Original Article

CROPPING SEASON AFFECT THE PERFORMANCE OF BASIL CULTIVARS AND HYBRIDS

ÉPOCA DE PLANTIO AFETA O DESEMPENHO DE CULTIVARES E HÍBRIDOS DE MANJERICÃO

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ABSTRACT: The objective of this work was to evaluate the performance of basil cultivars and hybrids in two cropping seasons. The experiments were conducted in a randomized block design, with three replications. Twenty-four basil genotypes were tested (20 commercial cultivars and four hybrids), in the dry season (oct.-dec./2015) and in the rainy season (apr.-jun./2016). The evaluated variables were: plant height (cm plant^{-1}), canopy width (cm plant^{-1}), leaf dry weight (g plant^{-1}), and essential oil yield (mL plant^{-1}). The data of each period were subject to analysis of variance and the means were grouped by the Scott-Knott test ($p \leq 0.05$). The individual and joint analyses of variance were performed for the experiments in both seasons. The estimated parameters were: coefficient of genetic variation (CV_g), coefficient of environmental variation (CV_e), CV_g/CV_e ratio, and heritability (h^2). Leaf dry weight values per plant ranged from 6.23 to 75.00 g plant^{-1} (dry season) and from 9.17 to 31.34 g plant^{-1} (rainy season). The hybrid Cinnamon x Maria Bonita (1.50 mL plant^{-1}) and the cultivar Mrs. Burns (1.44 mL plant^{-1}) presented higher essential oil yield in the dry season. All the evaluated variables showed high heritability (h^2) (> 50%) and CV_g/CV_e ratio (> 1.0), in both cropping seasons, indicating a favorable condition for selection. The cropping season influences the biomass and essential oil yield of basil.

KEYWORDS: *Ocimum basilicum*. Cultivars competition. Biomass. Seasonality.

INTRODUCTION

Basil (*Ocimum basilicum* L.) belongs to the family Lamiaceae and is a medicinal, aromatic, and spice plant used worldwide. According to FAO (2015), basil world trade increased by 25% (from 613.772 to 820.162 mt) the amount exported between 2012 and 2013. Total global exports and imports were 820,162 and 8201.77 megatons, respectively. The main exporting countries were China, India, Madagascar, Egypt, Mexico; conversely, the leading importers were China, USA, Germany, and Madagascar. The world production of basil essential oil ranged from 50 to 100 tons, and the yield of Indian basil essential oil ranged from 132.0 to 162.5 kg ha^{-1} (SINGH et al., 2010; LUBBE; VERPOORTE, 2011).

The knowledge of the ideal genetic material for each cropping season is fundamental for basil producers. Thus, the performance of the genotypes available in the market must be evaluated to provide the producers information on which cultivar or hybrid to be planted in different seasons. Several factors may influence basil biomass and essential oil yield, including the cultivar used and the methods of cultivation and harvest adopted (BLANK et al., 2010).

Biomass yield and active principles content of medicinal plants depend on genetic and environmental factors, including soil and climatic conditions, harvesting season, and storage conditions (VERMA et al., 2012). Ferreira et al. (2016) reported seasonal variation due to climatic conditions as being a more limiting factor than nitrogen fertilization in sweet basil yield (*Ocimum basilicum*). Seasonality also affected biomass yield and essential oil concentration of *Mentha arvensis* L. and *Aloysia triphylla* (CHAGAS et al., 2011; SCHWERZ et al., 2015).

Genetic, phenotypic, and environmental correlations, together with the genotype-environment interaction between traits in different cropping seasons must be investigated to explore the full yield potential of the species. Cultivation techniques should be developed according to the climatic conditions of each region since the agronomic performance of the culture depends on the genotype x environment interaction. This

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interaction may influence plants growth and development (PRAVUSCHI et al., 2010; FERREIRA et al., 2015).

The objective of this study was to evaluate the performance of basil cultivars and hybrids during the dry and rainy seasons, aiming at obtaining information on basil biomass and essential oil yield.

MATERIAL AND METHODS

The experiments were carried out at the Research Farm "Campus Rural da UFS", located in the municipality of São Cristóvão, in the state of Sergipe, Brazil (lat. 10°55'27"S, long. 37° 12'01"W, at 46 m asl). The climate of the region is considered as As (tropical savanna climate), according to the Köppen classification), with annual average temperature of 25.2 °C (SANTOS, 2006).

Twenty-four basil genotypes were evaluated, being 20 commercial cultivars and four experimental hybrids of the UFS Basil Breeding Program. The following cultivars and hybrids were used in the experiment: 14 commercial cultivars belonging to the Richters corporation (Anise, Ararat, Edwina, Dark Opal, Genovese, Green Globe, Italian Large Leaf - Richters, Magical Michael, Mrs. Burns, Napoletano, Nufar F_1, Osmin, Purple Ruffles, and Sweet Dani); five cultivars belonging to the ISLA corporation (Grecco a Palla, Italian Large Leaf - ISLA, Italian Large Red Leaf, Red Rubin Purple Leaf, and Limoncino); cultivar Maria Bonita (BLANK et al., 2007); and four experimental hybrids (Cinnamon x Maria Bonita – hybrid Norine (BLANK et al., 2015), Genovese x Maria Bonita, Sweet Dani x Cinnamon, and Sweet Dani x Genovese). The experiment consisted of a randomized block design, with three replications, and two planting beds used as border. Each plot consisted of two rows of three plants, totaling six plants per plot, spaced 0.60 m between rows and 0.50 m between plants. A black plastic film was used as mulch in the beds. Experiments were performed in the dry season (October-December/2015) and rainy season (April-June/2016).

The plants were drip irrigated when needed, and weeds were manually picked (BLANK et al., 2004). Harvest occurred in December/2015 (dry season) and June/2016 (rainy season). The meteorological data (rainfall and temperature) were collected during the experiment (Figure 1).

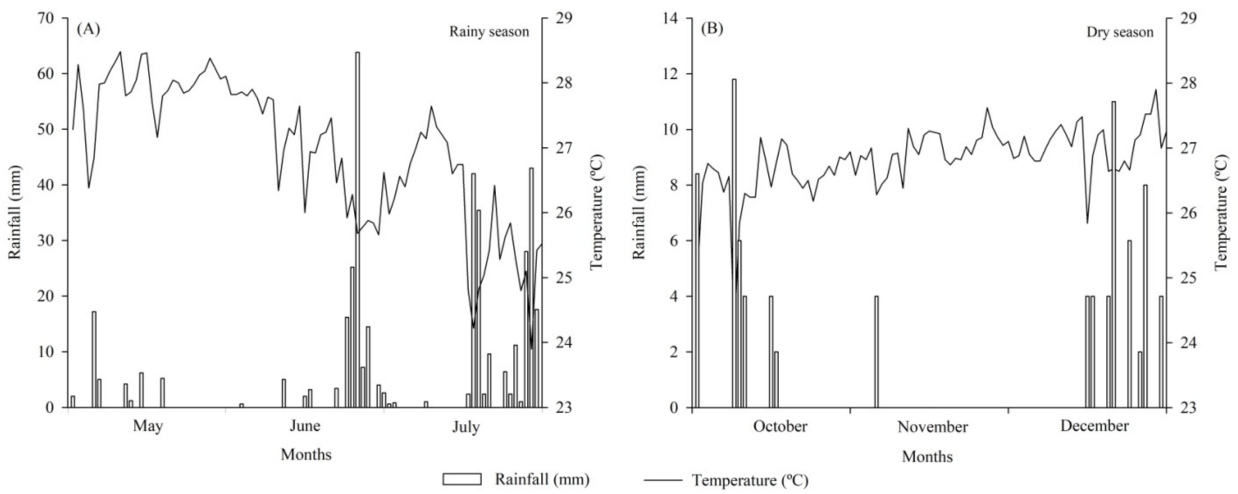

Figure 1. Rainfall (mm) and average temperature (°C) in the experimental area in the dry (October-December/2015) and rainy season (April-June/2016).

The soil of the experimental area, together with earthworm humus and coconut coir (2:1:1) were used as substrate, added with and 1 g of limestone and 6 g of Hortosafra® fertilizer (6-24-12) for each liter of substrate. Seedlings were produced in polyethylene trays containing 162 cells. Plowing, liming, and fertilization were performed according to the soil analysis. The soil was characterized as Red Yellow Podzolic, and presented the following chemical characteristics: O.M. = 11.40 g dm^{-3}; pH in water = 5.52; P = 69.0 mg dm^{-3}; K = 30.9 mg dm^{-3}; Ca = 2.10 cmolc dm^{-3}; Mg = 1.13 cmolc dm^{-3}; H + Al = 1.05 cmolc dm^{-3}; Cation Exchange capacity (CEC) = 4.42 cmolc dm^{-3}; Base Sum (BS) = 3.37 cmolc dm^{-3}, and Base Saturation (V) = 76.20%. Implantation and fertilization were performed with 800 kg ha^{-1} of Mono-Ammonium Phosphate (MAP), 300 kg ha^{-1} of Potassium Chloride (KCl), and 5 t ha^{-1} of cattle manure.

Evaluations were carried after the opening of the first flower of 50% of the plants in both seasons. Plant height and canopy width (cm^{-1}) were measured at full bloom stage, before cutting the plants of each useful plot. After that, the leaves harvested were dried in a forced-air-circulation oven at 40ºC for five days to obtain the leaf dry weight (g $plant^{-1}$). Subsequently, the essential oil was extracted by hydrodistillation in a modified Clevenger apparatus, using samples of 50 g of dried leaves distilled for 140 minutes (EHLERT et al., 2006) for the analysis of the essential oil yield (mL $plant^{-1}$).

The data of the experiment of each cropping season were subject to joint analysis of variance in both seasons. Means were clustered by the Scott-Knott test (P≤0.05), using the Sisvar® software.

The joint analysis of variance followed the method proposed by Vencovsky and Barriga (1992), using the mathematical model:

$$Y_{ijk} = m + B/A_{jk} + G_i + A_j + GA_{ij} + E_{ijk}.$$

where Yijk is the value observed for the i^{th} genotype, in the k^{th} block, within the j^{th} season; m is the overall mean; B/A_{jk} is the effect of the k^{th} block, within the j^{th} season; G_i the effect of the i^{th} genotype; A_j the effect of the j^{th} season; GA_{ij} the effect of the i^{th} genotype x j^{th} season interaction; and E_{ijk} is the experimental error.

Genetic and phenotypic parameters, such as heritability (h2), coefficient of variation (CV%), and phenotypic and genotypic correlations were estimated using the GENES software (Computational Application in Genetics and Statistics) version 2006.4.1 (CRUZ, 2005). From the mean squares expectation, the components of the genetic (σ_g^2) and environmental (σ_e^2) variance were estimated for the main traits evaluated. Genetic parameters were also determined, such as coefficients of heritability (h^2) and CV_g/CV_e ratio.

$$\sigma_f^2 = \sigma_g^2 + \sigma_e^2 + \sigma_{ge}^2$$

$$\sigma_g^2 = \frac{QM_G - QM_{GA}}{ar}$$

$$\sigma_{ge}^2 = \frac{QM_{GA} - QM_R}{r} \times \frac{g-1}{g}$$

$$h^2 = \frac{\sigma_g^2}{GM_G/ar}$$

$$CV_g = \frac{100\sqrt{\sigma_g^2}}{m}$$

RESULTS AND DISCUSSION

Differences between treatments (α = 0.05) were observed for all the traits evaluated (Table 1). The joint analysis and the genetic parameters also presented dissimilarities (Table 2).

Plant height of basil cultivars ranged from 22.33 to 74.05 cm in the dry season, and from 37.72 to 80.54 cm in the rainy season (Table 1). Taller plants were observed in the dry season for the hybrids Genovese x Maria Bonita and Sweet Dani x Cinnamon. In the rainy season, cultivars Mrs. Burns, Sweet Dani, and the hybrids Sweet Dani x Cinnamon and Sweet Dani x Genovese presented the tallest plants.

Similar results were observed by Verna et al. (2012) when evaluating the variation of two basil cultivars (*Ocimum basilicum* L.) grown in two seasons in India. The authors reported plant height values ranging from 44.6 to 82.3 cm for the spring-summer season, and from 59.6 to 94.6 cm for the fall-winter season. In a study carried out in Uberlândia, with cultivar Maria Bonita, in two seasons, plant height ranged from 50 cm (September-November) to 59 cm (February-May) (LUZ et al., 2014a). In the present study, plant height of cultivar Maria Bonita ranged from 39.72 cm (October-December) to 51.03 cm (April-June). These dissimilarities may be due to the different climatic conditions of the cultivation sites since the lack of rainfall is one of the climatic factors that influence basil plants growth.

Regarding canopy width, the means ranged from 27.33 to 88.75 $plant^{-1}$ in the dry season, and from 36.94 to 70.70 $plant^{-1}$ in the rainy season (Table 1). In the first season, the hybrids Cinnamon x Maria Bonita and Sweet Dani x Cinnamon presented the largest canopy width. Only two groups were formed in the rainy season; the commercial cultivars Ararat, Genovese, Mrs. Burns, Napoletano, Nufar F_1, Sweet Dani, Italian Large Red Leaf (Richters), and Limoncino formed the first group; and the experimental hybrids Cinnamon x Maria Bonita and Sweet Dani x Cinnamon formed the second group.

Table 1. Means of the variables plant height (cm), canopy width (cm), leaf dry weight (g plant^{-1}), and essential oil yield (mL plant^{-1}) of basil cultivars and hybrids cultivated in the dry (October-December/2015) and rainy seasons (April-June/2016).

	Plant height (cm plant^{-1})		Canopy width (cm plant^{-1})		Leaf dry weight (g plant^{-1})		Essential oil yield (mL plant^{-1})	
Genotypes	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Anise	36.67 dB	54.11 cA	42.83 cA	50.89 bA	19.98 cA	17.79 bA	0.34 dA	0.47 cA
Ararat	47.42 cB	70.15 bA	41.67 cA	51.98 aA	16.00 dA	17.80 bA	0.13 eA	0.18 eA
Edwina	47.58 cB	64.00 bA	46.67 cA	41.89 bA	27.74 cA	16.01 bB	0.22 eA	0.22 dA
Dark Opal	32.37 dB	52.22 cA	37.12 dB	50.30 bA	15.11 dA	14.60 bA	0.10 eA	0.12 eA
Genovese	42.00 cB	64.08 bA	43.87 cA	52.78 aA	26.59 cA	20.62 aA	0.21 eB	0.43 cA
Green Globe	22.33 eB	37.72 dA	27.33 dA	38.67 bA	10.00 dA	11.11 bA	0.11 eA	0.15 eA
Italian Large Leaf (Richters)	46.69 cB	69.89 bA	43.11 cA	48.22 bA	21.49 cA	14.67 bA	0.18 eA	0.23 dA
Magical Michael	28.72 eB	47.17 cA	33.28 dB	47.78 bA	13.19 dA	18.74 bA	0.19 eB	0.39 cA
Mrs. Burns	57.17 bB	80.54 aA	69.25 bA	70.70 aA	53.15 bA	31.34 aB	1.44 aA	1.29 aA
Napoletano	37.08 dB	58.14 cA	40.58 cB	59.51 aA	22.11 cA	26.49 aA	0.18 eA	0.32 dA
Nufar F1	40.94 dB	60.61 bA	47.33 cA	53.00 aA	23.33 cA	23.18 aA	0.28 dA	0.31 dA
Osmin	37.18 dB	50.42 cA	40.83 cA	42.11 bA	19.70 cA	11.13 bA	0.12 eA	0.08 eA
Purple Ruffles	39.50 dA	46.44 cA	32.50 dA	36.94 bA	21.25 cA	9.17 bB	0.40 dA	0.17 eB
Sweet Dani	62.67 bB	76.70 aA	59.87 bA	59.35 aA	40.84 bA	15.74 bB	0.34 dA	0.28 dA
Grecco a Palla	23.89 eB	41.29 dA	30.05 dB	45.99 bA	10.35 dA	13.86 bA	0.11 eA	0.20 eA
Italian Large Leaf (ISLA)	47.92 cB	69.50 bA	43.67 cA	45.83 bA	25.33 cA	19.12 bA	0.25 dA	0.27 dA
Italian Large Red Leaf	46.83 cB	70.03 bA	34.33 dB	58.28 aA	16.00 dA	26.43 aA	0.14 eB	0.42 cA
Red Rubin Purple Leaf	30.00 eB	50.09 cA	31.78 dA	41.99 bA	9.23 dA	10.02 bA	0.06 eA	0.08 eA
Limoncino	42.33 dB	61.67 bA	52.25 cA	64.72 aA	34.26 bA	22.08 aB	0.43 dA	0.24 dB
Maria Bonita	39.72 dB	51.03 cA	38.53 cA	44.94 bA	22.17 cA	18.10 bA	0.74 cA	0.71 bA
Híbrido Cinnamon x Maria Bonita ('Norine')	56.75 bB	66.28 bA	88.75 aA	55.22 aB	75.00 aA	24.04 aB	1.50 aA	0.50 cB
Híbrido Genovese x Maria Bonita	70.94 aA	66.39 bA	61.00 bA	50.72 bA	39.28 bA	17.47 bB	0.67 cA	0.33 dB
Híbrido Sweet Dani x Cinnamon	74.05 aA	77.22 aA	74.05 aA	54.00 aB	49.05 bA	23.69 aB	0.98 bA	0.56 cB
Híbrido Sweet Dani x Genovese	64.39 bB	74.09 aA	60.17 bA	47.42 bB	21.67 cA	16.31 bA	0.39 dA	0.29 dA
CV (%)	10.22	9.06	7.87	14.41	15.73	24.76	16.78	12.52

Means followed by the same lowercase letters in the columns (treatments), and uppercase letters in the rows (years), do not differ by the Scott-Knott test (p≤0.05).

The growth of medicinal plants is influenced by climatic conditions, such as temperature, relative air humidity, day length, and rainfall (CORRÊA JUNIOR; SCHEFFER, 2013). Lower rainfall (Figure 1) and higher levels of solar radiation were recorded in the dry season. These factors may have influenced the difference in canopy width of some genotypes between the study seasons. Ferreira et al. (2016) observed similar results when evaluating the impact of seasonality on the basil cultivar Verde Toscana.

The hybrid Cinnamon x Maria Bonita presented the greatest leaf dry weight in the dry season, with 75.00 g plant^{-1}, and was superior to its parent Maria Bonita (22.17 g plant^{-1}). In the rainy season, the leaf dry weight of the cultivars and hybrids ranged from 9.17 to 31.34 g plant^{-1} (Table 1). In addition, the cultivars with the greatest leaf dry weight were: Genovese (20.62 g plant^{-1}), Mrs. Burns (31.34 g plant^{-1}), Napoletano (26.49 g plant^{-1}), Nufar F_1 (23.18 g plant^{-1}), Italian Large Red Leaf (Richters) (26.43 g plant^{-1}), Limoncino (22.08 g plant^{-1}), and the hybrids Cinnamon x Maria Bonita (24.04 g plant^{-1}) and Sweet Dani x Cinnamon (23.69 g plant^{-1}) (Table 1).

Rainfall leads to nutrients loss due to leaching, which makes the plants look less developed (LUZ et al., 2014a). This factor was observed in the rainy season, during which the highest rainfall indices were registered (Figure 1). Schwerz et al. (2015) studied the biomass yield of *Aloysia triphylla* and verified the effect of the seasonal variation in leaf dry weight yield (g plant^{-1}), with the highest yield observed in plants collected in November. The season also significantly affected the dry weight yield of citronella (*Cymbopogon winterianus* Jowitt), which presented higher yield in the dry season than in the rainy season (BLANK et al., 2007). The establishment of the best harvesting season in function of biomass yield is fundamental in the management of medicinal plants to obtain higher quality and yield.

Essential oil yield ranged from 0.06 to 1.50 mL plant^{-1} and from 0.08 to 1.29 mL plant^{-1} in the dry and rainy seasons, respectively. The hybrid Cinnamon x Maria Bonita and the cultivar Mrs. Burns showed the highest essential oil yield in the dry season. The same cultivar had the highest yield in the rainy season. In the dry season, the highest average temperatures and the lowest rainfall indices resulted in higher biomass yield and consequently in greater absorption of secondary metabolites, which act as plant defense mechanisms. In a study with *Melissa officinalis*, Luz et al. (2014b) reported plants with higher essential oil yield under hot and humid climatic conditions. The harvest season also influenced the essential oil of *Lippia gracilis*, resulting in higher yields in the dry season (CRUZ et al., 2014).

Based on the analysis of variance (Table 2), genetic variability was observed between the means of genotype, environment, and genotype x environment interaction (GxE) for all variables.

Estimated genetic parameters (Table 2) can assist breeding programs in the selection process and serve as a theoretical reference for the recommendation of commercial materials (ROSADO et al., 2012).

Differences in the variables were observed within each cropping season (Table 2). The dry season presented the highest coefficients of genetic variation for all the traits, indicating greater difference when compared with the rainy season.

Table 2. Summary of the joint analysis of variance and genetic parameters for the variables plant height, canopy width, leaf dry weight, and essential oil yield of basil cultivars and hybrids cultivated in the dry (October-December/2015) and rainy seasons (April-June/2016).

		MS			
Source of variation	DF	Plant height	Canopy width	Leaf dry weight	Essential oil yield
Blocks/Seasons	4	263.70	513.77	1.50	0.02
Genotypes (G)	23	899.31*	644.17*	553.57*	0.57*
Seasons (E)	1	9835.68*	546.15*	2335.22*	0.15*
G x E	23	93.29*	248.32*	268.51*	0.10*
Error	92	26.19	51.77	45.05	0.01
CV (%)		9.61	14.79	30.04	30.36
Genetic parameters					
Genetic variance		134.33	65.97	47.51	0.08
Residual variance		22.36	51.77	45.05	0.01
h^2 % (mean)		89.62	61.45	51.49	82.37
CV_g (%)		21.77	16.69	30.85	77.08
CV_e (%)		9.63	14.77	30.24	30.34
CV_g/CV_e ratio		2.26	1.13	1.02	2.54

*significance at 5% and 1%, respectively, by the F test.
DF: degrees of freedom; MS: mean square; h^2: mean heritability; CV_g: coefficient of genetic variation; CV_e: coefficient of environmental variation).

High heritability values for all variables ($h^2 > 60\%$) (Table 2) indicate that the traits have strong genetic control with great possibilities of being transmitted to future generations. The knowledge of the variation between cultivars, especially when these dissimilarities are due to genetic differences, is ultimate in any breeding program, allowing the knowledge of the genetic control of the trait and the potential selection of hybrid combinations (BLANK et al., 2012).

The CVg/CVe ratio between the coefficients of genetic and environmental variation for all traits was higher than 1.0 (Table 2). A CVg/CVe ratio greater than 1.0 indicates a favorable condition for selection since the genetic variation surpasses the environmental variation. CVg/CVe ratio and heritability demonstrate the possibilities of genetic gains with selection as they play a major role in the understanding of the genotypes variation (GONÇALVES NETO et al., 2012; CARMONA et al., 2015). The highest value of the CV_g/CV_e ratio was observed for essential oil yield (2.54), indicating that the selection for this trait has the most favorable conditions for genetic gain. Santana (2014), when evaluating the phenotypic and genotypic behavior of hybrid cultivars of basil reported a high percentage of heritability (higher than 90%) for the variables leaf dry weight and essential oil content and yield.

The hybrid Cinnamon x Maria Bonita presented the best performance for leaf dry weight in both seasons. Mrs. Burns was superior regarding the essential oil yield. The present results indicate that the cropping season influenced the biomass and essential oil yield of some basil genotypes. The dry season provides higher yield for most of the cultivars.

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RESUMO: O objetivo do presente trabalho foi avaliar o desempenho de cultivares e híbridos de manjericão em duas épocas de plantio. Para o ensaio, utilizou-se o delineamento experimental em blocos casualizados, com três repetições. Foram avaliados 24 genótipos de manjericão, sendo 20 cultivares comerciais e quatro híbridos cultivados na época seca (out.-dez./2015) e chuvosa (abr.-jun./2016). As variáveis avaliadas foram: altura de planta (cm planta^{-1}), largura da copa (cm planta^{-1}), massa seca de folhas (g planta^{-1}) e rendimento (mL planta^{-1}) de óleo essencial. Os dados de cada época foram submetidos à análise de variância, e as médias foram agrupadas pelo teste Scott-Knott ($p \leq 0,05$). Realizou-se a análise de variância individual e conjunta para os experimentos das duas épocas. Foram estimados os seguintes parâmetros: coeficiente de variação genética (CV_g), coeficiente de variação ambiental (CV_e), razão CV_g/CV_e e a herdabilidade (h^2). As médias deferiram significativamente em relação à época de plantio para a maioria das cultivares. Os valores de massa seca de folha variaram de 6,23 a 75,00 g planta^{-1} (época seca) e 9,17 a 31,34 g planta^{-1} (época chuvosa). O híbrido Cinnamon x Maria Bonita (1,50 mL planta^{-1}) e a cultivar Mrs. Burns (1,44 mL planta^{-1}) apresentaram maior rendimento de óleo essencial na época seca. Na época chuvosa foi de 1,29 mL planta^{-1} (Mrs. Burns). Todos os caracteres avaliados apresentaram alta herdabilidade (h^2) (>50%) e razão CV_g/CV_e (>1,0), nas duas épocas, indicando condição favorável para seleção em um programa de melhoramento. A época de plantio influencia a produção de biomassa e óleo essencial de manjericão.

PALAVRAS-CHAVE: *Ocimum basilicum*. Competição de cultivares. Biomassa. Sazonalidade.

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