Chapter 18

Climatic Conditions and Production of Soybean in Northeastern Brazil

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http://dx.doi.org/10.5772/52184

1. Introduction

Brazil has become the second largest soybean producer after the USA. Projections to the year 2020 indicate the country's soybean production will increase to 105 million tons, largely due to Brazil's large expanse of potential arable land. This expansion of soybean production will occur mainly in the North and Northeast parts of the country that includes the states of Maranhão, Piauí, Tocantins and Bahia, a region collectively referred to as the MAPITOBA. Within this region, the Cerrados, an area of stable climate, consistent rainfall, and flat topography, is especially suited for soybean production [17].

Soybean was introduced into Brazil in the late nineteenth century. However,widespreadproduction did not occur until about 60 years ago in the southern part of the country. Cultivation then spread from the southern to the middle and northern sections of the country. In recent years, production has spread into the Cerrado Region, an area in the middle and northern parts of Brazil's interior containing 204 million hectares of land. The northern states of Piaui and Maranhao contain about 21 million hectares of land [6]. The savannas of this region are characterized by having acid soils of low fertility, high average temperatures (25-26 ° C) and average rainfall of 1,200 mm from October to April. However, they are subject to occurrences of dry spells [18].

The expansion of soybean into the low latitudes of northeast Brazil has been facilitated by cultivar development for adaptation to the soils and climate of this region. This process has allowed for a large expansion of soybean production into the Cerrado region of Brazil [1].

Cultivar Tropical was first released in 1980 for production in the low latitude regions of Brazil. This created a continual demand for more adapted cultivars [4]. Other cultivars released for northeastern Brazil between 1982 and 1998 are: Timbira; BR 10 (Teresina) and BR 11 (Carajás); BR-27 (Cariri) and BR-28 (Seridó); BR- 32 (Nova Tropical); BR/ EMGOPA 312 (Potiguar) and BR 35 (Rio Balsas); Embrapa 9 (Bays); Embrapa 30 (Vale do Rio Doce), Embrapa 31 (Mina), Embrapa 33 (Cariri RC) and the Embrapa 34 (Teresina RC); Embrapa 63 (Mirador); MA/BR 64 (Parnaíba) and MA/BR 65 (Sambaíba) and MA/BRS-164 (Patí) and MA/ BRS-165 (Seridó RCH).

Characteristics that have been selected for production in low latitude areas are: suitable maturity, adequate plant height, height to first pod of more than 12 cm ,a non-woody stem, erect plant stature, lodging resistance, pest resistance, good seed quality and high oil content and protein content, high yield, yield stability (robustness), uniform ripening, indehiscent pods, high capacity for N2 fixation, tolerance to aluminum and manganese toxicity, a long juvenile phase and photoperiod insensitivity. Across planting dates and environments, the growing season can vary from 75 to 200 days. Thus a wide range of cultivars have had to be developed for adaptation to many environmental conditions [22, 43]. The average height of the plant can range from 20 to 150 cm or more, according to the cultivar and environment, and the height to first pod may be characteristic of the cultivar. Environmental factors or cultural practices may also affect height to first pod [35], which prevents mechanical harvesting and can cause harvest loss.

2. Production of soybeans in Northeast Brazil

The Northeast region of Brazil is situated between latitudes 1°20'00'' and 19º00'00'' S. Maturity groups adapted to this region range from maturity group 7 to 9.Examples of cultivars developed for this region are BRS 326 (maturity group 8.7) and BRSMA Seridó RCH (9.7). Both cultivars have the long-juvenile trait which reduces the photoperiod sensitivity to the short days of this region; thus allowing soybean to have an adequate developmental period for optimal yield. Much of the success of soybean expansion into Northeast Brazil is due to the development of cultivars having the long-juvenile trait [3]. Development of these cultivars was done through breeding programs using the following cultivars and genotypes: PI 240664, PI 159925, Santa Maria, PR Paranagoiana 77-10001 [24, 20]. Experimental studies in the past century, especially in the United States, led to the classification of soybeans into maturity groups based on their photoperiod response. The maturity groups were: classify groups of soybean according to the response to photoperiod, a total of 13 classes of maturation, which are 000, 00, 0, I, II, III, IV, V, VI, VII, VIII, IX and X [27, 35].

Besides the issue of photoperiodism, soybean expansion into Northeast Brazil is also limited by drought, waterlogging, the harsh environment of the Amazon region, infrastructure, marketing, and the availability of manual labor [11]. Cultivar development was initiated in Piaui state in 1972 and resulted in the release of cultivar Tropical in 1980.This was followed by the development and release of more cultivars for production in Northeast Brazil [3]. Examples are the cultivars DM-Soberana and DM-Nobre released in the central region of Brazil in the states of Bahia and Maranhão. These cultivars were well adapted to the tropical

http://dx.doi.org/10.5772/52184

conditions of this region, demonstrated greater yield than check cultivars, had good yield stability across environments, proper maturity for the growing season, and were adapted for mechanical harvest [39]. In the states of Maranhão, Piauí and Tocantins, a new cultivar, BRSMA-Babacu, was developed for commercial production. Across seven environments in the late 1990's, it demonstrated an average yield of 2,952 kg/ha which was 4% higher than the local cultivar Doko Millionario. It is a late-maturing cultivarwith a maturity of 130 days from emergence to maturity, a plant height of 99 cm, moderately resistant to lodging, purple flower color, brown pod and pod pubescence, yellow seed coat, brown hilum, good resistance theto pod dehiscence, average seed quality and average seed weight of 15.8 g/100 seeds [23]. In these states, the time of planting depends on the rainy season, which occurs in summer (Table 1).

STATE	REGION	PLANTING PERIOD
Maranhão	south (Balsas – Tasso Fragoso city)	Novemberto 15 december
Maranhão	northeast (Chapadinha city)	January
Piauí	south-west (Uruçuí – Bom Jesus city)	November to 15 december

Source: [29].

Table 1. Sowing dates for soybean state and the northeast.

Cultivars	Testes				
	NDF (day)	NDFT (day)	PR (day)	ALTM (cm)	NNP
AVRDC 7	34 c	45 c	43 c	25,0 c	8 c
AVRDC 8	36 c	48 c	42 c	24,4 c	9 c
BRS 155	33 c	44 c	44 c	20,3 c	9 c
JLM 003	41 b	54 b	64 b	41,0 b	10 b
JLM 004	43 b	55 b	61 b	39,4 b	11 ab
Pirarara	57 a	75 a	60 a	62,9 a	12 a
Mean	41	54	52	36	10

Source: [40]
In each column, the same letter not differ at 5% probability by Tukey test.

Table 2. Number of days to flowering (NDF), number of days to fruit set (NDFT), reproductive period (RP), plant height at maturity (ALTM), number of nodes / plant (NPP) Observed in different cultivars of soybean-green. Sand-PB, UFPB, 2004.

Research conducted in the Brazilian states located in Northeast Brazil have shown promising results regarding the adaptation of cultivars to cultivation. Research conducted at the Federal University of Paraiba, Center for Agrarian Sciences, resulted in the development of cultivar Pirarara. This cultivar was adapted to the Entisol soils of the region, as well as the sort days, warm and humid climate, rainfall, and acid soils. It had a plant height of about 63 cm and developed about 12 main stem nodes. Days from emergence to maturity was about 75. Data for the cultivar is shown in Table 2 [40]. Further research with this cultivar demonstrated that when intercropped with corn, it had a vegetative period (days from planting to first flower) of about 55 days. This was a sufficient period to allow for enough dry matter accumulation to optimize yield. Other developed cultivars had shorter vegetative periods, such as Pati (50 days) and JLM 004 (39 days).The significant factor is to allow enough time for node production, since nodes are plant structures from which pods, seeds, and yield are made. This has been demonstrated in research conducted by [19] in which yield was shown to be related to the number of nodes formed. Cultivar Black Alliance had the most at 33, while Kanro had the fewest at 8.

Cultivars	Mean (kg ha^{-1})	Ii	ij	R^2
BRS TRACAJÁ	1882,87	0,52**	792,69**	99,25
BR JUÇARA	1555,41	1,84**	145934,72**	90,12
BRS MA 165 SERIDÓ	1511,10	1,04ns	21982,14**	95,07
BRR 219 BOA VISTA	1585,36	1,14ns	30844,36**	94,35
BRS SAMBAÍBA	1893,58	0,94ns	145903,06**	70,40
BRS CANDEIA	1552,88	0,91ns	10589,73**	75,27
MA BR 971665	1725,72	0,61**	14432,72**	91,06
CV (%)	22,52			
General mean (kg ha^{-1})	1672,42			

Source: [10]

^{ns} not significant; * Significant at 5% probability level; ** Significant to 1% probability by the F test

Table 3. Average linear regression coefficient (Ii), misuse of linear regression (ij) and coefficient of determination (R2) According to the methodology of Eberhart and Russell (1996) for grain production of soybean genotypes in Ceará.

Although production of soybean is still restricted in some areas for the northeastern states of Bahia, Maranhão and Piauí, it has shown potential for expansion for other states in the region such as Ceará. Near the city of Pentecost (3º 47′ S Latitude), cultivar trials during 2005 and 2005 have identified genotypes BRS TRACAJÁ, and BRS Sambaíba MA BR 97 1665as having potential to be grown in Ceará (Table 3). Certain soybean cultivars, when intercropped with corn, were capable of producing large biomass relative to other cultivars [42].

Preliminary testing of three soybean cultivars is being conducted by [9] in the coastal plains in the state of Alagoas, near the city of Rio Largo, at a latitude of 9°29'45''. Cultivars used in the study were MG / BR - 46 (Conquista), and BRS Tracajá MA/BRS-165 (Seridó RCH). Agronomic data for plant height is shown in Table 4 and data for yield and seed weight is in Table 5.Although plant height was somewhat lower than that which is usually required for mechanical harvesting, [9] demonstrated that yield production was good for all cultivars ranging from 2,620 to 3,600 kg ha^{-1} (Table 5), being equal to or superior to the traditional regions of production soybean.

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Cultivars	Plant height (cm)	
	Plant height stage R2	Plant height stage R9
MG/BR – 46 (conquista)	37.13 a	51.08 a
BRS Tracajá	41.95 a	63.88 a
MA/BRS – 165 (Seriado RCH)	35. 35 a	59.98 a
CV (%)	13.7	12.2

Source: [9]
Means Followed by the same letter not differ to the 5% level of probability by Tukey test.

Table 4. Height of plant growth stages R2 and R9 of three soybean varieties grown in the Coastal Plain region of the state of Alagoas.

Cultivars	Mass of 100 seeds	Grain yield
	---------------(g)--------------	--------------(kg ha^{-1})-----------
MG/BR – 46 (conquista)	19.22 a	2,620 a
BRS Tracajá	18.75 a	3,069 a
MA/BRS – 165 (Seridó RCH)	18.89 a	2,829 a
CV (%)	11.2	10.1

Source: [9]
Means Followed by the same letter not differ at the 5% level of probability by the Tukey test.

Table 5. Grain yield and mass of 100 seeds of three varieties grown on Coastal Plain region of the state of Alagoas.

In research conducted by [5], agronomic performance of several soybean cultivars in the rugged areas of the states of Bahia and Sergipe (latitude 10°14'S and 10°55' S). There were two series of screening studies conducted, the first having 14 genotypes and the second having 24. The tests were conducted during the growing seasons of 2006 and 2007 in several cities in remote rural areas of Sergipe and Bahia. Among the many cultivars tested, the ones performing the best were BRS SAMBAÍBA and EMGOPA, followed by BRS TRACAJÁ, BRS CONQUISTA, BRS BELA VISTA, BRS CORISCO and BRS BARREIRAS. All cultivars demonstrated a yield range of 2,285-3,373 kg/ha.

Studies with 18 soybean cultivars, performed by [28] in the state of Piauí, (Lat05°02'40 ''S), were planted on 28 February 2010. Based on differences in days to first flower, the cultivars were separated into four groups (Table 6): early (45 to 47.7 days), medium (48-57), late (>57 days), and average.

GENOTYPES*	Cycle (days)		Classification cycle	Reproductive period	
NDF days	NDM days		(PR) days	(% PR)	
BRS SAMBAÍBA	49.00 C	114.00 F	Medium	55.25 C	47.12 B

GENOTYPES*	**Cycle (days)**		**Classification cycle**	**Reproductive period**	
BRS CANDEIA	48.25 C	117.00 E	Medium	66.50 A	55.64 A
BRS 219 BOA VISTA	46.25 D	101.25 I	Early	56.00 C	47.14 B
BRS 271RR	45.75 D	104.50 H	Early	60.00 B	48.62 B
114 BCR336F8	50.50 C	134.00 A	Late	59.25 B	43.40 D
142 SOY94F5G	53.75 B	130.50 B	Late	65.00 A	49.34 B
164 SOY94F5G	51.00 C	114.50 F	Medium	55.50 C	45.63 C
168 BCR1069X7RG	53.25 B	120.75 D	Medium	55.50 C	45.30 C
169 BCR1069X7RG	45.00 D	121.25 D	Medium	55.50 C	45.31 C
170 BCR1069X7RG	48.50 C	123.00 D	Medium	50.00 D	39.52 E
171 BCR1069X7RG	50.25 C	120.25 D	Medium	65.25 A	53.59 A
172 BCR1069X7RG	50.50 C	126.00 C	Late	62.50 B	48.54 B
173 BCR1069X7RG	51.00 C	121.25 D	Medium	56.75 C	46.32 C
174 BCR1069X7RG	47.75 D	122.75 D	Medium	55.00 C	45.17 C
175 BCR1069X7RG	49.00 C	128.00 C	Late	62.00 B	48.06 B
176 BCR1069X7RG	57.25 A	117.50 E	Medium	63.00 B	48.64 B
177 BCR1069X7RG	58.00 A	114.00 F	Medium	56.25 C	45.93 C
179 SOY24F5G	50.25 C	107.50 G	Early	61.25 B	48.62 B
C.V. (%)	4.62	1.55		5.16	4.85
General mean	50.29	118.77		58.91	47.33

Source: [28]
* Means Followed by the same letter not differ by Scott-Knott test (P ≤ 0.05).

Table 6. Mean values for the number of days to flowering (NDF), number of days to maturity (NDM), reproductive period in days (PR) and percentage (RP%) of different soybean genotypes Evaluated in low latitude, in Teresina - PI.

[28] reported excellent yields with genotypes 171BCR1069X7RG and 174 BCR1069X7RG. They both produced yields of about 4000 kg ha^{-1}. These were much better than other genotypes, the lowest of which yielded below 2000 kg ha^{-1} (Table 7).

GENOTYPES*	**PRODUCTIVITY (kg ha^{-1})**
171 BCR1069X7RG	4,188.53 A
174 BCR1069X7RG	3,838.66 A
170 BCR1069X7RG	3,464.27 B
177 BCR1069X7RG	3,248.29 B
169 BCR1069X7RG	3,084.99 B
175 BCR1069X7RG	2,802.35 C

http://dx.doi.org/10.5772/52184

GENOTYPES*	PRODUCTIVITY (kg ha-1)
176 BCR1069X7RG	2,766.36 C
BRS 219 (BOA VISTA)	2,736.91 C
172 BCR1069X7RG	2,673.71 C
164 SOY94F5G	2,630.52 C
179 SOY24F5G	2,529.99 C
173 BCR1069X7RG	2,446.89 C
142 SOY94F5G	2,403.11 C
168 BCR1069X7RG	2,353.72 C
BRS SAMBAÍBA	2,352.66 C
114 BCR336F8	1,857.68 D
BRS CANDEIA	1,813.55 D
BRS 271RR	1,735.16 D
C.V %	13.21
General mean	2,718.19

Source: [28]
* Means followed by same letter do not differ by Scott-Knott test ($P \leq 0.05$)

Table 7. Mean values of grain yield in different soybean genotypes evaluated in low latitude, Teresina - PI.

Research conducted in western Bahia, near the city of São Desidério (Lat 12º45′S). Growth and yield of soybean at different planting dates are shown in Table 8. Although there were some planting dates at which all cultivars showed good yields, only cultivar M-SOY 8411 yielded well at all four planting dates [9].

Cultivars	Productivity (kg/ha)			
	Ep1	Ep2	Ep3	Ep4
M-SOY 8411	3,924 aA	3,518 aA	2,460 aB	938 aC
BRS Corisco	4,142 aA	2,768 bB	1,745 bC	585 aD
BRS 263	3,956 aA	2,518 bcB	1,163 bcC	659 aC
BRS Barreiras	3,930 aA	1,956 cB	715 cC	642 aC
M-SOY 9350	4,006 aA	2,635 bB	1,029 cC	851 aC
D.M.S = 238,38			C.V. (%)= 14.35	

Source: [9]

Table 8. Average grain yield (kg / ha) from five soybean sown in times Ep1 (29/11/2006), Ep2 (12/14/2006) Ep3 (28/12/2006) and ep4 (01/12/2007), in western Bahia.

Data for Value for Cultivation and Use (VCU) of soybean BRS 278RR for the state of São Paulo indicated that it belongs to a medium maturity group (maturity group 9.4), with the number of days to maturity ranging from 115 to 127 days [26]. According to these authors, the average yield of soybean tested in 24 environments of evaluation was 2,973 kg/ha, and 5.2% more productive than the standard transgenic BRS 271RR, and 5% less productive than the conventional BRS tracajá (Table 9).

Cultivar	Productivity (Kg/ha)				Relative productivity (%)
	2004/05	2005/06	2006/07	Média	
BRS 278RR	2,960	3,059	2,890	**2,973**	**105.2**
BRS Tracajá	3,083	3,298	2,942	**3,115**	**110.2**
BRS 271RR	2,720	3,154	2,568	**2,825**	**100.0**

Source: [26]

Table 9. Average grain yield (kg / ha) and relative yield (%) of BRS 278RR, BRS and BRS 271RR turtle in the agricultural years 2004/05 to 2006/07 of the southern regions of the Maranhão, Piauí southwestern and northern Tocantins.

Because of these pioneering studies to develop cultivars adapted to different regions of northern Brazil, soybean production has expanded rapidly throughout the region. For all the soybean growing regions of Brazil, the greatest expansion has occurred in the North and Northeast regions of the country [8]. Across the region, between the 2008/2009 growing season to the 2009/2010 season, the area of production increased by 8.9% from 2,105,600 to 2,292,600 hectares. A more recent survey by [7] highlights the states of Bahia, Piauí and Maranhão. In the state of Piaui area there was a 16.6% increase in soybean acreage between 2011 and 2012, with the entire state having a production area of 447,300 hectares for soybean. In the state of Bahia, the largest producer of oilseeds in the Northeast, the area planted to soybean increased by 6.6%, from 1,040,000 to 1,110,000 hectares across the same period. The same type of expansion occurred in Maranhao where the growing area increased 12.2%, from 518,200 to 581,400 hectares.

Development of adapted cultivars for Northeast Brazil has greatly aided this expansion into tropical regions. This has made a significant contribution to strengthening the regional agricultural economy. Soybeans provides oil for the food industry and livestock meal for meat production, enhances agricultural development in undeveloped areas, and helps to add a protein-rich source of human food to ameliorate the widespread protein deficiencies common to Northeast Brazil [3].

3. Edaphoclimatic Factors

Expansion of soybean into tropical areas of Brazil has been made possible by development of genotypes having the long juvenile or late flowering trait in short-day photoperiods. This was required to allow soybean to have a sufficiently long developmental period to achieve enough size for optimal yield [37]. Soybean cultivars are affected by photoperiod, humidity, temperature, planting date, altitude, latitude, level of soil fertility and other factors [35]. According to [44], these are the main elements responsible for the variability and difficulties for growing the crop in Brazil. Environmental factors interact with soybean's developmental periods in affecting the growth and yield production of the crop.

Although soybean originated in the temperate world, it has a wide range of adaptability and can be grown well in tropical and subtropical locations. Average temperatures optimal for the best soybean development are between 20 and 35°C. At temperatures outside this range there can be physiological disorders with flowering and rhizobial inoculation, as well as poor growth. [35] claimed that at temperatures below 24°C flowering is retarded by two to three days for each decrease of 0.5°C. Such conditions can happen in the Northeast at altitudes greater than 500 m in the rainy winter period. Such cases occur in Areia-Paraíba, Garanhuns-Pernambuco and Triumfo-Pernambuco, among other cities.

Temperature has a strong influence on the rates of all the metabolic and physiological processes occur during development. This has a direct effect on growth rate and yield. Temperature also has a significant effect on the duration ofthe different developmental periods that make up soybean's crop cycle. In particular, the periods from emergence to flowering and flowering to maturity are affected by it [16]. It is recommended that the planting of soybeans should not be done when the soil temperature is below 20 °C so that germination and plant emergence are not compromised. Once temperatures reach this level, the germination rate increases exponentially with increasing temperature [21]. Thus, the number of days from sowing to the state of emergency (LV) can vary from about 5-15 days, depending on temperature [35]. Also according to the authors, temperature is the main factor influencing plant development, where low temperatures delay and high temperaturesaccelerate seedling emergence and leaf development.

The time course of the vegetative activity of plants is adjusted to local conditions during the growing season. In the dry tropics and subtropics, the growing season is limited by the intensification of water stress when the dry season begins [21]. Under the conditions of northeastern Brazil, the predominant climate is hot and dry. According to some authors [14, 35], for soybean temperatures above 40 °C have an adverse effect on the rate of growth, the rate of formation of the nodes and internode growth and floral initiation. This causes problems with flowering, pod formation and retention, and results in lower yield. These problems are accentuated with the occurrence of water deficits.

Differences in flowering date between yearsby a cultivar sown in the same season are due to temperature variations. Thus, high temperatures can cause soybean to flower too early, which may cause a decrease in plant height,and accelerate the maturity of the crop [14]. The nodulation and nitrogen fixation in soybean are greatly affected by soil temperature and the growth of Bradyrhizobiumjaponicum is limited by temperatures above 33 °C [35]. When facing environmental stress, there is always a genotype x environmental interaction which must be considered during the breeding program for cultivar development [32].Solar radiation is a critical environmental factor because it directly affects the crop growth rate and the ability to obtain enough dry matter for optimal yield potential. Water availability is also very important, because it affects leaf expansion, photosynthetic rate, crop growth rate, and nitrogen fixation [30].

Not only is the level of light important, but length of day, or photoperiod, is also important. Photoperiod affects many developmental processes such as flowering, seed germination, growth of stems and leaves, formation of storage organs and assimilate partitioning [38]. It also affects leaf expansion, photosynthesis, senescence, dormancy of buds, and other processes [16]. Photoperiodism is a term describing all these plant responses to day length or photoperiod. Photoperiod will be determined by the latitude of where the crop is grown and the planting date.For soybean, the effective photoperiod includes the time from sunrise to sunset and some of civil twilight. Three types of photoperiodic response are recognized: short-day response in which flowering is induced and/or accelerated at a certain critical day length or less; long-day response in which flowering is induced and/or accelerated at a certain critical daylength or longer; and day neutral in which flowering time is unaffected by day length. Soybean is a short-day plant.

Since vegetative growth in soybean occurs between emergence and the start of seed filling, it is important that soybean be planted at a latitude and planting date where day lengths will be long enough to allow enough time to the start of seed filling so that dry matter accumulation is large enough for optimal yield potential. The major problem with the expansion of soybean into northern Brazil is in these low latitudes, day length is seldom longer than 12 hours per day. Ideally, it is best to plant in October or November to take advantage of the lengthening days that occur at this time and continue until the summer solstice in late December. Since the critical short-day period to hasten flowering occurs when the photoperiod is shorter than 13.5 to 14.5 hours (the length varies with maturity group and cultivars within maturity groups), the typical soybean planted in this region will have too short a time to flowering and the start of seed filling to achieve enough size for optimal yield. For this reason, much research in Brazil has concentrated on incorporating the “long-juvenile” trait into soybean cultivars. The juvenile period is the initial period in the plant’s growth when it’s developmental rate does not accelerate in response to short days. Thus, cultivars having this trait will have a longer time to flowering and the start of seed filling compared to those that do not. Incorporation of this trait into Brazilian cultivars has greatly facilitated soybean expansion into northern Brazil. [25, 15, 14] .

The physiology of the mode of action of the long juvenile period is still unknown. The trait is either caused by a delayed ability of the plant to respond to short days or a requirement for more short day cycles to induce and promote flowering relative to other soybeans [14].The problem of short-day induced premature flowering in northern Brazil was approached by selecting genotypes with insensitivity to photoperiod and/or having a long juvenile period [27]. Several breeding programs have contributed to the development of high-yielding cultivars adapted to different agro-climatic conditions of Brazil. For expansion into central and northern Brazil, breeding programs have followed a strategy of developing genotypes adapted to low latitudes, through the incorporation of the long juvenile trait. Research conducted by [33] concluded that the germplasm bank of soybeans genetic variability has remained relatively constant over the last 30 years.

The availability of water is another important environmental stress for soybean culture in northern Brazil. The first critical period is seed germination and seedling development. Soybean seeds need to absorb enough water to achieve 50% moisture content to ensure good germination. Soil water content needs to be between 50-85% of total available water. According to [25], an annual rainfall 700-1200 mm that is well distributed during the soybean cycle (500 to 700 mm) will meet the crops water needs. Soybean's water requirement increases with plant development, reaching a maximum during the flowering and grain filling periods (7-8 mm / day), and decreasing thereafter [12].

The growing season in northern Brazil is largely determined by occurrence of the rainy and dry seasons of the region. The dry season occurs between May to September and any agriculture during this time requires irrigation [16]. Drought is usually the main factor responsible for crop losses. The two most critical periods for drought stress in soybean are during seed emergence to seedling establishment and the grain filling period. During germination, both excess and lack of water are harmful to crop establishment. Soils having a low water storage in general are unfit for soybean production for most cultivars and planting dates [13].

The soybean plant requires more water as growth and development proceed. Peak demand is during flowering and early pod formation and remains high until physiological maturity. The most critical period is during flowering and early pod formation. Drought stress at this time will cause abortion of flowers and pods, resulting in lower seed production and reduced yield [27]. Rainfall data from the state of Bahia indicates that there is a 80% chance for receiving sufficient rainfall to avoid drought stress during the critical periods [36]. The most important variable to be considered when dealing with drought stress is water retention in the soil during the growing season [27]. In summary, obtaining optimal yield in a given environment, depends upon maximizing the genetic potential of a given cultivar [31]. This involves having a long enough time for vegetative growth so that the prevailing photoperiod does not reduce yield, and the avoidance of drought stress [34]. Experimental trials in Brazil have shown there is a genetic yield potential of more than 5,000 kg/ha grain [2]. Genetic potential for most cultivated crops has increased greatly over the last 100 years. However, realizing this potential will depend on coping with environmental stress [27]. Soybean is recognized as having wide genetic diversity and with proper genetic and breeding research it can be adapted to a wide range of environmental conditions. Efforts in Brazil over the last 40 years to deal with problems presented by photoperiodic adaptation and coping with other environmental stresses have shown how this can happen through cooperative research efforts involving breeders, physiologists, geneticists, and agronomists.

4. Conclusion

Brazil has become the second largest producer of soybeans in the world. This has occurred largely because of our success at developing soybean cultivation in the low latitude regions (1°20'00'' and 19º00'00'' S) in central and northern Brazil. Much of the area opened to soybean production lies in the Cerrado region which is Brazil's agricultural frontier.

Northeast Brazil is also an area for agricultural development. It has a wide variety of environmental zones and is suitable for mechanized agriculture on small- or medium-sized farms. It has potential for production of many crops ranging from pastures for dairy cattle to bio-energy crops like sugar cane (ethanol) and biodiesel (soybean). Our progress in the agricultural development of this region is due to concentrated investment of financial and human resources in genetic improvement of cultivars and their adaptation to different climates in this region. The largest effort has been the development of cultivars with the long-juvenile trait which has overcome the problem of the short photoperiods common to this tropical region. Thus, short-day induced premature flowering is no longer a problem, and soybean can be grown in northern Brazil that achieve a size suitable for optimal yield. The greatest expanse of soybean production in northern Brazil has occurred in the states of "Bahia, Maranhão and Piauí". It is in these states that the public and private research efforts have been focused. Similar efforts have now been started in other northern states such as "Ceará, Sergipe, Paraiba, Pernambuco, Alagoas and Rio Grande do Norte". University and state research efforts are now being conducted to develop adapted soybean cultivars for the small and medium-sized farms of this region. Much effort will also have to be invested into marketing and transport. We firmly believe that with continued research efforts, soybean production in northern Brazil will expand into the future and that Brazil will become the largest soybean producer in the world within the next 20 years.

Author details

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