C₃ and C₄ photosynthetic pathways and life form types for native species from agro-forestry region, Northeastern China

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Abstract
Of the total 570 species, 194 species in 116 genera and 52 families were found with C₃ photosynthesis, 24 species in 17 genera and 6 families with C₄ photosynthesis, and 2 species in 1 genera and 1 family with CAM photosynthesis. 90 % of the total species can be found in Changbai Mountain flora, more a half (69 %) in North China flora, and about 1/3 in Mongolian flora and Xinan flora, respectively. The occurrence of C₄ species was not as common as that in adjacent grasslands and deserts, but relatively more than in the adjacent forests. Of the total 24 C₄ species, 63 % C₄ species (15 of 24) was found in Gramineae. Nine life form types can be found, reflecting the moist climate in the region, especially the occurrence of epiphyte and liana forms. Relatively more geophyte life form plants suggested the winter in the region was much colder than in grasslands. These indicated that both ecological studies and land management decisions must take into account plant photosynthetic pathway and life form patterns, for both of them are closely related to climatic changes and land use.

Additional key words: agro-forestry region; C₃ and C₄ species; CAM plants; Tumen Mountains.

Introduction
C₄ biota account for approximately 18 % of the total global phyto-productivity, but it was estimated that in the world only one half of the 10 000 grass species and a thousand of the 165 000 dicotyledonous plants have C₄ photosynthesis (Hattersley 1987, 1992, Ehleringer et al. 1997). Only 30 % of these C₄ species have been identified worldwide (Li 1993) since the works by Downton and Tregunna (1968) and Black (1971). C₃, C₄, and CAM plants are the main plant functional types and the popular means for studying the logical links between physiological and life-history strategies at plant level, as well as ecological process at ecosystem and global levels (Collins and Jones 1985, Collatz et al. 1998, Keeley 1998, Pyankov et al. 2000, Wang 2003). Some studies proved that vegetation management decisions must take into account photosynthetic types, because they are closely related to climate, land use, and human activities (Williams and Markley 1973, Wang 2004). Many methods, e.g. carbon isotope ratio (δ¹³C), “Kranz” type leaf anatomy, low CO₂ compensation concentration, and photosynthetic enzyme ratio, have been used for C₃ and C₄ identification, but many studies suggested that the carbon isotope ratio method is more reliable (Redmann et al. 1995, Liu et al. 2004). Tumen Mountains, located at latitude 44°6’N, longitude 126°2’E in Jiutai, Jilin province, is a typical agro-forestry region that covers an area of about 2 400 km² in the Northeastern China. The east of this area is Changbai Mountain, a typical forestry region, while the west is the Northeast China Plain with large expansion of agricultural lands and meadows. The transitional climatic conditions of the region make its community composition more complex, with both forest species and grassland species (Qian et al. 1957). However, few studies on flora, community classification, and land use had been well conducted in the region (Qian et al. 1957, Wang 2004). The patterns of photosynthetic pathway types and plant life forms in the region remain unclear and the information could be important for the interpretation of relationships between the changes of plant flora and land use, climate changes, as well as for deterioration land restorations. Present study investigated C₃, C₄, and CAM composition and life forms in the region. The results may contribute new information for better understanding of photosynthetic pathway types, life forms, and their relations with ecosystems, climate changes, and land use.
Materials and methods

This study was conducted in Tumen Mountains, a typical agro-forestry region in Northeastern China. The area is on the eastern end of the Northeastern China plain, on average 260 m above sea level, varying from 140 to 542 m. The relief is very complicated and it is primarily a hill landscape mixed with deciduous broadleaf forest, rangeland, cultivated land, valley, and wetland. Most of the region has mountain dark brown forest soils and brown soils, with 5 to 9 % organic matter in the surface layer. The main determinants of the climate in Northeast China are the Mongolian anticyclone and the moist Pacific air mass. In winter, the climate of the area is dominated by the Mongolian anticyclone, which produces a westerly flow of cold, dry air and much snowfall. As the anticyclone breaks down in spring, the region comes increasingly under the influence of moist Pacific air masses, reaching a climax in the summer monsoon, which lasts 4–5 months. The mean annual air temperature is about 5.6 °C, varying from −18 °C in January to 23 °C in July. Average annual precipitation is 850 mm, with 81 % falling between April and September.

Floristic composition of photosynthetic pathway types: 570 vascular plant species (about 70 % of the total species), in 305 genera and 87 families, were identified in Tumen Mountain region. Only 220 species (39 % of 570 species) were classified into their types of photosynthetic pathway (C₃, C₄, and CAM) (Table 1). Of these species, 19 species in 14 genera and 6 families were identified in Pteridophyta, 551 species in Angiospermae. 431 Angiospermae species in 233 genera and 68 families were found in Dicotyledoneae, e.g. Compositae (78 species), Rosaceae (31 species), Ranunculaceae (27 species), Liliaceae (27 species), Labiatae (24 species), Fabaceae (24 species), Polygonaceae (20 species), Umbelliferae (19 species), Caryophyllaceae (19 species), and Chenopodiaceae (11 species). 120 Angiospermae species, in 58 genera and 13 families, were in Monocotyledoneae, e.g. Gramineae (43 species), Lemnaceae (27 species), Cyperaceae (25 species), and Iridaceae (4 species). Of all species listed in Table 1, 90 % can be found in Changbai Mountain flora, 69 % in North China flora, and 33 and 32 % in Mongolian flora and Xinan flora, respectively.

As for photosynthetic pathway types, 194 species (34 % of the identified species in Table 1) in 116 genera and 52 families were found with C₃ photosynthesis, 24 species in 17 genera and 6 families with C₄ photosynthesis, and only 2 species in 1 genera and 1 family with CAM photosynthesis. Of the identified C₃ species, 163 species in 96 genera and 46 families were classified into Dicotyledoneae, e.g. Compositae (23 species), Rosaceae (16 species), Fabaceae (12 species), Ranunculaceae (12 species), and Salicaceae (12 species), while the other 31 species in 20 genera and 6 families in Monocotyledoneae, e.g. Gramineae (17 species), Lemnaceae (4 species), and Cyperaceae (4 species). 4 % of identified species in the Table 1, or about 3 % of the species in local flora, was found with C₄ photosynthesis. Five C₄ species in 5 genera and 4 families were identified in Dicotyledoneae, e.g. Chenopodiaceae (2 species), Amaranthaceae (1 species), Portulacaceae (1 species), and Euphorbiaceae (1 species). 19 species in 12 genera and 2 families were found in Monocotyledoneae, e.g. Gramineae (15 species), Cyperaceae (2 species), and Commelinaceae (2 species). This suggested that the occurrence of C₄ species was not as common as that in grassland and desert vegetations in the north China.

The occurrence of C₄ species was remarkably related with habitats in Tumen Mountains. 15 C₄ species were found in disturbed and cultivated land (DB), e.g. Amaranthus retroflexus L., Kochia scoparia (L.) Schrad., Salsola collina Pall., Commelina communis L., and Setaria gigantean Makino, six species in rangeland (RL), e.g. Spodiopogon sibiricus Trin., Chloris virgata Sw., Cleistogenes squarrosa (Trin.) Keng, Eragrostis ferruginea Beauv., and E. pilosa (L.) P. B., and 5 species in wet soil (WS), e.g. Echinocloa clandestina Rostov., Arthroxiphion hispidus (Thunb.) Makino., Arrundinella hirta (Thunb.) Tanaka., Cyperus amuricus Maxim., and C. serotinus Rott. This indicated that the occurrence of C₄ species was mainly in the unstable ecosystems or habitats in the region.