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Review

Key Strategies Underlying the Adaptation of Mongolian Scots Pine (*Pinus sylvestris* var. *mongolica*) in Sandy Land under Climate Change: A Review

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Abstract: Forest degradation and mortality have been widely reported in the context of increasingly significant global climate change. As the country with the largest total tree plantation area globally, China has a great responsibility in forestry management to cope with climate change effectively. Mongolian Scots pine (*Pinus sylvestris* var. *mongolica*) was widely introduced from its natural sites in China into several other sandy land areas for establishing shelterbelt in the Three-North Shelter Forest Program, scoring outstanding achievements in terms of wind-breaking and sand-fixing. Mongolian Scots pine plantations in China cover a total area of ~800,000 hectares, with the eldest trees having >60 years. However, plantation trees have been affected by premature senescence in their middle-age stages (i.e., dieback, growth decline, and death) since the 1990s. This phenomenon has raised concerns about the suitability of Mongolian Scots pine to sandy habitats and the rationality for further afforestation, especially under the global climate change scenario. Fortunately, dieback has occurred only sporadically at specific sites and in certain years and has not spread to other regions in northern China; nevertheless, global climate change has become increasingly significant in that region. These observations reflect the strong drought resistance and adaptability of Mongolian Scots pines. In this review, we summarized the most recent findings on the ecohydrological attributes of Mongolian Scots pine during its adaptation to both fragile habitats and climate change. Five main species-specific strategies (i.e., opportunistic water absorb strategy, hydraulic failure risk avoidance strategy, water conservation strategy, functional traits adjustment strategy, rapid regeneration strategy) were summarized, providing deep insights into the tree–water relationship. Overall, the findings of this study can be applied to improve plantation management and better cope with climate-change-related drought stress.

Keywords: Mongolian Scots pine; drought resistance; adaptation; water use; climate change

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Citation: Dang, H.; Han, H.; Zhang, X.; Chen, S.; Li, M.; Liu, C. Key Strategies Underlying the Adaptation of Mongolian Scots Pine (*Pinus sylvestris* var. *mongolica*) in Sandy Land under Climate Change: A Review. *Forests* **2022**, *13*, 846. https://doi.org/10.3390/f13060846

Academic Editor: Heli Peltola

Received: 10 March 2022
Accepted: 25 May 2022
Published: 28 May 2022

1. Introduction

Scots pine (*Pinus sylvestris* L.) is one of the widely distributed pines from western Europe [1,2], eastern Russia [3], Mongolia [4], to northeastern China [5]. Scots pine distributed in China is named Mongolian Scots pine (*Pinus sylvestris* var. *mongolica* L.) as one of the varieties of Scots pine [6]. In China, this pine variety is naturally distributed in two central regions: one northwest of the Greater Khingan Mountains, which is called the mountain-land-type Mongolian Scots pine, and the other corresponding to Hulun Buir Sandy Land, which is called the sandy-land-typed Mongolian Scots pine [5]. Both regions are included in the southeastern corner of the natural distribution region of Scots pine (Figure 1) and have a typical continental climate characterized by frigid winters, hot summers, sharp diurnal variations in temperature, and short spring and autumn seasons [7]. Mongolian Scots pine is believed to have similar characteristics in many aspects to Scots pine in evolution [5].

Mongolian Scots pine naturally grows mainly on leached black soil, coarse soil with thin layers, and aeolian sand soil, showing drought and barren tolerance [8,9]. Nevertheless, these trees' growth (or stand productivity) tends to increase with annual precipitation [10], indicating limited growth due to water lack, and trees respond positively.

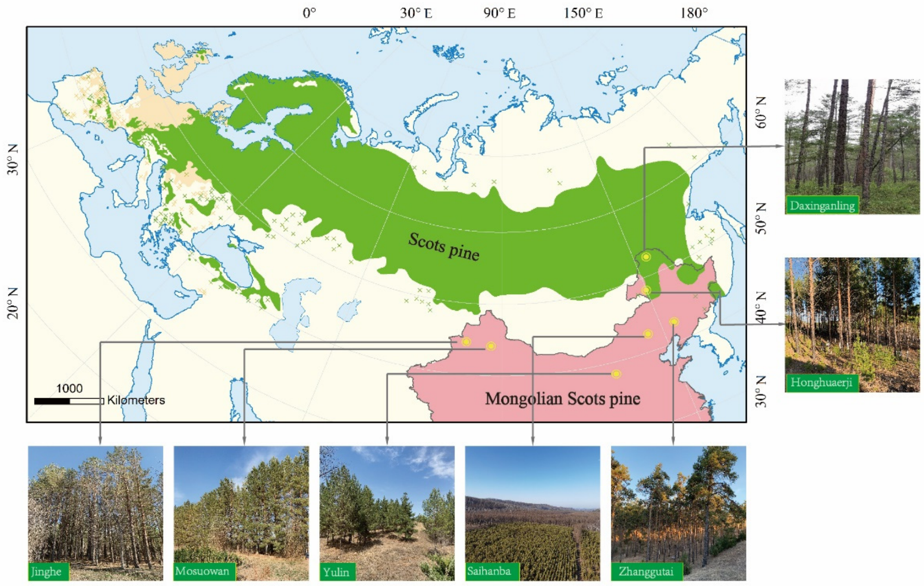

Figure 1. Distribution area of Scots pine (redrawn from distribution maps available in http://www.euforgen.org/species, accessed on 21 April 2022) and study sites (circles) of Mongolian Scots pine in China. Scots pine is naturally distributed in China and is named Mongolian Scots pine. The two photos to the right of the map show two kinds of natural forests: one is mountain-land-typed Mongolian Scots pine; the other is sandy-land-typed Mongolian Scots pine. The bottom five photos show five places with Mongolian Scots pine plantations in northern China. From right to left, they are Zhanggutai (in Horqin Sandy Land), Saihanba (in Otindaq Sand Land), Yulin (in Mu Us Sandy Land), Mosuowan (at the edge of Gurbantunggut Desert), and Jinghe (at the edge of alluvial gobi).

In China, the practice of plantation with Mongolian Scots pine for shelter forest belt started in 1952 at Zhanggutai in Horqin Sandy Land [7]. Based on survival and growth comparative tests, Mongolian Scots pine was screened out among >10 tree species (e.g., *Populus pseudo-simonii*, *Populus simonii*, *Salix matsudana*, and *Pinus tabuliformis*) for its optimal growth performance and successful seed breeding in sandy soil [5]. Since then, Zhanggutai has become a crucial seedling base for introducing Mongolian Scots pine in northern China for wind-breaking and sand-fixing [5]. Afterward, Mongolian Scots pine has been planted in a wide range of geographical sites (135°04′–80°07′ E, 33°16′ N), encompassing temperate continental and temperate monsoon climates [9,11–13] such as the Mu Us Sandy Land (Yulin), the Otindaq Sand Land (Saihanba), the edge of Tengger Desert, and the Gurlbantungut Desert (Mosuowan and Jinhe) [14,15] (Figure 1). At present, sand-fixation forests of Mongolian Scots pine are among the most representative of the large Chinese shelterbelt systems [16,17]. Notably, the total planting area of Mongolian Scots pine in China has almost doubled over the last ten years [17,18]. It will expand further with increased national investments in the famous Three-North Shelter Forest Program. In Horqin Sandy Land, Mongolian Scots pine is superior to *P. tabuliformis* (Chinese pine) in terms of tree height, diameter, and timber volume growth [9]; moreover, the anti-dehydration ability (i.e., water-holding capacity) of Mongolian Scots pine's leaves is better than that of two local native species (i.e., *P. tabuliformis* and *Populus simonii*) under similar site conditions [18]. Accordingly, Mongolian Scots pine plantations are favoured for their more substantial protective effects than *P. tabuliformis* and *P. densiflora* [7].

Climate change profoundly impacts terrestrial ecosystem composition, structure, and function worldwide [19–21], including the semiarid and arid areas in China, which have recently experienced less rainfall and higher air temperature [22]. In recent years, forest decline characterized by increased tree mortality and reduced resistance of forest ecosystems against drought and warming (directly related to climate change) has been widely observed in Europe, Australia, North America, and Africa, among other regions [23–30]. Pinus genera, including Scots pine, inevitably undergo significant adverse effects from climate-change-related water stress [31,32]. In contrast, a positive impact on forest productivity may be found in the higher latitude area [33]. Mongolian Scots pine plantations are experiencing more pronounced climate-change-induced water stress than natural forests. A phenomenon of premature senescence characterized by advanced maturation age, improved productivity before maturation, and shorter life span, has appeared in 35–40 years old Mongolian Scots pine plantations rather than in natural forests in China [7,14,17]. This has caused great concern about the adaptability of this tree species in the water-limited areas under climate change [7,16,34].

Native tree species usually possess unique abilities and mechanisms, developed during the long-term process of evolutionary succession (i.e., elasticity and resilience to climate changes), which allow them to adapt to the habitat [35,36]. However, introducing a tree species into a new location far/outside of its natural distribution range provides an opportunity to explore possible new features of its adaptation to complex disturbances/stressors (i.e., elasticity and resilience to a range of environmental changes) [37]. The adaptability of Mongolian Scots pine communities in sandy land to varied ecological conditions can be expressed in morphological, ecological, and physiological strategies [38]. Here, we summarize the latest findings of their species-specific ecohydrological behaviour under drought stress conditions by considering five aspects: root water uptake efficiency, osmotic regulation, stomatal regulation, accelerated metabolism, and precocious growth (Figure 2). On this basis, we extracted the key ecohydrological strategies that allow the adaptation of Mongolian Scots pine to environmental changes. Our findings can be applied to management practices to improve further the adaptability of sand-fixing vegetation ecosystems for longer-term ecological services.

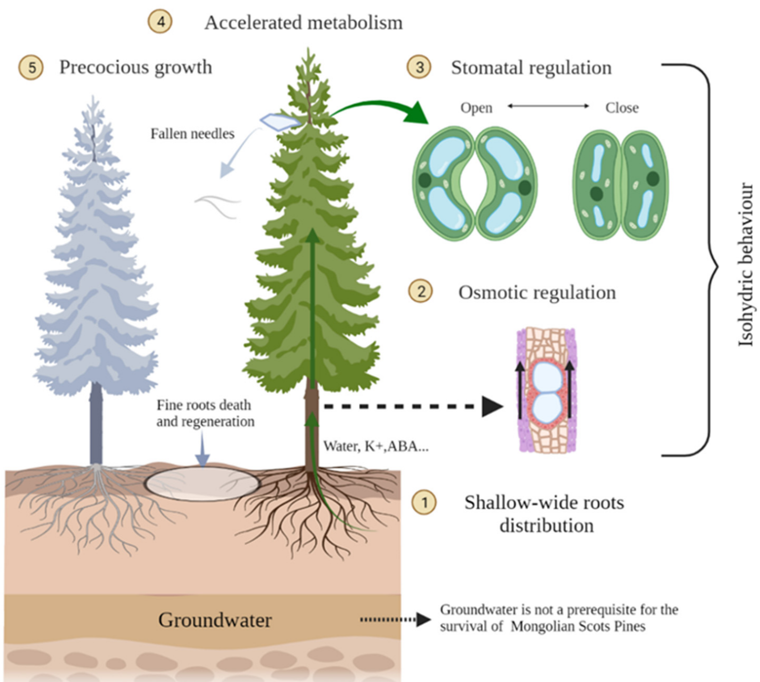

Figure 2. Schematic diagram showing the five key strategies behind the drought-resistance and the climate change adaptability of Mongolian Scots pine: shallow–wide root distribution, osmotic regulation, stomatal regulation, accelerated metabolism, and precocious growth. The schematic diagram was created with BioRender.com (accessed on 21 April 2022).

2. Key Strategies

2.1. Opportunistic Strategy of Water Uptake through a Shallow–Wide Root System

The root distribution of Scots pine typically reflects a brush-like pattern, with underdeveloped taproots and well-developed lateral roots that are horizontally distributed in shallow soil [5]. Similarly, the root system of Mongolian Scots pine is characterized by shallow–wide distribution with horizontal roots reaching as far as 0.65 times the tree height [39], and about 99.2% of the fine roots (diameter $\leq$ 1 mm) distributing in the upper 0–1 m soil layer. Furthermore, ~63.4% of the total fine root biomass is concentrated within the upper 40 cm of soil [40,41], and ~50–60% is in the upper 20 cm of soil layer [42,43]. Occasionally, some taproots reach a depth of 4.0 m [40] or even 5.2 m [39] and can serve as mechanical support; moreover, since the fine root biomass on the deeper part of taproots is very small, they do not represent an exception to the shallow-root attribute of Mongolian Scots pine [40,42].

Shallow-rooted species are likely to compete for resources if they share places with shrubs. Field investigations have shown that >80% of the total root biomass of typical sand-fixing shrubs in Horqin Sandy Land (e.g., *Salix gordejevii*, *Hedysarum fruticosum*, *Caragana korshinskii*, and *Artemisia wudanica*) is distributed in the upper 50 cm of soil [44–47], this creates a severe niche overlap between Mongolian Scots pine and shrubs. Pulse rainfall characterized by infrequently, discrete, and largely unpredictable precipitation events bringing sparse and sporadic moisture inputs have been suggested to be an essential driver of arid land ecosystem structure and function [48]. Pulse rainfall is a prevalent form of precipitation in arid and semiarid areas in China. The shallow-root attribute of Mongolian Scots pine allows efficient capture of low-intensity pulse rainfall [5] and ensures the survival of this tree species in arid and barren sandy lands [44]. Notably, shallow root systems lead to a more intense water competition between trees and under-canopy shrubs (or herbs), inducing the imbalance between water supply and demand during drought years [40]. Predictably, this competition or inequality will intensify under the continuous effects of increasing drought frequency and warming air due to climate change as years pass [20].

The amount of groundwater utilization in Mongolian Scots pine depends mainly on the depth of the groundwater table, the distribution of the root system, and the composition of the soil particles. Since the capillary water rising height of loose sandy soil with particle size > 0.05 mm is generally <1.0 m [49], together with the shallow–wide root system of Mongolian Scots pines, the utilization of groundwater by this tree species in sandy land may be limited to small areas with a high groundwater level due to topography effects (e.g., interdunal lowland) [50,51]. Mongolian Scots pine can hardly use any groundwater in most sandy land in northern China due to decreasing ground table (e.g., it is >5 m at Zhanggutai, the southern edge of Horqin Sandy Land) [44]. Additionally, Mongolian Scots pines that have been planted at ecotone of desert and oases for wind-breaking, such as at Mosuowan in an arid area, have grown well by utilizing water from farm field irrigation with a frequency of 2–3 times each year. Specifically, a 20-year-old Mongolian Scots pine stand planted at Jinghe, where the average annual precipitation is 103 mm and >10 m groundwater depth, has survived even without irrigation during the later 10-year period. Therefore, the use of groundwater or irrigation water directly does not appear to be a prerequisite for the survival of Mongolian Scots pine in most desert–oases ecotone areas in northern China [52,53].

2.2. Hydraulic Failure Risk Avoidance Strategy by Biochemical Osmotic Regulation

Osmotic regulation by the active accumulation of solutes, which include inorganic ions (i.e., K^+, Na^+, Cl^-, Ca^{2+}, and Mg^{2+}) and organic matter (e.g., soluble sugars, proline, betaine, sorbitol, and mannitol) in plant cells, keeps the water potential relatively high under drought stress and is an essential drought-resistant biochemical mechanism for trees [54]. This mechanism enables cells to maintain certain turgor pressure, preventing an excessive decline in hydraulic conductance [55]. Plants achieve drought tolerance when a high total elastic modulus matches a large total osmotic potential during the cytoplasmic wall separation of tissues [56]. A comprehensive study focused on 14–16-year-old Mongolian Scots pines at several sites in northern China indicated that the needle's total osmotic potential of the initial deswelling point (π_p) at the beginning of the annual growth period dropped from −1.24 to −1.39 MPa. In comparison, the elastic modulus of cells (ε) increased from 3.09 to 4.14 MPa. Then, at the end of the annual growth period, π_p dropped from −2.59 to −2.82 MPa, while ε rose from 3.79 to 5.37 MPa [57]. The significant variations in both π_p and ε reflect the ability of Mongolian Scots pine to adapt to drought environments through osmotic regulation and explain their survival over vast areas.

A noticeable decrease in hydraulic conductance along the water transport path generally occurs in Mongolian Scots pine after it experiences water stress characterized by a long-term but moderate drought or a short-term but severe drought [37,54]. This situation may be accompanied by xylem embolism or cavitation, according to reports based on other tree species [58]. Generally, the recovery from a decline in hydraulic conductivity requires a relatively long time [25]. In particular, when many embolisms are formed and cannot be removed entirely due to a sharp drop in hydraulic conductance, the chances of hydraulic failure increase, likely leading to tree death [59,60]. Xylem embolism is more common in conifers [61], such as the Scots pine [62,63] and Aleppo pine [64]. Embolism removal represents the tree's most robust drought resistance ability [65]. The transpiration intensity of Scots pine after a severe drought cannot be fully restored to its original level even in the presence of sufficient rainfall [25]. Xylem embolism occurs in Scots pine when the water potential is <-2.5 MPa [62,63]. Similar behaviour is presented on Mongolian Scots pine with significantly reduced water consumption and recovery ability when subjected to continuous and severe drought [17,66–68]. The occurrence of significant environmental changes, including climate and soil between the natural sites and each afforestation site, has aggravated the issues related to water use in Mongolian Scots pine plantations [17]. This has led to a decline in stem hydraulic conductance and hydraulic safety margins and intensified the water stress syndrome during the growing stage. The hydraulic conductance decreased, but the leaf-to-sapwood area ratio (A_L:A_S) increased in Mongolian Scots pine plantations in Horqin Sandy Land than that from the natural sites [6].

2.3. Water Conservation Strategy by Physiological Stomatal Regulation

Under drought conditions, plants can maintain internal water balance and necessary physical strength for growth through water absorption reinforcement and water loss reduction (mainly by stomatal regulation) or maintain a certain turgor pressure through changes in cell wall elasticity (mainly by osmotic regulation). Stomatal regulation is considered the primary mode of self-regulation in most trees coping with drought stress [69–71]. In contrast, stomatal and osmotic regulation is closely related and synergistic [36,63,72].

Stomatal conductance decreases earlier and faster in most plants than hydraulic conductance [73]. Stomatal closure is usually short-term and can be quickly reversed after rainfall [63]; however, carbon starvation may occur during a long period of stomatal closure, leading to tree death [27]. A decrease in soil–root water conductance is one of the main factors that induce stomatal closure [74]. In the seedling stage, the stomatal conductance of Mongolian Scots pine already tends to diminish when the soil water content decreases to 40% of the field water capacity; nevertheless, the minimum stomatal conductance is reached when the soil water content drops to 20% of the field water capacity [75]. The stomatal conductance decreases for the mature Mongolian Scots pines when the daily mean soil water content reduces to 49% of the field water capacity [76]. After two consecutive dry years, the stomatal conductance of 35-year-old Mongolian Scots pine can become 52% lower than in average years [66]. A series of complex physiological and biochemical processes, such as increased synthesis of the intracellular hormone abscisic acid (ABA), triggers stomatal closure [77,78]. Besides ABA, a rapid increase in superoxide dismutase (SOD), proline (Pro), malondialdehyde (MDA), catalase (CAT), chlorophyll (Ch1), and other regulatory substances in Mongolian Scots pine under drought stress have been confirmed [79].

Fundamentally, the ultimate drought tolerance of a plant is determined by the dehydration tolerance of its cell protoplasm. In this respect, Mongolian Scots pine has developed many xerophytic, leaf-related physiological characteristics for drought resistance during their long-term natural evolution and selection [80]. The needles of Mongolian Scots pine have a robust water-retention ability with a water saturation deficit of ~23.8–29.4% and a water loss rate of ~22% in the first two hours in vitro, which remain stable for 196 h (until the needle leaves reach a constant weight) [81]. The total number of needles in Mongolian Scots pine is relatively small compared to that in *P. tabuliformis*, which share the same afforestation area [82]. The needle leaves possess a developed cuticle (thickness = 2.7 μm), 2–3 layers of epidermal cells (thickness = 25.8 μm), a low epidermal stomatal density (93.3 per mm^2), deep sunken stomata (11 μm), a small stomatal opening degree (38.4 μm), a small leaf area per mass (23.37 cm^2/g), high leaf chlorophyll (1.77 mg/g), high coniferous tissue water (50.8–52.3%) contents [82–84], and a relatively high ratio of bound water to free water in leaf (0.55–1.68) [81,84,85]. All of these characteristics maximize water conservation and utilization [5,86]. The water potential of needles is between −1.37 MPa and −1.11 MPa, and the critical value of water potential of 2-year-old needles of just −1.68 MPa when the stomatal opening is closed [83].

Water conservation strategies of trees have been assigned to two main behaviours: isohydric and anisohydric [87]. In the first case, a specific leaf water potential is maintained by lowering stomatal conductance at the early stage of drought; in the second case, a high stomatal conductance is held, and the leaf water potential is significantly reduced [26]. Isohydric behaviour is believed to be more common in plants inhabiting arid habitats, while anisohydric behaviour is prevalent in wet ones [88]; however, there is still much debate on this issue [89,90]. Trees might adopt different water-use strategies when subjected to environmental changes [91], seasonal changes, and aging [92–94]. Scots pine is considered a typical isohydric tree species [26,95], characterized by sensitive stomatal responses to drought and a robust regulation ability [55,65,96]. Similarly, Mongolian Scots pine is regarded as a typical isohydric variety, characterized by sensitive stomatal control during its sapling and adult stages [53,66].

Mongolian Scots pine is believed to have strong adaptability to arid habitats through nonprodigal water use [90]. The percentage of total transpiration to annual precipitation (T/P, %) is only 4.5–6.6% for 20-year-old Mongolian Scots pines in sparse grasslands (tree density = 104 individuals/ha) in the semiarid area of northern Horqin Sandy Land [97]. Zhanggutai, a semihumid area in southern Horqin Sandy Land, T/P for 32-year-old Mongolian Scots pine forests (tree density = 404 individuals/ha) is 25.7% [98]. According to the reported results for Mongolian Scots pine from different study sites in Horqin Sand Land [17,66,76,97–99], T/P shows nearly a linear relationship to stand density (Figure 3). Specifically, the total water consumption by transpiration of Mongolian Scots pine plantations is <13% of that for all kinds of land use types in the region [100,101].

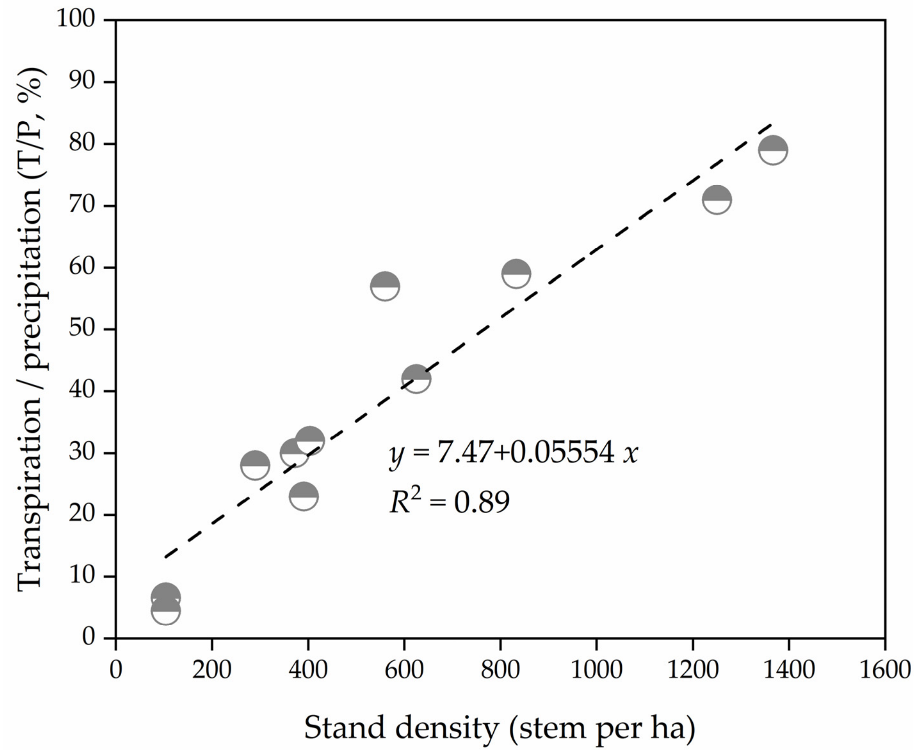

Figure 3. Relationship between the percentage of transpiration to annual precipitation (T/P) and the stand density of Mongolian Scots pines plantations. Data collected from reports on study sites in Horqin Sandy Land, northern China [17,66,76,97–99].

2.4. Functional Traits Adjustment Strategy through Accelerated Metabolism

Variations in plant functional traits reflect some aspects of the whole plant leaf energy and water balances, contrasting resource allocation strategies, and a tradeoff between growth and mortality [102]. Variations in functional traits of roots reflect plant acquisition of soil resources and drive ecosystem processes such as nutrient cycling and organic matter decomposition [103]. Scots pine display significant hydraulic adjustment to local climatic conditions primarily through modification of A_L:A_S [104]. Mongolian Scots pine generally holds four generations of needles at the same time. This enhances nitrogen use by needle leaves, and increases the leaf area available for photosynthesis [5]. Under severe, repeated drought stress, the adaptation of Mongolian Scots pine depends more on changes in leaf area ratio to mass of current-year needles than on changes in the water-use efficiency of needles [105]. Reducing water stress in trees through leaf shedding is considered an active defence measure against drought. Old leaves are the first to be shed under severe stress, leading to a significant decrease in A_L:A_S [106]. The canopy of Mongolian Scots pine is relatively sparse, with needles mainly concentrated in the outside layer of the crown and photosynthetic leaves growing only on young branches (1–3 years old). Needles with low photosynthetic intensity are eliminated under stress, reducing transpiration area, increasing water utilization, and stabilizing the internal water balance. Although a decrease in A_L:A_S might bring water security, it also potentially leads to carbon hunger, resulting in a carbon imbalance [6]. Should the soil water content decrease to <30% of field water capacity, soluble sugar and nonstructural carbohydrate contents would generally decrease in 2-year-old Mongolian Scots pine seedlings; in this case, starch would be mainly accumulated in their coarse and fine roots. This might ultimately cause seedlings to die from carbon depletion [68].

Another functional trait variation for Scots pine to adapt to drought conditions is that more biomass tends to be allocated to roots rather than to stems [100,107]. The space occupied by the underground part of Mongolian Scots pine is considerably larger than that occupied by its aboveground part. This configuration adapts the variety to soil drought and atmospheric dryness [5]. The specific length (root length/biomass) of Mongolian Scots pine's fine roots decreases with the age of the tree, while their specific surface area (surface area/biomass) increases [41]. Therefore, this tree species can adapt to dry habitats by reducing the biomass input to the length of fine roots and increasing the investment in the surface area of fine roots [41]. The production and death of fine roots in Mongolian Scots pine show a pronounced seasonality. The production peak occurs between late spring and mid-summer (June–July), while death peaks occur in late summer, late autumn, and winter. The average life span of the fine roots of 23-year-old Mongolian Scots pines is 322 days [108]. The life of fine roots in topsoil is shorter than in subsoil due to the more variable environmental conditions in topsoil. Otherwise, the fine roots of Mongolian Scots pines show an apparent compensatory growth after removing understory vegetation due to changed soil hydrothermal conditions [71].

2.5. Rapid Regeneration Strategy through Precocious Growth

Regeneration is essential for tree species' genetic continuation and keeps the forest ecosystem vigorous [109]. Some individuals in forest ecosystems are eliminated through natural thinning to make more space and resources available and to maintain the health of the whole system. Trees in harsh environments tend to mature earlier, completing the generation succession at the cost of shortening their life span. The life span of Mongolian Scots pines planted in Zhanggutai (Horqin Sandy Land) is ~20–40 years shorter than that of individuals in natural forests in Honghuaerji (in Hulun Buir Sandy Land), primarily due to a warmer climate in the latter, with a −1.5 to 6.3 °C higher in mean air temperature [5]. This shortened life span can be further reduced in the case of climate-change-related water deficit and pest damage. In this case, Mongolian Scots pine plantations enter the regeneration stage only after 40–45 years, which is significantly earlier than natural forestry [7,110]. Precocious growth involves an accelerated growth rate of the young tree, early maturity, shortened life span, low vigour, and high susceptibility to diseases. This phenomenon, observed in Mongolian Scots pine plantations [7], reflects the effects of a new growth environment rather than the degradation of the tree species. Increased photosynthetic activity, derived from elevated carbon dioxide, temperature, or light levels in a new environment, can cause plants to progress through their seasonal cycle more rapidly, ultimately resulting in early maturity [111]. The occurrence of precocious growth does not lead to certain death or irreversible decline; rather, it comprehensively embodies threshold effects [112], cumulative effects [113], and delay effects [114] involved in drought resistance. Notably, even if a tree dies after experiencing precocious growth, its stands would have undergone "self-thinning". This is significant for preserving acceptable genes within the species and favours the maintenance of a developing succession in a population. The precocious growth of individuals can hence be prevented or mitigated by active forest management measures such as timely thinning.

The leading causes of precocious growth in Mongolian Scots pine plantations have been summarized in three aspects in a theory of forest decline disease [115]. They are changes in the environment (especially soil moisture) as the inducing factor, insect pests as the promoting factor, and pine shoot diseases as the intensifying factor [80,115]. The decline and death of trees are gradual from quantitative to qualitative changes. The weakening of tree growth, caused by water stress, promotes the occurrence of two types of insect pests: *Aphrophora flavipes* and *Dendrolimus*. Notably, the pathogen *Sphaeropsis sapinea* (*Dipbodia pinea*) is a weak parasitic bacterium in forest trees [7,39]. Widespread latent infections are typically observed in healthy Mongolian Scots pines, but the symptoms are insignificant; however, when a forest grows weak, the symptoms increase and harm the trees, accelerating their decline [80,115]. Generally, stands characterized by old trees, high density, and poor site conditions suffer more severe damages [115].

3. Conclusions

Mongolian Scots pine, a geographical variant of Scots pines naturally distributed in the arid sandy environments of northeast Asia, has shown geographical and climatic robust adaptability. This adaptability mainly results from its considerable drought resistance reflected in five key strategies: opportunistic water absorption strategy through shallow–wide root system, hydraulic failure risk avoidance strategy by biochemical osmotic regulation, water conservation strategy by physiological stomatal regulation, functional traits adjustment strategy through accelerated metabolism, and rapid regeneration strategy through precocious growth. These attributes explain why Mongolian Scots pine can rapidly grow and create forests on dry and barren sandy lands and survive even in arid areas without groundwater or irrigation; moreover, it justifies its introduction in northern China as the protagonist of coniferous tree species in the famous green projects in China. The precocious growth observed in Mongolian Scots pines introduced southward from the original natural distributed area should have resulted from the combined effects of geographical and climatic changes. Although precocious growth can be prevented or alleviated for the perdurability and productivity by improving the habitat (through active forest management practices), it benefits the generational succession in the view of evolution. Afforestation efforts involving the broad introduction of Mongolian Scots pine should be further encouraged. Nevertheless, the trees should be reforested by matching species with the sites, balancing forest density to local water resources.

Author Contributions: Conceptualization and methodology, H.D. and H.H.; software, H.H.; validation, H.D., H.H. and X.Z.; formal analysis, C.L.; investigation, M.L.; resources, X.Z.; data curation, H.D.; writing—original draft preparation, H.D.; writing—review and editing, S.C. and M.L.; visualization, M.L.; supervision, H.D.; project administration, X.Z.; funding acquisition, H.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (32071836; 31570704; 32001372).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data generated during the study have not yet been reported in any public repository.

Acknowledgments: We thank the staff at the Zhanggutai National Desertification Control Experimental Station, Chinese Desert Ecosystem Research Net (CDERN), for their support during the field operations. We also thank two anonymous reviewers for constructive comments on an earlier version of this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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