My dates with Perithecial Fungi

J. S. Dargan
Department of Botany, Punjabi University, Patiala-147002
Corresponding authors Email: darganj@gmail.com
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ABSTRACT

Perithecial fungi traditionally known as Pyrenomycetes, a class under division Ascomycota has recently been treated under class Sordariomycetes of sub-division Pezizomycotina under Ascomycota. Several fungi belonging to this group of fungi have been reported by the author and his associates from various regions of North -West India. In the recent years several monographic contributions on various families and genera have been made by the experts in the field. Based on these recent works, various taxa of perithecial fungi, reported from this region of India have been reassessed and assigned to their respective taxonomic groups.

Keywords: Ascomycetous fungi, perithecia, taxonomy, Indian contribution

The Father of Asian mycology, Prof. Thind, laid the foundation of fungal taxonomy at Panjab University Chandigarh, some five decades ago. Since then it has flourished to heights of excellence in the country. More than two dozens of his students contributed to the taxonomy of Himalayan higher fungi (both from western and eastern Himalayas), belonging to Basidiomycota and Ascomycota, in addition to a world class work on Myxomycota and Physiology of Fungi. At the same time, I express my gratitude to Prof. N.S Atri, Chief Editor, Kavaka, for inviting me to contribute an article towards Prof. K.S.Thind commemorative volume.

THE BEGINING

It was in the summer month of July 1969, when I was first introduced to the fascinating world of fungi by Prof. K.S. Thind. My first collection was of Xylaria thysus (Berk.) Fr. from Chandigarh forests which ultimately created in me a life long passion for perithecial fungi. First step towards this journey was joining a PL480, US sponsored research project entitled “Mycoflora of western Himalayas” under Prof. Thind in 1971 in Punjab University, Chandigarh. Extensive explorations were undertaken to hunt various taxa of perithecial fungi, in several localities of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and some sub-mountainous parts of Punjab and Haryana during the five years of the project. The explorations were continued in the subsequent years at Punjabi University, Patiala by the author and his students, after joining the department of Botany as a faculty member, through various major research projects: “Pyrenomycetes fungi of North West India” sponsored by UGC, “Pyrenomycetous fungi of eastern Himalayas” sponsored by UGC and “Biological studies on wood-rot fungi of North west India” sponsored by CSIR and a project on wood rotting fungi of Punjab, financed by Government of Punjab.

WHAT ARE PERITHECIAL FUNGI?

Perithecial fungi are traditionally grouped into class Pyrenomycetes of Ascomycotina. The term “Pyrenomycetes” is no longer used in a taxonomic sense and have been replaced by the term Sordariomycetes which is recognized as a class of fungi in the subdivision Pezizomycotina of Division Ascomycota (Kirk et al., 2008) and Miller and Huhndorf (2009) in “Pyrenomycetes of the World: http://www-s.life.illinois.edu/pyrenos”.

Sordariomycetes generally produce their asci in perithecial ascomata (flask-shaped fruiting bodies) on a wide range of substrates including soil, dung, leaf litter, decaying wood, as well as other fungi. These “little black dots” comprise the largest numbers of fungi in the Phylum Ascomycota. Sordariomycetes are economically and ecologically important since they contain the “fruit flies” of the fungal world (e.g. Neurospora crassa, Podospora anserina, Sordaria fimicola) as well as significant destructive pathogens including the causative agents of chestnut blight (Cryphonectria parasitica), dutch elm disease (Ophiostoma ulmi), and the recently discovered beech bark disease (Nectria coccinea). These fungi occur in all ecosystems and geographical areas throughout the world primarily as saprobes where they play an integral role in nutrient cycling and decomposition of organic matter.

Sordariomycetes possess great variability in morphology, growth form, and habitat. Except for having perithecial (flask-shaped) fruiting bodies, ascomata can be less frequently cleistothecial, fruiting bodies may be solitary or gregarious, superficial, or immersed within stromata or tissues of the substrates and can be light to bright or black. Members of this group can grow in soil, dung, leaf litter, and decaying wood as decomposers, as well as being fungal parasites, and insect, human, and plant pathogens.

Systematics of perithecial fungi has been extensively undertaken by the author and his students in the North west and eastern Himalayan region of India. In this paper, however, an account of the fungi met with in north-west region is given. Western Himalayas, the area surveyed falls in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and shivalik hills near Union territory of Chandigarh and some areas of District Roopnagar, Hoshiarpur, Nawanshar and Gurdaspur districts of Punjab with altitude ranging from few hundred meters to more than 700 m. It presents a varied topography, climate and vegetation. The author and his associates have done extensive study on these fungi, from various localities of North-west India, during the last four decades.
These studies reveal that many important families of these fungi are fairly well represented in the study area where practically no such systematic studies had been undertaken earlier. As many as three orders namely Xylariales, Hypocreales and Diaporthales of the class have been investigated from the study area. In view of the latest literature on taxonomy of these fungi, the concepts of families and genera have undergone few changes. In view of this an up to date positions and diversity of the fungal taxa, reported from the region, is given in this paper.

Detailed descriptions with illustrations of individual taxa have been published, by the author, in the series of papers mentioned against each family.

**TAXONOMY**

**Class : Sordariomycetes (Sub class: Xylariomycetidae)**

**Order: Xylariales**

Characteristic features of the order include production of well-developed stromata, perithecial ascomata with thick walls, eight-spored unistinate asci with a J+ apical apparatus. Paraphyses are apically free and develop from a hymenial layer, while ascosporas, usually pigmented, possess germ pores or germ slits, and may or may not be transversely septate, or have a mucilaginous sheath (Kirk et al., 2008).

*Xylariales* is the only order, under the sub class *Xylariomycetidae*, created by Nanfeldt (1932). Seven families *Amphisphaeriaceae*, *Caimiaceae*, *Clypeosphaeriaceae*, *Diatrypaceae*, *Graphostromataceae*, *Hyponectriaceae*, and *Xylariaceae* have been recognized in the recent edition of Dictionary of Fungi. (Kirk et al., 2008). Out of these only two families of the order namely Family *Xylariaceae* and Family *Diatrypaceae* were investigated during the present study.

**Family Xylariaceae**: This is an old and traditional family of order *Xylariales* and is considered as one of the specialized groups of *Sordariomycetes under Ascomycota*. It was established by Tulsane, L. and Tulsane, C. (1863) to include members with predominantly dark colored stomaata and dark unicelled ascosporas a concept subsequently embodied in the studies of later workers in this field. It includes 85 genera and 1343 species (Kirk et al., 2008). The family is characterized by well developed, effused to pulvinate, sometimes stipitate and branched, usually black stromata. The internal tissue is white or concolorous with surface; ascomata perithecial, black, globose, the ostioles periphysate, intervascular tissue well developed, paraphysis present. Asci cylindrical, persistent ± thick walled almost always with a large ± complex J+ structure. Ascospores usually dark brown asceptate with a germ slit.

The floristics of the family in India, had never been specifically studied until later part of the twentieth century and whatever was known during this time, was through the scattered reports of different workers of fungi in general. Many members of the family were reported with different names, from time to time. Although search of the literature reveals that many of the previously reported species are synonyms while a few are altogether wrongly identified and some do not even belong to *Xylariaceae*. Approximately 250 taxa belonging to only 13 genera have been reported so far from India. A complete review of the family *Xylariaceae* in India, with its all aspects and present status was presented in the Presidential address to the Mycological Society of India in its annual meeting at Bangalore in 2006 (Dargan, 2006).

There has been a major thrust in the systematics of *Xylariaceae*, during the last four decades, through contributions of K. S. Thind, J. S. Dargan and their coworkers mainly from Northwest Indian region (Dargan 1976,80,82,83,84,87a,b, 2003; Dargan and Mann 1985; Dargan and Singh1982a,b c,86; Dargan, Singh and Bhatia 1982; Dargan, Singh and Rogers 1984; Dargan and Sood 1996; Dargan and Thind 1979,80,82 84a,b; Sood and Dargan 1994; Thind and Dargan 1975, 1978 a,b,c,80) Comprehensive study of more than 100 taxa relating to 6 genera, namely *Daldinia, Rosellinia, Hypoxylon, Xylaria, Kretzschmaria*, and *Helicogermisla* have been studied by the author and his co workers. Genera *Peridoxylon* and *Camarops*, earlier reported from this region have been now placed under family *Boliniaceae*.

*Daldinia* Ces. & De Not. Commentario della Società Crittogamologica Italiana I(4): 197 (1863)

The genus is a small assemblage of 30 species. Some of the species seem uncommon and are thus not frequently encountered. Stromata spherical, turbinate, clavate, or cylindrical, sessile, sub sessile to definitively stipitate, solitary to aggregated, surface colored, darkened and dull or blackened and varnished in age; the tissue below the perithecial layers composed of alternating zones, the darker zones and the lighter zones. Perithecia obovoid to tubular. Asci eight-spored, cylindrical, stipitate with ascosporas arranged uniseriately or partially biseriately, with apical ring discoid, amyloid. Ascospores light brown, brown, or dark brown, unicellular, ellipsoid, or nearly equilateral, with narrowly or broadly rounded ends, with straight or slightly sigmoid germ slit.

The genus is world wide in its distribution. The first comprehensive monographic account of the genus was given by Child (1932), who recognised only 13 taxa in it. Ju, Rogers and Martin (1997) revised the genus and recognised 22 taxa. Many of the previous species have been treated as synonyms and few more new species have been added. Studlar et al. (2014), in “Polyphylatic taxonomy of *Daldinia*,” however, recognised 48 taxa under the genus.

Dargan and Thind (1984a), based on the anatomical features of the stromata and various tissue types met within different species of the genus, segregated the genus into two new subgenera:

**Sub genus Eu-Daldinia** Dargan & Thind

**Sub genus Ento-Daldinia** Dargan & Thind.

*Daldinia* is a well represented genus in India. Approximately 12 or more taxa have been previously reported. However, on account of revision of the genus by Ju, Rogers and Martin (1997), only 8 established species are known from India, 7 of which are reported from N.W. India. The recognized species are listed below under the respective subgenus.

Subgenus **Ento-Daldinia**  Dargan & Thind : Two species, namely *Daldinia graminis* Dargan & Thind and *D. saccharii* Dargan & Thind belong to subgenus **Ento-Daldinia**.

Genus **Rosellinia** de Not. *Giornale Botanico Italiano* 1: 334 (1844)

It is an important cosmopolitan genus with 142 species (Petrini 2013—"Rosellinia a world monograph")

Stromata superficial, normally uniperitheciate, usually occurring in dense swarms upon a common blackish hyphal mass, the subiculum which may sometimes be absent. Perithecia globose to ovoid, prominent, sometimes closely aggregated with prominent black ostiolar papillae. Asci 8-spored, long cylindrical, stalked with broad ascal plug with constriction which stains blue with Melzer's reagent. Ascospores uniseriate, inequilateral ellipsoid, with or without constriction which stains blue with Melzer's reagent. Perithecia globose to ovoid, pr

Subgenus **Rosellinia** : Subiculum present around perithecia, at least at young stages and persistent at the base of mature stromata. Ectostroma thicker, hard, smooth to rugulose

Subgenus **Corrugata** : Subiculum present around perithecia at young stages, and persistent at the base of mature stromata. Ectostroma thin, brittle.

Sub genus **Calomastia** : Subiculum absent or non persistent around mature stroma.

The genus is well represented in India. Approximately 40 *Rosellinia* taxa are reported in literature. On account of recent revision of the genus by (Petrini 2013), only 30 established species are known from India. As many as following 10 species, namely *Rosellinia aquila* (Fr.) de Not, *R. corticium* (Schw.) Sacc., *R. mammaniformis* (Pers.) Ces. & de Not., *R. Medullaris* (Wallr.) Ces. &de Not., *R. indica* Dargan & Thind, *R. sublimbata* (Dur.& Mont.) Pass.and *R. thindii* Dargan have been reported from North-west India.

Genus **Hypoxylon** Bull. *Histoire des champignons de la France.* 1: 168 (1791)

**Hypoxylon** Bull. as delimited by Ju & Rogers (1996) encompasses Xylariaceous fungi with unipartite, never erect stromata with a solid and homogenous basal tissue below the perithecial layer. Stromata are very frequently waxy with coloured granules yielding pigments in 10% KOH. Ascospores often have a dehiscent perispore and usually have the germ slit on the more convex side and ascal apical rings are discoid or flattened. It is a cosmopolitan genus with 130 species the world over. Highest diversity of the genus is in tropics and sub-tropics. Many of them are weak to damaging pathogens causing cankers.

Majority of them usually found fruiting on dead wood, following invasion of living host tissue. The genus is well represented in India. Approximately 65 *Hypoxylon* taxa are reported in literature. Ju and Rogers (1996) in an excellent account of the genus “A Revision of the Genus Hypoxylon”, gave a new circumscription of the genus. They recognised under the genus two sections.

**Section Hypoxylon** : Ostioles usually lower than the level of stromal surface, never encircled with annular disc.

**Section Annulata** : Ostioles always higher than the level of surrounded stromal surface, with or without annular disc.

On account of recent revision of the genus by Ju and Rogers (1996), only 36 established species are reported from India, The revised list of recognized 26 species reported from the study area is given under respective section.


**Section Annulata** : Hypoxylon *annulatum* (Schw.) Mont., *H. archeri* Berk., *H. cohaerens* (Pers.:Fr.)Fr., *H. multiforme* (Fr.) Fr., *H. stygium* (Lev.) Sacc. and *H. truncatum* (Schw.:Fr.) Mi.

**Xylaria** Hill ex Schrank. *Baierische Flora* 1: 200 (1789)

It is a well established genus, known the world over by approximately 300 species. (Kirk et al. 2008). Stromata erect, elongated, simple or branched, variable in shape and size cylindrical, fusiform, clavate, massive or filiform, capitulate or strap like, long or short stalked. Colour ranging from greyish brown to copper brown or black. Flesh (Entostroma), white to creamish or yellow within, usually dark and carbonaceous above, solid. Perithecia may be completely or semi immersed in the stroma or may be superficial on wiry axis. Asci cylindrical, stalked eight spored and with prominent ascal plug, staining deep blue with Melzer's reagent. Ascospores usually uniseriate, light brown to dark brown or black usually with longitudinal or spiral germ slit.

Majority of the species are saprophytic and grow on dead stumps, branches and leaves of various types of hard wood tree species. However, a few may also grow on coniferous wood, cones or needles. A few species are terricolous, while some may be associated with termite nests. As many as 40 taxa of the genus are stated to be reported from India. Out of
these following 31 species including 2 sub species, have been reported from North west India. These are X. nigripes (Klotzsch) Ck., X. thyrsus (Berk.) Fr., X. papyrifera (Link) Fr., X. convoluta Dargan, X. polymorpha (Pers.: St. Amans) Grev., X. anisopleura (Mont.) Fr., X. phosphorea Berk., X. rogersii Dargan & Bhatia, X. alpina Speg., X. robustus Dargan, X. trachelina (Lev.) Lev., X. longipes Nits., X. fejeensis (Berk.) Fr., X. fejeensis (Ber.) Fr. sub species fejeolis (Lloyd) D. Hawks., X. grammica (Mont.) Fr., X. nainitalensis Dargan, X. aristata Mont., X. helioidea Penz. & Sacc., X. hypoxylon (L: Fr.) Grev., X. hypoxylon (L: Fr.) Grev. sub species ascendentis, X. maillandii (Denn.) D. Hawks., X. mellissii (Berk.) Cke., X. multiplex (Kunze) Fr., X. gracilimima (Fr.) Fr., X. punjabensis Dargan & Singh, X. mussooriensis Dargan, X. coccophora Mont., X. filiformis (Alb. & Schw.) Fr., X. dehzradensis Dargan, X. carpophila Fr. and X. putranjivi Dargan & Mann.

Kretzschmaria Fr., Summa vegetabilium Scandinavae 2: 409 (1849)

The genus has been circumscribed by Swedish mycologist E.M. Fries in 1849, and is worldwide in distribution. Rogers and Ju (1998) revised the genus and recognized only 16 species. However, Kirk et al. (2008) mentioned 28 species of the genus in 'Dictionary of Fungi'.

Stromata erect, short stalked, terminated by a clavate or flat topped, umbonate clava, closely aggregated in swarms. Perithecia completely immersed. Ascospores dark, slightly curved. In India, the genus is represented by five species, namely K. micropus (Fr.) Sacc., K. microspora P. Henn., K. Phonencis Kale & Kale, K. clava (Fr.) Sacc., And K. helicsus (Mont.) Massae. Only one species, K. helicus is reported from the study area.


The genus has been erected by Hawksworth and Lodha (1983) based on a single species, H. celastri (Kale & Kale) Lodha & Hawksw. It is a small genus and is represented by only 4 species (Kirk et al. 2008). In North West India it is represented by H. celastri. The distinctive feature of the genus are: Uniperitheciate to multi peritheciate stromata, dark ascospores with a helical germ slit running from end to end.

Family Diatrypaceae: Morphologically, the members of Diatrypaceae are characterized by perithecial ascomata, long stalked asci and allantoid ascospores (Glawe and Rogers, 1984). The family contains 13 genera and 229 species and the most common diatrypaceous genera consist of Cryptosphaeria Ces. & De Not., Cryptovalsa (Ces. & De Not.), Diatrype Fr., Diatrypella (Ces. & De Not.) De Not., Eutypa L. Tul. & C. Tul., and Eutypella (Nitschke) Sacc. Several species in this family have been shown to cause plant diseases. Eutypa lata (Pers.) L. Tul. & C. Tul., the causal agent of Eutypa dieback, is the best known plant pathogen in this family. This fungus has a cosmopolitan distribution and occurs on many woody plant species (Carter, 1991; Trouillas and Gubler, 2004). Other diatrypaceous taxa, such as Eutypa leptoploca (Mont.) Rappaz, Eutypella parasitica Davidson & Lorenz and E. vitis (Schwein.) Ellis & Everh. were also shown to cause canker diseases and wood decay in various woody plants.

During the present study four genera: Diatrype Fr., Diatrypella Ces. & De Not., Eutypella (Nitsch.) Sacc., and Eutypa Tul.&Tul. have been investigated from the study area (Bhatia and Dargan, 1988, 89, 90; Dargan, 1994; Dargan and Bhatia, 1986b, 88b,89a, c, 91; Dargan and Gill, 1996).

Diatrype Fr., Summa vegetabilium Scandinavae 2: 384 (1849)

The genus was erected by Fries (1849) and recognized by subsequent workers. Kirk et al. (2008) in the latest edition of Dictionary of fungi recognized the genus with 59 species all over the world.

It is marked by stromata of various sorts within the bark of woody stems. Stromata may be applanate or pulvinate, erumpent to superficial, determinate to indefinitely effused, discoid, circular or irregular in shape; surface smooth or rough due to slightly projecting ostioles, light brown to black. Flesh white to yellow or brown to black. Perithecia elliptic to pyriform or tubular, numerous, closely packed, ostiolate, with 33 species the world over (Kirk 2008). It is a well recognized and well spread genus of the family Diatrypaceae.
As many as 18 species are reported from India out of which 13 species, namely Diatrypella aspera (Fr.) Nke., D. borassii Chona & Munjal, D. bougainvillii Dargan & Bhatia, D. discoidea Cke. & Pk., D. herbarceae Ell. & Ev., D. himalayensis Dargan & Bhatia, D. linearis Dargan & Bhatia, D. nigroanulata (Grev.) Ell. & Ev. var. capillosa Dargan & Bhatia, D. opaca Cke., D. paontensis Dargan & Bhatia, D. ribea (Schw.) Ell. & Ev., D. tocciaena de Not and D. verruciformis (Ehr.) Nk. have been collected from the study area.


The widespread genus is estimated to contain 32 species. (Kirk *et al.*, 2008). It is characterized by poorly developed, widely extended stromata beneath the surface layer of wood with flask-shaped single layered perithecia with cylindrical strongly protruded necks. Ascii cylindrical long stipitate, 8 spored. Ascospores cylindrical allontoid, pale yellow.

The genus is represented in India by only 12 species. Only two species, namely *E. leioplaca* (Fr.) Ell. & Ev. and *E. milliaria* (Fr.) Ell. & Ev. have been reported from the study area.

**Eutypella** (Nitschke) Sacc. Atti della Societa Venetiana-Trentina-Istriana di Scienze Naturali 4: 80 (1875)

It is a large wide spread genus and is known the world over by as many as 78 species (Kirk *et al.*, 2008). It is characterized by possession of dark brown to black, poorly developed stromata, made up of host and fungal tissue with rough surface due to protruding, sulcate ostioles, embedded in stroma; 8 spored, cylindrical to clavate, stipitate asci with allontoid (slightly to moderately curved) ascospores. The genus is represented by 40 species in India. However, only six following species, namely *E. aleuriana* (Berk. & Curt.) Ell. & Ev., *E. punjabensis* Dargan & Bhatia, *E. prunastri* (Las.) Nits., *E. nainitalensis* Dargan & Bhatia, *E. russoides* (Berk. & Curt.) Berl. and *E. stellulata* (Fr.) Ell. & Ev. var. *microspora* Dargan & Bhatia are known from North-west India.

**Order Diaporthales** Nannf.

The members of *Diaporthales* are characterized morphologically by brown to black perithecial fruiting bodies immersed in a stroma or the substrata, lack of true paraphyses at maturity, and uniloculate ascii that float free within the stroma; 8 spored, cylindrical to clavate, stipitate with refractive non amyloid ascospores (Rossman *et al.*, 1999 and Rossman, 2000). This family includes around 55 genera. The majority of these species are soil-borne saprobes or weak to virulent, facultative or obligate plant pathogens, while some are facultative fungicolous.

**Family Nectriaceae** Tul. & Tul.: the family *Nectria*ae is characterized by unicellulate ascocar tumata that are white, yellow, orange-red or purple. These ascocar tumata change colour in KOH, and are not immersed in a well-developed stroma. They are associated with phialidic asexual morphs producing amerosporous to phragmosporous conidia (Rossman *et al.*, 1999 and Rossman, 2000). This family includes around 55 genera. The majority of these species are soil-borne saprobes or weak to virulent, facultative or obligate plant pathogens, while some are facultative fungicolous.

**Nectria** (Fr.) Fr. Summa vegetabilium Scandinaviae 2: 387 (1849)

Genus is characterized by weakly to well developed stroma with solitary or aggregated, globose to pyriform,
smooth or rough walled, brightly coloured perithecia; cylindrical clavate asci having oval to ellipsoid, bi-celled, light brown to hyaline ascospores. 

_Nectria_ (Fr.) Fr. is a cosmopolitan genus of the family and is represented by 82 species (Kirk et al., 2008). The genus is represented by approximately 34 species in India. Some of the species have been reported to cause diseases such as coral spots of woody plants and canker and eye rot of apple and pear, whereas others inhabit dead wood and twigs of various plant species.


**Family Hypocercaceae** de Not.: Species of _Hypocercaceae_ are usually recognized by their brightly colored, perithecial ascomata, typically yellow, orange or red. The _Hypocercaceae_ is similar to the _Nectriaceae_ but differ in having more extensive stromata. Family is represented by 22 genera and 454 species throughout the world. One species each of genus _Hypocrea_ Fr. (_H. rufa_ (Pers.: Fr.) Fr.) and _Hypomyces_ (Fr.) Tu. & Tul. (_H. aurantius_ (Pers.: Fr.) Fr. var. _microspora_ Dargan & Bhatia) are reported from the study region. (Dargan and Singh, 1982a; Dargan and Bhatia, 1986a).

**Family Clavicipitaceae** Ericss.: _Clavicipitaceae_ is a large family of obligate biotrophs and necrotrophs of plants, arthropods and fungi. It is represented by 43 genera and 321 species as reported by Kirk et al. (2008). During our investigations on perithecial fungi in the North-west India, a peculiar fungus was collected parasitizing on Bamboo, which on detailed study was found to be belonging to the following new genus (Doi, Dargan & Thind, 1977).


The genus was proposed by Doi et al. (1977) based on a Himalayan collection The characteristic feature of the genus are subglobose, yellowish and wholly fertile stromata with watery cavities at their central portion; perithecia obclavate, immersed in stroma; asci filamentos 8 spored; ascospores filamentous, septate, non-separable at maturity. It is a small genus and is known by only two species, _C. indica_ Yoshim. Doi, Dargan & Thind and _C. borneensis_ Yoshim, Doi, Dargan & Thind. The former being type species of the genus.

North-west India is one of the nine floristic regions of India, recognized by Champion and Seth (1968), from where the above perithecial fungi are reported by the author and his associates. More fungal forays are needed by enthusiastic workers to investigate many more remaining taxa of different orders and families of the group from this region and remaining eight regions of the country.

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