

# Botanical Studies in the Genus *Oryza*

## II. Germination Behaviour

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Germination of seeds is a complex physiological phenomenon. It is determined by a number of internal and external factors, such as seed age, soil and water condition, temperature and other factors.

Using *Oryza* for his experiments, the writer studied the germination behaviour, including the number of days from sowing to germination, germination process, duration and germinability and germination percentage, in the hope to obtain a useful information on the phylogenetic differentiation of the genus. A preliminary report was already published in 1960 (1).

### Materials and Method

One thousand seven hundred and eighty nine strains belonging to 20 species of the genus *Oryza*, including 2 cultivated and 18 wild species, were used in the present investigation. Most of them were collected by the members of the National Institute of Genetics and some were obtained from foreign workers.

Enumeration of the species, their distribution and chromosome number were given in Table 1 of the previous paper (4). Code number and their origin will be described in detail in each chapter. However, 5 species used in the previous paper (4), *i. e.*, *O. grandiglumis*, *O. meyeriana* subsp. *abromeitiana*, *O. longiglumis*, *O. schlechteri* and *O. coarctata*, are omitted, because the first three set only a few seeds; the seeds of the next one did not germinate and those of the last one had very short germinability. In all the experiments, the seeds were used at the time when the dormancy was completely finished.

Seeds of wild and cultivated species were all husked in order to get uniform germination and were sterilized with 0.1 % Uspulun solution for 4 to 6 hours. Then, they were washed twice in sterilized water and incubated at 30°C in Petri dishes on filter paper. When the coleoptile broke out through the seed coat, the seed was considered as germinated. Forty to 400 grains of each strain were used for each experiment. The experiments were made five to ten times for each strain. Average values were calculated for the germination of each strain. Observations were made every day.

In long term experiments, seeds were washed twice in sterilized water and transferred to new Petri dishes and new filter paper at one week intervals, unless otherwise stated.

## Results

### 1. *Cultivated species*

#### i: *O. sativa* L.

In Japanese strains, germination started within 1 day after sowing. Afterwards the percentage rapidly increased within 2 days. In strains from the Philippines, Viet Nam and Java, germination started within 2 days after sowing. Afterwards the percentage rapidly increased within 2 days. In strains from Ceylon, Burma, India and Africa, germination started within 2 days after sowing. Afterwards the percentage increased within 3 days. In strains from Malaya, germination started within 2 days after sowing. Afterwards the percentage gradually increased within 7 days (Table 1 and Fig. 1). The figures of the table show the percentages.

Table 1. Germination behaviour of *O. sativa*. Forty to 400 grains of each strain were used.

| Origin      | No. of days after sowing |    |     |     |     |    |    |     | No. of strains tested |
|-------------|--------------------------|----|-----|-----|-----|----|----|-----|-----------------------|
|             | 1                        | 2  | 3   | 4   | 5   | 6  | 7  | 8   |                       |
| Japan       | 16                       | 81 | 100 |     |     |    |    |     | 52                    |
| Philippines | 0                        | 96 | 100 |     |     |    |    |     | 81                    |
| Viet Nam    | 0                        | 47 | 96  | 100 |     |    |    |     | 37                    |
| Java        | 0                        | 71 | 97  | 100 |     |    |    |     | 30                    |
| Ceylon      | 0                        | 46 | 73  | 91  | 100 |    |    |     | 24                    |
| Burma       | 0                        | 77 | 85  | 93  | 100 |    |    |     | 205                   |
| India       | 1                        | 78 | 84  | 97  | 100 |    |    |     | 479                   |
| Africa      | 0                        | 81 | 86  | 96  | 100 |    |    |     | 245                   |
| Malaya      | 0                        | 73 | 75  | 90  | 97  | 97 | 99 | 100 | 63                    |
| Average     | 2                        | 81 | 87  | 96  | 99  | 99 | 99 | 100 | 1,216<br>(Total)      |

#### ii: *O. glaberrima* STEUD.

In strains of Sierra Leone, germination started within 2 days after sowing and the percentage increased until it reached more than fifty % within 1 day. Afterwards it gradually increased within further six days. In strains from Sénégal, germination started within 1 day. Afterwards the percentage steadily increased within 6 days. In strains from other countries, germination started within 1 day, and the percentage increased till more than 80 % within 1 day. Afterwards it gradually increased within five days (Table 2 and Fig. 2).

Germination behaviour of *O. sativa* and *O. glaberrima* are almost similar in their averages (Fig. 3).

### 2. *Wild species*

#### i: Short term experiment

Germination behaviour of 18 wild species is summarized in Table 3. The species are

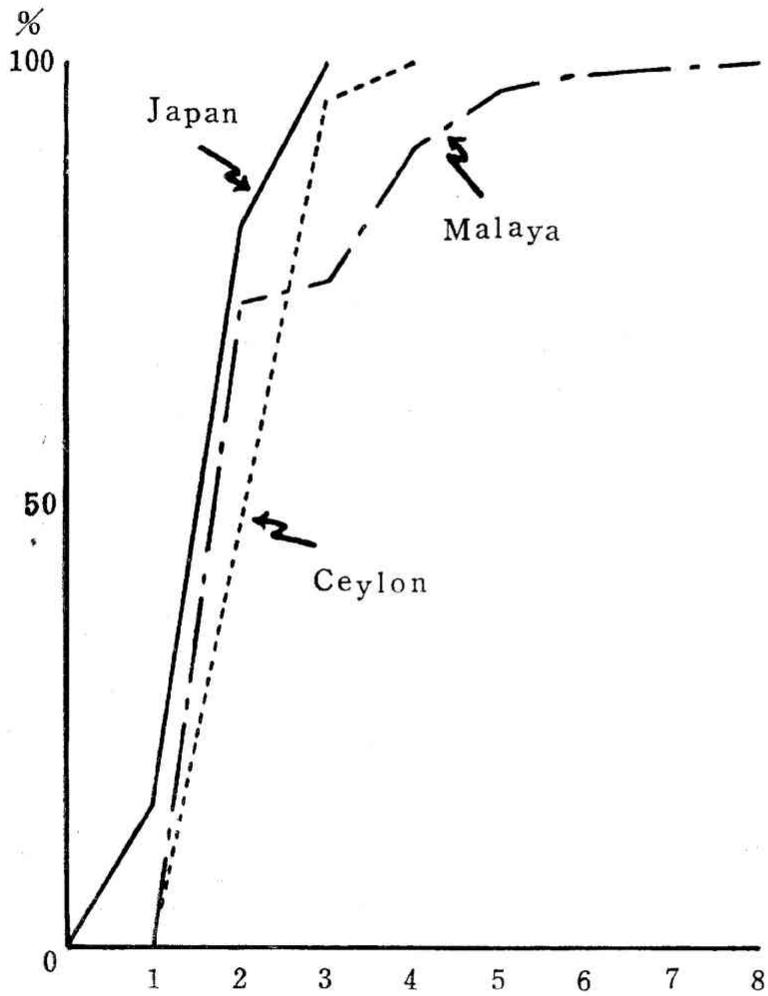


Fig. 1. Germination processes of *O. sativa*

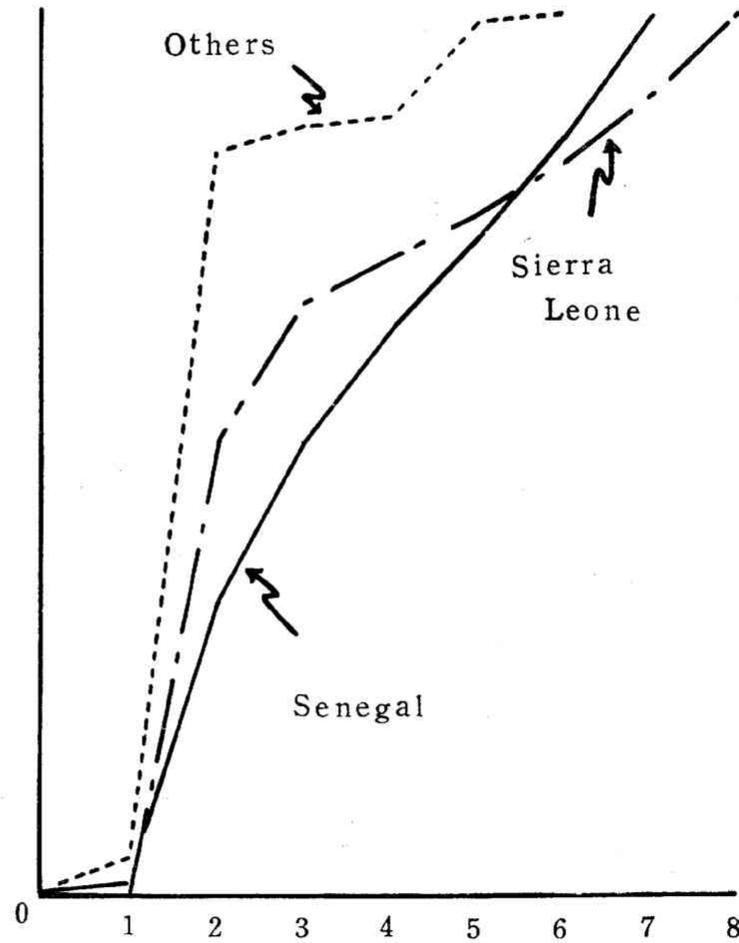


Fig. 2. Germination processes of *O. glaberrima*

Table 2. Germination behaviour of *O. glaberrima*. Forty to 400 grains of each strain were used.

| Origin       | No. of days after sowing |    |    |    |    |     |     |     | No. of strains tested |
|--------------|--------------------------|----|----|----|----|-----|-----|-----|-----------------------|
|              | 1                        | 2  | 3  | 4  | 5  | 6   | 7   | 8   |                       |
| Sénégal      | 1                        | 33 | 51 | 64 | 74 | 86  | 100 |     | 31                    |
| Sierra Leone | 0                        | 52 | 67 | 72 | 77 | 83  | 91  | 100 | 22                    |
| Others       | 4                        | 84 | 87 | 88 | 99 | 100 |     |     | 278                   |
| Average      | 3                        | 77 | 83 | 85 | 96 | 98  | 99  | 100 | 331<br>(Total)        |

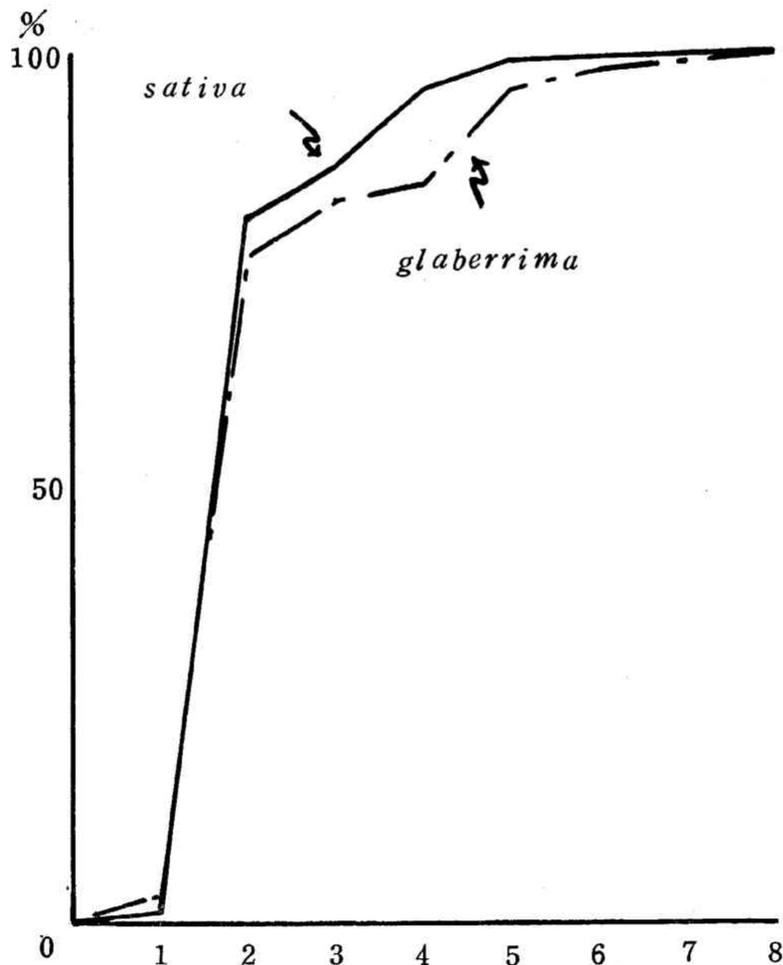


Fig. 3. Germination processes of *O. sativa* and *O. glaberrima*

arranged in taxonomical order. The experiments described in this chapter were continued until nine days. As the table shows, all species used could germinate no less than hundred per cent of all sown grains within 9 days.

*Interspecific variations:* The species could be classified into five groups with respect to their germination behaviour according to the data obtained. First group: Germination

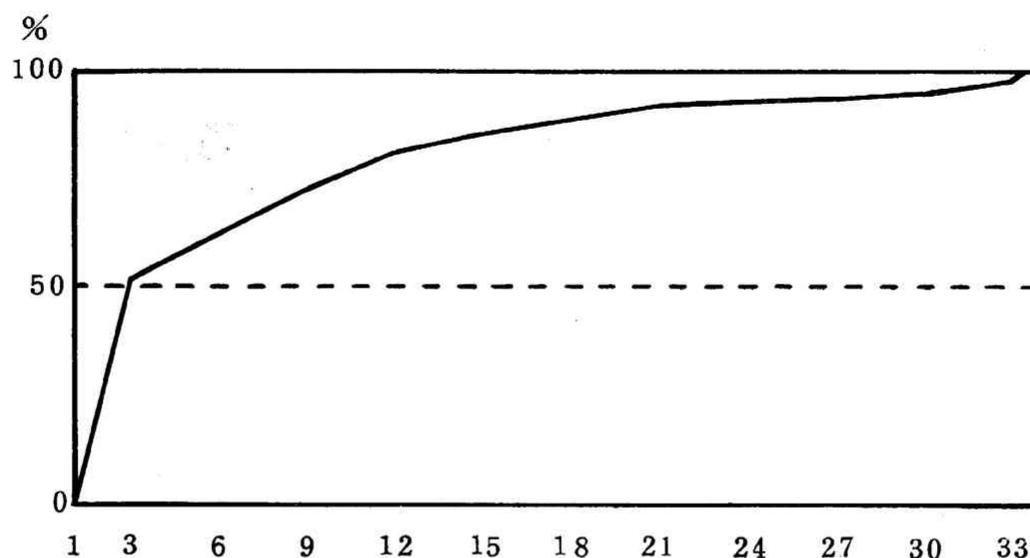


Fig. 4. Germination behaviour of wild *Oryza* species in the view point of final dates ( $\times 10$ )

Table 3. Germination behaviour of wild species. Forty to 400 grains of each strain were used.

| Species                                     | No. of days after sowing |    |    |    |    |    |    |    |    | No. of strains tested | Group No. |
|---------------------------------------------|--------------------------|----|----|----|----|----|----|----|----|-----------------------|-----------|
|                                             | 1                        | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |                       |           |
| <i>O. sativa</i> var. <i>spontanea</i>      | 2                        | 39 | 49 | 59 | 62 | 63 | 64 | 67 |    | 112                   | 4         |
| <i>O. perennis</i>                          | 1                        | 61 | 71 | 74 | 76 | 77 | 78 | 79 |    | 49                    | 4         |
| <i>O. barthii</i>                           | 0                        | 60 | 70 | 75 | 80 |    |    |    |    | 4                     | 2         |
| <i>O. stapfii</i>                           | 0                        | 85 |    |    |    |    |    |    |    | 2                     | 1         |
| <i>O. breviligulata</i>                     | 0                        | 11 | 21 | 31 | 38 | 39 | 39 | 43 |    | 6                     | 5         |
| <i>O. officinalis</i>                       | 0                        | 34 | 47 | 62 | 66 | 69 | 71 | 72 |    | 18                    | 4         |
| <i>O. australiensis</i>                     | 15                       | 85 | 93 | 93 | 93 | 93 | 93 | 93 | 94 | 3                     | 4         |
| <i>O. minuta</i>                            | 0                        | 36 | 52 | 57 | 64 |    |    |    |    | 4                     | 2         |
| <i>O. malampuzhaensis</i>                   | 0                        | 63 | 70 | 80 |    |    |    |    |    | 2                     | 2         |
| <i>O. eichingeri</i>                        | 0                        | 43 | 71 | 74 |    |    |    |    |    | 3                     | 2         |
| <i>O. latifolia</i>                         | 2                        | 49 | 57 | 61 | 62 |    |    |    |    | 12                    | 2         |
| <i>O. alta</i>                              | 0                        | 62 | 64 | 68 |    |    |    |    |    | 3                     | 2         |
| <i>O. punctata</i>                          | 0                        | 30 | 50 | 80 |    |    |    |    |    | 1                     | 2         |
| <i>O. meyeriana</i> subsp. <i>granulata</i> | 0                        | 0  | 0  | 18 | 32 |    |    |    |    | 2                     | 3         |
| <i>O. meyeriana</i> subsp. <i>meyeriana</i> | 0                        | 27 | 58 | 67 | 77 | 80 | 82 | 83 |    | 15                    | 4         |
| <i>O. ridleyi</i>                           | 0                        | 43 | 50 | 53 | 63 | 63 | 67 |    |    | 1                     | 4         |
| <i>O. brachyantha</i>                       | 0                        | 7  | 7  | 13 | 24 | 25 |    |    |    | 4                     | 3         |
| <i>O. subulata</i>                          | 0                        | 60 | 65 |    |    |    |    |    |    | 1                     | 1         |

occurred within 2-3 days after sowing. Afterwards no germination occurred. *O. stapfii* ROSCHEV. and *O. subulata* NEES belong to this group. Second group: Germination started within 2-3 days after sowing, and afterwards the percentage gradually increased within 3 days. Final percentage was more than fifty % of all sown grains. *O. barthii* A. CHEV., *O. minuta* PRESL, *O. malampuzhaensis* KRISH. et CHAND., *O. eichingeri* PETER, *O. latifolia*

DESV., *O. alta* SWALLEN and *O. punctata* KOTSCHY belong to this group. Third group: Germination started within 2-4 days after sowing, and afterwards the percentage gradually increased within 3 days. Final percentage was less than one third of the total of sown grains. *O. meyeriana* subsp. *granulata* TATEOKA and *O. brachyantha* A. CHEV. et ROEHR. belong to this group. Fourth group: Germination started within 1-2 days after sowing, and afterwards the percentage gradually increased within 7 days. Final percentage was more than sixty % of the total of sown grains. *O. sativa* var. *spontanea* ROSCHEV., *O. perennis* MOENCH, *O. officinalis* WALL., *O. australiensis* DOMIN, *O. meyeriana* subsp. *meyeriana* TATEOKA and *O. ridleyi* HOOK. belong to this group. Fifth group: Germination process was similar to that of the fourth group, but final percentage was less than fifty % of the total of sown grains. *O. breviligulata* A. CHEV. et ROEHR. belong to this group.

*Intraspecific variations*: *O. sativa* var. *spontanea*: One hundred and twelve strains, *i. e.*, 56 of India proper, 1 of Formosa, 3 of Thailand, 3 of Malaya, 9 of Burma, 1 of Ceylon, 39 of Sikkim and Assam, were used. Many strains from Sikkim and Assam and two of Thailand seemed to belong to the second group according to germination behaviours. *O. perennis*: Also some from Sikkim and Assam seemed to belong to the second group, *i. e.*, germination occurred relatively earlier than in strains from other countries. *O. officinalis*: Strains collected in Borneo showed wide variation, but others showed no remarkable intraspecific variations. *Other species*: Sixty three strains belonging to 15 species showed a few intraspecific variations, *i. e.*, they had a uniform pattern as to germination behaviour.

## ii: Long term experiment

As mentioned above, seeds of all wild species used could germinate at less than hundred per cent of the total of sown grains within 9 days. Then, long term experiments were made, using 50 strains belonging to 11 species to make clear whether grains that did not germinate within 9 days after sowing could germinate after such period. The experiments were continued during one year. Experimental data obtained are shown in Tables 4-8 and Figs. 4-6. Strains are arranged in order as to the final day after which no grain germinates, in disregard of the species order of Tables 4-8 and Figs. 4 and 6, and in regard of species order of Fig. 5.

According to the data obtained, the number of days until complete germination was in the following order; 334, 330, 319, 269, 207, 199, 154, 154, 148, 130, 119, 119, 106, 99, 90, 85, 84, 76, 61, 49, 48, 36, 35, 33, 32, 29, 29, 28, 28, 27, 27, 24, 21, 21, 21, 20, 17, 17, 16, 16, 16, 16, 16, 16, 15, 15, 15, 13 (Tables 4-8). However, as shown in Fig. 4, 50.7 % of all grains completed germination within 30 days, 61.8 % within 60 days, 72.0 % within 90 days, 80.2 % within 120 days, 85.3 % within 150 days, 88.1 % within 180 days, 92.1 % within 210 days, 92.4 % within 240 days, 94.0 % within 270 days, 94.4 % within 300 days, 98.0 % within 330 days and 100.0 % within 334 days. Eventually, half of them finished germination within 30 days, and three fourths within only 100 days. The last one fourth gradually continued for further 234 days.

*Intraspecific variations*: Intraspecific variations found in the final dates are shown in Fig. 5. In this figure, species number is as follows; 1, *O. sativa* var. *spontanea* ROSCHEV.; 2, *O. perennis* MOENCH; 3, *O. breviligulata* A. CHEV. et ROEHR.; 4, *O. minuta* PRESL; 5, *O. malampuzhaensis* KRISH. et CHAND.; 6, *O. latifolia* DESV.; 7, *O. meyeriana* subsp. *granulata* TATEOKA; 8, *O. meyeriana* subsp. *meyeriana* TATEOKA; 9, *O. ridleyi* HOOK.; 10, *O. brachyantha* A. CHEV. et ROEHR., 11, *O. subulata* NEES.

Table 4. Germination of wild *Oryza* species in long term experiments (I-1).  
Forty to 400 grains of each strain were used.

| Strain | No. of days after sowing |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
|--------|--------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|
|        | 1                        | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 | 32 |    |  |
| W0120  | 30                       | 76 |    |    | 80 |    |    |    |    | 81 | 82 | 87 | 88 |    |    |    |    |    |    |    | 89 |    |    |    |    |    |    |    |    |    |    |  |
| W0149  | 0                        | 20 | 25 | 34 | 37 | 39 |    | 42 |    |    |    | 43 | 44 | 56 | 57 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 58 |  |
| W0108  | 9                        | 20 | 29 |    | 30 |    |    |    |    | 32 |    | 35 | 37 |    |    |    | 38 |    |    |    |    |    |    |    |    |    |    |    |    |    | 39 |  |
| W0023  | 0                        | 20 |    | 30 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0107  | 0                        | 20 | 28 | 31 | 38 | 47 | 50 | 51 | 57 |    | 58 |    |    |    | 74 | 75 |    |    |    |    |    |    |    |    | 77 |    |    |    |    |    |    |  |
| W0636  | 0                        | 47 | 67 | 68 | 70 |    | 71 |    |    |    | 75 | 76 |    |    |    |    |    |    |    |    |    |    | 87 | 92 |    |    |    |    |    |    |    |  |
| W0148  | 0                        | 5  | 27 | 32 | 33 | 45 |    | 49 | 60 |    |    | 61 | 63 | 64 | 65 | 69 | 71 | 72 |    |    |    | 73 | 74 |    |    | 75 |    |    | 76 |    |    |  |
| W0121  | 0                        | 26 |    | 78 | 82 |    |    |    |    |    |    |    |    | 84 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 86 |    |  |
| W0145  | 0                        | 60 | 69 |    |    | 73 | 81 |    |    |    |    |    |    |    | 83 |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 84 |    |  |
| W0106  | 0                        | 2  | 6  | 22 |    | 24 | 25 |    | 30 |    | 31 |    |    | 37 | 39 | 40 |    | 41 | 42 | 45 |    |    |    | 46 | 47 |    |    |    |    |    |    |  |
| W0128  | 0                        | 45 | 55 | 57 |    | 58 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 75 | 82 |    |    |    |  |
| W0003  | 0                        | 0  | 0  | 0  | 0  | 9  |    |    | 13 |    | 16 | 19 | 23 |    | 26 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0169  | 0                        | 10 |    | 20 | 30 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0119  | 0                        | 30 | 60 | 82 | 87 | 90 | 92 | 93 |    |    |    |    |    | 95 | 99 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0034  | 0                        | 21 | 82 | 96 | 98 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0132  | 0                        | 47 | 72 | 84 | 85 | 86 | 87 |    | 88 | 89 | 90 | 91 |    | 92 | 93 | 94 |    |    |    |    | 95 | 96 |    |    |    | 97 |    |    |    |    |    |  |
| W0150  | 3                        | 23 | 43 | 44 |    | 45 | 46 | 48 | 50 |    |    | 79 | 80 | 81 |    |    |    | 82 |    |    |    |    |    |    |    |    |    |    |    | 83 |    |  |
| W0042  | 0                        | 10 | 45 | 69 | 73 | 79 | 80 |    | 85 |    |    |    |    |    | 86 |    |    |    |    |    | 87 |    |    |    |    | 89 | 92 |    |    |    |    |  |
| W0004  | 0                        | 0  | 0  | 0  | 0  | 0  | 20 |    |    |    | 24 |    | 28 |    | 44 | 60 | 64 |    | 68 |    |    | 72 | 76 | 80 |    |    |    |    | 84 |    |    |  |
| W0144  | 0                        | 61 |    | 74 |    | 77 | 97 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0152  | 0                        | 24 | 25 | 82 |    |    |    | 83 |    |    |    |    |    | 85 | 91 |    |    |    |    |    | 92 | 95 |    |    |    |    |    |    |    |    |    |  |
| W0168  | 0                        | 20 | 40 | 60 | 70 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| W0009  | 0                        | 15 | 22 | 65 | 68 | 69 |    |    | 71 | 72 |    |    |    | 74 |    |    |    |    |    |    | 77 | 78 |    |    |    |    | 82 |    |    |    |    |  |
| W0005  | 0                        | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 7  |    | 23 |    | 31 |    | 38 | 46 |    | 54 |    |    |    |    | 61 |    |    |    |    |    |    |    |    |  |
| W0146  | 0                        | 23 | 47 | 76 | 86 |    |    |    |    |    |    |    |    |    | 87 |    |    |    |    |    |    |    |    |    |    |    |    | 93 |    | 95 |    |  |



Table 6. Germination of wild *Oryza* species in long term experiments (I-3).

| Strain | No. of days after sowing |    |    |    |    |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
|--------|--------------------------|----|----|----|----|----|----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
|        | 79                       | 80 | 81 | 84 | 85 | 87 | 88 | 90  | 91 | 99 | 100 | 105 | 106 | 107 | 116 | 117 | 119 | 122 | 123 | 126 | 130 | 134 | 136 | 139 | 144 | 146 | 147 | 148 |  |
| W0120  |                          |    |    | 90 |    |    |    |     |    |    |     |     |     |     |     |     |     |     | 91  |     |     |     |     |     |     |     |     |     |  |
| W0149  |                          |    |    |    |    |    |    |     |    |    | 62  |     |     |     |     |     | 63  |     |     |     |     | 64  |     |     |     |     |     |     |  |
| W0108  |                          | 47 |    | 48 |    |    |    |     |    |    | 49  |     |     |     |     | 50  |     |     |     |     |     | 51  | 52  |     |     |     |     | 53  |  |
| W0023  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 60  |     |  |
| W0107  |                          |    |    |    |    | 84 |    |     |    |    |     |     | 86  |     |     |     |     |     | 87  |     |     |     |     |     |     |     |     |     |  |
| W0636  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0148  | 82                       |    |    |    |    |    | 83 |     |    |    |     |     |     |     |     |     |     |     |     | 84  |     | 85  |     |     | 86  |     |     |     |  |
| W0121  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     |     | 94  |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0145  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     | 87  |     |     |     |     |     |     |     |     |     |     |     |     | 89  |  |
| W0106  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     | 51  |     |     |     |     |     |     |  |
| W0128  | 89                       |    |    |    |    | 90 |    |     |    |    |     |     |     |     |     | 92  | 93  |     |     |     |     |     |     |     |     |     |     |     |  |
| W0003  |                          |    | 61 |    |    |    |    |     |    | 65 |     |     |     |     |     |     | 68  |     |     |     |     |     |     |     |     |     |     |     |  |
| W0169  |                          |    |    |    |    |    |    |     |    |    |     | 40  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0119  |                          |    |    |    |    |    |    |     |    |    |     |     |     |     | 100 |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0034  |                          |    |    |    |    |    |    | 100 |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0132  |                          |    |    |    | 99 |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |
| W0150  |                          |    |    | 84 |    |    |    |     |    |    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |  |

Table 7. Germination of wild *Oryza* species in long term experiments (I-4).

| Strain | No. of days after sowing |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|--------|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|        | 153                      | 154 | 155 | 157 | 163 | 165 | 168 | 175 | 182 | 183 | 185 | 191 | 197 | 199 | 204 | 207 | 221 | 267 | 269 | 270 | 298 | 309 | 317 | 319 | 330 | 334 |
| W0120  |                          |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 92  |
| W0149  |                          |     |     | 66  |     | 69  |     | 70  |     |     |     |     | 73  |     |     |     | 74  |     |     |     |     |     |     |     | 77  |     |
| W0108  |                          | 54  |     |     | 55  |     | 56  |     | 57  | 58  |     |     |     |     | 59  |     |     | 60  | 61  | 62  | 63  | 64  | 65  | 66  |     |     |
| W0023  |                          |     | 70  | 80  |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 90  |     |     |     |     |     |     |     |
| W0107  |                          |     |     |     |     |     |     |     |     |     | 88  | 89  |     |     |     | 90  |     |     |     |     |     |     |     |     |     |     |
| W0636  |                          |     |     |     |     |     |     |     |     |     |     |     | 94  |     |     |     |     |     |     |     |     |     |     |     |     |     |
| W0148  | 87                       | 88  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| W0121  |                          | 96  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Species names of respective strains used are as follows:

*O. sativa* var. *spontanea* ROSCHEV.: W0103, W0105, W0106, W0107, W0122, W0123, W0124, W0125, W0126, W0128, W0130, W0132, W0133, W0135, W0136, W0137, W0144, W0145, W0146, W0148, W0150, W0151, W0152, W0153, W0154, W0157, W0168.

*O. perennis* MOENCH: W0034, W0036, W0108, W0119, W0120, W0121, W0149, W0169, W0636.

*O. breviligulata* A. CHEV. et ROEHR.: W0009, W0042.

*O. minuta* PRESL: W0051.

*O. malampuzhaensis* KRISH. et CHAND.: W0021.

*O. latifolia* DESV.: W0047.

*O. meyeriana* subsp. *granulata* TATEOKA: W0003, W0004, W0005, W0022.

*O. meyeriana* subsp. *meyeriana* TATEOKA: W1356.

*O. ridleyi* HOOK.: W0001.

*O. brachyantha* A. CHEV. et ROEHR.: W0023, W0654.

*O. subulata* NEES: W0510.

Table 8. Germination of wild *Oryza* species in long term experiments (II).  
Forty to 400 grains of each strain were used.

| Strain | No. of days after sowing |    |    |    |    |    |    |    |    |    |    |    |    |    |     |    |    |    |     |    |    |     |     |    |
|--------|--------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|----|----|----|-----|----|----|-----|-----|----|
|        | 1                        | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15  | 16 | 17 | 20 | 21  | 22 | 24 | 27  | 28  | 29 |
| W0021  | 0                        | 29 | 77 | 91 | 93 |    |    |    |    |    |    |    | 95 |    |     |    |    |    |     |    |    |     |     | 98 |
| W0001  | 0                        | 0  | 44 | 60 |    |    |    |    |    |    |    |    |    |    |     |    |    |    |     |    |    |     |     | 64 |
| W0103  | 0                        | 42 | 72 | 84 | 88 |    |    |    |    |    |    |    |    | 91 | 92  |    |    |    | 93  |    |    |     | 94  |    |
| W0123  | 0                        | 0  | 27 | 42 | 48 | 49 | 55 | 58 | 59 |    |    |    |    | 72 | 85  |    |    |    | 89  | 95 |    | 97  | 100 |    |
| W0105  | 0                        | 12 | 54 | 86 | 97 | 98 | 99 |    |    |    |    |    |    |    |     |    |    |    |     |    |    | 100 |     |    |
| W0047  | 0                        | 38 | 55 | 69 | 74 | 85 |    |    |    |    |    |    |    |    |     |    |    |    |     |    |    |     | 86  |    |
| W0654  | 0                        | 29 | 49 | 58 |    | 74 | 81 |    | 84 |    | 90 |    |    |    |     | 94 |    |    |     |    | 97 |     |     |    |
| W0122  | 0                        | 6  | 33 | 43 | 72 |    | 73 | 78 | 79 |    |    |    | 80 | 84 | 89  |    |    |    | 92  |    |    |     |     |    |
| W0126  | 0                        | 1  | 26 | 68 | 81 | 89 | 92 |    |    |    | 93 |    |    |    | 96  | 98 |    |    | 100 |    |    |     |     |    |
| W0153  | 0                        | 8  | 23 | 62 | 80 |    | 82 | 85 | 86 |    |    |    | 91 | 98 |     |    |    |    | 100 |    |    |     |     |    |
| W0022  | 0                        | 0  | 0  | 21 |    | 47 |    |    | 57 | 74 |    |    |    | 79 | 84  |    |    | 89 |     |    |    |     |     |    |
| W0154  | 0                        | 1  | 2  | 20 | 55 | 65 | 67 |    | 73 |    |    |    |    |    |     |    | 75 |    |     |    |    |     |     |    |
| W0051  | 0                        | 46 | 61 | 71 | 88 |    |    |    |    |    | 90 |    |    |    |     |    | 92 |    |     |    |    |     |     |    |
| W0124  | 0                        | 4  | 23 | 54 | 62 |    |    |    | 65 |    | 66 | 68 |    |    |     | 73 |    |    |     |    |    |     |     |    |
| W0125  | 0                        | 59 | 76 | 89 | 92 | 95 |    |    |    |    |    |    | 98 |    |     | 99 |    |    |     |    |    |     |     |    |
| W0130  | 0                        | 26 | 45 | 89 | 96 |    | 97 |    |    |    |    |    |    |    |     | 98 |    |    |     |    |    |     |     |    |
| W0136  | 0                        | 30 | 70 | 81 | 89 | 90 |    | 92 |    | 93 | 94 |    |    |    | 96  | 97 |    |    |     |    |    |     |     |    |
| W0151  | 0                        | 35 | 69 | 75 | 80 |    | 81 |    |    | 82 | 83 |    | 84 | 85 | 96  | 97 |    |    |     |    |    |     |     |    |
| W0157  | 0                        | 71 | 86 | 93 |    |    | 94 |    |    |    |    |    |    |    |     | 96 |    |    |     |    |    |     |     |    |
| W1356  | 0                        | 11 | 67 |    |    |    |    |    |    |    |    |    | 78 |    |     | 89 |    |    |     |    |    |     |     |    |
| W0510  | 0                        | 39 | 81 | 83 | 85 | 87 |    |    |    |    |    |    |    |    | 91  | 94 |    |    |     |    |    |     |     |    |
| W0133  | 0                        | 64 | 84 | 92 | 94 | 96 |    |    |    |    | 97 |    |    |    | 100 |    |    |    |     |    |    |     |     |    |
| W0135  | 0                        | 35 | 65 | 82 | 87 |    |    |    |    | 88 | 91 |    | 95 | 97 | 100 |    |    |    |     |    |    |     |     |    |
| W0137  | 0                        | 5  | 29 | 45 | 60 | 62 | 65 | 82 | 87 | 88 |    | 93 | 94 |    | 98  |    |    |    |     |    |    |     |     |    |
| W0036  | 0                        | 8  | 15 | 36 | 41 |    | 46 | 59 | 72 | 79 |    |    | 82 |    |     |    |    |    |     |    |    |     |     |    |

| Species | No. of days after sowing ( × 10 ) |       |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
|---------|-----------------------------------|-------|---|----|----|------|----|----|----|----|----|----|----|----|-----|----|
|         | 3                                 | 5     | 7 | 9  | 11 | 13   | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31  | 33 |
| 1       | •••••                             | ••••• | • | •• | •  | •••• |    |    |    | •  |    |    |    |    |     |    |
| 2       | •                                 |       |   | •• | •  | •    | •  |    | •  |    |    |    |    |    | ••• |    |
| 3       |                                   | •     |   | •  |    |      |    |    |    |    |    |    |    |    |     |    |
| 4       | •                                 |       |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
| 5       |                                   | •     |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
| 6       |                                   | •     |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
| 7       | •                                 | •     | • |    |    |      | •  |    |    |    |    |    |    |    |     |    |
| 8       | •                                 |       |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
| 9       |                                   | •     |   |    |    |      |    |    |    |    |    |    |    |    |     |    |
| 10      |                                   | •     |   |    |    |      |    |    |    |    |    |    | •  |    |     |    |
| 11      | •                                 |       |   |    |    |      |    |    |    |    |    |    |    |    |     |    |

Fig. 5. Intraspecific variations of final dates found in the germination behaviour

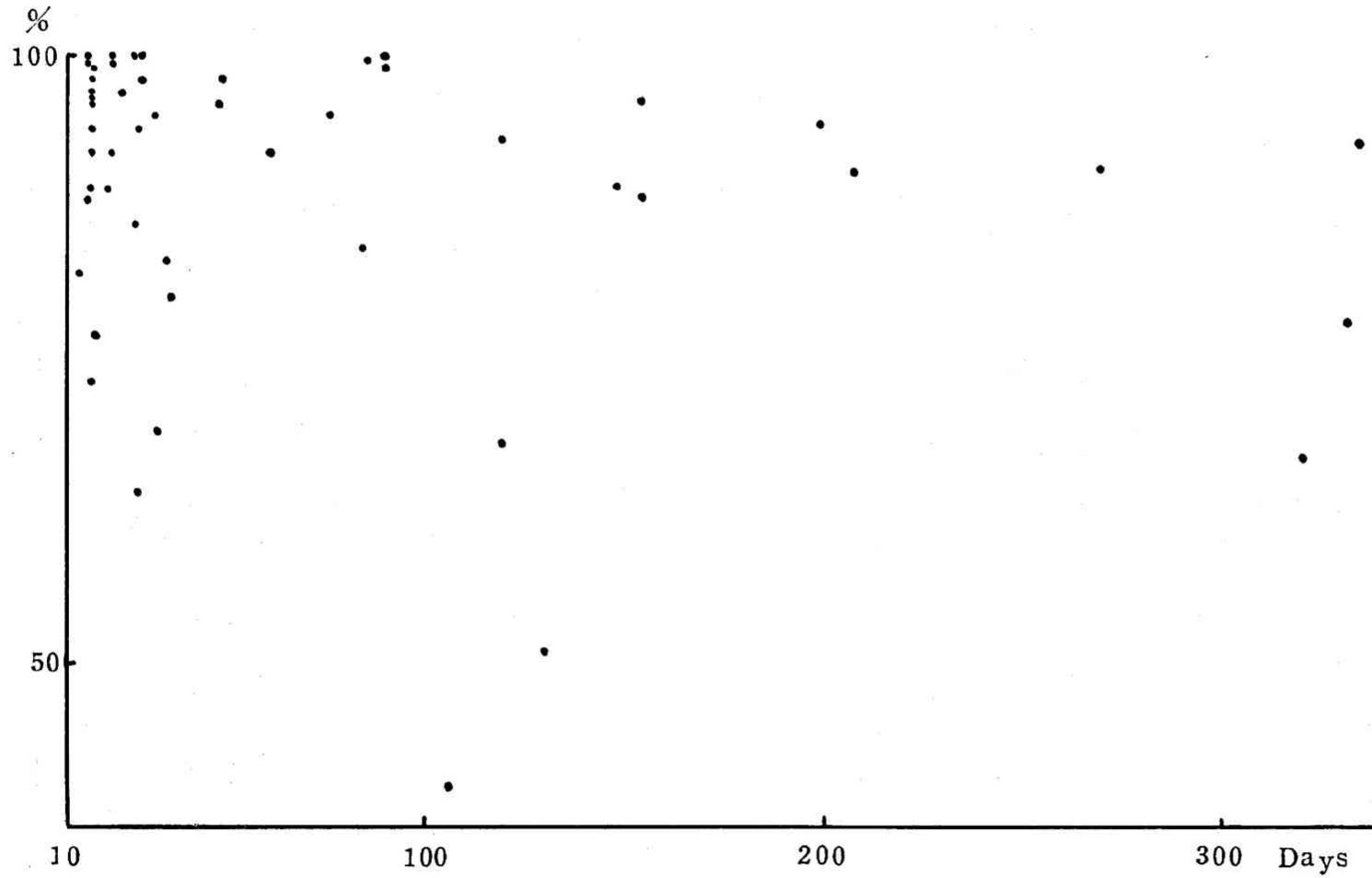


Fig. 6. Correlation between the final germinating date and final percentage of respective strain

*O. perennis* showed the widest intraspecific variation, *i. e.*, 13 to 334 days, *i. e.*, duration of 321 days; *O. brachyantha* 24 to 269 days, *i. e.*, duration of 245 days; *O. sativa* var. *spontanea* 15 to 207 days, *i. e.*, duration of 192 days; *O. meyeriana* subsp. *granulata* 20 to 119, *i. e.*, duration of 99 days. Other 7 species showed only small intraspecific variations.

It is a question, regardless of the species, whether a strain having higher final germination percentage shows in general a later final germination date than those having lower final germination percentage. Correlations between the final dates and final germination percentages were calculated (Fig. 6). The correlation coefficient was  $r = -0.2254$ , which has statistically low significance. Linear regression of the final date on the final percentage was calculated as follows;

$$Y = -0.087 X + 3.189 \quad (C_x = 10, C_y = 5)$$

where Y and X indicate the final percentage of germination in 5 per cent units and the final date of germination in 10 days units, respectively. Regardless of the species, strains that have lower final germination percentage showed in general later final germination dates than those having higher final germination percentage.

*Intrastrain's variations*: The germination process of each strain was traced to make clear intrastrain's variation, using data given in Tables 4-8. Relationships between the dates, at which 50 percent of the final percentage were germinated, and the corresponding number of strains were calculated. Then, 7, 18, 10, 4, 4, 1, 1, 1, 1, 1, 1, 1 strains reach the final 50 percent within 2, 3, 4, 5, 6, 7, 8, 10, 15, 17, 28, 48 days after sowing, respectively. Ninety two percent of all strains germinated within 10 days after sowing. One half of seeds of strains W0005, W0004, W0003 and W0023 germinated within 15, 17, 48, 28 days after sowing, respectively. The first three strains belong to *O. meyeriana* subsp. *granulata* and the last one belongs to *O. brachyantha*. Except those two species, one half of the seeds germinated within a few days in spite of their having long germinability.

## Discussion

1. *Cultivated species*: Cultivated species, *O. sativa*, of Japan and the Philippines, germinated earlier than those from other countries. The cause of the difference found in the respective countries may be sought in much less intensive artificial selection. Within country, variation was very small. However, it is not clear, why the strains of Malaya germinated very slowly, irrespective of the strain with which they were compared.

*O. glaberrima*, strains of Sénégal and Sierra Leone, germinated slower than when obtained from other countries. But strains outside of the African West Coast did not show any difference. No clear difference in the germination behaviour between *O. sativa* and *O. glaberrima* was found on the average (Fig. 3), in spite of clear differences in other physiological characters, such as photoperiodic response (2).

2. *Wild species*: For wild species, the average value of germination was not calculated, as it seemed of no particular importance to find the averages owing to large interspecific variations. From a short term experiment, it was clear that on the whole *O. sativa* var. *spontanea* and *O. perennis* collected in Assam and Sikkim germinated within 2-3 days, showing high germination percentage. This germination process seems to end in a shorter period than in the material from other countries. It is assumed that those strains may

be phylogenetically very near to the cultivated species, *O. sativa*, as mentioned in the previous paper (2). It was concluded that complete and rapid germination is generally characteristic of the cultivated species and of a strain of the closely related wild species, *O. sativa* var. *spontanea* and *O. perennis*.

In the short term experiment, it was not determined whether grains, which did not germinate within 9 days after sowing, can germinate after that period. Long term experiments in the course of a year are required to answer this question. From practical viewpoint, we may consider that the ungerminated grains of a cultivated species within 9 days after sowing will no more germinate. On the contrary, in the wild species, patience is indicated, because some seeds can germinate even 334 days after sowing. In the case of *O. longiglumis* and some of *O. perennis*, which show typical floating habit (3), the germination ends within a few days, even if the germination percentage is less than 80 %. This is simply due to the fact that the remaining grains are covered with deep water in the natural habitat and can not completely germinate. In the case of *O. meyeriana* subsp. *granulata* and *O. meyeriana* subsp. *meyeriana*, seeds germinate very slowly. This is due to the fact that very dry land is their natural habitat (3) and the phenomenon seems to be a kind of adaptation to the natural condition. Such adaptation will be found in intraspecific variations of several species (Fig. 5).

Some species show a typical threshold phenomenon in the germination process and behaviour and most of the species show a linear progress. Relationship and biological significance between various taxa of the genus *Oryza* and their germination characteristics are not clear.

*O. coarctata* ROXB. and *O. schlechteri* PILGER were omitted from this experiment. The germination behaviour of the former is peculiar. About forty days after flowering, the germinability is already lost. This is due to the fact that the former is growing on saline soil of the India and Burma delta. This habitat requires immediate germination soon after flowering. In the case of *O. schlechteri*, only dead seeds were obtained for herbarium specimens.

3. *Method*: On the whole in the present experiments husked grains were used in order to get a uniform germination pattern, though such condition is clearly different from the natural one. Unhusked grains were used in preliminary experiments and they germinated clearly later than the husked grains, but germination behaviour including germination curve, final date, final percentage are quite the same as from husked grains.

During the experiment, attention was paid to keeping suitable temperatures, which were ascertained for the individual species for healthy and normal germination of the seeds with regard to their natural habitats. The seeds on the whole of the used species germinated well under 30°C. Moreover, all experiments were repeated five to ten times and the results were always uniform. During the experiment, heat shocks were given several times of 40-50°C during 2-3 hours in several periods after sowing. Though sometimes an effective increase of germination was recorded, a clear advantage was not found. In long term experiments, seeds were washed in sterilized water at a week intervals. Sometimes a few seeds germinated immediately after washing. But it was not determined whether this was due to washing or to natural internal factors.

All seeds used were tested about half a year after flowering, because the majority shows strong dormancy during this period (6), when kept in a desiccator at 0°C, otherwise most

of the seeds will lose germinability in this period. During half a year, some germination test was done; and it was concluded that half-year storage under such condition is suitable for the sake of convenience and does not impair germinability except for *O. coarctata*. How long germinability lasts was examined by ROBERTS (5) and TAKAHASHI (6), and now the writer is under way in testing it under 0°C, -12°C and -24°C keeping the seeds in desiccators to make clear how long a seed of wild species, belonging to the genus *Oryza*, can keep germinability under those temperatures. According to a preliminary experiment, the seeds, which were harvested in the fall of 1959, and kept in desiccators at 0°C, had 85 % germination within 4 days after sowing in 1965.

4. *Biological significance of longevity of seeds*: It is quite important to elucidate the biological significance of seed germination after a relatively long time after sowing, such as after 334 days. The biological significances will be different under the following external conditions. i) Dry or wet condition in the growing season; if wet, shallow or deep sowing; ii) The same as to resting period; iii) Inter-populational or intra-populational competition; iv) Germination after about a year from sowing. Though some plants are subjected to serious damage such as quick drying up, bird attack, flood or others at germination time, the population may be kept alive by plants from later germinated seeds (i and ii). Those later germinated seeds will suffer from natural competition under favorable condition. However, they will become the important ones under unfavorable condition, when the earlier germinated seeds had received serious damage and died in young stage (iii). Seeds, having germinability even about a year after sowing, are very important in some years, when most of the seeds have been suffered with serious damage such as strong winds, birds, crowds of locusts, fire or others (iv). Actually, we may assume that a natural plant population consists of plants, which flowered last year and a year before last.

### Summary

Using 1,789 strains belonging to 20 species of the genus *Oryza*, including 2 cultivated and 18 wild species, germination behaviour, including days from sowing to germination, germination process, germination duration, germinability after some period, final germination percentage and biological significance of these characters were studied.

Most of the cultivated species of *O. sativa* and *O. glaberrima*, germinated within 1-2 days after sowing and the percentage increased within 9 days. Afterwards it remained stationary. Ungerminated grains within 9 days after sowing were considered, in the case of cultivated species, to have lost germinability.

Wild species could be classified into five groups with respect to germination behaviour according to the data obtained. Most of the wild species used could germinate at less than hundred percent during 9 days after sowing. Long term experiments had to be carried out during one year. Some strains could germinate even 334 days after sowing. It was concluded that complete and rapid germination is a general characteristic of the cultivated strains and those taxonomically related to them. The biological significance of germination behaviour was discussed. The germinability found in these experiments is interpreted in terms of botanical requirements as natural conditions.

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