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Morphological and biochemical characterization of *Capsicum annuum* landrace Durgada for potential geographical indication status in Andhra Pradesh, India

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Abstract

Durgada chilli (also known as *Potti mirchi*) is a traditional landrace of *Capsicum annuum* L., cultivated exclusively in Gollaprolu mandal of East Godavari district (presently in Kakinada district), Andhra Pradesh, India. This landrace is conserved and propagated by local farmers using traditional and ethnobotanical knowledge. It is highly valued for its intense red colour, moderate pungency, and suitability for colour extraction and export. However, limited scientific data exist regarding its biochemical traits, distinctiveness, and cultivation practices, which are essential for its wider recognition, conservation, and commercial utilization. Agro-morphological traits were recorded using standard descriptors. Field visits and farmer interviews were conducted in the major *Durgada chilli* growing areas including Durgada, Chendurthi, Tatiparthi, and Chebrolu. Biochemical analysis of fruit samples was carried out to determine total extractable colour (ASTA value), carotenoid content, and capsaicinoid composition. *Durgada chilli* plants exhibit an upright habit with tall, medium-spreading architecture and drooping solitary fruits. Biochemical characterization revealed a high total extractable colour value of 122.17 ASTA, with 0.15% red carotenoids and 0.12% yellow carotenoids. The landrace showed medium pungency with a total capsaicinoid content of 114.60 mg/100 g, corresponding to 17,446 Scoville Heat Units (SHU). The fruit has a thick pericarp (3–4 mm) and deep red colour at maturity. This chilli is exported to markets like Mumbai and subsequently to international destinations such as Dubai and Malaysia. Scientific characterization of its morphological and biochemical properties confirms its potential for commercialization, value addition, and Geographical Indication (GI) registration.

Keywords Durgada chilli landrace · Morphological traits · Biochemical traits · Characterization and marketing

Introduction

Chilli (*Capsicum spp*.) is one of the most economically important horticulture crop grown globally for its pungency and spicy taste. Globally, dry chilli is grown in an area of 1.80 million hectares (mha) with a production of 5.82 million tonnes and productivity of 3229.80 kg/ha. In India, it is produced in an area of 0.85 mha with 2.78

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million tonnes and 3265.30 kg/ha of production and productivity respectively[1]. India exports 0.5 million tonnes of chilli valued at 1299.73 million US dollars during 2022–23[2]. Andhra Pradesh (A.P.) state currently ranked as the leading producer of chilli in India, contributes a major portion of overall chilli production in the country. In A.P., Chilli is grown in an area of 2.58 lakh hectares with a production of 14.58 lakh tonnes and productivity of 5649 kg/ha[3].

A Geographical Indication (GI) is a designation applied to products that originate from a particular geographical area and exhibit qualities, reputation, or characteristics that are fundamentally linked to that place of origin. As a result of TRIPS agreements GIs were given the status of one form of intellectual property rights. Geographical Indications (GIs) have served mainly to designate agricultural products whose characteristics are attributed to their geographical origin and influenced by distinct local factors such as climate and soil. Till date, 12 GI tags were given for different local land races or cultivars of chilli in India (Table 1). "Durgada chilli" or "Potti mirchi" is also a landrace of chilli grown exclusively in Gollaprolu mandal encompassing Durgada, Chendurthi, Tatiparthi and Chebrolu villages of East Godavari District of Andhra Pradesh[4]. It is grown in an area of 600 acres in and around Gollaprolu mandal[5]. This chilli is prominent for its good colour value apart from its thick pericarp and medium pungency.

Materials and methods

Study area and cultivation practices

Durgada chilli cultivation was studied in farmers fields in Durgada village, Gollaprolu mandal, and surrounding areas during 2023–24. The region is characterized by well-drained red soils, favorable for chilli cultivation. The cultivation area extends from 17.04627°N to 17.2462°N latitude and 82.18408°E to 82.36109°E longitude. The climate is tropical with a distinct monsoon period during June to September. The seeds were sown in flat nursery beds surrounded by wooden planks during the second fortnight of June or first fortnight of July. to Seed treatment is done to control seed and soil borne fungal pathogens. Prior to transplanting the mainfield is properly leveled and farmyard manure is incorporated during the land preparation. Urea, SSP and DAP were used as straight fertilizers apart from complex fertilizers containing N, P and K. Micronutrient formulations were also used as foliar spray to correct the micronutrient deficiencies. As a part of integrated pest management strategy Neem oil is

Table 1 GI tagging in chilli and different GI tags in chilli[20].

S.No	Chilli type	State	Colour (ASTA)	Pungency (SHU)	GI Date
1	Guntur Sannam Chilli	Andhra Pradesh	32.11	35,000–40,000	28.5.2010
2	Byadagi Chilli	Karnataka	Byadagi Kaddi:150–160 Byadagi Dabbi:180–200	Negligible or Nil	27.1.2011
3	Mizo Chilli	Mizoram	38.00	55,348	23.3.2015
4	Naga Chilli	Nagaland			2.12.2008
5	Bhiwapur Chilli	Maharashtra	36.3	20,000	30.11.2016
6	Khola Chilli	Goa	34.3	17,100	28.8.2019
7	Harmal Chilli	Goa	48.8	28,200	14.9.2021
8	Edayur Chilli	Kerala	22.9	1968	14.9.2021
9	Sirarakhong Hathei Chilli	Manipur	164	7542	14.9.2021
10	Dalle Khursani	Sikkim	–-	100,000 to 350 000	10.12.2018
11	Ramnathapuram Mundu Chilli	Tamilnadu	37.4	17,500	22.2.2023
12	Warangal Chatpata	Telangana	134–149	3100–6500	2024

applied as foliar spray. To protect the crop from thrips, mites, whiteflies and fusarium wilt plant protection chemicals were applied as per recommended dosages, following standard safety guidelines. During 2024–25, Durgada chilli was also grown in 1000 square meters area in black soil farm of ICAR-National Institute for Research on Commercial Agriculture (Formerly CTRI), Rajahmundry which is located 80 km away from Durgada chilli growing area with limited fruitset. The Durgada chilli seeds used in this study were procured from the farmers of the Farmer Producer Organization cultivating Durgada chilli on a payment basis facilitated by the Director of ICAR-National Institute for Research on Commercial Agriculture (Formerly CTRI). All methods were carried out in accordance with relevant guidelines and regulations.

Morphological characterization

Morphological traits were recorded as per the Distinctiveness, Uniformity, and Stability (DUS) guidelines of the Protection of Plant Varieties and Farmers Rights Authority (PPVFRA). Observations included plant habit, length of main stem, length of first internode, anthocyanin, plant height, plant spread, stem pubescence, stem shape, length of leaf blade, leaf colour, intensity of green colour, leaf shape, leaf undulation of margin, leaf pubescens, flower petal colour, flower anther colour, flower/fruit orientation, fruit bearing habit, fruit length, fruit diameter, fruit shape in longituidinal section, fruit curvature, fruit neck at basal end, cross sectional corrugation, fruit sinuation of pericarp, fruit texture of surface, fruit colour at ripe maturity, intensity of colour at maturity, fruit glossiness, fruit shape at the base, fruit shape at apex, number of locules, pericarp thickness, stalk length, calyx cover, calyx margin, calyx constriction, pedicel attachment, blossom end appendage. DUS characterization of Durgada chilli was done along with Arka Abhir as a check variety (Table 2).

Biochemical analysis

All the morphological characters of Durgada chilli landrace were recorded according to the Distinctiveness, Uniformity and Stability (DUS) testing guidelines of PPVFRA for chilli crop. The genotypes of chilli that have received GI tagging were given in Table 1 to provide established reference of check varieties for colour and pungency attributes against Durgada chilli. All the characters were recorded from the farmers fields of Durgada village who were growing the Durgada chilli exclusively. The colour components comprising of red carotenoids (%), yellow carotenoids (%), total extractable colour (ASTA value) were estimated through spectrophotometric method. The pungency components viz., Capsaicin (mg/100 g), Nordihydrocapsaicin (mg/100 g), Dihydrocapsaicin (mg/100 g), Total Capsaicinoids (mg/100 g) were estimated through HPLC method. Biochemical analyses were conducted in triplicate, and the results are expressed as mean ± standard deviation (SD). Statistical analysis was carried out using R software version 4.4.1.

Carotenoids (%)

Red ripe durgada chilli fruits were harvested and subsequently dried. The dried fruit tissues were then ground into a fine powder. A total of 100 mg of this dried powder was subjected to extraction four times using 25 ml of acetone until all colour was completely extracted. The resulting extract was filtered and transferred to a volumetric flask, where it was diluted to a final volume of 50 ml. The absorbance of the samples was measured at two wavelengths, 472 nm and 508 nm, utilizing acetone as the blank. Pure capsanthin and β-carotene standards were used for external calibration of major carotenoids in red chilli following validated HPLC–PDA analytical protocols[6] and[7]. The carotenoid pigments found in peppers were grouped into Red carotenoids and Yellow carotenoids. The determination of yellow and red fractions was done utilizing the UV–vis spectrophotometric method[8]. The concentrations of red (R) and yellow (Y) carotenoid fractions were calculated by solving simultaneous equations based on experimentally determined specific absorption coefficients (εR,472, εR,508, εY,472, and εY,508) for

Table 2 DUS characters of Durgada chilli land race in comparision with check Arka Abhir.

S.No	Character	Durgada chilli	Arka Abhir
2	Plant habit	Upright	Semi-Upright
3	Length of main stem	Medium (5–10 cm)	Short (Upto 5 cm)
4	Length of first internode	Medium (2–4 cm)	Medium (2.01–4 cm)
5	Anthocyanin	Absent	Present
9	Plant height	Tall (>80 cm)	Medium (40.01–80 cm)
10	Plant Spread	Medium (50–100 cm)	Narrow (<50 cm)
12	Stem Pubescence	Absent	Present
13	Stem Shape	Round	Round
14	Length of leaf blade	Long (>8 cm)	Long (>8 cm)
16	Leaf colour	Green	Green
17	Intensity of green colour	Dark green	Medium Green
18	Leaf shape	Lanceolate	Lanceolate
19	Leaf undulation of margin	Weak	Medium
20	Leaf Pubescens	Absent	Present
23	Flower petal colour	White	White
24	Flower anther colour	Purple	Pale Blue
27	Flower/fruit orientation	Drooping	Drooping
28	Fruit bearing habit	Solitary	Solitary
31	Fruit length	Short (2–5 cm)	Medium (5.01–10 cm)
32	Fruit diameter	Broad (>1.5)	Medium (0.81–1.5)
33	Fruit shape in longituidinal section	Cordate	Moderately triangular
34	Fruit curvature	Absent	Absent
35	Fruit neck at basal end	Absent	Absent
36	Cross sectional corrugation	Slightly corrugated	Round
37	Fruit sinuation of pericarp	Weak	Weak
38	Fruit texture of surface	Smooth	Slightly Rough
39	Fruit colour at ripe maturity	Red	Red
40	Intensity of colour at maturity	Dark	Dark
42	Fruit glossiness	Strong	Medium
43	Fruit shape at the base	Round	Round
44	Fruit shape at apex	Blunt	Blunt
45	Fruit: Number of locules	2–3	2–3
46	Pericarp thickness	Thick (3.01–4 mm)	Medium (2.01–3 mm)
47	Stalk length	Medium (2.6–3.5 cm)	Medium (2.6–3.5 cm)
48	Calyx cover	Non-enveloping	Non-enveloping
49	Calyx margin	Smooth	Dentate
50	Calyx constriction	Absent	Present
51	Pedicel Attachment	Strong	Strong
52	Blossom end Appendage	Absent	Absent

red and yellow pigments in acetone[9,10]. Total carotenoids are the sum of Red carotenoids and Yellow carotenoids. The calculations yielded:

- Red carotenoid fraction (R)
- Yellow carotenoid fraction (Y)
- Total carotenoids (R+Y)
- Red to yellow carotenoid ratio (R/Y)

Results were expressed as:

- **Red carotenoids (%)**: calculated as capsanthin equivalents on a sample weight basis
- **Yellow carotenoids (%)**: calculated as β-carotene equivalents on a sample weight basis
- **Total carotenoids (%)**: expressed as the sum of red and yellow carotenoid fractions relative to sample weight.

Total Capsaicinoids (mg/100 g)

The three major components of capsaicinoids i.e. capsaicin, dihydrocapsaicin and nor-dihydrocapsaicin and total capsaicinoids were estimated through High Pressure Liquid Chromotography (HPLC)[11] with slight modifications. Three replicates of red ripe Durgada chilli samples were analysed for total capsaicinoids (mg/100 g) estimation. The HPLC chromatograms were attached as supplementary material.

HPLC methodology: 2 g of dried powder was weighed and boiled with 95% ethanol for 30 min for extraction and the final extract was made up to 50 ml. The mixtures were filtered with filter paper, and then with a syringe driven filter (RanDisc Nylon 0.22 m). A 20 µl aliquot of flow through solution (capsaicinoid extract) was analyzed by high performance liquid chromatography (HPLC) using a GEMINI 5 m C18 110A column (100 mm (L) × 1.0 mm (D) (Phenomenex Chemicals) with a mobile phase of 40% acetonitrile and 60% distilled water at a flow rate of 1.0 ml/ min at 28◦C. The UV absorbance at 205 nm was measured. Total capsaicinoids (mg/100 g dry weight) were calculated as the sum of capsaicin and dihydrocapsaicin (and nordihydrocapsaicin, when present), each expressed on a mass basis using its own calibration curve[12,13]. Total capsaicinoids were calculated as the sum of the individual capsaicinoids. The peak areas were converted to milli grams based on the reports. Capsaicinoids concentrations were converted to Scovellie Heat Units (SHU) by multiplying the pepper dry weight concen trations by the coefficients of heat value 16,000,000[14]. A SHU is defined as the number of parts of sugar water needed to neutralise the heat of one part sample extract.

Colour Value (ASTA)

The colour was assessed following the ASTA 20.0 method. A quantity of 1 g of dried red pepper powder was placed into a 100 mL volumetric flask containing acetone and agitated in a dark environment for 16 h. The absorbance of the resulting extract was recorded at 460 nm utilizing a UV/VIS spectrophotometer.

DNA fingerprinting

24 SSR primers viz., CAMS-051, CAMS-65, CAMS-101, CAMS-358, CAMS-378, CAMS-808, CAMS-811, CAMS-855, CAMS-864, CAMS-865, CAMS-892-2, CAMS-071, HPMS 1–62, HPMS 1–148, HPMS 2–9, HPMS-2-21, HPMS-MADS, CACCEL1, $(GAGGGC)^2$, AF242732, AA840677, CM0005, CM0011, HPMSE006 were used for the DNA fingerprinting study of Durgada chilli in comparision with Arka Abhir an paprika variety with high colour value.

Farmers survey

The ethno-botanical and farmer practices for Durgda chilli or potti mirchi were recorded based on the organized interviews with farmers cultivating this landrace and farmer producer organizations working in the area. A total of around 50 farmers were interviewed and the information of seed selection, seed treatment, sowing, transplanting, fertilizer management, irrigation management, pest management, harvesting and post-harvest processing including drying and packaging followed by marketing was recorded. All experimental protocols were reviewed and approved by the Institute Research Committee of ICAR-National Institute for Research on Commercial Agriculture (Formerly ICAR-CTRI) for this study. Human participants, specifically farmers who grow Durgada chilli, were involved solely for interview purposes using a structured questionnaire prepared for this study. Informed consent was obtained from all participants prior to data collection. All methods were performed in accordance with the relevant guidelines and regulations of the committee.

Economic analysis

The economic data regarding cultivation costs, yield, market prices and marketing strategy was collected to assess the profitability of Durgada chilli cultivation. Present export markets and future potential export destinations were assessed through review of global spice trends.

Results and discussion

Morphological characteristics

Durgada chilli (*Capsicum annuum* L.) is an annual shrub exhibiting an upright growth habit. Plants are generally tall, exceeding 80 cm in height, and display a medium spreading nature with a canopy spread of 50–100 cm. The first node on the main stem appears at a height of 5–10 cm from the base. Each plant bears solitary, white flowers at each node in an extra-axillary position. The calyx is green, the anthers are purple, and the style is slender, terminal, and linear, surrounded by the anthers. The flowers and fruits are drooping in orientation, with the plant exhibiting a solitary fruit-bearing habit.

The fruit is short, measuring 2–5 cm in length, and broad, with a diameter of more than 1.5 cm. During ripening, the fruit undergoes a colour transition from dark green to dark red (Figs. 1 and 2). A distinguishing feature of Durgada chilli is its thick pericarp, which measures approximately 3–4 mm, contributing to its firmness and



Fig. 1 Fruit characteristics of Durgada chilli.

Fig. 2 Field view of Durgada chilli.



Table 3 Biochemical analysis of Durgada chilli.

A)	Colour components	Mean ± SD
1)	Red carotenoids (%)	0.15 ± 0.01
2)	Yellow carotenoids (%)	0.12 ± 0.01
3)	Total Extractable Colour (ASTA value)	112.17 ± 0.65
B)	Pungency components	Mean ± SD
1)	Capsaicin (mg/100 g)	45.89 ± 0.80
2)	Nordihydrocapsaicin (mg/100 g)	14.78 ± 0.35
3)	Dihydrocapsaicin (mg/100 g)	53.93 ± 0.75
4)	Total Capsaicinoids (mg/100 g)	114.60 ± 0.85
5)	Total Capsaicinoids (Scoville Heat Units; SHU)	17,446 ± 144.04

processing quality. The Distinctiveness, Uniformity, and Stability (DUS) characteristics of Durgada chilli are summarized in Table 2, highlighting its key morphological traits and landrace identity.

Arka Abhir was utilized as a check variety for the morphological DUS characterization (Table 2). However, yield and biochemical quality traits were not documented for this check, since its purpose was solely to provide a reference variety for DUS descriptors.

Biochemical composition

Biochemical analysis of *Durgada* chilli indicates a high total extractable colour value of 112.17 ASTA, making it suitable for the commercial extraction of natural edible colour. Among the carotenoids, red carotenoids comprised of 0.15%, while yellow carotenoids accounted for 0.12% of the total pigment content (Table 3). These pigments contribute to the deep red colouration of the fruit at maturity. The observed weak correlation between total carotenoid content and colour intensity in the Durgada chilli landrace aligns with previous studies that suggest fruit colour is more significantly affected by the ratio of capsanthin and its esterified accumulation within chromoplast fibrils than by total carotenoid concentration alone (Berry et al. 2019)[15]. Total carotenoid content in capsicum core collections ranged from 7.09 to 2566.67 µg/g, emphasizing the diversity[15]. In large *C. chinense* and *C. annuum* panels, total carotenoids span 7–2430 mg/100 g DW, with ASTA values from 0 to 233 and the

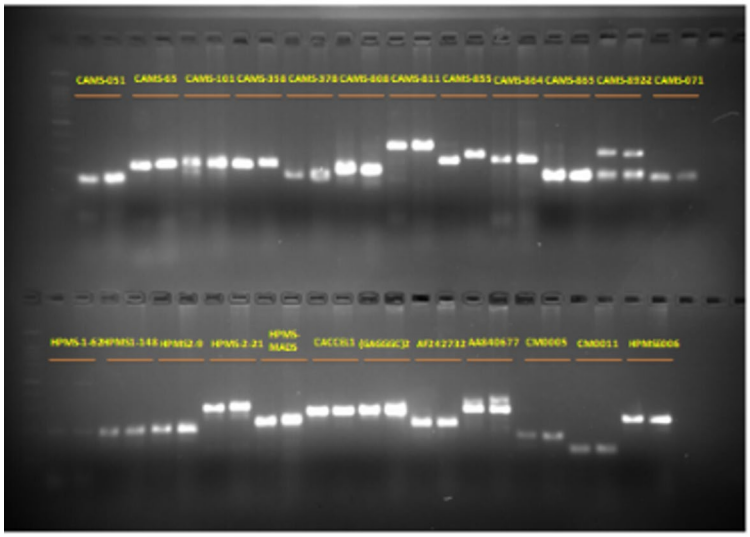

Fig. 3 DNA Finger printing of Durgada chilli in comparision with Arka Abhir.

Durgada landrace had middle to upper mid-to-upper part of this range, consistent with a reasonably intense red powder[7,16].

In addition to its colour properties, *Durgada* chilli exhibits medium pungency, with a Scoville Heat Unit (SHU) value of 17,446, attributed to a total capsaicinoid content of 114.60 mg per 100 g of dry weight. The major capsaicinoid compounds identified include capsaicin (45.89 mg/100 g), dihydrocapsaicin (53.93 mg/100 g), and nordihydrocapsaicin (14.78 mg/100 g) (Table 3). The levels of capsaicinoids in Indian chilli ranges from 0.02 mg/g to 72.05 mg/g dry weight, depending on the cultivable landraces[17]. These results confirm the dual-purpose potential of *Durgada* chilli for both natural colour extraction and culinary applications requiring moderate heat levels.

DNA fingerprinting

Among the 24 SSR primers screened to assess genetic variation between *Capsicum annuum* cultivars Arka Abhir (Sample 1) and Durgada chilli (Sample 2), two primers viz., CAMS 855 and AA840677 exhibited polymorphism (Fig. 3). The primer CAMS 855 amplified a fragment of approximately 260 bp in Arka Abhir and 290 bp in Durgada chilli. Similarly, AA840677 produced amplicons of approximately 390 bp in Arka Abhir and 398 bp in Durgada chilli, indicating allelic variation between the two genotypes. Arka Abhir is a high-colour paprika variety primarily used for pigment extraction, whereas Durgada chilli is a high-colour landrace with potential for genetic improvement programs. Bhat et al.[18] verified the genetic identity of GI tagged Nanjangud Rasabale banana using tissue culture and DNA barcoding techniques.

Farmers package of practices for Durgada chilli

Durgada chilli is cultivated exclusively in the well-drained red soils of Gollaprolu mandal in Kakinada district (formerly East Godavari district), Andhra Pradesh, India. The crop is established through transplanting, with nursery sowing conducted in flat beds bordered by wooden planks during the month of June. Prior to sowing, seeds are treated with fungicides such as Ridomil, Mancozeb (M-45), or SAAF to manage seed-borne and early soil-borne diseases.

For main field preparation, 3–4 truckloads of farmyard manure (FYM) per acre are incorporated into the soil to improve organic matter content and soil fertility. Additionally, neem cake or Godavari Gold is applied at a rate of 3 bags per acre as a soil amendment and to aid in pest management. Seedlings are transplanted into the main

field at 35–40 days after sowing, typically in August, ensuring optimal plant establishment under prevailing agro-climatic conditions.

In Durgada chilli cultivation, fertilizers are applied either at 15–20 day intervals or following each irrigation event to support optimal plant growth. Commonly used soluble fertilizer formulations include NPK blends such as 20:20:20, 28:28:28, 14:35:4, and 10:26, selected based on the crop growth stage and nutrient requirements. Foliar nutrition is administered every 10 days using a micronutrient mixture at a rate of 375 g per acre, which corresponds to 30 g per 16-L spray tank. In some cases, a foliar spray of boron is applied to address specific micronutrient deficiencies. To promote vegetative growth and plant vigor, a growth regulator (Fantac Plus) is applied at a dose of 100 ml per acre (equivalent to 8 ml per 16-L spray tank).

Weed management begins with manual weeding for the first round. From the second weeding onwards, chemical control is implemented using Quizalofop-ethyl 5% EC, a post-emergence herbicide, applied at a concentration of 30 ml per 16-L spray tank.

Pest and disease management is a critical component in durgada chilli cultivation due to the crop's susceptibility to various biotic stresses. Mite infestation typically begins in October and is managed by the application of acaricides such as Diafenthiuron at 25 g per 16-L spray tank. Other effective miticides used include Spinetoram and Oomite. Dieback disease is controlled through fungicidal applications including Amistar Top at 150 ml per acre, Custody at 200 ml per acre, and Contaf Plus, depending on disease severity and stage of crop growth. For the management of fruit borers, insecticides such as a combination of Novaluron 5.25% + Indoxacarb 4.5% SC are applied at a rate of 375 ml per acre (equivalent to 30 ml per 16-L spray tank). Other effective options include Chlorantraniliprole (marketed as Coragen) and Flubendiamide (marketed as Fame).

To support integrated pest management and reduce pest pressure, Neem oil (10,000 ppm) is applied at 15 ml per 16-L spray tank every 15 days as a botanical pesticide. Black thrips (*Scirtothrips dorsalis*) infestation begins from the first week of November and continues through the harvest period, requiring regular monitoring and timely intervention. In addition to thrips and mites, the crop is also affected by several diseases such as chilli leaf curl virus (ChiLCV), powdery mildew (*Leveillula taurica*), and collar rot (*Sclerotium rolfsii*), which necessitate appropriate chemical or cultural control measures.

The harvest of red ripe *Durgada* chilli typically commences in December or January, depending on the planting time and crop maturity. The average yield is approximately 50 bags per acre, with each bag containing 66 kg of fresh red ripe chillies. After drying, each 66 kg of fresh produce yields approximately 15–18 kg of dry chillies, influenced by environmental conditions and drying practices. Of the total dried produce, around 15 kg consists of marketable-grade fruits, while up to 3 kg may be classified as lower-grade or substandard fruits.

The harvested chillies are sun-dried in open fields, manually graded based on size, colour, and quality, and then packed for marketing. Procurement is generally carried out on-site by traders, who purchase the produce directly from farmers at the field level. The minimum price reported for a 66 kg bag of fresh red ripe *Durgada* chilli is approximately ₹15,000. The average market price for dried chilli ranges from ₹240 to ₹300 per kg[4], with peak market prices reaching up to ₹600 per kg in certain years[5], reflecting high demand and superior quality.

Marketing strategy

In Durgada village, pesticide shop owners are actively involved in the production and marketing of Durgada chilli through an informal credit-based system. Under this arrangement, agrochemicals are provided to farmers on credit, with a binding condition that the chilli produce must be sold exclusively to the lending pesticide shop owner. Currently, four pesticide shops operate under this system. Farmers are not permitted to sell their produce to any other buyers due to their indebtedness. In the event of crop failure, the outstanding loan is carried forward with interest, and the amount is recovered from the subsequent season's chilli harvest through a continued exclusive purchasing agreement.

Based on information gathered from farmers, the Durgada chilli is transported to the Mumbai market, where it is stored by traders until market prices become favourable. Once prices rise, the produce is sold, and eventually

exported to international markets including Dubai and Malaysia[5]. However, farmers often lack accurate knowledge regarding the post-harvest handling, final marketing, or export pathways of their produce. The marketing information presented here is based on prior interactions between farmers and traders, peer discussions among farmers, and consultations with state government officials.

Performance of Durgada Chilli (Potti mirchi) at ICAR-NIRCA Research farm, Rajahmundry

During 2024–25, Durgada chilli was grown in area of 1000 m^2 at Katheru black soil farm of ICAR-NIRCA, Rajahmundry during 2024–25. The nursery was grown under raised bed conditions and free from disease. The crop growth at katheru farm was not successful as there was no good growth of durgada chilli compared to its original growing area of Durgada, Gollaprolu and their surrounding areas. The Plants showed low to medium flowering habit and very limited fruitset. The other chilli genotypes grown in the research farm showed good flower and fruitset. The pest infestation for this landrace was also more under Rajahmundry conditions which is 80 kms away from its actual cultivated area. This infers that the climate and soil favoured the Durgada chilli (Potti mirchi) cultivation in its original habitat of Durgada, Gollaprolu and their surrounding areas.

Geographical indication (GI) prospects

Durgada chilli commands a high price in both local and regional markets due to its exceptional quality features. It offers a profit margin of 20–30% higher than other chilli varieties or hybrids. Its export potential is enhanced by its rich colour and medium heat level which aligns well with the global demand for premium spices. Geographical Indications (GI) create opportunities to strengthen local economies, preserve cultural heritage, and promote sustainable agriculture through biodiversity conservation, thereby contributing to economic, social, and environmental sustainability[19]. GI tagging could help maintain its unique identity, prevent imitation, and improve marketability. GI can further increase the Durgada chilli (Pottimirchi) cultivation area along with increased investment in processing infrastructure and enhanced economic returns.

Conclusion

The Durgada chilli landrace exhibited significantly higher total extractable colour in comparision to various commercially cultivated and GI-tagged chilli landraces documented in India, suggesting its promising suitability for natural colour extraction and processing industries. The comparison with GI-tagged chili varieties indicates that Durgada chilli possesses colour and pungency traits that are competitive with, and in some aspects superior to, recognized GI-tagged chilli genotypes, thereby reinforcing its potential for achieving similar premium cultivar status. This landrace is characterized by a significant carotenoid content and medium pungency, making it suitable for culinary as well as industrial applications. Morphological traits like a thick pericarp, cordate-shaped fruits, and an attractive dark red colour of mature fruits contribute to its processing quality, market desirability, and export potential.

The cultivation of Durgada chilli is currently limited to certain villages such as Durgada, Chendurthi, Tatiparthi, and Chebrolu within the Gollaprolu mandal, indicating a significant relationship between the genotype and the local agro-climatic conditions as well as soil properties. The distinct morphological, biochemical, and molecular characteristics observed in this study validate its identity as a unique local landrace. Moreover, the existing market demand and onsite procurement practices reflect its commercial importance among traders and farmers.

Based on these findings, Durgada chilli possesses considerable potential for Geographical Indication (GI) registration owing to its unique quality attributes, regional specificity, and traditional cultivation practices. GI

recognition could lead to improved market visibility and value enhancement, in addition to promoting the conservation and sustainable cultivation of this precious landrace.

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Author contributions B. Rajasekhar Reddy and M. Sheshu Madhav contributed to the study conception and design. Material preparation, data collection and analysis were performed by B. Rajasekhar Reddy, M. Sheshu Madhav and Ponnam Naresh. The first draft of the manuscript was written by B. Rajasekhar Reddy and all the authors read and approved the final manuscript.

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Data availability The datasets generated during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no conflict of interest.

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