Variation in Response of Conifer Seed Germination to Soil Moisture Conditions*

Taisitiroo SATOO

Variation in the responses of physiological processes of forest tree species to soil moisture conditions was reported by many authors. However, studies on the response of seed germination to soil moisture are very few. Most of the studies on this line were made by germinating seeds in solutions of various concentrations as a substitute to variation in soil moisture stress. The author reported previously on the effect of diffusion pressure deficit of soil and sucrose solution on germination of seeds of some conifers[1]. In this paper, data of the previous experiments using dry soil were reanalysed along with unpublished data of the experiment with excessive soil moisture.

Seeds of *Pinus densiflora, P. thunbergii,* and *Chamaecyparis obtusa* were collected from each one tree in Tanasi Experimental Field, Tokyo University Forest. Soil of Tanasi Nursery of volcanic ash origin was used. Field capacity of the soil was 64.3%, and soil moisture content at 15 atmospheres of diffusion pressure deficit (D.P.D.), which is nearly equivalent to permanent wilting percentage, was 33.5%. The relation between D.P.D. and soil moisture content was graphically shown in a previous paper[2]. The soil was filled in metal containers, 20 cm in diameter, 5 cm in depth, with bottom of blotting paper on metal screen. They were watered sufficiently, and left to drain and dry until they were used at different time after watering, so as to get different soil moisture content. Soil of different moisture contents were filled in Petri dishes, 10 cm in diameter, 100 seeds were planted in each dish, covered with soil of the same lot to about 2 mm thick. After covered with the lid of the dishes, they were put into other Petri dishes, 15 cm in diameter, to prevent evaporation loss of soil moisture. When the outer dishes were tightly sealed, seed did not germinate and decayed, so the dishes were only covered with their lids. Soil was sampled at the time of planting seeds and at the end of the experiment, and moisture contents were determined. Evaporation loss during the experiment was not so large. Mean of the soil moisture contents of the two samples was used as representing the soil moisture content of the corresponding experiment. 13 different soil moisture contents were used for each species. Germination percent was determined after keeping them at 23℃ for three weeks.

The results of the experiments are shown in Fig. 1. As all three species showed the highest germination percent at soil moisture content (dry weight basis) between about 50 and 65%, the effect of soil dryness was analysed for the soil moisture content ranging from field capacity to permanent wilting percentage, or so-called readily available

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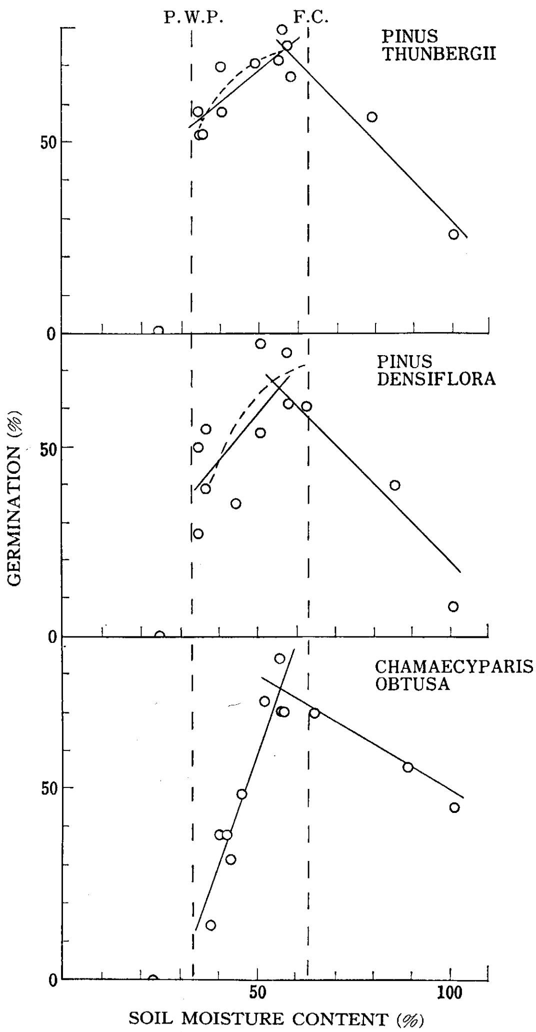

Fig. 1. Germination in relation to soil moisture content.
P.W.P.: Permanent wilting percentage
F.C.: Field capacity

Table 1. Slopes of the Regression Lines in Fig. 1.

Range of soil moisture	F.C. to P.W.P.	Above 50%
Ch. obtusa	2.93	−0.596
P. densiflora	1.25	−1.05
P. thunbergii	0.830	−1.05
	(%:%)	(%:%)

moisture, and the effects of excessive soil moisture were analysed for soil moisture content above 50%.

It was reported that seeds of several species of vegetable crops germinated equally within the range of readily available soil moisture[3]. However, in this experiment, germination percent decreased with decreasing soil moisture below field capacity. Experiments were divided into a few groups by soil moisture, and the mean of germination percent of each group was plotted against the mean of soil moisture of the corresponding group. The relation of germination to soil moisture expressed in this way is shown by the dotted lines in Fig. 1. For pines it seemed that germination decreased more markedly in drier soils, but this trend was not clear in *Ch. obtusa*. As the relation between soil moisture and the power that retains water to soil is not linear, the relation between germination and soil moisture may not be linear. However, the deviations from straight lines were very few and could be neglected. As the relation was practically linear, regression was determined by means of least square and shown by the solid lines in Fig. 1. The regression coefficients are shown in Table 1. The regression coefficient between germination percent and soil moisture content was least in *P. thunbergii* and largest in *Ch. obtusa*, and the difference between the two pines was very slight. *Ch. obtusa* was about three times as sensitive as pines to soil moisture stress. These trends substantiate the result of the experiments with sucrose solutions[1].

Excessive soil moisture inhibited germination of all three species but the inhibiting effect was different by species. The regressions between germination percent and soil moisture content are shown in Fig. 1 with solid lines. The slope was, as shown in Table 1, smallest for *Ch. obtusa* but there was not appreciable difference between the two pines. *Ch. obtusa* tolerated excessive soil moisture better than pines.

As the meaning of soil moisture content as percentage of dry weight is different by the properties of soil, soil moisture contents were converted into values of more general nature.

As decrease of germination by soil dryness is due to difficluties in water absorption by seeds caused by diffusion pressure deficit, soil moisture contents were converted into D.P.D. by means of a calibration curve[2]. The relations between germination percent and D.P.D. are shown in Fig. 2. Germination decreased roughly proportionally with increasing D.P.D. Regression coefficients are shown in Table 2. When D.P.D. increased by one atmosphere, germination decreased about 6% in *Ch. obtusa,* 2.5% in *P. densiflora,* and 1.5% in *P. thunbergii.*

As the harmful effect of excessive soil moisture on seed germination is probably not caused by abundant water itself but by deficient air supply to the seeds. The percentage of soil moisture to soil dry weight was converted into percentage of soil pore space occupied by air, with the aid of physical constants of the soil, and related to germination percent. As shown by Fig. 3, germination decreased with decreasing air contained in the soil pore space. The slopes are shown in Table 2. The effects of the increase of air content of the soil were least in *Ch. obtusa,* and largest in *P. thunbergii*

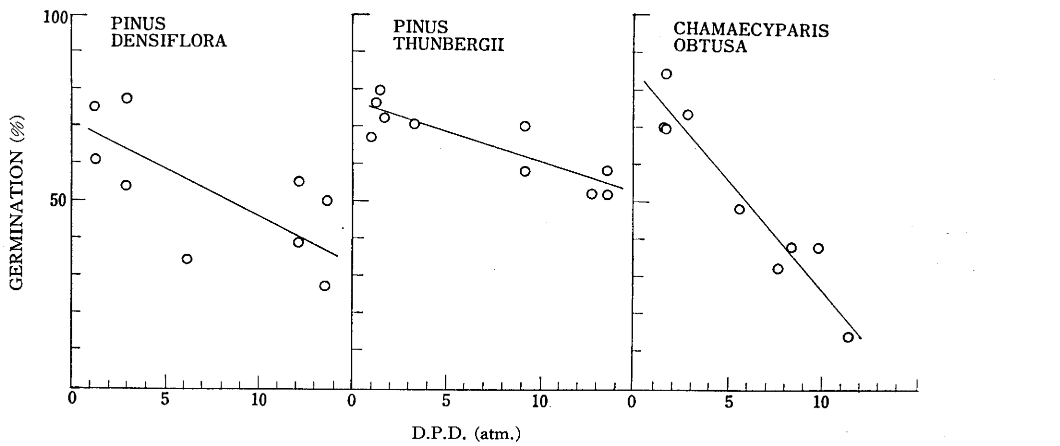

Fig. 2. Germination in relation to diffusion pressure dificit of soil moisture.

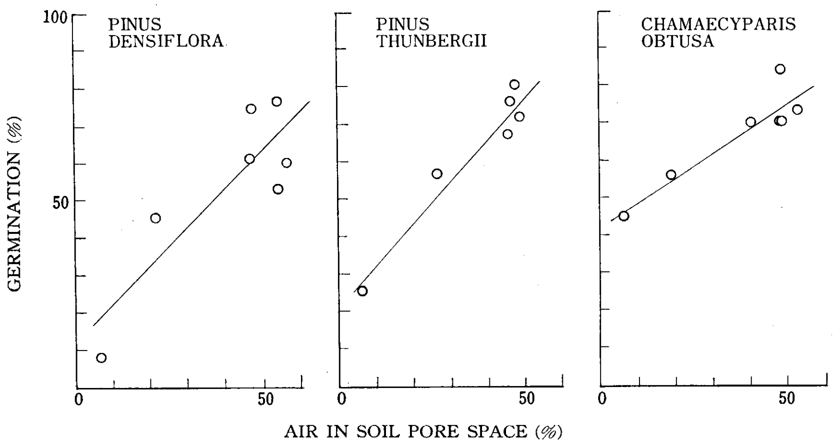

Fig. 3. Germination in relation to the air content of soil pore space.

Table 2. Slopes of the Regression Lines in Fig. 2 and 3.

Range of soil moisture	F.C. to P.W.P.	Above 50%
Ch. obtusa	−5.84	0.653
P. densiflora	−2.46	1.04
P. thunbergii	−1.58	1.13
	(%:atm.)	(%:%)

though the difference between the two pines was very slight.

The species difference in the response of germination to excessive and deficient soil moisture showed similar trend as other physiological processes. It was reported that young seedlings of *P. densiflora* were more drought-resistant than *Ch. obtusa*[2], and that aeration of culture solution was more effective to *P. densiflora* than to *Ch. obtusa* in water culture experiment with young seedlings[4].

SUMMARY

Responses of germination of seeds of *Chamaecyparis obtusa, Pinus densiflora,* and *P. thunbergii* to soil moisture conditions were compared. Linear relationships were established in relation of germination percent to diffusion pressure deficit of soil moisture and to percentage of the pore space occupied by air. By comparison of the slopes of the regression lines, it was concluded that *Ch. obtusa* was most sensitive to soil moisture stress and least sensitive to excessive soil moisture, or deficient soil air, and that *P. thunbergii* was least sensitive to soil moisture stress and most sensitive to excess of soil moisture or lack of air in the soil pore space, among the three species compared. The differences between the two pines were slight.

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