

ミズナラ天然林の種子の生産・落下・発芽(予報)

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論 文

Production, Dispersal and Germination of Acorns in Natural Stands of *Quercus crispula* —A Preliminary Report*—

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KANAZAWA, Yōichi: **Production, dispersal and germination of acorns in natural stands of *Quercus crispula*—A preliminary report** J. Jap. For. Soc. 57: 209~214, 1975 As a part of the study on natural regeneration in *Q. crispula* forest, production, dispersal and germination of the acorns were surveyed in two closed stands in 1972 and 1973. The average number of dispersed acorns amounted to 17 (1972) and 14 (1973) per m² at stand A, and 28 (1972) and 1 (1973) per m² at stand B. The germination percentage increased with increasing weight of acorns. One half of the dispersed acorns had been invaded by insect larvae. But the germinability of acorns was not affected by the invasion unless their embryos were injured. A part of mature acorns was probably consumed on the tree by several mammals and birds, and the amount of acorns produced may be estimated using the number of dispersed cups. Since it is most probable that the weight of dispersed acorns decreases with the growth of invading insect larvae, the original dry weight of acorns produced was calculated by applying the length-dry weight relation in sound acorns. The amount of acorns produced, dispersed and germinable at stand A in 1973 was estimated at 19, 14 and 4 per m² in number, and 9.34, 7.16 and 2.93 g per m² in dry weight.

金沢洋一: ミズナラ天然林の種子の生産・落下・発芽 (予報) 日林誌 57: 209~214, 1975 ミズナラ林の天然更新の研究の一環として、種子の生産・落下・発芽を日光市に近い国有林内の A・B 2 林分で 1972 年と 1973 年の 2 年にわたって調べた。1972 年の落下量は林分 A 17 個/m², 林分 B 28 個/m² で、1973 年は林分 A 14 個/m², 林分 B 1 個/m² であった。落下種子中にはシギゾウムシなどの幼虫がはいっていたので、1973 年の林分 A について幼虫のはいる前の乾重を健全な種子の長さとの関係から推定すると 7.16 g/m² となった。またかく斗の落下数から樹上で生産された種子量は乾重で 9.34 g/m² と推定された。発芽率は軽い種子ほど低く、種子の重さが増すにつれて高くなった。また種子中の幼虫が胚さえおかさなければ種子は発芽すると考えられた。1973 年の林分 A の種子の生産量・落下量・発芽能力をもつ種子量はそれぞれ個数では 19 個/m²・14 個/m²・4 個/m² となり、乾重では 9.34 g/m²・7.16 g/m²・2.93 g/m² となった。

I. Introduction

In the cool temperate zone in Japan, *Quercus crispula* is an important deciduous forest tree species. During a year of abundant seed production, the acorns are spread all over the floor of *Q. crispula* forests. However, the acorns disappear during the winter and few seedlings grown from them are found in the next spring.

There have been many studies concerning disappearance of acorns or seedlings in oak forests in

Europe and U. S. A. (WATT, 1919; DOWNS & MC-QUILKIN, 1944; OVINGTON & MACRAE, 1960; MEL-LANBY, 1968; DASMANN, 1971; GOODRUM *et al.*, 1971). The studies indicated that the disappearance is related not only to inorganic factors such as light, nutrients etc., but also to biotic factors. Among the latter the effect of animals may be important, because acorns are eaten largely by several birds, mammals and insect larvae. Therefore, in the study of natural regeneration of *Q. crispula* at initial stages, it is necessary to take the effect of

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animals into consideration.

The present paper deals with the production, dispersal and germination of the acorns, and the effect of insect larvae on germination of the acorns.

II. Study area

The study area is part of the National Forest of Utsunomiya District Forest Office and is situated near Nikkô City (Fig. 1).

In this area *Q. crispula* forests are found on slopes from about 800 m to 1600 m in altitude. Production, dispersal and germination of acorns were studied in 1972 and 1973 on two natural stands, A and B, both at an altitude of 1300 m. General descriptions of these stands are summarized in Table 1. The forest floor of the *Q. crispula* stand in this area is usually covered with *Sasa nipponica* like the stands A and B.

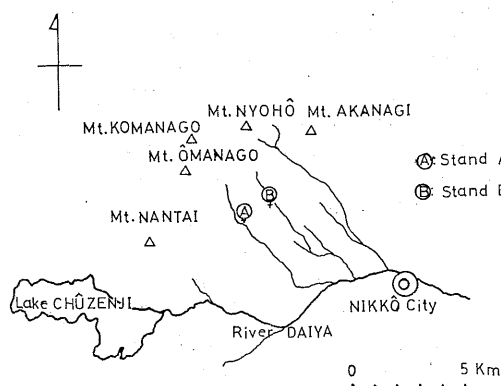


Fig. 1. Location of the study stands

Table 1. Description of stands A and B

stand	A	B
Number of trees per ha	540	470
Averaged D.B.H. in cm	24.7	28.6
Basal area in m ² per ha	26	30
Inclination	20°	20°
Direction of the slope	south	east
Floor vegetation	<i>Sasa nipponica</i>	<i>Sasa nipponica</i>

III. Methods

1. Seed-traps and measurement of samples trapped

To estimate the amount of acorn dispersal in the stands A and B, 42 traps were arranged in a square—6 rows across the slope and 7 rows down along the slope. The traps in each row were placed at a distance of 7 m from each other. The opening of the trap was circular in shape and 0.5 m² in area. A wire netting of 2.4 cm mesh was fitted into the middle between the opening and the bottom of the trap to protect the dispersed acorns from invading animals. Since the mesh must be large enough to

allow acorns to pass through the wire netting, this mesh was not small enough to keep off small mammals (TAGAWA, 1969).

The traps were placed in late August, 1972, and in late May, 1973. Collection of the sample was made in 1972 at intervals of two weeks, in 1973 at monthly intervals from May to August, and at two week intervals from September to November when the acorn dispersal culminated. To avoid destruction by snow pressure, the traps were withdrawn in winter.

Samples collected were carried back to the laboratory and classified into mature acorns, immature acorns, cups, leaves, twigs, woody pieces and others. They were counted and their fresh weight was measured. A part of the mature acorns and all of the immature ones and cups were dried at 80°C to estimate dry weight. The rest of the mature acorns were used in 1972 for germination testing, and in 1973 for examining invasion of insect larvae by means of cutting and soft X-ray radiographs.

2. Distinguishing mature and immature acorns

The acorn samples varied widely in size, from smaller acorns fully covered by cup to larger ones of 3 g in fresh weight. SHAW (1968) distinguished mature acorns of *Q. petraea* by cups whose rims have the angle above 90°. However, in *Q. crispula* the acorns with cups having rims of less than 90° were observed to germinate on the forest floor. In this study, the acorns with apex protruding from the cups were classified as mature acorns. In the following descriptions, the terms "acorn" and "cup" will be used instead of "mature acorn" and "cup of mature acorn", respectively.

3. Germination tests

In 1972, after soaking, acorns in water for five days, the germination test was made in petri dishes filled with washed sand. The test was run for two months at ca. 22°C in the dark. The germination percentage of this test gave probably a high value, because insect larvae in the acorns were killed by soaking, thus diminishing their effect on germination. In 1973, acorns collected from the floor of stand A and another stand near A were used for germination testing, and they were not soaked. The test was continued for two months using agar medium. The number of acorns used for germination testing was 314 in 1972 and 260 in 1973.

To examine effect of insect larvae in the acorns on the development of seedlings, the acorns collected from stands at lower altitude were sown in trays filled with soil in 1973. Four trays, sown with about 100 acorns each, were placed for two months

in a green house.

IV. Results and Discussion

A. Acorn production

1. Acorn dispersal

The amounts of dispersed acorns, immature ones and cups are shown in Table 2. The amounts differed with years and with stands. At stand B the difference in acorn dispersal between years was remarkable. IMADA (1972) reported that a large crop of acorns of *Q. crispula* occurred with intervals of four or five years in Hokkaido. According to IMADA, the crop size varied from 1 to 5 thousand in a poor year, 17 to 28 thousand in an average year, and 29 to 38 thousand acorns per ha in a good year at stands of 132 and 135-year-old. Crop size of stand A seems to have been normal both in 1972 and 1973, while that of stand B was somewhat good in 1972, and poor in 1973.

Table 2. Amount of acorns dispersed

year	1972		1973	
	No./m ²	g d.wt./m ²	No./m ²	g d.wt./m ²
(stand A)				
Acorns	16.82±3.38*	8.5	14.38±3.44*	6.4
Cups	18.10±4.53*	4.6	18.67±4.52*	5.9
Immature acorns	13.98	2.2	34.95	3.4
(stand B)				
Acorns	28.01±7.37*	21.3	0.95±0.54*	0.2
Cups	32.96±8.37*	8.2	1.29±0.69*	0.3
Immature acorns	17.57	1.9	17.67	0.8

* means at confidence coefficient of 95%

The number of dispersed cups was larger than that of acorns and fluctuated similarly to acorn dispersal.

The number of immature acorns at stand A in 1973 was more than twice as much as in 1972, while the number of acorns did not differ greatly between 1972 and 1973, i.e. the ratio of immature to mature acorns was higher in 1973. Similar difference in the ratio was also found at stand B. This difference between years may be partly due to lack of collection before August, 1972, because abundant immature acorns fell in July, 1973.

In order to estimate the amount of acorn dispersal in a good crop year and the interval of good crop years, long term studies will be required.

2. Variation of fresh weight of acorns

Figure 2 illustrates the frequency distribution of fresh weight of acorns collected from traps. The frequency distribution for stand B in 1973 is not shown because the crop was poor. The frequency distribution of fresh weight of acorns differed with stands and with years. Acorns from stand A distributed more frequently in smaller weight

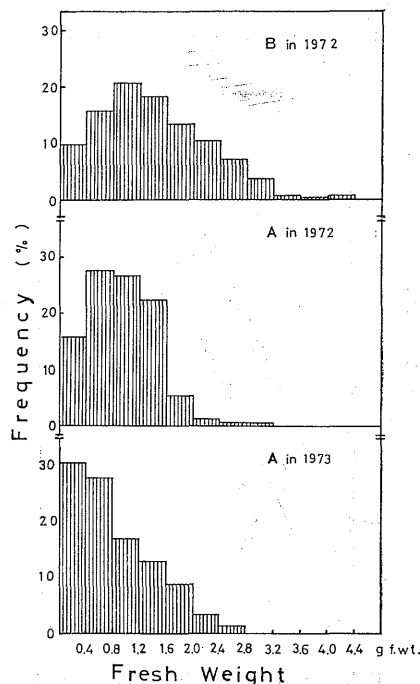


Fig. 2. Frequency distribution of fresh weight of acorns

A: stand A, B: stand B

classes than those from stand B.

3. Estimation of acorn production

a. Estimation of the number of acorns produced

Since the acorn is one of the nutrient foods preferred by several birds and mammals, there is a possibility that a part of acorns was taken away from the tree before dispersal.

There are several methods for estimating acorn production. In the methods based on the allometric relations in bearing trees, the felling of sample trees is usually needed, but this method is not applicable to this study. Therefore, the amount of acorn production was estimated on an assumption that the number of dispersed cups was equal to the number of acorns produced (SHAW, 1968). There still remains the problem that some acorns are possibly carried away with cups.

The estimated number of the acorns produced, based on the premise that they are equal to those of the cups, was 18.10 acorns per m² in 1972 and 18.67 in 1973 for stand A, and 32.96 in 1972 and 1.29 in 1973 for stand B. But the difference of these values from dispersed acorns in Table 2 was not significant at 95% confidence level.

b. Estimation of the dry weight of acorns produced

The acorns collected include those invaded by

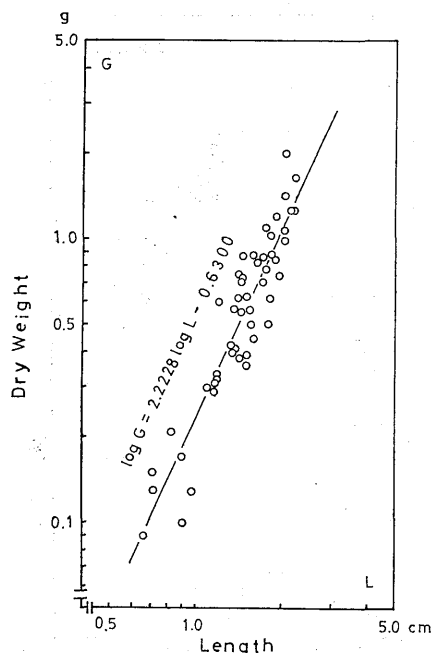


Fig. 3. Relation between dry weight and length in sound acorns at stand A in 1973

insect larvae. Since it is most probable that the weight of invaded acorns decreases with the growth of the larvae, the estimation of the original dry weight of total acorns collected at stand A in 1973 was attempted by application of the relation between length and dry weight in sound acorns (Fig. 3). The relationship was represented by the following equation:

$$\log G = 2.2228 \log L - 0.6300$$

where G is dry weight in g, and L is length in cm. By measuring the length of total acorns collected, dry weight of dispersed acorns as sound ones was calculated as 7.16 g per m^2 at stand A in 1973. The calculated value was 1.13 times as much as the measured one.

A multiplication of mean dry weight of a sound acorn by the number of dispersed cups produces total dry weight of acorns on the tree. Acorn production in dry weight amounted to 9.34 g per m^2 at stand A in 1973. If the birds or the mammals prefer larger acorns, the frequency distribution of the size of dispersed acorns will deviate to smaller range as compared with that of total acorns produced. The above estimation may result in an underestimation due to this bias.

B. Germination of acorns

1. Germination percentage in relation to size of acorn

The results of germination tests are shown in

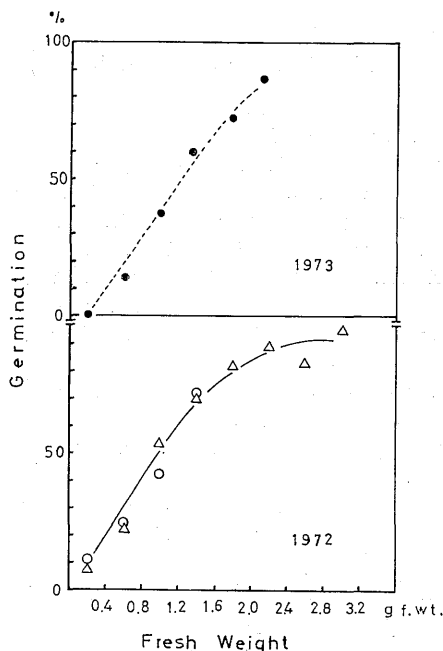


Fig. 4. Germination percentage of acorns sampled from traps at stands A and B in 1972, and acorns from the floor of stand A and another stand near A in 1973

△: stand B in 1972, ○: stand A in 1972,
●: stand A and another stand near A

Fig. 4 in relation to acorn size. The number of acorns tested in each class was between 34 and 85 at stand B, between 36 and 56 at stand A in 1972, and between 17 and 39 at stand A in 1973. As seen in Fig. 4, the germination percentage increased with weight. There was no difference in the relation between the stands in 1972. In 1973 the germination percentage was lower than in 1972 over the whole range of acorn size, which may result from the fact that acorns used for the test in 1973 were collected from the floor.

2. Number of dispersed germinable acorns

Using the relation in Fig. 4 and the frequency distribution of fresh weight in Fig. 2, the germination percentage of total dispersed acorns was estimated at 43.1% for stand A and at 57.9% for stand B in 1972. The number of dispersed germinable acorns was calculated as 7.09 per m^2 for stand A and 16.22 per m^2 for stand B from the above percentage. The percentage of germinable acorns was estimated at 27.3% in 1973 for stand A. The number of them per m^2 was calculated as 3.93 acorns.

Dry weight of germinable acorns of each size class was calculated from the germination percentage and dry weight of acorns for each class at

stand A in 1973. The percentage of germinable to collected acorns in dry weight was 40.9%, which means 2.93 g in dry weight per m² (Table 3).

3. Effect of insect larvae on germination

Insect larvae were found in many acorns. The

Table 3. Dry weight of germinable acorns at stand A in 1973

Class (g f. wt./acorn)	Total dry weight of collected acorns (g)	Germination percentage	Dry weight of germinable acorns (g)
≤0.4	16.58	0	0
0.4~0.8	35.98	15	5.40
0.8~1.2	32.92	36	11.85
1.2~1.6	27.17	56	15.22
1.6~2.0	22.46	72	16.17
2.0~2.4	8.86	84	7.44
2.4~2.8	6.32	86	5.44
Total	150.29 (100%)		61.52 (40.9%)*

* ratio of germinable to collected acorns in dry weight in percentage

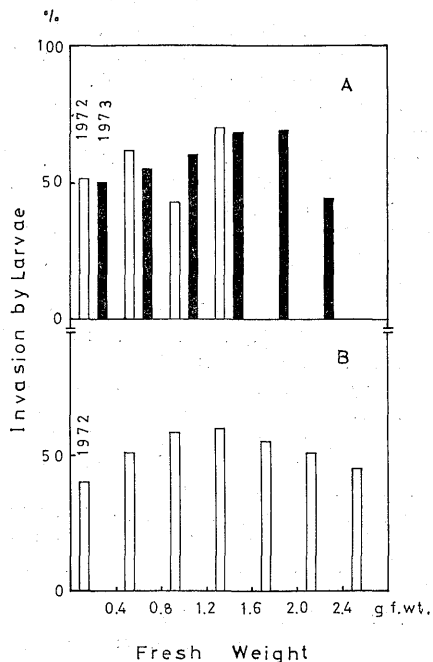


Fig. 5. Percentage of acorns invaded by insect larvae

A: stand A, B: stand B

percentages of invaded acorns to tested acorns are presented in Fig. 5 in relation to acorn size. The number of tested acorns in each class was between 36 and 41 for stand A, between 35 and 86 for stand B in 1972, and between 9 and 91 for stand A in 1973. The larvae which crawled out from the acorns soaked in water for stimulating germination in 1972 were identified as *Curculio arakawai*, *C. conjugal* and *C. dentipes*.

About one half of the acorns tested had been invaded in each class. Among classes the percentage in medium class appears to be highest for both stands. This trend may not be reliable because only a small number of acorns were tested in light or heavy class.

The percentage of invaded acorns in total germinated as well as in total ungerminated acorns in 1972 was calculated from data Figs. 4 and 5 and shown in Fig. 6. There was no significant difference in the percentage of invaded acorns between germinated and ungerminated groups. As mentioned above, in the germination test in 1972, the larvae in acorns were killed as the result of soaking in water, and their effect on germination was diminished. To examine their effect on germination and subsequent development, the seedlings were grown for two months after germination. The results are shown in Table 4.

Relatively large acorns were used in this test,

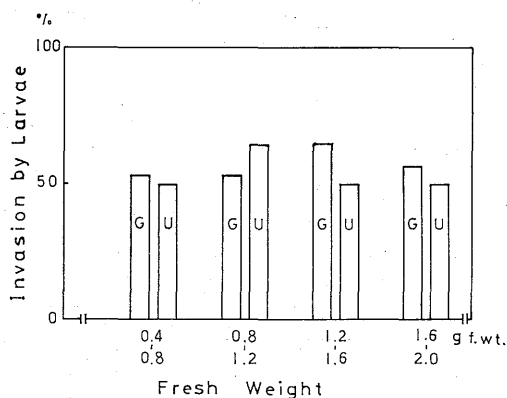


Fig. 6. Percentage of acorns invaded by insect larvae in germinated (G) and in ungerminated acorns (U) at stand B in 1972

Table 4. Effect of insect larvae on germination of acorns

Lot	Number of acorns used	Germination percentage	Percentage of invaded acorns	Germination percentage of invaded acorns	Percentage of acorns invaded in lower part to total invaded acorns
I	100	97 (93)	37	95 (86)	100
II	98	97 (96)	53	94 (92)	90
III	100	100 (99)	30	100 (100)	100
IV	100	95 (92)	50	90 (86)	88

In the figures in parentheses, the acorns which died after germination were excluded

and the germination percentage was higher than 90%. The percentage of acorns invaded by the larvae was between 30% and 53%. The germination percentage of acorns invaded was between 90% and 100%, and between 86% and 100% unless the acorns died after germination were included. The acorns, whose cotyledons had been eaten up by the larvae, did not germinate. But acorns injured only partly by the larvae germinated and developed into the seedlings as vigorously as sound ones did.

To study the effect of injury by the larvae, the acorns were divided into the following three groups by area of injury: with upper part damaged at the apex, with middle part damaged, or with lower part damaged at the base.

The injuries to the upper part, embryonic tissues, were fatal, while those to the middle and/or lower part were not serious, except for smaller acorns in which sufficient food was not left for developing into seedling.

C. The amount of acorns produced, dispersed and germinable at stand A in 1973

The process from production to germination of acorns at stand A in 1973 is summarized in Table 5. The germinable acorns was 21% of produced acorns and 3.93 per m² in number, 31% and 2.93 g per m² in dry weight. This amount may decrease before germination on the forest floor due to invasion by animals. MARUYAMA *et al.* (1970) reported an instance that the acorns of *Q. crispula* occupied about half of the stomach contents of deer living near the study area. The writer also observed the disappearance of all of the artificially dispersed acorns in one night, which was probably the work of voles or mice. The number of mature trees at stand A was 540 per ha, which means only 0.054 acorns per m² will grow into mature trees, though

Table 5. Amount of acorns produced, dispersed and germinable at stand A in 1973

	No./m ²	(%)	g d.wt./m ²	(%)
Produced	18.67	(100)	9.34	(100)
Dispersed	14.38	(77)	7.16	(77)
Germinable	3.93	(21)	2.93	(31)

a large amount of acorns are being produced annually.

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