Understanding Soybean Maturity Groups in Brazil: Environment, Cultivar Classification, and Stability

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ABSTRACT

Maturity classification is an important concept to provide the best allocation of resources for soybean [*Glycine max* (L.) Merr.] research and commercialization. A similar maturity group system used in North America is being used for some seed companies in Brazil and needs research to improve its use. This study evaluated the maturity stability of 48 midwestern and 40 southern Brazilian commercial cultivars ranging from North American maturity groups VI to VIII at 15 locations. Relative maturity groups were attributed to all cultivars. All trials were planted in the first half of November. The effect of location was very important in influencing the number of days to maturity, number of days to flowering and reproductive growth period (RGP). The genotype × environment interaction, although statistically significant, was much lower than the individual effects of environment and genotype for all traits and regions. Genotype × latitude and genotype × altitude, considering also years of evaluation, were generally low or nonsignificant. A recommended list was developed of the most stable genotypes and, consequently, of the most suitable check genotypes for each maturity group classification in the southern and midwestern regions. Results indicate that the use in Brazil of a maturity group system similar to that used in North America to classify soybean genotypes is an efficient method for describing relative maturity on a broad environmental basis.

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Abbreviations: MG, maturity group; NDF, number of days to flowering; NDM, number of days to maturity; RGP, reproductive growth period; RM, relative maturity.

Understanding and quantifying photoperiod × temperature interactions often directly affects soybean [*Glycine max* (L.) Merr.] breeders and producers when selecting varieties, determining dates of planting, predicting dates of flowering and maturity, and predicting final yields (Zhang et al., 2001). Effect of the photoperiod response on area of adaptation is more pronounced in the soybean than in any other major crop. As soybean is classified as a short-day plant, sensitivity to photoperiod is a hindering factor in increasing its adaptation range. When soybeans are cultivated under short-day conditions, in out-of-season plantings or in low latitude, those plants with the classic response to photoperiod flower early and result in short plants and low grain yields (Carpentieri-Pípolo et al., 2000). The length of the growing season for photoperiodic sensitive crops such as soybean is defined by complex interactions between temperature and photoperiod (Raper and Kramer, 1987).

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The development of elite Brazilian cultivars of different maturities has long challenged breeders due the effects of large differences in latitude, climate, altitude, diversity of soil type, farming and planting practices, plant growth habit, presence or absence of the long-juvenile trait, differing stress conditions, and diseases, resulting in large genotype × environment interactions (Alliprandini et al., 1993, 1994, 1998; Arantes and Souza, 1993; Rocha and Vello, 1999; Spehar, 1994; Vello et al., 1988).

As soybean breeding developed in the United States and Canada, it became a general practice to group soybeans according to their photoperiod response and general area of adaptation. Thirteen maturity groups (MGs) are now recognized. They are designated by roman numerals, starting with "000" for the earliest maturity group adapted to the long days and short summers of southern Canada and northern United States, and ending with "X" for the latest maturity group, which is adapted to the short days of tropical regions on either side of the equator (Poehlman, 1987).

Relative maturity is a rating designed to account for all of the factors that affect maturity date and number of days from planting to maturity. These factors include variety, planting date, rainfall, latitude and disease. The MG is divided into tenths to get a relative maturity value. The method used to determine maturity is the 95% brown pods reading. According to Beuerlein et al. (1999), a variety with a relative maturity rating of 3.5 can reach the 95% brown pod stage 5 d later than a variety with a rating of 3.0. Zhang et al. (2007) determined changes in U.S. cultivated materials regarding their maturity groups, and the latest groups are now cultivated on a limited basis. The classical approach to describe relative maturity in Brazil has been the use of early, mid-, and full-season cultivars (EMBRAPA, 1998; Spehar, 1994). This method can describe relative maturity on a local basis, but it has not been successful in describing relative maturity over the wide range of environments and latitudes that occurs throughout the Brazilian soybean growing area.

The traditional Brazilian approach of classifying varieties as early, medium, and late, by region, is gradually being replaced as more and more private companies entering the commercial soybean market are using the North America system used by their parent companies (Monsoy, 1998a,b; Alliprandini et al., 2002; Prado et al., 2002; Fundação MT, 2003). Due to the large use of commercial U.S. germplasm, Argentina adopted this system earlier than Brazil, and groups II through VIII are grown throughout the country (Paschal et al., 2000). Monsanto was the first company to introduce the concept of maturity groups in Brazil (Penariol, 2000). Despite this increase in the use of the U.S. maturity classification system by private companies in Brazil, however, little or no research has been published to validate its use and to establish checks for improving the use of this approach under Brazilian conditions.

The objective of this study was to evaluate a collection of Brazilian commercial cultivars, in a series of different locations, and to attempt to classify their responses to different latitudes and altitudes, as well as the genotype × environment interactions, utilizing a relative maturity group approach. This information will be useful in breeding research by providing a method for maturity classification of soybean materials that can become a standard for breeding lines in the entire Brazilian production system.

MATERIALS AND METHODS

As a starting point, the selection of the cultivars for this study was based partly on previous knowledge, comparisons and discussions of existing maturity groups, existing commercial cultivars, and trial checks developed and/or used by Monsanto (Monsoy, 1998a,b), Syngenta Seeds Ltd. (Alliprandini et al., 2002), Pioneer Seeds Ltd. (Prado et al., 2002), and FT Sementes (J.L. Alberini, personal communication, Naturalle, Ponta Grossa, PR, Brazil). Other commercial materials were added by recommendation of the participant companies. A total of 48 midwestern and 40 southern Brazilian commercial cultivars were planted in seven southern and eight midwestern Brazilian locations (research stations) during the agricultural years of 2002–2003 and 2003–2004. Morro Agudo is a transition region, and although it shown as a midwestern location in Fig. 1, the tested cultivars were those tested in the southern region. Five cultivars (ranging from maturity groups VI to VIII) were common to all 15 different locations that represent the most important Brazilian soybean cultivated areas. Locations were chosen also on the basis of their diversity of latitude and altitude (Fig. 1). Each plot consisted of four rows, 5 m long, spaced 0.5 m apart, and 80 seeds were sown in each row. Two replications were used in a randomized complete block design. All trials were planted during the first 2 wk of November to eliminate the possible effect of the long juvenile trait in some southern and midwestern cultivars (Toledo et al., 1993). Seed source for each cultivar was the same for all trials, and fungicide sprays of a triazol plus a strobirulin were applied at least twice to prevent foliar disease effects on maturity. Data were collected from the two center rows. Flowering dates were recorded when 50% of plants in a plot had open flowers. Reproductive growth period (RGP) was estimated by difference between number of days to maturity (NDM) and number of days to flowering (NDF). Number of days to maturity was measured by counting days from planting to the date when plants had 95% of their pods dry (R8 on the scale of Fehr and Caviness, 1977). Analysis of variance was performed using a mixed model for southern and midwestern regions. The GLM procedure from SAS (SAS Inst., Cary, NC) was used because some locations as Morro Agudo (southern cultivars) had one missing replication. For joint analysis, both regions with five cultivars, years, latitude, and altitude were considered as a random effects and cultivars as a fixed effect. Stability parameters were determined using the Eberhart and Russell (1966) model and were interpreted as described by Alliprandini et al. (1998), where *b* values represent the response of the cultivar to environmental changes, R^2 indicates the predictability of genotype across tested environments and s^2d represents the deviation from regression. Stability was designated for materials with high predictability and lower environmental variance. A regression of NDM on assumed relative maturity group was performed using the most well known and widely grown checks for each maturity group. This regression was used to calculate the maturity group for all cultivars in southern and midwestern regions.

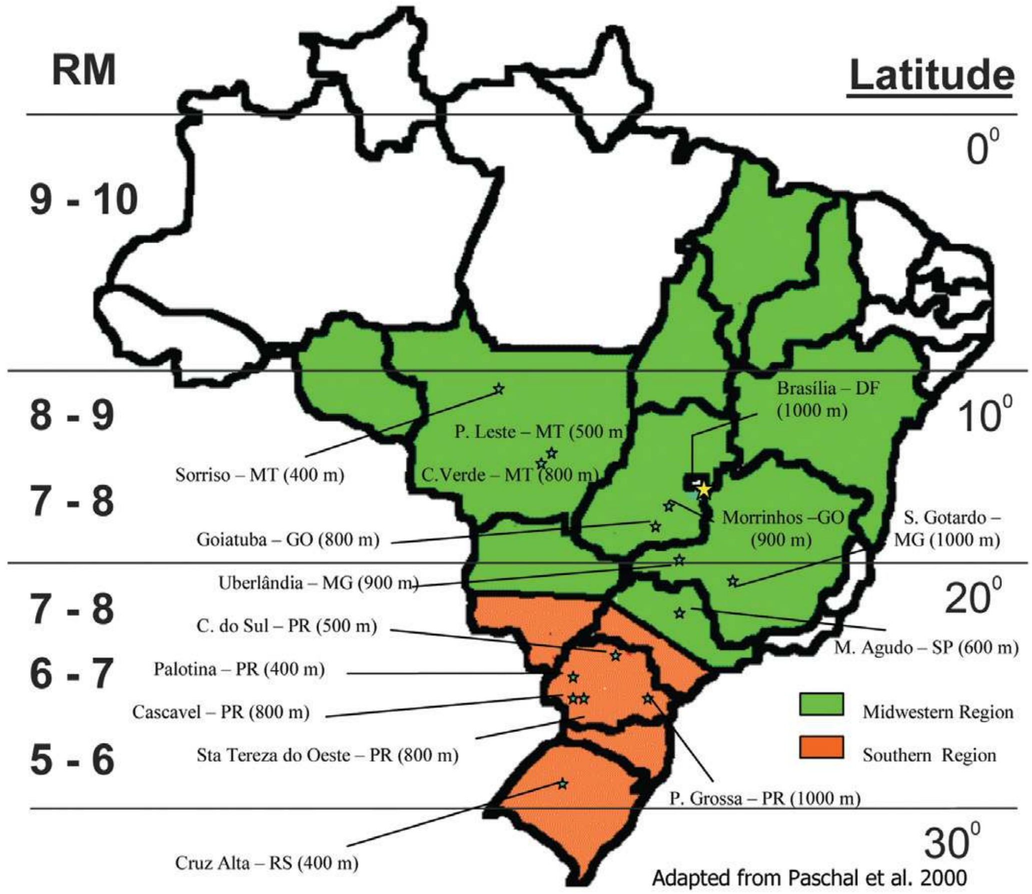

Figure 1. The distribution of relative maturity groups for soybean cultivars in Brazil and localization of trials for stability analyses, 2002–2003 and 2003–2004 seasons.

RESULTS AND DISCUSSION

The variance analysis in each region (Table 1) shows that the location and cultivars effects were significant for NDM. Location accounted for 76% (midwestern), 91% (southern), and 62% (Brazil) of total variability for the trait in both regions, indicating the importance of that factor in the determination of maturity differences. Latitude and altitude were both significant for all regions, indicating that the soybean maturity response was greatly affected by both. These results demonstrate that a good maturity group classification should rely on data from trials grown in different locations with a broad range of latitudes and altitudes that represent the adaptation region of the targeted lines and/or cultivars.

The year effect was significant and represented 11% of the variability for the midwestern region but was not significant for the southern trials. A nonsignificant response was found for the five tested cultivars common to both Brazilian regions. These results can be explained by the climate differences within the two regions. Such differences are greater in the midwestern region, which represents a larger crop area and with much divergence in farming practices, weather, type of soils, and rainfall pattern. The nonsignificance for the year effect in the joint analysis can be due to the fact of the five common cultivars having lower relative maturities (up to RM 8.0) than most cultivars evaluated in the midwestern region. Thus, they would not be affected in a similar way by rainfall shortage or other environmental condition. Year × location was

Table 1. Analysis of variance for number of days to maturity of commercial cultivars in midwestern, southern, and combined midwestern and southern regions in Brazil, 2002–2003 and 2003–2004.

Source	Midwestern		Southern		Combined	
	df	Mean square	df	Mean square	df	Mean square
Year	1	2938*	1	419	1	391
Location (loc.)	7	20,368**	6	34,941**	14	4102**
Latitude (lat.)	5	6029**	4	32,811**	10	4435**
Altitude (alt.)	4	6090*	4	31,643**	5	2861*
Year × loc.	7	578**	6	1544**	14	153**
Year × lat.	5	447**	4	1981**	10	178**
Year × alt.	4	884**	4	1812**	5	263**
Rep (year × loc.)	16	6	13	3	29	4
Cultivar (cult.)	47	2996**	39	1227**	4	1893**
Cult. × year	47	18	39	18	4	20
Cult. × loc.	329	35**	234	22*	56	28*
Cult. × lat.	235	40**	156	21	40	37
Cult. × alt.	188	45**	156	28**	20	30*
Cult. × year × loc.	323	13**	231	13**	54	17**
Cult. × year × lat.	229	15**	156	10	40	16
Cult. × year × alt.	182	15**	156	19	20	12
Error	746	4	503	2	114	3
R^2		0.99		0.99		0.99
CV		1.60		1.23		1.31

*Significant at the 0.05 probability level.

**Significant at the 0.01 probability level.

significant and ranged from 2 to 4%, indicating that year × location constitutes different environments and as such can be used to evaluate genotypic maturity. Therefore it is important to note that the magnitude of the response to locations across the evaluated years was much less important than locations per se and that locations may substitute for years for the purpose of maturity classification.

Cultivar effect was highly significant and responsible for 11 and 3% of total variability accountable to midwestern and southern trials for NDM, respectively. When both regions were taken together, the five tested cultivars represented about 29% of the total variation for the model. These differences can be explained by the divergence of tested environments that exposed the variability of the tested cultivars. It also indicates that this phenotypic variability can be used to classify cultivars in different relative maturity groups, as long as those cultivars are a representative sample of the maturities of all cultivars actually commercialized in Brazil.

The interaction of cultivar × location was also significant, suggesting that some of the genotypes evaluated had distinct maturity across environments. This interaction was significant for all regions but accounted for just 0.1% (midwestern), 0.05% (southern), and 0.5% (Brazil) of total variability for NDM. Despite the significant response, the low importance of this interaction suggests that well-conducted and well-distributed trials can lead to a satisfactory relative maturity group classification once the majority of tested genotypes demonstrates a consistent maturity performance across different environments (Tables 2 and 3). It is also important to note that although this interaction is small, it does exist and should be considered for regional evaluations to adequately attribute relative maturity groups to new cultivars. When partitioned between latitude and altitude, genotype × altitude interactions seem to be slightly more important than genotype × latitude, mainly for the southern region (Table 1). This result suggests that the evaluation of cultivars for determining maturity groups should consider locations both below and above 700 m altitude high for a precise evaluation. In Brazil, altitude is associated with differences in both temperatures and rainfall.

Figures 2, 3, and 4 show the variation of maturity for all cultivars, together with the latitude and altitude effect. Even with the interactions, the mean of all tested cultivars showed a similar response to the effects of latitude and altitude. There is an increase of days to maturity concomitant with the increment of latitude and altitude. The average difference of NDM of tested cultivars across environments ranged from 33 d for the midwestern to 39 for the southern and 49 for the combined areas. This response seemed to

Table 2. Number of days to flowering (NDF), reproductive growth period (RGP), number of days to maturity (NDM), relative maturity groups (MG), and stability parameters of southern Brazilian soybean cultivars.

Cultivar	NDF	RGP	NDM	MG†	*b*‡	R^2	s^2d§	Cultivar	NDF	RGP	NDM	MG	*b*	R^2	s^2d
FT-Cometa	42	64	106	5.0	0.75**	0.97	4.5*	BRS 184	53	70	123	6.7	1.01	0.98	5.0
NK8350 Spring¶	42	66	108	5.2	0.79**	0.97	3.6 ns#	RB603	49	75	124	6.8	1.05	0.98	3.7 ns
M-Soy 5942¶	44	68	112	5.6	0.85**	0.95	8.8	CD208	53	71	124	6.8	1.09**	0.99	2.7 ns
NK412113¶	45	69	114	5.8	0.85**	0.94	10.0	Embrapa 48	51	73	124	6.8	1.04	0.98	6.0
CD215	48	67	115	5.9	0.91*	0.97	6.3	CD206¶	54	70	124	6.8	0.98	0.98	5.4
Fundacep 41	49	67	116	6.0	0.89	0.97	5.7	RB604	51	74	125	6.9	1.00	0.98	3.8*
CD207	53	64	117	6.1	0.95	0.98	4.7	Carrera¶	57	69	126	7.0	1.07	0.99	3.8*
Ocepar-14	50	67	117	6.1	0.94	0.98	5.9	Embrapa 59	56	71	127	7.1	1.01	0.98	5.2
RB501	54	65	119	6.3	0.91*	0.97	6.5	KIS602	53	74	127	7.1	1.09	0.94	17.3
CD203	49	71	120	6.4	0.97	0.97	6.2	BRS 154	53	75	128	7.2	1.06	0.98	4.8
IAS-5¶	49	71	120	6.4	0.96	0.97	6.4	Fundacep 38	52	76	128	7.2	1.20**	0.96	13.1
BR-16	50	70	120	6.4	1.00	0.92	18.4	BRS 133	60	70	130	7.4	1.12*	0.96	10.5
M-Soy 6101¶	50	70	120	6.4	0.97	0.98	5.2	M-Soy 7501¶	55	75	130	7.4	1.07	0.96	9.3
CD210	51	70	121	6.5	1.03	0.98	4.0*	CD204	60	70	130	7.4	1.12*	0.97	7.9
CD202	52	69	121	6.5	1.02	0.98	3.8*	CD209	54	77	131	7.5	1.09	0.94	16.5
BRS 183¶	54	68	122	6.6	0.99	0.97	6.9	Fundacep 39	59	72	131	7.5	1.09	0.97	9.2
CD201¶	51	71	122	6.6	1.04	0.97	7.6	BRS 134	56	76	132	7.6	1.06	0.97	7.2
RB502	52	70	122	6.6	0.92*	0.99	2.7 ns	KIS702	57	76	133	7.7	0.76**	0.85	22.0
BRS137	51	71	122	6.6	0.90**	0.98	3.5 ns	CD205	58	78	136	8.0	1.17**	0.98	5.6
RB605	50	73	123	6.7	0.99	0.98	5.3	M-Soy 8001¶	58	79	137	8.1	1.22**	0.97	10.6

*Significant at the 0.05 probability level.

**Significant at the 0.01 probability level.

†Estimated regression for relative maturity adjustment. Southern MG = 0.099 × NDM – 5.499 (R^2 = 0.986).

‡*b* of regression was tested by *t* test considering the hypothesis of *b* different from value 1.

§Deviation from regression.

¶Cultivars used as relative maturity groups standards and regression estimates.

#ns, not significant at 0.01 probability level.

be very clear for the midwestern area, but for the southern area and Brazil, the R^2 value was not as high, showing the importance of choosing locations with different latitudes and altitudes for good maturity group classification. When we used only location × NDM, the regression (Table 2 and 3) was adjusted to the model and R^2 values were very high, but when we used both latitude and altitude regressions in the same context with the same NDM scale (Fig. 2, 3, and 4), the model had lower values of R^2, probably due to more complex interactions. More studies evaluating daylength and temperature effects and possible interactions with Brazilian germplasm can help to explain those results. Zhang et al. (2007) demonstrated the effect of latitude as a very important factor in adaptation of cultivars with regard to maturity groups in different U.S. zones.

The three-way interaction cultivar × location × year (Table 1), although low, was significant when year is included in the model and should be taken into account in maturity classification trials. Again, latitude and altitude across years was nonsignificant for cultivar response in the southern area and in both areas with the five control cultivars. The midwestern region was again the exception. The range in latitude of this study can simulate differences in planting dates. Insertion of different planting dates into the model introduces complexity and may produce different results due to the presence of the Long Juvenile trait in most of the midwestern cultivars. This will require additional research. Low genotype × environment interactions were demonstrated by Tomkins and Shipe (1997) for Long Juvenile genotypes working with several traits evaluated between R1 and R8 for different planting dates and years. Toledo et al. (1993), evaluating the growth of Brazilian determinate soybean genotypes, in three photoperiods, described November as the most desirable month for planting in Londrina, PR, Brazil.

Although these results indicate that experimentation with a great number of environments is probably not needed for relative maturity group classification, the particular interactions between cultivars, planting dates, latitudes, and altitudes across years could constitute different representative environments and are an indication of a need for further research. Superior environments for testing purposes

Table 3. Number of days to flowering (NDF), reproductive growth period (RGP), number of days to maturity (NDM), relative maturity groups (MG) and stability parameters of midwestern Brazilian soybean cultivars.

Cultivar	NDF	RGP	NDM	MG[†]	b[‡]	R^2	s^2d[§]	Cultivar	NDF	RGP	NDM	MG	b	R^2	s^2d
M-Soy 6101	48	60	108	7.2	0.72*	0.73	19.9	Monarca[#]	56	76	132	8.5	1.18**	0.98	3.5 ns
Emgopa-302	49	61	110	7.3	0.81*	0.87	10.1	FMT Mutum	60	73	133	8.6	0.83*	0.92	6.0 ns
Carrera[¶]	53	60	113	7.5	0.92	0.87	13.5	FMT Xingú	64	70	134	8.6	0.97	0.93	7.3*
Emgopa-316	52	64	116	7.6	0.84*	0.90	8.4	UFV-18	62	73	135	8.7	1.22**	0.97	4.4 ns
CD205	50	67	117	7.7	0.87	0.87	11.8	FMT Perdiz	63	72	135	8.7	0.82	0.76	21.3
Splendor	54	64	118	7.7	0.84	0.87	11.0	Garantia	62	74	136	8.7	0.95	0.90	10.5
CD204	56	63	119	7.8	0.90	0.82	18.4	P98C81[¶]	64	72	136	8.7	1.15*	0.97	4.2 ns
DM118	54	65	119	7.8	0.93	0.86	14.0	DM339	65	71	136	8.7	1.26**	0.95	9.5
M-Soy 8001[¶]	52	69	121	7.9	1.02	0.94	6.3 ns[#]	M-Soy 8866	66	71	137	8.8	1.12*	0.95	6.4*
Vencedora	55	67	122	8.0	0.89	0.91	8.4	DM Vitória	62	76	138	8.9	0.93	0.88	12.6
Conquista	55	69	124	8.1	1.03	0.93	8.6	BRS GOJatai	60	78	138	8.9	1.13	0.93	10.0
BRS GOGoiania	56	69	125	8.1	0.76**	0.84	11.2	DM309	63	75	138	8.9	1.15*	0.95	7.0*
FMT Cachara[¶]	55	70	125	8.1	0.93	0.94	6.2 ns	FMT Nambu[¶]	62	77	139	8.9	1.04	0.95	6.5*
CD211	56	70	126	8.2	0.85*	0.92	6.3 ns	FMT Tucano	64	76	140	9.0	1.08	0.94	8.3
FMT Tucunaré	57	69	126	8.2	0.93	0.95	4.7 ns	FMT Kaiabi	63	77	140	9.0	1.02	0.96	3.9 ns
M-Soy 8326	58	69	127	8.2	0.96	0.95	5.5 ns	M-Soy 8914	64	76	140	9.0	1.10	0.96	5.4 ns
Emgopa-315	60	68	128	8.3	0.76**	0.87	9.3	FMT Uirapuru[¶]	65	75	140	9.0	1.08	0.97	3.7 ns
DM247[¶]	59	70	129	8.4	0.95	0.96	4.4 ns	Elite	65	76	141	9.0	1.20*	0.93	10.7
M-Soy 8411	61	68	129	8.4	1.06	0.96	4.6 ns	FMT Maritaca	67	74	141	9.0	1.05	0.87	17.7
FMT Pintado	57	73	130	8.4	1.03	0.92	9.4	Emgopa-314	66	76	142	9.1	1.10	0.94	6.9*
M-Soy 8400[¶]	58	72	130	8.4	1.04	0.97	3.7 ns	M-Soy 9001	67	75	142	9.1	1.19*	0.92	13.0
A7002	56	76	132	8.5	1.11	0.91	12.3	DM Nobre	68	74	142	9.1	1.18	0.88	19.9
FMT Tabarana	58	74	132	8.5	0.97	0.84	18.6	Sambaíba[¶]	65	80	145	9.3	1.09	0.90	14.0
LA Suprema	58	74	132	8.5	0.95	0.91	9.0	FMT Arara Azul	67	80	147	9.4	1.24*	0.89	20.5

*Significant at the 0.05 probability level.

**Significant at the 0.01 probability level.

[†]Estimated regression for relative maturity adjustment. Midwestern MG = 0.056 × NDM + 1.117 (R^2 = 0.992).

[‡]b of regression was tested by t test considering the hypothesis of b different from value 1.

[§]Deviation from regression.

[¶]Cultivars used as relative maturity groups standards and regression estimates.

[#]Not significant at 0.01 probability level.

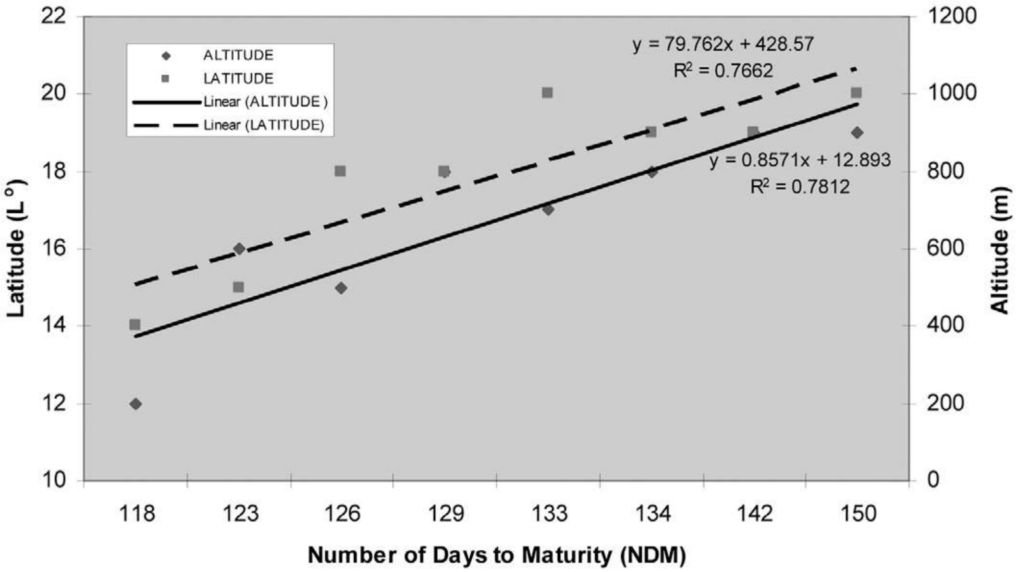

Figure 2. Latitude and altitude regressions on number of days to maturity, midwestern region, Brazil, 2002–2003 and 2003–2004.

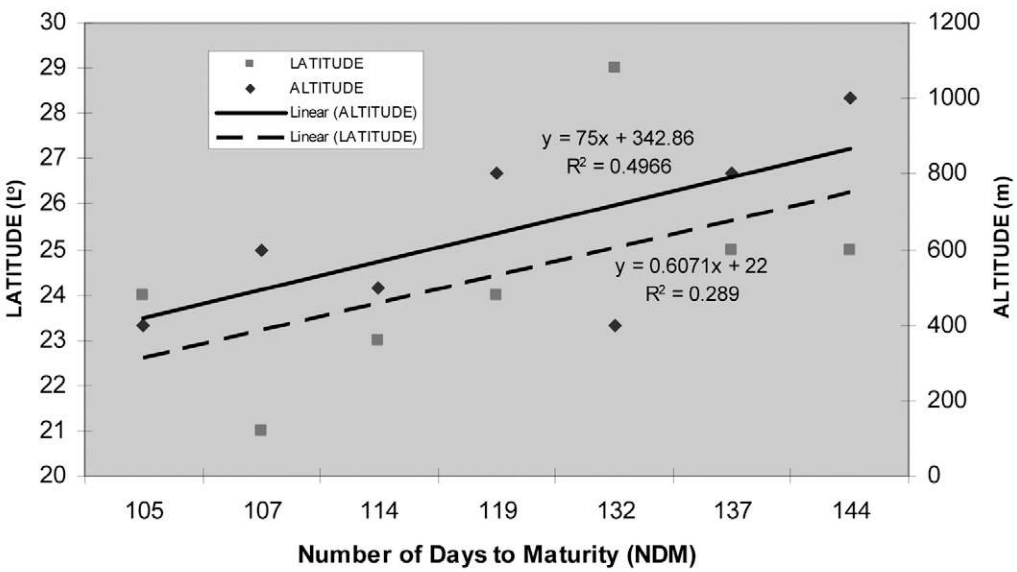

Figure 3. Latitude and altitude regressions on number of days to maturity, southern region, Brazil, 2002–2003 and 2003–2004.

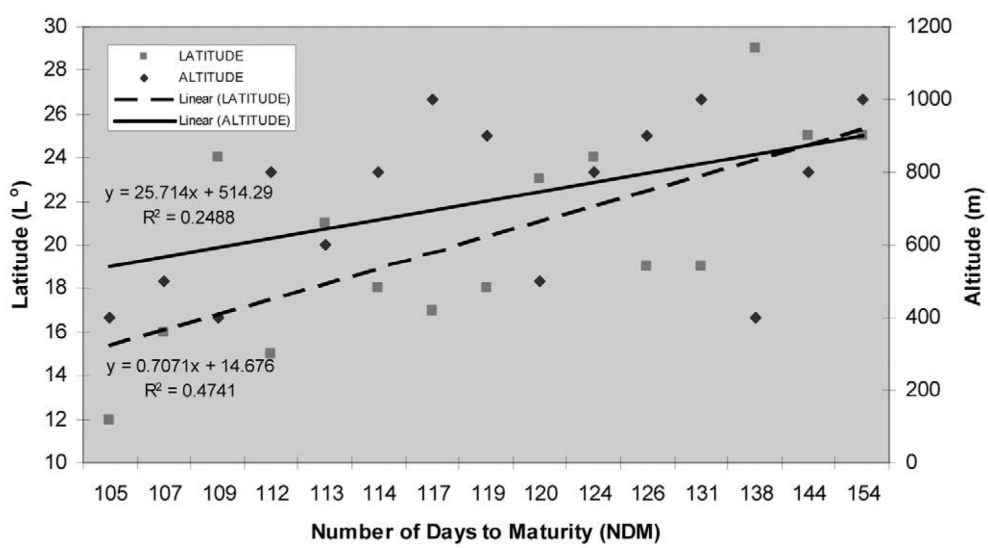

Figure 4. Latitude and altitude regressions on number of days to maturity, combined regions, Brazil, 2002–2003 and 2003–2004.

need high correlations between the performance of a genotype relative to a test environment and its performance relative to the entire population of environments in which a selected genotype would be used (Allen et al., 1978).

Regression of number of days to maturity on the relative maturity of cultivars explained about 99% of the response over all environments. Using Brazilian maturity classification, relative maturity in the south, started with group V, with FT Cometa being the earliest material (RM 5.0 and 106 d). Maturity Group VIII represented the latest maturity in the southern regional trial with M-Soy 8001 classified as RM 8.1 with a mean of 137 d to maturity. The midwestern regional trial started in maturity group VII, with M-Soy 6101 the earliest material (RM 7.2 and 108 d) and Arara Azul the latest (RM 9.4 and 147 d). According to Paschal et al. (2000), cultivars ranging from North American MG V to VII account for approximately 56% of the planted soybean area in Brazil, mainly in the southern region, while MGs from VIII to IX account for 44% of the planted area in the midwestern region. Regressions successfully explained all the tested materials over the differing locations with values of R^2 ranging from 0.85 to 0.99% for the southern area (Table 2) and 0.75 to 0.98% for the midwestern area (Table 3). These results indicate that almost all materials have excellent maturity stability and that data from maturity trials can be used for predicting phenology and culture management for other areas (Zhang et al., 2001; Yan and Rajcan, 2003).

The regression coefficients (*b* values) showed a tendency for responses under 1.0 for early materials (Table 2 and 3). This behavior indicates that most early materials, when compared with late ones, are more environmentally stable for maturity. FT-Cometa, NK Spring, CD211, and FMT Mutum showed *b* values much lower than 1.0, and considering also the calculated values for R^2 and the deviation from regression (s^2d), it is possible to classify them as less responsive, more predictable, and more environmentally stable than others in terms of their maturities. The *b* values of all genotypes and high values for R^2 explain in part the genotype × location interaction presented in Table 1. The low magnitude of this interaction can be due to the fact that the majority of cultivars have coefficients near to 1.0 and similar responses across environments. When *b* values are near unity for the majority of genotypes, we can assume that materials with high values of R^2 and low s^2d, or low environmental variance are quite predictable and less variable within and across locations, being also the most suitable for use as checks for relative maturity classification. Following this concept, and the importance of having a range of RMs to build regressions to classify new genotypes, we can suggest as the most suitable checks for each maturity group the following cultivars for the southern region: FT-Cometa (5.0), NK8350 Spring (5.2), CD215 (5.9), CD207 (6.0), CD210 (6.5), CD202 (6.5), RB502 (6.6), BRS 137 (6.6), CD208 (6.8), Carrera (7.0), BRS 154 (7.2), BRS 134 (7.6), and CD205 (8.0); and for the midwestern region: Emgopa-316 (7.6); M-Soy 8001 (7.9), FMT-Cachara (8.1), CD211 (8.2), FMT Tucunaré (8.2), M-Soy 8326 (8.2), DM247 (8.4), M-Soy 8400 (8.4), M-Soy 8411 (8.4), Monarca (8.5), FMT Mutum (8.6), UFV-18 (8.7), P98C81 (8.7), M-SOY 8866 (8.8), FMT-Nambú (8.9), FMT Kaiabi (9.0), M-Soy 8914 (9.0), FMT Uirapurú (9.0), and Emgopa-314 (9.1). The designated relative maturity for most cultivars agrees closely with a previous Brazilian classification made by companies that were using them as relative maturity checks, with a few examples where a much larger discrepancy was observed (Monsoy, 1998a,b; Alliprandini et al., 2002; Prado et al., 2002; Fundação MT, 2003). The main exception has been M-Soy 6101, previously classified as group 6.1 (VI) by Monsoy (1998b), which was positioned as 6.4 (VI) in the southern region and as 7.2 (VII) in the midwestern region. This behavior has been confirmed since this was the first time that this material was tested for maturity simultaneously in both regions (Penariol, 2000). Other cultivars that were also tested in both regions (Carrera, CD204, CD205, and M-Soy 8001), were classified with almost the same relative maturity, with a few minor differences between the southern and midwestern regions. This can be explained because these cultivars were planted in different trials and the regressions that were used to classify their maturities were based on different cultivars.

Correlation coefficients (Table 4) indicated that under the current conditions, NDF was highly correlated with NDM (0.88 and 0.85) for southern and midwestern regions and can be used for early prediction of maturity, but low values were achieved for NDF × RGP (0.39 and 0.38). These results show that RGP was more closely associated with the maturity of the cultivars, and that the grain filling period seems to have a response not so dependent of the vegetative period for most cultivars tested. Anticipating or delaying planting time would lead to different results and making the relative maturity classification of cultivars more difficult as demonstrated by Toledo et al. (1993) and Tomkins and Shipe (1997). Although this study recognizes that relative maturity group is a very reliable tool for classifying cultivars in Brazil, more research is needed to measure the effects of planting date and photoperiodic-temperature interactions.

Table 4. Pearson correlation coefficients among number of days to flowering (NDF), number of days to maturity (NDM), and reproductive growth period (RGP) for southern and midwestern regions of Brazil.

Trait†	NDF	NDM	RGP
NDF		0.88**	0.39**
NDM	0.85**		0.78**
RGP	0.38**	0.81**	

**Significant at the 0.01 probability level.

†Southern correlations are represented above and midwestern below the diagonal.

CONCLUSIONS

The results reported in this paper provide a method for assigning relative maturity groups to Brazilian commercial germplasm and can be used by plant breeders, soybean seed producers, and crop managers. Results of investigations conducted to date indicate that the use, in Brazil, of maturity groups to classify soybean genotypes could become an efficient method for describing relative maturity on a broad environmental basis. More research is needed to evaluate the influence of biotic and abiotic factors such as growth type, juvenile trait, latitude, altitude, and planting time on the maturity response of different cultivars and its relative classification in Brazil.

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Dedication (in memoriam)

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