THE INFLUENCE OF SITE FACTORS ON THE

GROWTH OF PINUS TABULAEFORMIS

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INTRODUCTION

Pinus tabulaeformis is one of the most important native coni-
ferus trees in the mountainous areas of North China. It has
been widely used in afforestation since the establishment of
the People's Republic of China. Western Hills,where our rese-
arch work was carried out,are located to the west of Beijing
city and characteristic, in terms of their natural conditions,
of the typical low-elevation mountainous areas of North China.
Climate of this region is mild and relatively dry with mean
annual temperature of atmosphere 11.8°C and annual precipita-
tion of 630 mm.Relatively shallow and rocky soils, mainly
eluvial brown soil according to their genesis, are developed
on the mountain slopes with base rock composed of sandstone
and shale. Layer of deposited loess as parent material can be
found only in a limited area mostly at the foot of northern
slopes. Western Hills had long been deforested and soil erosion
occurred there frequently in the past. A project of affores-
tation in the whole area of Western Hills was completed in the
fifties. More than 20 tree species have been tested, among
them Pinus tabulaeformis was planted widely on about 1/3 of
the total cultivated area. The growth of this coniferous tree
species varies significantly with the various combination of
site factors. The influence of those significant site factors
on the growth of Pinus tabulaeformis was studied in order to
determine the suitable site for pine plantation.

METHODS

Of 119 temporary plots established in even-aged pine planta-
tion in Western Hills 72 are in pure stands and 47 in mixed
stands. The area of every plot was so designed that there were
more than one hundred pine trees in each plot. The total
height of trees, the height increment of the last 5 years,
the diameter at breast height (1.3 meters), and the length
and width of tree crown were measured for every tree (or for
20% of total number) in the plot. The age of pine stands was

in the range of 22-25 years. The average height of 8-10 domi-
nant trees in each plot was taken as its top height. The top
height of pine at the age of 25 for every plot was determined
by revising its initial top height in accordance with the
height increment in late years.

A soil pit was dug at the center of every plot. Site factors,
such as elevation, aspect (exposure) of slope, position on
slope, degree of inclination of slope, total soil depth, soil
texture, condition of humus horizon, and condition of parent
material were taken into consideration for each plot. Obser-
vation showed that soils of all plots were similar in texture
and belonged to the texture class loam. Therefore, no further
study on the influence of this factor has been done. In the
process of investigation we encountered the difficulties in

Table 1:   Site factors in relation to the growth of pine
           plantation

Variable	Symbol	Explanation
Elevation	El	Elevation in meters above sea level, 200=1, 201-400=2, 401-600=3, > 601=4
Aspect (exposure) of slope	As	The 8 aspects are divided into 3 groups according to the humidity gradient: S(SW,S,W) = 1, E(SE,E) = 2, N(NW,N,NE)= 3
Degree of inclination of slope	Is	$<10^{O}=1$, $11^{O}-20^{O}=2$, $21^{O}-30^{O}=3$, $>31^{O}=4$
Position on slope	Ps	upper part of slope = 1, middle part of slope = 2, lower part of slope = 3
Total soil depth	Sd	Total soil depth in centimeters excluding the soil horizon with gravel content more than 70%
Grade of soil fertility	Sf	Expressed in effective soil depth in centimeters: 1 grade=90, 2 grade=65, 3 grade=40, 4 grade=15

*Detail about the classification in grades of soil fertility
 can be found in the textbook "Silviculture" (in Chinese)
 published in 1961 by the senior author.

determining the condition of humus horizon quantitatively on
spot. We only devided it into two grades: the soil with nor-
mally developed humus horizon and the soil with deteriorated
humus horizon, that means the humus horizon is thinner than
10 cm and the content of humus in it is less than 2 per cent.
In such case the factor of condition of humus horizon can
hardly be used independently. In previous research work on
site classification we have used the concept of grade of soil
fertility which is determined in this mountainous areas mainly
according to the total soil depth with the revision according
to the condition of humus horizon and parent material. The
four-grade system of soil fertility, suggested by us, has
been proved to be a successful indicator of productivity of
the stand *)   So we adapted the four-grade system in this
research as a complex factor.

The site factors that were investigated in relation to the
growth of pine plantation are listed in Table 1.

All data of measurement collected from the plots were ana-
lysed with the application of various statistical methods in-
cluding multiple regression method. In this paper only the
data from pure stands have been analysed. Among all the
growth parameters the top-height growth of stand has been
chosen for calculation as it is the most sensitive parameter
to the variation of site factors.

                    ANALYSIS AND RESULTS

The simple correlation coefficients between site variables
and the top-height of pine plantation are presented as
following:

            Elevation to Ht   0.1475
            Aspect of slope to Ht   0.3740
            Degree of inclination to Ht   0.2577
            Position on slope to Ht   0.1015
            Total soil depth to Ht   0.6789
            Grade of soil fertility to Ht   0.8123

The most significant single site factor that effects the
growth of pine plantation is the total soil depth, which va-
ries from 12 to 110 cm in all plots with an average of 60.8 cm.
So it is because on the eroded slopes with relatively shallow
soil depth the importance of the volume of soil in supplying
the trees with water and nutrient mineral elements is ecologi-
cally evident. The complex factor of soil fertility which is
shown by grades 1-4 and determined on the base of soil depth
with supplementary information of the conditions of humus
horizon and parent material shows more significant effect on
the growth of pine plantation (0.8123) than soil depth alone

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(O.6789). In our Western Hills experiment not only the growth
of Pinus tabulaeformis, but also the growth of Placycaldus
orientalis, Robinia pseudoacacia, and others is closely corre-
lated with the grade of soil fertility. For instance, the single
regression equation of Sf for the top-height growth of Placycal-
dus at the age of 25 is as following:

$$Ht = 3.2545 + 0.0316Sf \qquad\qquad R = 0.894$$

The same equation for Robinia at the age of 22 is:

$$Ht = 8.611 + 0.03702Sf \qquad\qquad R = 0.533$$

The aspect of slope also shows some important effect on the
growth of pine plantation. The analysis of variance for the
top-heights of pine plantation growing on slopes with different
aspects but with similar grade of Sf shows a high degree of
significance (variance ratio F= 45.47, while $E_{0.01} = 3.32$) for
the effect of aspect on the growth of pine. This is mainly due
to the difference in moisture content on slopes facing various
aspects. In mountainous areas of North China the deficit in
soil moisture is one of the serious problems causing the stag-
nation in growth or even failure of pine plantation. Besides
the volume and structure of soil, the aspect of slope is reco-
gnized as the important site factor influencing the soil-mois-
ture content. On the warm and dry slopes facing South and
Southwest, especially on the shallow and eroded soils, the
height growth of Pinus tabulaeformis is slow and its current
annual height increment at the age of 25 is scarcely over 15 cm,
while that of pine on the slopes facing northern aspects is
about 20-30 cm.

Elevation varying from 50 m to 630 m above sea level in the
investigated area shows less significant influence on the growth
of pine plantation in comparison with the factors mentioned
above. It seems at first contradictory to common knowledge. Eco-
logically speaking, elevation would have more significant
influence on the growth of pine plantation. But is has not
been observed in our experiment. The explanation is rather
simple. Firstly, the difference of elevation in the investi-
gated area is not large. Secondarily, the elevation as a site
factor shows different influence on the slopes with different
aspects. On the southern slopes with increase of elevation the
pine plantation grows better due to the increase in moisture
supply. But on the northern slopes with increase of elevation
the growth condition of pine plantation remains practically
unchanged because of the combined effect of shorter growth
period and better soil-moisture supply. This can be illustrated
by the data of top-height growth of pine on slopes with different
elevation and aspects (see Table 2). From the data in Table 2
we come to the conclusion that elevation also has significant
influence on the growth of pine plantation. But owing to the
special feature of its different influence for the slopes with
different aspects the correlation coefficient on the whole is
relatively low.

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Table 2   Top-height growth of pine plantation (A = 24) on
           slopes with different elevation and aspects

Aspects	Grade of Sf	Elevation (m)	No.of plots	Average top height (m)	t value test
Southern	2	below 400	6	5.08	t = 4.80
		above 400	3	6.27	$t_{0.01}$= 3.50
Northern	1	below 400	3	6.77	t = 1.95
		above 400	3	6.37	$t_{0.05}$= 2.45

The topographical factors, degree of inclination of slope and
position on slope, have not close correlation with the growth
of pine plantation. Human disturbance in the past is the main
cause. In the undisturbed area the tendency of increase of
soil depth and soil fertility is noted with decrease of the
degree of inclination of slope and its lowering in position.
However, in most part of Western Hills the mountain slopes
had been wrongly utilized in the past and the moderate and
lower part of slopes was often more effected and subjected to
erosion.

The multiple regression of site factors with the top height
of Pinus tabulaeformis is shown in Table 3. This table evidently
shows that the total soil depth is the most significant
site factor and was first introduced into the equation
(R= 0.6789). The grade of soil fertility gives a better re-
presentation of the soil condition and serve as an efficient
substitute (R= 0.8123) for the soil depth. After that the
aspect of slope was introduced into equation to improve the
correlation between site factors and the top-height growht of
pine plantation (R= 0.8607). The introduction of degree of
inclination and elevation only slightly improved the equation
(R= 0.8764). And the position on slope in this experiment was
proved to be insignificant to the growth of pine plantation.

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Table 3   Regression coefficients for estimating top-height
           growth of Pinus tabulaeformis (A = 25)

Variable	Steps along gradual regression				
	1	2	3	4	5
Elevation (El)					0.114
Aspect of slope (As)			0.3295	0.3457	0.3546
Degree of inclination of slope (Is)				-0.1920	-0.2031
Position on slope (Ps)					
Total soil depth (Sd)	0.03489				
Grade of soil fertility (Sf)		0.04204	0.04038	0.03895	0.03827
Intercept a	3.5343	3.1797	2.5537	2.9926	2.8656
R	0.6789	0.8123	0.8607	0.8724	0.8764

CONCLUSION

In the region of Western Hills in Beijing several site factors
have significant influence on the top-height growth of Pinus
tabulaeformis. In our case the top-height of pine is not used
as its site index, because the average age of pine plantation
(A= 25) is too young to be taken as standard age.

From the above data the following equation was selected to
estimate the top height from site factors for Pinus tabulae-
formis in Western Hills:

$$Ht= 2.8656 + 0.1114El + 0.3546As - 0.2031Is + 0.03827Sf$$

$$\text{multiple correlation coefficient } R = 0.8764$$
$$\text{partial correlation coefficient } R_{Sf-Ht} = 0.8089$$
$$R_{As-Ht} = 0.5334$$
$$R_{Is-Ht} = 0.2965$$
$$R_{El-Ht} = 0.1731$$

Obviously, this equation can be applied efficiently in site
classification and in choice of species for afforestation.
These problems are of great importance in investigated region
as well as in all mountainous areas of North China.