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Development of Chilli (Capsicum chinense Jacq.) Genotype with High Yield and Capsaicin for Industrial Purpose

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Abstract

The Capsicum genus is native to tropical Central and South America and comprises 27 species, though only five of these are domesticated viz., Capsicum annuum, Capsicum chinense, Capsicum pubescens, Capsicum frutescens and Capsicum baccatum. Among these, Capsicum annuum with its diversity of market types of pungent and non-pungent fruits is the most widely cultivated worldwide. Capsicum fruits are grown mainly for use as a fresh vegetable (hot and sweet peppers), for drying as spice (paprika, chilli powder), for extraction of food coloring and flavoring, and extraction of other compounds for medicinal or industrial uses. The present investigation was carried out using six genotypes of chilli (Capsicum chinense Jacq.) to evaluate the genotypes for yield and capsaicin content to suit the industrial purpose. The study was conducted at the College orchard, Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The experiment was conducted in a Randomized Block Design with three replications. The genotypes included CC-CBE-001, CC-CBE-002, CC-CBE-003, CC-CBE-004, CC-CBE-005 and CC-CBE-006. Observations on biometric, yield and quality parameters viz., Plant height (cm), number of branches per plant, days to first flowering, days to 50% flowering, number of fruits per plant, mean green fruit weight (g), mean dry fruit weight (g), single fruit weight (g), fruit length (cm), fruit girth (cm), fresh fruit yield/plant (g), dry fruit yield/plant (g), capsaicin content (SHU), capsanthin content (ASTA colour value) and oleoresin content (%) were recorded. Among the genotypes evaluated, CC-CBE-003 was the earliest to flower (27.5) and the days to 50% flowering were 32.75. The highest plant height (171.67cm) and the number of branches per plant (5.47) were recorded in the genotype CC-CBE-003. Similarly the maximum number of fruits per plant (262.20) and the highest fresh fruit yield per plant (620.37 g) was recorded in CC-CBE-003. The highest capsaicin content (170264 SHUs) was found in the genotype CC-CBE-003. The capsaicin content of commercially cultivated Capsicum annum ranges between 15,000 and 20,000SHU. Since the capsaicin content recorded in the present study is high, it can be concluded that the genotype CC-CBE-003 with highest capsaicin content and oleoresin content can be recommended for industrial exploitation.

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Introduction

Capsicum chinense Jacq., commonly known as a "habanero-type pepper", is a species of chilli native to America and is a member of the Solanaceae family. The hottest peppers in the world are members of this species, with Scoville Heat Unit scores of over 1.5 million. Some taxonomists consider them to be part of the species C. annuum, and they are a member of the C. annuum complex; however, C. chinense and C. annuum pepper plants can sometimes be distinguished by the number of flowers or fruit per node – two to five for C. chinense and one for C. annuum – though this method is not always correct. In warm climates, it behaves as a perennial and can last for several years, but in cooler climates, C. chinense does not usually survive the winter. It is an evergreen shrub growing to 1.5 m (5ft) by 1.5 m (5ft) at a fast rate. It is suitable for: light (sandy), medium (loamy) and heavy (clay) soils and prefers well-drained soil. Suitable pH is acid, neutral and basic (alkaline) soils and can grow in very acidic and very alkaline soils. It cannot grow in the shade. It prefers moist soil. The extremely hot and pungent fruits are commonly used as a flavouring in savoury dishes. The fruits vary in size and shape, ranging from 6mm in diameter, smooth and rounded, to wrinkled and elongated and up to 10cm long. Presently there is a good scope for exporting this crop as a whole dehydrated product to the USA and Europe, where it is becoming an important source of extractable oleoresin. Pepper fruits and its derivatives are also commercialized worldwide as condiments, additives, and as the lachrymatory agent in pepper sprays; as well as a fungicidal and cytotoxic agent [1].

The pungency is measured in Scoville units, a subjective scale based on the ratio of dilution needed to eliminate the spicy taste. It is about 200,000 to 300,000 Scoville units for habanero and 16 million for pure capsaicin. The content and the hotness of capsaicin increase during the process of ripening of the fruits. In general, dried forms of chilli pepper are spicier than fresh fruits, because the lower water content concentrates capsaicin. It is resistant to high and low temperatures, such as from cooking and freezing, and is not a pigment. The present study was undertaken to evaluate Capsicum chinense Jacq., genotypes for high yield and capsaicin content for industrial purpose.

Materials and Methods

The study was conducted at the Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Tamil Nadu, to evaluate Capsicum chinense Jacq., genotypes for high yield and capsaicin content for industrial purpose. The experiment was laid out in a randomized block design with three replications. The chilli genotypes viz., CC-CBE-001, CC-CBE-002, CC-CBE-003, CC-CBE-004, CC-CBE-005 and CC-CBE-006 were evaluated for biometric, yield and quality parameters. Observations on plant biometric and quality traits viz., Plant height (cm), Number of branches per plant, Canopy spread (cm), Days to 50% flowering, Days to first harvest, Number of fruits per plant, Single fruit weight (g), mean green fruit weight (g), mean dry fruit weight (g), Fruit length (cm), Fruit girth (cm), Fruit yield/plant (kg), Estimated Yield (t/ha), Capsaicin content (%), Capsanthin content (ASTA) were recorded.

Capsaicin Content (%)

The Capsaicin content in chilli genotypes was quantified by High-Performance Liquid Chromatography (HPLC) as per Thapa et al. (2009). The chilli fruits harvested were dried in a Hot air oven at 55°C for a week and the dried fruits were grounded finely using mixer and jar then sieved in one mm screen. One gram of chilli powder samples was taken in 120 ml glass bottles to which 10 ml of methanol was added. The glass bottles were sealed with Teflon-lined lids and placed in a water bath which was maintained at 80°C for four hours with intermittent manual swirling every one hour. The

samples were removed from the water bath and cooled down to room temperature.

Two ml of supernatant were collected using a five ml glass syringe and filtered through millipore nylon syringe tip filter of pore size 0.22µm into a 2 ml sample vial made of glass which was capped and stored. Capsaicin content for chilli genotypes was determined by injecting 10 µl sample solution into HPLC apparatus.

Capsanthin Content (ASTA)

The Capsanthin content in chilli genotypes was determined by following the procedure given by American Spice Trade Association ASTA (1986). Sun dried chilli fruits were powdered finely using mixer and jar which was then sieved through U.S No. 20 sieve. 100 mg of sieved chilli powder was accurately weighed and taken in a 100 ml of volumetric flask in which 100 ml of acetone was added up to the mark and closed tightly using a stopper. The volumetric flask was vortexed to mix well and kept in dark at room temperature for 16 hours. And then the volumetric flask was again shaken well and made to stand for two minutes for the particles to settle. The sample extract solution was filtered using Whatman No.1 filter paper and the absorbance of the final extract (A) was read at 460 nm with acetone as the blank using spectrophotometer.

Calculation

$$\text{ASTA colour value for Capsanthin} = \frac{\text{A at 460 nm with acetone as the blank} \times 16.4}{\text{Weight of the sample taken (g)}}$$

Where, 16.4 is the conversion factor to American Spice Trade Association (ASTA) colour value.

Statistical Analysis

Data were assessed using R- program (Version 4.3.1) using the Agricolae package 1.2 -8. The Analysis of Variation was performed to determine the significance of the variance. Least significance difference (LSD) at 0.05 significance level was used to compare the difference between treatment means.

Results and Discussion

Biometric Parameters

Observations on plant biometric traits viz., Days to first flowering, Days to 50% flowering, Plant height (cm), Number of branches per plant and number of leaves per plant showed significant difference among the different genotypes in the present study. (Table.1)

Table 1: Biometric Parameters of Chilli Genotypes

Genotypes	Days to first flowering	Days to 50 % flowering	Plant height (cm)	Number of branches per plant	Number of leaves per plant
CC-CBE-001	32.0	44.75	160.48	4.59	304.94
CC-CBE-002	33.0	44.00	158.41	5.09	368.25
CC-CBE-003	27.5	32.75	171.67	5.47	488.11
CC-CBE-004	30.0	40.75	75.01	4.59	175.59
CC-CBE-005	35.5	49.75	117.21	3.89	478.95
CC-CBE-006	36.0	45.25	99.14	5.39	235.96
SED	28.8	38.4	116.7	4.3	306
CD 0.05	64.4	85.6	261.1	9.7	681.9
CV	9.7	12.7	28.7	11.8	35

The plant height was found to be the highest (171.67cm) in the genotype CC-CBE-003 whereas it was the lowest (75.01) in CC-CBE-004. Similarly the highest number of branches per plant (5.47) and the maximum number of leaves per plant (488.11) was observed in CC-CBE-003.

The height of Capsicum chinense is variable, ranging from 75 to 120 centimeters under greenhouse conditions as reported by Ruiz-Lau et al., [2]. In this work, Rey Pakal (RP) hybrid and Jaguar (Ja) and Mayapán (Ma) varieties registered the highest height in both evaluations with values ranging from 23.14 to 28.24 cm at 15 DAT and from 59.64 to 68.29 cm at 45 DAT being statistically similar. The Calakmul (Ca) variety showed the lowest height with 20.38 cm at 15 DAT and 53.39 cm at 45 DAT being statistically different as compared to Rey Pakal (RP) but similar to Jaguar (Ja) and Mayapán (Ma). All varieties did not reach their maximum height potential which may be due to the low light intensity that normally occurs under greenhouse conditions [3].

It has been documented that the potential height for Jaguar (Ja) variety ranged from 80 to 90 cm under open field conditions and up to 1.8 m under in protected agriculture systems (macro-tunnels and greenhouse) [4]. In the case of the semi-erect Mayapán (Ma) variety, an average height of 80 cm has been reported while for the Calakmul (Ca), with dichotomous growth habit, its height ranged from 70 to 90 cm with good canopy development [5].

In the present study, among the genotypes evaluated, CC-CBE-003 was the earliest to flower (27.5) and the days to 50% flowering were 32.75 while CC-CBE-006 took 36 days to first flowering and CC-CBE-005 took 49.75 days.

The flowering data are similar to those reported by Hernández-Pinto et al. wherein the production of flower buds ranged from 23.4 and 25.6 DAT, flower opening from 38.3 to 40.5 DAT and fruit set from 42.2 to 45.3 (DAT) [6]. Ramirez-Meraz et al., have mentioned 70 to 85 DAT for the flowering of Jaguar (Ja) variety [4].

On the other hand, Garruña-Hernández et al., reported that flowering of Habanero Pepper can be delayed at temperature above 35˚C and even inhibited above 40˚C, which occurs during the Spring-Summer season in the state of Yucatan, Mexico [7]. The optimum temperature for Habanero Pepper, in Yucatan, occurs during the Fall-Winter season, when the temperature range from 24˚C to 28˚C [8].

Yield Parameters

The yield parameters of chilli genotypes such as Fruit length (cm), Fruit girth (cm), Number of fruits per plant, Single fruit weight (g), Single dry fruit weight (g), fresh fruit yield per plant (g) and dry fruit yield per plant (g) recorded in the experiment are given in Table.2

Table 2: Yield parameters of chilli genotypes

Genotypes	Fruit length (cm)	Fruit girth (cm)	Number of fruits per plant	Single fresh fruit weight (g)	Single dry fruit weight (g)	Fresh fruit yield per plant (g)	Dry fruit yield per plant (g)
CC-CBE-001	3.24	6.18	202.12	2.75	0.48	565.86	96.01
CC-CBE-002	3.45	6.58	191.80	3.58	0.66	691.07	125.08
CC-CBE-003	3.32	6.39	262.20	7.94	1.54	620.37	178.49
CC-CBE-004	4.77	6.09	79.45	7.34	1.35	584.08	105.96
CC-CBE-005	4.69	7.04	77.97	3.76	1.09	619.54	121.08
CC-CBE-006	3.53	6.23	101.55	3.06	0.69	311.12	69.06
SED	3.4	5.7	136.7	4.2	0.86	503.1	103.9
CD0.05	7.6	12.7	304.5	9.4	1.9	1120.8	231.5

CV	17.2	5.2	47.4	45.3	41.1	22	29.7

Among the genotypes evaluated, the maximum fruit length (4.77cm) was recorded in CC-CBE-004, while the maximum fruit girth (7.04cm) was observed in CC-CBE-005. The maximum number of fruits per plant (262.20) and the highest fresh fruit yield per plant (620.37 g) and dry fruit yield per plant (178.49 g) was recorded in CC-CBE-003.

Wilson et al., recorded 30.88 and 28 fruit set per plant in Jaguar (Ja) and Mayapán (Ma) varieties respectively [9]. Calakmul (Ca) Ca was the variety with the lower number of fruit set (20.58). The Rey Pakal (RP) hybrid (Control) had the higher yield with 25.32 and 23.46 t·ha−1 respectively. On the other hand, Jaguar (Ja) yielded 22.29 and 20.11 t·ha−1 and Mayapán (Ma) 25.17 and 22.73 t·ha−1, respectively. Calakmul (Ca) was the variety with significantly lower yield with 13.21 and 11.71 t·ha−1.

Coronado Navarro, 2017 has reported a yield of 31.9 t/ha for Mayapán (Ma) variety while for the Jaguar (Ja) variety very good yields (around 15 t·ha−1), have been achieved under good rainfall conditions in South-Central area of the Mexican states or when irrigation with medium or high technology is applied [10]. Under field conditions, using drip irrigation and fertigation systems, yield of Jaguar (Ja) variety can be up to 30 t·ha−1 and even higher than 43 t·ha−1under protected closed systems. In the same production systems, local commercial Habanero Pepper varieties and the native ones have shown yield from 10.8 to 26.5 t·ha−1 and 12 - 21.7 t·ha−1 respectively as reported by Ramírez Meraz et al., [4].

In the case of Calakmul (Ca) variety, yield of 15 t·ha−1 have been reported in open field conditions and from 25 to 29 t·ha−1 in shade house systems while the yield of Mayapán (Ma) have been documented to be 30 t·ha−1 under open field conditions (Tut,et al.,2014).

Quality Parameters

The quality parameters viz., Capsaicin content (%), Capsanthin content (ASTA) and oleoresin content (%) are given in Table.3

Table 3: Quality parameters of chilli genotypes

Genotypes	Capsaicin (Scoville Heat Unit, SHU)	Capsanthin (ASTA colour value)	Oleoresin content (%)
CC-CBE-001	95512	94.03	10.45
CC-CBE-002	100040	64.06	10.55
CC-CBE-003	170264	60.50	19.20
CC-CBE-004	99192	44.59	15.40
CC-CBE-005	97528	140.83	10.50
CC-CBE-006	92960	59.50	11.15
SED	98045	69.2	11.1
CD0.05	215488	154.3	25.6
CV	25.83	42.7	26.6

The highest capsaicin content (170264 SHUs) and oleoresin content (19.20 %) was found in the genotype CC-CBE-003 whereas the highest capsanthin content (140.83ASTA) was observed in 140.83.

The typical spicy taste is conferred by alkaloids called capsaicinoids. It also contains other substances, such as vitamins and antioxidants (flavonoids, carotenoids), which have biological activity in relieving pain and

inflammation [11]. The ripening augments the content of carotenoids, and so the redness of chilli pepper increases [12]. Correlation analysis of two major capsaicinoids, capsaicin and dihydrocapsaicin had shown a highly significant and positive correlation between capsaicin and dihydrocapsaicin. It clearly indicates that accumulation of capsaicin enhances the accumulation of dihydrocapsaicin irrespective of the genotype. The concentration of capsaicin was higher as compared to that of dihydrocapsaicin in all the Capsicum with high pungency .The content of capsaicinoids and the pungency of chili pepper are extremely variable. They are influenced by the species, the local variety, the degree of maturity of the fruit, and the form of storage (fresh, dried). Some species (for example, habanero pepper, a variety belonging to C. chinense) have an intrinsic, very high capsaicin content.

Conclusion

From the present study it can be concluded that the genotype CC-CBE-003 with the highest capsaicin content and oleoresin content can be exploited for industrial application. The recovery of chilli phytochemicals finds a place in agro-food, cosmetic and pharma industries as replacements for the synthetic compounds. Besides being used as a condiment, providing characteristic pungency, colour and flavour, the high pungent genotypes could be used for the preservation and extension of industrial products' lifespan, as well as additives or technological ingredients with antioxidant and antimicrobial activities. Moreover, the application of the new products in pharmaceutical formulations for the treatment of inflammatory and pain-related conditions is also a possibility, since chilli contain capsaicinoids, carotenoids, phenolic compounds, vitamin C and A, and minerals, such as iron and calcium, which have a health-promoting potential. Further studies on appropriate extraction protocols, stability, safety and bioactivity are necessary to provide novel and promising chilli ingredients for food, cosmetic, and pharmaceutical applications.

Data availability statement

All data underlying the results are available as part of the article.

Conflict of interest statement

The author declares that they have no conflict of interest.

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