7
NA 5909 RG	6.9	CZ 48B71 RR	8.7
W 691 RR	6.9	ST 871 RR	8.7
M 6952 IPRO	6.9	M 8766 RR	8.7
NS 6909 IPRO	6.9	P98Y70 RR	8.7
ST 693 IPRO	6.9	M 8372 IPRO	8.7
M 6972 IPRO	6.9	CZ 58B81 RR	8.8
ST 700 RR	7.0	M8808 IPRO	8.8
NS 7000 IPRO	7.0	M 9144 RR	8.9
W 712 RR	7.1	W 891 RR	8.9
W 711 RR	7.1	P99R03 RR	9.0
M 7211 RR	7.2	ST 920 RR	9.2

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