Distributions and Some Morphological Characters of the Wild Rice in the Ganga Plains (PART III)

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I. Introduction

From October in 1971 to January in 1972, the writer has been sent to India and Ceylon for collecting the wild and cultivated rice under the project, "The Origin and the Alteration of Cultivated Rice in Tropical Asia", supported by a Grant from the Ministry of Education, Japan. The writer left Japan on October 24 and stayed in India for 63 days. Then, he proceeded to Ceylon to stay there for 13 days. He returned to Japan on January 11.

During this trip, many wild, cultivated and natural hybrid strains of rice have been collected. Seeds of Italian millet, sorghum, bean, pea and others have been also collected.

On the distribution of wild rice in India, some reports have been already published (11, 12, 13, 14, 16). In the previous papers (9, 10), abstracts of natural habitats and morphological characters of grains collected during the trip were reported. Although some conclusions on the distribution will be drawn after the experiments made with the use of the materials collected from the several viewpoints, in the present report, considerations on the the distribution of wild rice in the Ganga Plains has mainly been described. The records on the wild rice in south India and Ceylon and other crops will be reported in the separate articles.

He is most grateful to Dr. B. P. PAL, Indian Agricultural Research Council, who helped and gave his kind considerations to accomplish his task. Thanks are due to OMIC Office, who helped him greatly with travelling affairs. He is also most grateful to Dr. T. WATABE and other members of our party, who all helped and gave their accurate assessment to accomplish his task. He wishes to express his hearty thanks to Drs. M. KANIE and K. UEKI, Faculty of Agriculture, Kagoshima University, for their guidances.

II. Considerations on the distribution and natural habitat of wild rice

Distribution and habitat of wild rice and natural hybrids collected in the Ganga Plains are listed up in Table 1. In this table, collection number, species name, date of collection, detailed locality and some information of habitat were described. In the Table 1 of the previous paper (9), distribution and habitat of wild rice, which were observed but not collected, were reported, too. Geographical positions, in which the wild rice was collected, are shown in Figure 1. In this figure, route of trip and rivers are also given. A numeral in this figure shows the collection number used in Table 1. Natural habitats concerned in text are exhibited in Figures 5 to 36.

Table 1. Distribution and habitat of wild rice and natural hybrids collected in the Ganga Plains.
Abbreviations: **s**; *Oryza sativa* var. *spontanea* ROSCHEV., **p**; *Oryza perennis* MOENCH, **h**; natural hybrid, m; meter or meters.

Collection No.	Species	Date	Place	Detailed locality, habitat and remarks
W 1	**s**	Oct. 28	Melatola	Road-side ditch, open field, adjacent to paddy field. Mostly just flowering stage and a few seeds collected. Growing continuously between 10 miles from location mentioned above to north-west locality. Open road-side tank, 10 m width. Clayey soil. Flowering between 12 a. m. to 3 p. m.
W 2	**s**	Oct. 28	Burdwan	8 miles west from Burdwan Railway Station. Road-side ditch, 20 m width. Native name "Joadan" or "Uli".
W 3	**s**	Oct. 29	Santi Niketan	4 miles north from Santi Niketan. Open pond, 30 m × 20 m. Clayey soil. Several hundred meters apart from the nearest paddy field.
W 4	**s**	Oct. 29	Santi Niketan	14 miles north-west from Santi Niketan. Open pond, dia. 30 m. Many plants growing together only in central part of the pond and a few plants growing in edge. Native people collecting a kind of pond-snail for food in this pond. Plant growing in central region relatively higher than those in edge, but flowering time, the same.
W 5	**s**	Oct. 30	Dumka	19 miles north from Dumka. Road-side ditch. Growing only about 10 plants.
W 6	**p**	Nov. 2	Darbhanga	20 miles north-east from Darbhanga to Jaynagar. Road-side pond, 30 m × 50 m, 1 m deep. Growing 10 m from each other in edge, but thickly in central region. Plant height 1. 5 m. Mostly flowering stage, but collected a few matured grains. Native name "Johl".
W 7	**p**	Nov. 4	Lauriya	150 m separated from Nandangarh Stupa Site by road. Open pond, dia. 20 m. *O. sativa* growing in central region, showing floating habit. *O. perennis* growing only in edge, and natural hybrids growing between them. 1 m high above water. 0.5 m deep in edge. 5 m high forest around the pond. People sometimes harvesting seeds of wild rice by boat. Maturing behaviours of cultivated and wild species synchronized.
W 8	**s**	Nov. 7	Patna	5 miles west from Patna City. Road-side ditch, 8 m × 400 m, 30 cm deep, growing sporadically.
W 9	**s**	Nov. 7	Arrah	Southern ditch adjacent to Indo-Japanese Agricultural Extension Centre, 8 m × 50 m, 60 cm deep. Growing thickly.
W 10	**s**	Nov. 7	Arrah	Road-side pond, dia. 50 m. Growing only in central shallow area, 40 cm deep.
W 11	**s**	Nov. 7	Arrah	8 miles west from Arrah, Biligangi Village. Road-side swamp. Growing sporadically. Several meters apart from the nearest paddy field.
W 12	**s**	Nov. 7	Buxal	5 miles east from Buxal. Road-side swamp.
W 13	**s**	Nov. 8	Arrah	3 miles south from Arrah. Small pond, 60 cm deep.
W 14	**s**	Nov. 8	Arrah	45 miles south from Arrah. Road-side ditch, 5 m × 100 m.
W 15	**s**	Nov. 8	Sasaram	23 miles west from Sasaram. Road-side ditch. Plants were looked upon as host-plant of bacterial leaf blight of rice (*Xanthomonas oryzae*).
W 16	**s**	Nov. 8	Bhabua	4 miles west from Bhabua. Road-side ditch.
W 17	**s**	Nov. 9	Ghazipur	9 miles west from Ghazipur. Small road-side ditch, 30 cm deep. Plants 60 cm height above water. Growing only about 50 plants.
W 18	**p**	Nov. 10	Kushinagar	9 miles west from Kushinagar. Road-side ditch, 5 m × 50 m,

		1 m deep. Growing only 10 plants.
W 19	**s**	Nov. 11 Gorakhpur 17 miles west from junction to Kasia and Varanasi. Road-side ditch, 10 m × 20 m. Growing sporadically.
W 20	**p**	Nov. 11 Gorakhpur 24 miles west from junction to Kasia and Varanasi. Road-side ditch, 10 m × 40 m. Growing thickly.
W 21	**s**	Nov. 11 Gorakhpur 58 miles west from junction to Kasia and Varanasi. Road-side ditch, 5 m × 10 m. Growing only 10 plants.
W 22	**p**	Nov. 11 Gonda 2 miles south from Gonda. Road-side swamp, 10 m × 20 m.
W 23	**s**	Nov. 11 Gonda Same locality as above. Road-side swamp. Growing sympatrically together with **W 22.**
W 24	**p**	Nov. 12 Balrampur 6 miles west from Balrampur. Pond, 100 m × 800 m. Just maturing stage. People harvesting the seeds by boat and selling at market. People using them at some festival, and more expensive than *O. sativa* (cultivated species). Growing sympatrically together with lotus. Separating from cultivated rice and some bean fields by an embankment.
W 25	**s**	Nov. 12 Gonda 16 miles north from Gonda. Shallow water swamp, 30 m × 50 m. Post-maturing stage. Growing thickly.
W 26	**p**	Nov. 13 Faizabad 29 miles west from junction to Faizabad and Basti. Road-side swamp, 5 m × 10 m. Growing only 2 plants. Post-maturing stage. Growing only in central region. No cultivated field in the area around, but 20 m apart from the nearest paddy field, separated by high embankment. Cultivated varieties just at milky stage.
W 27	**p**	Nov. 15 Lucknow 27 miles west from Lucknow. Deep water pond, 40 m × 100 m. Post-maturing stage. Growing only in central region.
W 28	**s**	Nov. 15 Bareilly 44 miles east from Bareilly. Road-side swamp, 100 m × 200 m. Growing only a few plants in edge, and sporadically in central region. Growing together with sedge. Several hundred meters apart from the nearest paddy field, separated by upland field.
W 29	**p**	Nov. 16 Rampur 5 miles west from Rampur; 29° N, 79° E (distributing area of northern limit of wild rice in the Ganga Plains ?). Road-side pond, 30 m × 40 m, deep water. Growing about 100 plants. Post-maturing stage.
W 30	**s**	Nov. 20 Agra 10 miles east from Agra; 27° N, 78° 10′ E (distributing area of western limit of wild rice in the Ganga Plains ?). Growing sporadically in the edge of water-caltrop pond, 2 m deep. Growing together with several off-type of cultivated varieties. Post-maturing stage. 80 cm high above water.
W 31	**s**	Nov. 20 Firozabad 26 miles east from Firozabad. Road-side ditch, 1 m × 3 m. Post-maturing stage. 50 cm high above water. Growing only 20 plants.
W 32	**s**	Nov. 20 Sikandra 9 miles east from Sikandra. Road-side swamp, 5 m × 50 m. Growing about 300 plants. Separated from cultivated field by an embankment. Just maturing stage.
W 33	**s**	Nov. 21 Kanpur 13 miles east from Kanpur. Road-side swamp, 10 m × 50 m. Growing only in edge. Post-maturing stage. 50 cm high above water.
W 34	**s**	Nov. 21 Palhana 21 miles south from Palhana. Road-side swamp, dia. 30 m. Growing sporadically in only edge. Post-maturing stage. Water remaining only in central area.
W 35	**s**	Nov. 22 Allahabad 20 miles east from Allahabad. Road side ditch, 3 m × 50 m. Growing only in edge. Growing together with plants of pre-, just- and post-maturing stages. Shallow water. Cultivated species growing in central area.
W 36	**s**	Nov. 23 Varanasi 17 miles east from Varanasi. Road-side ditch, 15 m × 100 m. Growing sporadically only in edge. Post-maturing stage. Separated from paddy field by an embankment.

W 37	**s**	Nov. 24 Gaya 11 miles north from Gaya. Road-side ditch, 7 m × 15 m. Growing about 20 plants. Post-maturing stage. Separated from paddy field by an embankment.
W 38	**s**	Nov. 24 Nalanda Near Nalanda Stupa. Pond, dia. 40 m, 30 cm deep. Growing sporadically in the whole area together with thistle and other grass species. Half-shaded by palm trees. Post-maturing stage.
W 39	**p**	Nov. 26 Ranchi 41 miles south west from Ranchi. Pond, dia. 50 m, 1 m deep. Growing in edge and centre. Post-maturing stage. People catching some fishes in this pond.
W 40	**p**	Nov. 27 Topchanchi 2 miles east from Topchanchi. Pond, dia. 100 m, more than 1 m deep. Growing thickly in the whole area. Just maturing stage, 1 m high above water.
W 41	**p**	Nov. 27 Asansol 5 miles east from Asansol. Growing in the whole area of road-side swamp, between road and steam power plant, 20 m × 100 m, 1 m deep, together with *Eichhornia* sp. Post-maturing stage. 1 m high above water.
W 42	**p**	Nov. 28 Durgapur 27 miles east from Durgapur. Growing in the whole area of swamp, 15 m × 200 m.
H 1	**h**	Nov. 2 Darbhanga Road-side pond. Showing high seed sterility. Growing between cultivated and wild species (**W 6**). Luxuriating from each other.
H 2	**h**	Nov. 2 Darbhanga Same locality and same habitat as above.
H 3	**h**	Nov. 2 Darbhanga Growing in road-side ditch, 10 m × 30 m, half shaded by mango trees. Only 7 plants were found. Adjacent to pond (growing **W 6**, **H 1**, **H 2**), separated by road.

Factors affecting the distribution of wild rice will be briefly discussed in this chapter from the two large points, *i.e.*, factors preventing collection and limiting the distribution of wild rice.

(1) Populations observed and collected during this trip were only confined to those along the main road. Of course, the natural habitats of wild rice could not be grasped only within such a narrow area. For estimation of the actual distributing areas of wild rice, some extensive considerations and cautious attentions should be paid. Unfavorable conditions for observation and collection of wild rice are considered to be as in the following; i) route of trip, ii) road position, iii) flood damage, iv) changing natural habitat by inanimate factors, v) changing natural habitat by animate factors, vi) disturbance by men, vii) a time lag found in season of trip, viii) soil condition.

i) The qualities and quantities of wild rice observed amid the natural habitats and sources may not be the same as the present ones, because areas observed during this trip were strictly limited areas quite small, if compared with the natural ones, in other words, limited only along the main and submain road (Fig. 24). Of course, areas, which could be looked around from the such road, depended on configuration and construction of the ground.

ii) It was looked upon as true that the higher was the road traversed from field, the wider was the areas, which could be looked around. Indeed, most of the main road in the Ganga Plains was built on the higher place by laying stone, soil and paving bricks upon the road. The former two have been digged the ground near the road (Figs. 24 and 27). The latter was made by soil, digged out of the ground in the vicinity of the road. In such area, the field observations were practicable extending over so many dimensions, without oversight of the natural habitat. On the other hand, in the case of the field observations from the road, built on the relatively lower position, especially in the one lower than its suburbs, found near the hill in several times, an oversight of the natural habitat is liable to occur.

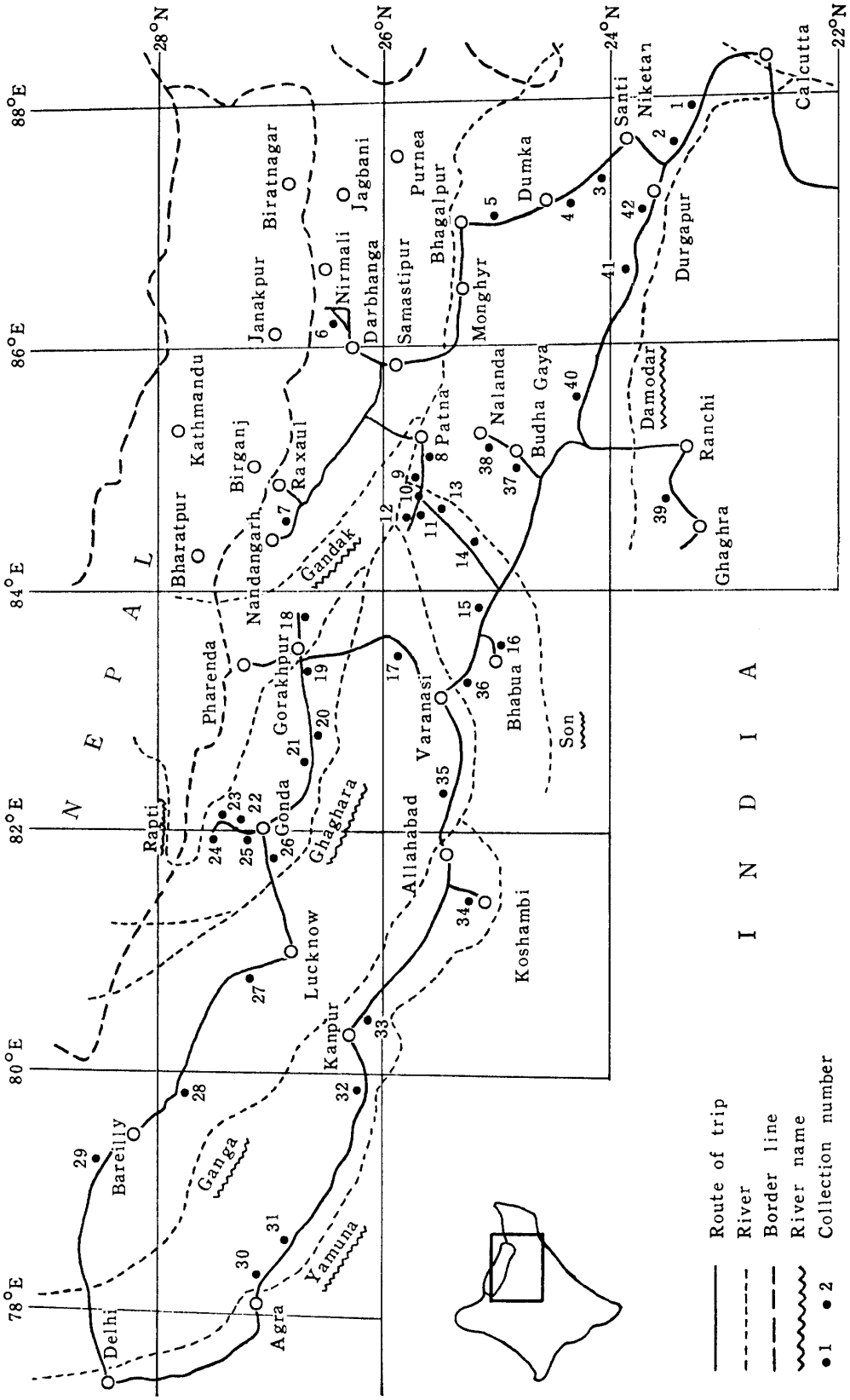

Figure 1. Map showing localities where the wild rice was collected in the Ganga Plains.

iii) Though there is no help for flood damage, the flood is one of the most serious natural calamities for the growing of wild rice in India (Fig. 32). In 1971, many crop plants and wild plants were carried away by a flood on a large scale. For example, at some locality along the Ganga, no plant was found extending over so many dimension, even under the small bridge. It should be decided in this area by some method, whether wild rice are growing there or not during the unflooded period. During the trip, however, the area was considered to be no growing area of wild rice, when no plant or any part of plant was found even in the field and under a bridge girder. This method was adopted, basing on the following reasons; if wild rice is growing there, a plant or a part of plant will be expected to remain in the field or under bridge girder after the serious flood, at which case flooded water goes up and down, even if the flow of water has been brought forth quickly for a fairly long period.

iv) It is an another serious problem for collection of wild rice that the natural habitat changed frequently by inanimate objects, *i.e.*, changing flood mentioned above in small scale, changing water flow in large river, unstable yearly rainfall, changing soil condition, during a very long drainage it dies, which was looked upon as quite an unusual phenomenon. In such cases, the habitat was disturbed by the respective cause, and the plant, not only annual but also perennial species, could not be available for living. The latter species propagated ordinarily by rhizome. For example, habitat will shift its locality from one to another by flood as found in New Guinea extending the very long distance (6). Though the rhizome has been generally seen to be advantageous organ for resisting to strong drainage, but it will die during the very long drainage, which was seen as unusual phenomenon.

v) It is also a serious problem for changing the habitat of wild rice that the natural habitat was changed by animate objects, *i.e.*, being eaten by bird and buffaloes, being cut by men, etc. The seeds of wild rice were eaten by bird or buffaloes in several localities, and moreover the green and withered grasses of wild rice were also eaten by buffaloes (Fig. 36). In such area, habitat becomes narrower, getting finally extinct. Optimum scale of natural flora and population size of animals for co-existence will be one of the most important factors for keeping the habitat of wild rice. In Uttar Pradesh, grassland was seen to be more abundant than that of Bihar State. Then, changing scale found in that habitat of wild rice caused by animals becomes smaller in Uttar Pradesh than that in Bihar State.

vi) There is another cause of changing the habitat of wild rice in disturbance by men at the natural habitat. Some of the most notable disturbance are construction of the road (Fig. 24), building the house, making crop field (Fig. 26) or water reservoir, cutting and digging the plant. The first former one was already discussed as mentioned above. Such artificial construction drove the habitat away into migration to another locality or into final extermination of the species, for both of the annual and perennial species.

The making of the farmland or water reservoir drove away finally their habitat into extermination on the one hand, but brought satisfactory results for new habitat in or along the farmland or water reservoir on the other hand. In fact, habitats of wild rice were found along the paddy field at several localities (Fig. 20), which were said to have been established in the latest date. The last one was observed at several localities, for example, at Lucknow, Burdwan, Saheto, etc., where men cut off the upper-ground part or dug the under-ground part of the plant for fuel.

So in such area, population of wild rice becomes gradually smaller and smaller.

vii) As mentioned in the introduction, the trip in the Ganga Plains was made during the term from the late October to the early December. There is fairly long period on the flowering and maturing stages of the wild rice populations. Indeed, the plants collected near Melatola (W1 in Table 1) on October 28, showed mostly just flowering stage in view of the population average. On the other hand, the plants collected near Lucknow on November 15 (W 27), showed mostly post-maturing stage. The collection of the matured grains was exceedingly difficult very much, because the trip was frequently done at the too early or too late stages, aparting from the optimum stage of the respective strain. But the observation and detection of wild rice was not so difficult even in the vegetative stage of individual plant, owing to the plant shape and surface structure of the leaf. Then, the observations have no apprehension to overlook the habitat, so far as the data obtained during this trip in the Ganga Plains are concerned.

viii) Paddy field, established recently, does not have, strictly speaking, highly-developed-population of wild rice. In India, establishment of irrigation canal and paddy field is going now to be extensively very much (Fig. 25). Then, the distinction of old paddy field or newly developed paddy field seems to be the effective method for collecting wild rice species. For example, some case of paddy field found near Bhagalpur, is occupied in typical savannah area (Fig. 27). Then, this area may be recently established for the extension of paddy field. In such areas, wild rice plant is not growing at all. Other case of paddy field was also established in the reclaimed land, in which *Miscanthus* sp. was growing but *Eichhornia* sp. or *Carex* sp. was not growing. These plants can be used as decision of habitat of wild rice. In addition to these factors, it is also another factor for nothing wild rice that the area is always exposed to the sea breeze.

It was ascertained that area near Agra is of alkaline soil, in which sagebrush is growing. Even if configuration of area was looked upon as adequate locality for living of wild rice, soil condition was found to be a working factor for preventing the habitat of wild rice in such case.

(2) As mentioned above, populations of wild rice observed and collected during this collection trip were within the limit of relatively narrow areas. For estimation of the actual distribution areas of wild rice, more extensive considerations and careful attentions should be paid in natural conditions as in the following; i) dry and wet seasons, ii) degree of water depth, iii) population size, iv) topographical constitution, v) flows of large and small rivers, vi) relation to old ruin and village.

i) As shown in Table 1, populations of wild rice were found in pond (Figs. 6, 7, 9, 10, 12, 17, 20 and 22), road-side ditch (Figs. 5, 8, 11, 13, 14, 18 and 19), river side (Fig. 21), swamp (Figs. 15 and 16) or near paddy field (Fig. 23) during this trip. In Figures 2, 3 and 4, topographical configurations of twenty eight among forty two localities, in which population of wild rice were growing, were picked up and schematically shown. They are differing with one another in view of dryness and wetness during the year according to the respective growing season. In some pond and swamp, relatively deep water is found throughout the year, in those localities perennial plant can grow even in dry season by vegetative growth (Fig. 9). On the other hand, in road-side ditch (Fig. 5) and in some swamp (Fig. 15), relatively deep water is found only during the wet season and not during the dry season, in such a place perennial plant can live in dry season by resting organ, *i.e.*, rhizome (Fig. 13). A perennial plant propagates by seed in some case and by rhizome

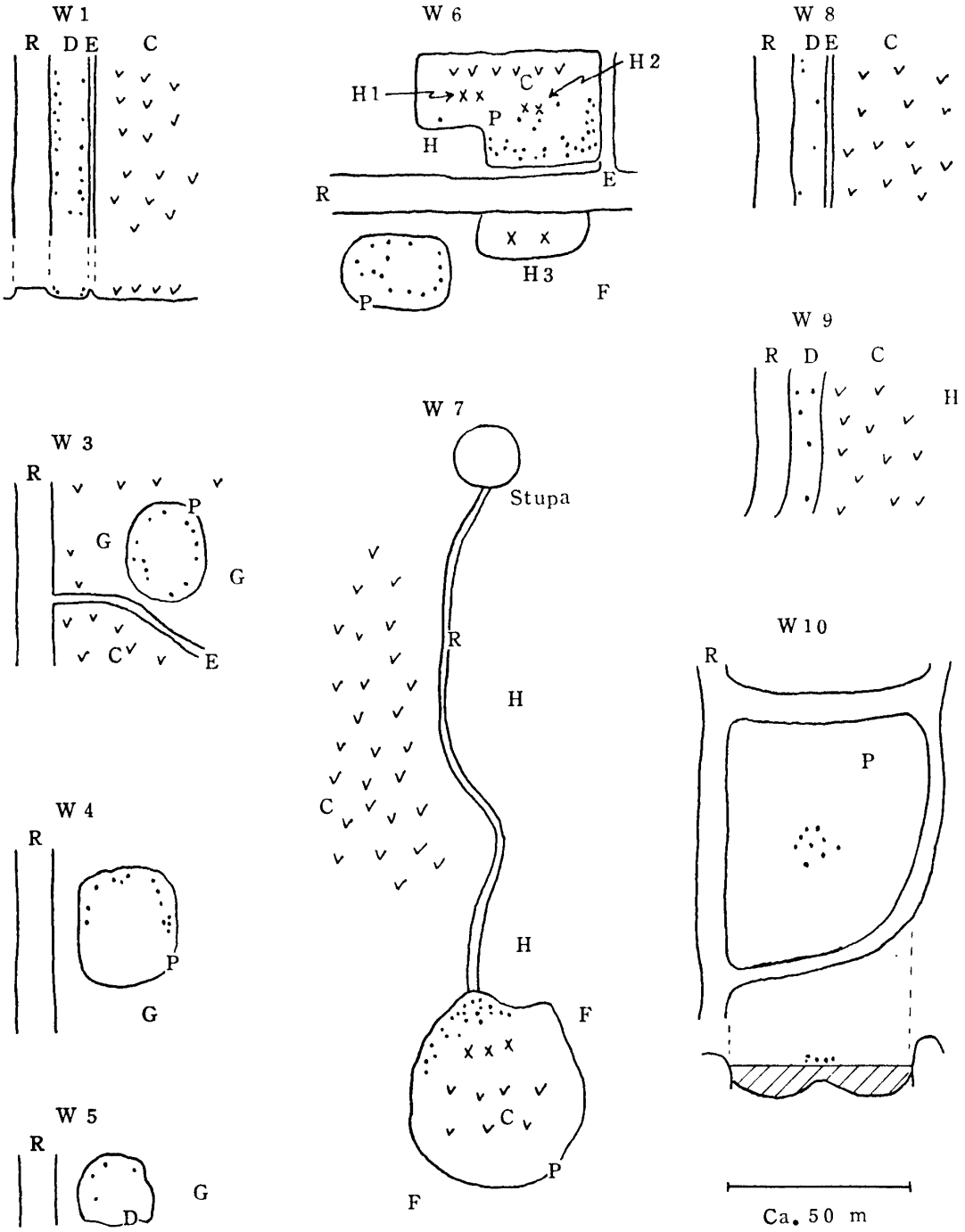

Figure 2. Sketch maps of habitats of wild population and natural hybrid. Dots show wild rice. C(v marked) : cultivated rice field ; x marked : hybrid rice ; P : pond ; D : road-side ditch ; S : swamp ; R : road ; E : embankment ; F : forest ; G : grassland ; H : house.

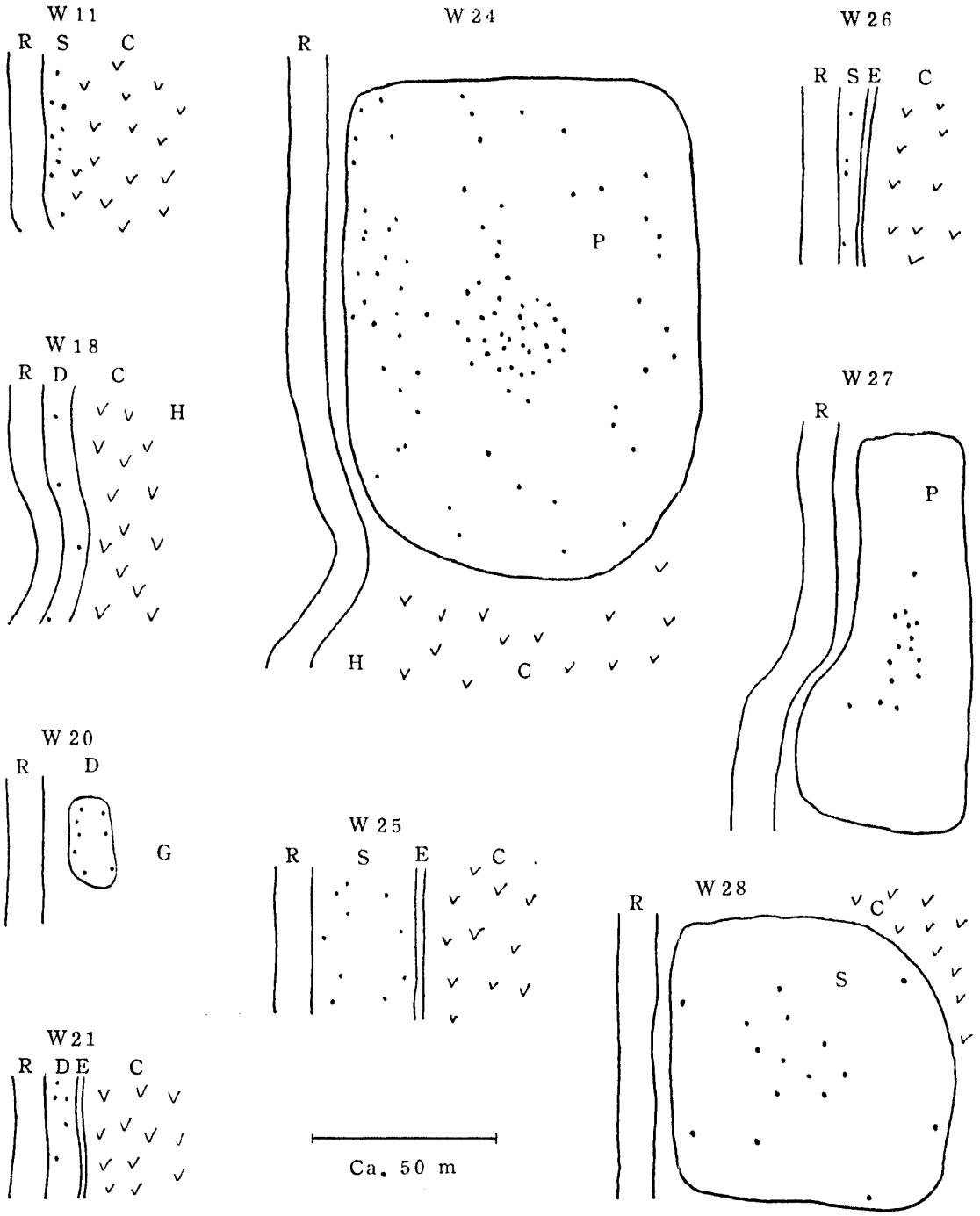

Figure 3. Sketch maps of habitats of wild population. Dots show wild rice. C(v marked) : cultivated rice field ; P : pond ; D : road-side ditch ; S swamp ; R : road ; E : embankment ; G : grassland ; H : house,

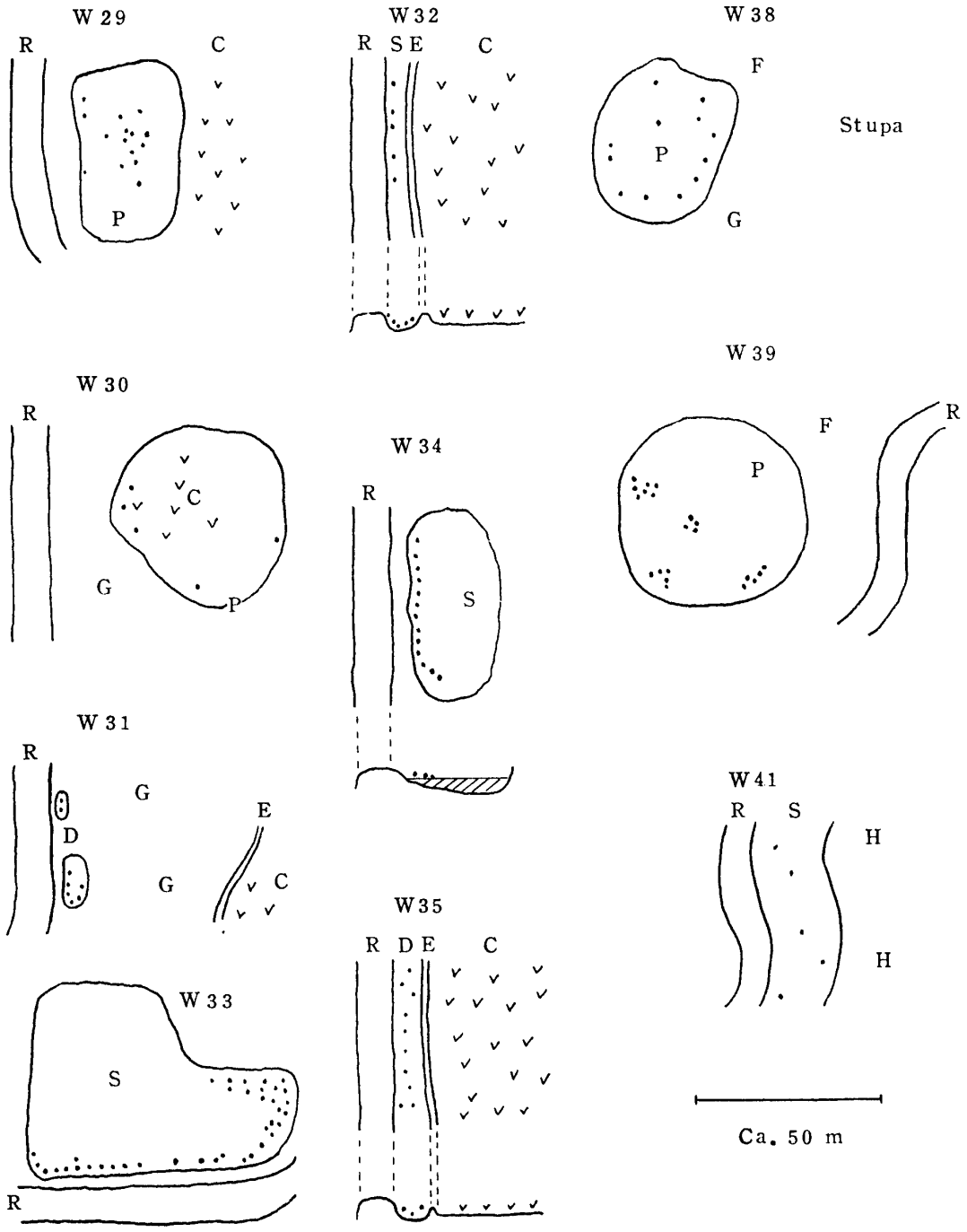

Figure 4. Sketch maps of habitats of wild population. Dots show wild rice. C(v marked) : cultivated rice field ; P : pond ; D : road-side ditch ; S : swamp ; R : road ; E : embankment ; F ; forest ; G : grassland ; H : house.

in other case. An annual plant can live in both cases mentioned above, because it grows through only relatively short duration. So it should be ascertained whether wetness degree of the respective habitat is to be regarded as only wet-season's aspect or as whole season's aspect.

It has been looked upon as another aspect of wetness in the field that artificial transplantation of "boro" varieties of cultivated species was done in December, which was found in several localities in southern Calcutta. In these areas, wild rice can live throughout the year in swamp or road-side ditch near cultivated field, even such paddy field has been kept only in shallow water condition.

ii) As shown in Figures 2 and 10, a strain, W 7, collected in open pond near Lauriya, showed slightly floating habit, growing in 0.5 meter deep area. Sometime people harvest the seeds of wild rice by boat. It can grow only in shallow water edge of the pond and can not grow in central deep portion, in which only cultivated species can grow, showing typical floating habit. The degree of water depth of the respective area, in which wild rice was growing, could be seen as one of the important remarks of habitat, which controlled the possibility for the growing of wild rice throughout the respective growing season.

In another aspect, water depth was used as a species indicator. At the field survey, it was ascertained that the shallower was the water depth of the habitat, the larger was the possibility of growing *O. sativa* var. *spontanea*, and the deeper was the water depth of the habitat, the larger was the possibility of growing *O. perennis*. This means that the plant of *O. perennis* can grow even in relatively deep water in comparison with *O. sativa* var. *spontanea*. This pattern of habitat was frequently found in many localities. In the case of W 10 (Fig. 12), collected in road-side pond near Arrah, wild rice was growing only in central region, where there lies relatively shallow water about 40 cm deep, as shown in the plane and cross section views of Figure 2. Wild rice was not growing and only *Eichhornia* sp. was growing in around the portion, about 80 cm deep, which was said to be dried up in the dry season.

iii) Population size will be useful as one of the indicators of the population newcomer. For example, the population of *O. sativa* var. *spontanea* (W 30) was sporadically found in the edge of water-caltrop pond near Agra, in which many off-types of cultivated species were also sporadically growing. They showed very small population as shown in Figure 4. Population of *O. perennis* (W 26) was found only in the central part of swamp, regarded as relatively deep portion, as shown in Figure 3. The populations mentioned above were observed to have recently migrated to that site from the other site.

iv) Along the road near the habitat of wild rice, the different constitution seem from the topographical viewpoint were found as the limiting factor for the distribution of wild rice. If a road, an embankment or a small river is located on the same level as its suburbs, a habitat of wild rice is not disturbed by the ground configuration for its migration, extension or curtailing changes of the population size. If they are located on the level lower than its suburbs, a habitat of wild rice is not disturbed so far as small scaled one is concerned, but is disturbed in the case of large scale for its changes. If they are located on the level higher than their suburbs, a habitat of wild rice is disturbed even if they show small scale for its changes. Such configurations were frequently found in several localities, especially in the so called GT (Grand Track) road (Fig. 24).

Populations of *O. sativa* var. *spontanea* were intermittently found from Santi Niketan to the

other localities, situated 2 miles north to Canadian Dam. In area northern from there, no population was found at all. It may be due to the gradual going up in view of the elevation, and going down in view of the temperature.

Typical configurations of old village were found at Vaishali (Fig. 31). Buddist Temple, crop field and swamp were concentrically arranged from the centre to the outside, respectively. In vertical view, they were terraced from the up-side to the down-side, respectively. Swamp terraced in down-most area was used for artificial irrigation source (Fig. 30), and wild rice was growing only there throughout the whole landscape.

Another configuration of field was found near Ghazipur (W 17 in Table 1). In this case, farmer's house, sugar cane plantation, peanut plantation, paddy field, swamp and road-side ditch were arranged from up-side to down-side over the gradual slope in this order, without remarkable terraces and any embankment. Wild rice was growing, of course, only in swamp and road-side ditch. When such configuration was found in the large scale, habitat of wild rice was forecasted to be found in the lower-most area of these slopes.

v) There are many natural rivers and artificial irrigation canals in the Ganga Plains. The former is represented by Ganga (=Ganges), Yamuna, Rapti (Fig. 33), Damodar. The latter is represented by elaborate canals (Figs. 28 and 30). Both of them disturb the habitat of wild rice for its extending and migrating changes. Moreover, owing to their large scale, the habitat of wild rice was compelled to change, its direction and speed, by them, when natural transference of flowing-route of the river, very frequent in the Ganga Plains (Fig. 32), was brought forth.

vi) As shown in Figures 2, 3 and 4, many populations of wild rice were found near old villages or ruins, which had been established in the remote past. As will be discussed in the next chapter, populations of wild rice have been seen to be keeping in close touch with old ruins in view of their original distributing area. Old ruins and villages were always situated on an eminence, commanding a good view (Figs. 31, 35 and 36). This situation or arrangement has been looked upon as very important adjudication for establishing its settlement. Moreover, ruin and village have certainly large swamp or pond in its suburbs. Such configurations were found at Lauriya (W 7 in Table 1, Figure 10), Vaishali (Fig. 31), Moharia, Bhabua (W 16), Kushinagar (W 18, Fig. 13), Saheto (W 24), Maheto (Fig. 33), Agra, Sikandra Akbar, Koshambi (W 34, Fig. 34), Sarnath (Fig. 35), Rajgir, Nalanda (W 38, Fig. 36). Then, it should be fairly considered, whether old ruin or old village is situated there or not, and whether it has been built on a large scale or on a small scale, for estimating the habitat of wild rice.

On the contrary in some localities, village was built on relatively high land for keeping aloof from the flood damage, independent from ruin. At such village, no population of wild rice is to be found at all.

III. On the relationships between cultivated and wild rice species

From the view of the origin of cultivated rice, relationship between cultivated and wild species occupies an important portion. So in this chapter, this problem will be discussed in the order of the following sub-chapters; natural hybrid, weed or not, *i.e.*, sympatric or allopatric growth between cultivated and wild rices, plant height, flowering order, flowering time, soil condition of

the paddy field.

(1) As mentioned in the previous papers (9, 10) and shown in Figures 2, 9 and 10 of the present paper, natural hybrid plants were found in several localities. As clear example, the population of wild rice and natural hybrid found near Darbhanga will be explained here. As shown in Figures 2 and 9, the first and the second hybrid groups, *i.e.*, H 1 and H 2, respectively, were growing in road-side pond, 30 meters x 50 meters and about 1 meter deep, allopatrically between cultivated and wild species (W 6). They were growing thickly from each other and luxuriating, showing plant height about 1 meter above the water surface. Seed sterilities of them were ascertained to be very high. No clear borders between cultivated species and wild species, cultivated and hybrid, hybrid and wild species, could be recognized.

The last hybrid group, *i.e.*, H 3, was sporadically growing in road-side ditch, 10 meters x 30 meters, half-shaded by mango trees. Only seven hybrid plants were found. The ditch was separated by road from the pond, in which the first, the second hybrid groups (H 1 and H 2), wild rice (W 6) and cultivated rice were growing, and separated by grassland from another pond, in which population of wild rice (no collection) was found, too, as shown in Figure 2.

For discussion on the relationship between these hybrids and wild rice (W 6), the data obtained in morphological characters of unhusked and husked grains were compared with each other, as shown in tables and figures of the previous papers (9, 10). Basing on these characters obtained here it became clear that the first (H 1) and the second (H 2) hybrid groups were relatively nearer to the wild population (W 6) than the last hybrid group (H 3), though all of them were growing in the very near area from one another. So, the first and the second hybrids could be affirmed to have originated from natural hybridization between the wild and cultivated rice, which were growing together in the same pond, at the recent period. On the other hand, the last hybrid could be fixed to have originated through the same method but at the older period, and was slightly differentiated from the original hybrid one for some period.

Another sample of natural hybrids was found near Nandangarh Stupa Site as shown in Figure 2. They were growing in the pond, with diameter 20 meters long, separated 150 meters by road from Nandangarh Stupa Site. In this pond, wild rice (W 7, Fig. 10) was growing only along the edge, and cultivated rice was growing only in the central region, showing typical floating habit. The natural hybrid was growing between them. This distribution pattern shown by wild, cultivated and hybrid rice species, *i. e.*, habitat segregation, was quite the same as the case of Darbhanga mentioned above (Fig. 9). People sometimes harvest the seeds of wild rice by boat but not those of the hybrid one. Unfortunately the seed of them could not be collected, because it showed mostly pre-maturing stage.

(2) The second point of relationship between cultivated and wild rice is the growing pattern between them. OKA *et al.* reported that wild rice occurs as a weed in rice fields (11). Owing to its close resemblance to the cultivated varieties, its weeding-out being impossible, and due to its characteristic shedding of grains it is propagated year after year. In badly infested fields, the percentage of wild rice reaches the point as high as 30 percentage. The wild rice, co-existing as a weed in rice fields, seemed to belong to *O. sativa* var. *spontanea* (11). Indeed in some cases, wild rice grows sympatrically with cultivated rice as a serious weed in rice fields. For weeding out the wild rice, farmers persevere in ameliorating rice field by several methods. For example, for weeding the

wild rice, purple strain of the cultivated species was used in some rice fields of the Ganga Plains. Practically, when the seed of wild rice was observed germinating naturally, the seeds of purple strain were sown by ordinary method in the paddy field, in which the wild species occurred greatly as a weed. In early stage of the growing period, the plants showing green leaves and belonging to wild rice were picked out, but plants showing purple leaves and belonging to cultivated rice were left untouched. If these procedures repeated during the several years, the wild plants would be decreased its population size year after year. This method is effective, because the wild rice growing there is belonged to an annual species, *i.e.*, *O. sativa* var. *spontanea*, which propagate only by seed and not by rhizome.

Though some wild rice could be looked upon as a weed in some rice fields, as mentioned above, sympatric growth with cultivated and wild species was very rare despite exceptions, so far as observations done in this trip are concerned. The population of *O. sativa* var. *spontanea* found near Agra (W 30) was an example showing sympatric growth with cultivated and wild rice, as shown in Figure 4. Wild plants were sporadically growing together with several off-type of cultivated varieties in the edge of water-caltrop pond. However, this off-type one was not used by farmers and was not noted as "true" cultivated species. In population of *O. sativa* var. *spontanea* collected near Melatola (W 1), for example, wild rice was growing only in road-side ditch having about 30 cm width and lying near paddy field separated by an embankment, as shown in Table 1 and Figure 2. In population of *O. sativa* var. *spontanea* collected near Arrah (W 11), wild rice was sporadically growing in road-side swamp. Several meters apart from the swamp, cultivated rice was allopatrically growing with wild rice, though there is no remarkable embankment between them, as shown in Figure 3. These patterns of habitat segregation were frequently found in the Ganga Plains.

In the population of perennial wild rice, *i.e.*, *O. perennis*, allopatric growth with cultivated and wild species was more clearly ascertained. As mentioned already in the previous chapter, wild rice was growing in a region separated from cultivated one even in the same pond (W 6, Figs. 2 and 9; W 7, Figs. 2 and 10). In these ponds, no clear border was found among the respective region of wild, hybrid and cultivated species.

It may be concluded that wild rice occurred as an independent plant from the cultivated rice and was fundamentally not as a weed plant for the cultivated rice in the Ganga Plains, even if there is no embankment, ditch or road between them, and even if the plants of wild rice were thickly growing together in one group. Furthermore, the following considerations would not be unreasonable to make on the habitat segregation concerning the relations between cultivated and wild rice species. Sometimes the wild rice occurs as a weed in rice field, which was already reported by OKA *et al.* (11) and others. The populations of wild rice found in such paddy field would be looked upon as a newly established population; in other words, there is not so long time after the migration of these wild populations from other place to this one.

(3) In view of plant height, the following facts were ascertained during this trip. The plant of wild rice showed the height slightly taller than that of cultivated rice, when both of them were sympatrically or nearly growing with one another (Figs. 9, 10 and 19). The plant of wild rice showed its height slightly lower than that of cultivated rice, when both of them were allopatrically growing in near part of the habitat, aparting with some dimensions (Figs. 11, 13, 14 and 15).

(4) The flowering of spikelets in a panicle takes place in a regular sequence. Several characters are included in this category. Whole of them have been noted to be the same in cultivated and wild rice, *i.e.*, *O. sativa*, *O. sativa* var. *spontanea* and *O. perennis* (7).

(5) KATAYAMA reported (8) that the flowering time of *O. sativa*, *O. sativa* var. *spontanea* and *O. perennis* vary mainly with the time of sunrise, *i.e.*, it becomes gradually later from summer to autumn in accordance with the progression of the calender. There are a few intra-strain's variations. Correlation coefficients of the time of the flowering starting on the respective day are 0.907 in *O. sativa*, 0.927 in *O. sativa* var. *spontanea* and 0.930 in *O. perennis*, respectively, showing high significances among them at 0.1% level. Flowering time of the three species is not different from one to another and flowered in the morning. These data mentioned above are very important for the consideration of the relationship between cultivated and wild rices. The flowering time of all species observed was recognized as synchronized phenomenon in all populations. For example in populations found near Lauriya (W7) as shown in Table 1 and Figures 2 and 10, populations of each species showed the flowering-, pre-maturing- and maturing-stages, but they showed same time in view of the flowering time, even in two species. From the view of strain differentiation, in population of *O. sativa* var. *spontanea* (W4, Fig. 7),the plant growing in central region of pond showed the plant height higher than those in the edge, but both of them showed synchronized flowering times. All species mentioned above have genetically the same back-ground on the characters concerning in flowering time, and this phenomena have an advantage for natural intra- and inter-specific hybridization between them, which was frequently found in the Ganga Plains.

(6) Lastly, relations between soil conditions of paddy field and population of wild rice will be discussed here. As mentioned in the previous chapter, some paddy field was found in savannah region near Bhagalpur (Fig. 27) and others. Cultivated rice found in such region was noted to be very poor in its growth. It was ascertained that the poorer was the soil, the lower was the plant height, the fewer was the number of tillers, and the paler was the color of plant leaves. In other words, the poorer was the soil, the fewer was the possibility to find the locality, in the location where wild rice was growing. It would be used as one of the agronomical indicators that the productivity of cultivated rice, growing near the population of wild rice, was clearly larger than that of cultivated rice, growing far from the population of wild rice.

IV. Some considerations on the migration route and pattern of wild rice

Judging from view of origin of cultivated rice, the Ganga Plains occupies a pivotal position. So in this chapter, the migration route and pattern of wild rice in India will be discussed in the order of the following sub-chapters; natural migration, artificial migration, and domiciliation.

(1) Throughout this sub-chapter, the words "natural migration" was used to signify a tendency toward more or less indefinite large scale migration occasioned by inanimate objects, *i.e.*, water, wind, bird, and by animate objects, *i.e.*, plant and racial migration, under the certain favorable environmental conditions.

i) River …… One of the most important route for the migration of wild rice seems to be the river. As mentioned below, however, the role of river in respect of these migration was different

in accordance with the respective scale. In case of a very large river such as Ghaghara, Ganga, Yamuna Rivers (Fig. 1) and others, it is open to question, whether a river really plays an important part in the migration of wild rice. As mentioned already in the previous chapter (II–1–iii), the living plants including crop plants, weeds and trees, were wholly carried out in miraculous flood caused by large river, as shown in Figure 32. On these occasions, it was observed that no plant was entirely found extending over so many dimensions in the field and even under the small bridge girder. Such river would not be looked upon as a carrier of wealth, but as a carrier of a calamity for the native people. Establishment of strongly-built embankment for preventing the river from the flood was impossible for the time being in India. Because river water exhibits always dark brown color, plant-being at vegetative growth stage can not survive, when the plant was carried out in its entirety from the original site.

On the other hand, middle-scale river, such as Gandak, Rapti (Fig. 33), Son or Damodar Rivers (Fig. 1), would play the part as a carrier of plant migration, *i.e.*, as one of the most important migration routes. As clear example, configuration and route of Rapti River shall be explained here. Originally, Rapti River flows to the westwards in Nepal and to the south-eastwards after flowing in the Ganga Plains. It flows through the valley about 2 miles north from Maheto Stupa Site (Fig. 33), and it sets to the eastwards. After that, it sets to south-south-eastwards through the large valley from Maheto to Pharenda and joins the Ghaghara River at east of Dohrighat and the Ganga River at Chapra. Rapti River glides gently through the valley. As mentioned in the previous chapter, many populations of wild rice were found near the stupa and village, which are adjacent to this river. In the vicinity of Damodar River, a quite similar role is ascertained for the migration of wild rice. Such system or pattern found in these rivers could be fixed as one of the most important routes for migration of wild rice.

A quite little creek is running through the paddy field, grassland or waste land, which was frequently found in the Ganga Plains, such as Santi Niketan (Fig. 25), Lohardaga (Fig. 21), Ranchi, Vaishali (Fig. 30), Hoogly, and others. In these areas, small population of wild rice was considerably found in the edge- or middle-portion of the respective creek. It glides also quite gently. Then, the flowing wild rice through a creek could be noted as having a justifiable means for its migration. Artificial irrigation canals established in recent year or as of old could also be looked upon as having quite a similar favorable means for its migration.

In southern New Guinea it was found that the large population of *O. perennis* was floating and being carried away in Koembe River (6). A similar case would be found in some river, even in India. It is presumable that such migration behaviour is one of the most important procedures by which the plant is differentiated and spreads their population size.

ii) Companion plant …… It is well known that some plant species can live as a companion plant or crop to another species, and they migrate together by several methods from one place to the other locality. Wild rice is noted to be one of the companion plants of cultivated rice. Though wild rice has independently migrated on cultivated rice in the most cases, wild rice has been migrated dependently on cultivated rice as a companion plant of the latter in other cases. In the latter case, the migration route of wild rice was certainly noted to be the same as that of the cultivated rice. If the migration route of the cultivated rice was ascertained, it will naturally throw light on that of the wild rice. For this matter, the tribe of the people and road, which had been

used by the people for the migration of themselves, would have played an important role for spreading the cultivated rice, including naturally wild rice, in the view of speciology.

iii) Road and tribe …… Incidentally it was considered during this trip that the main route, which had been anciently used by the people for the migration of themselves, was mainly expected to be limited along the road, excepting for going up- and down-stream by boat. During the collection trip from November 3 to November 13 in 1971, populations of wild rice were frequently found along the road in some areas and not found along the road in the other areas. Basing on such observations, the following route of the migration of tribe and rice was reasonably expected; *i. e.*, the road from Lumbini to Motihari via Nandangarh has played remarkable role for the migration of the rice in relation to distribution of them from west Nepal to the Ganga Plains or *vice versa*. But the road from Lumbini to Gorakhpur via Pharenda or *vice versa* has not played any remarkable role for the migration of the rice in the same respect. This idea based its argument on the following facts in the other viewpoint. Populations of wild rice and old type of cultivated rice were found near Nandangarh, but no population of them was perfectly found in area between Gorakhpur and Pharenda, in which the road was observed to be recently established. Along there, flora was also looked upon as new habitat. Cultivation of rice along there was found but ascertained to be a new work. Migration of tribe and wild rice along Rapti River was also certainly assumed in the same respect. In conclusion, main migration route of wild rice from west Nepal to the Ganga Plains or *vice versa* in this sense would be assumed to be the following two routes : Lumbini → Nandangarh → Motihari → Muzaffarpur → Vaishali → Patna (mainly along Gandak River) or *vice versa*; Jalkundi → Srabasti → Balrampur → Gonda → Faizabad, Basti and Gorakhpur (mainly along Rapti River) or *vice versa*.

On the other hand, as mentioned in the previous chapter, floras between Bhagalpur and Santi Niketan, Nalanda and Gaya, Nirsa and Hoogly have many populations of old type of cultivated rice and wild rice. In these areas, it was expected that tribe has long history of rice cultivation and has migrated along the road bringing together cultivated and wild rice.

As the collection trip in north-eastern part of the Ganga Plains, *i.e.*, Nirmali, Jagbani, Purnea and others (Fig. 1) was cancelled owing to the large scale flood damage, contrary to the first schedule, migration route of wild rice from east Nepal to the Ganga Plains or *vice versa* could only be assumed so far as data obtained in this trip is concerned.

iv) Topographical condition …… Topographical configurations, in a sense of large scale, will be one of the most important factors in view of migration of wild rice. Throughout this subchapter, the term "direction" was used to show a tendency of migration from the original locality to the new locality migrated, *i.e.*, from the older to the newer localities. In this sense, three cases must be briefly considered. At first, the migration occurs easily at an area of smoothly going down direction in view of elevation, provided environmental circumstances are permissible for the growing of wild rice, *i.e.*, temperature, rainfall, light intensity or soil constitution. Such cases were frequently found in the Ganga Plains, and some sorts of wild rice are growing there, such as Patna, Gonda, and others. Secondly, the migration is difficult at a little eminence, even if in going down direction in view of elevation from the large landscape. Indeed, wild rice was not found in these areas at all, such as Samastipur. However, the migration occurs possibly in such topographical configuration, if pond or swamp is situated at the little eminence. Such topographical config-

uration was found in Gorkha Hill, Ranchi, and the large population of *O. perennis* was found in the pond. Thirdly, the migration occurs easily at an area of smoothly going up direction in view of elevation, so far as environmental circumstances are permissible for the growing of wild rice. Some configurations such as Nandangarh (W 7, Fig. 10) and others were found many times in the Ganga Plains, and wild rices were growing there.

v) Disturbance …… Factors of disturbance for migration of wild rice considered in three points are as follows; First, the migration is difficult at an area of smoothly going up and down direction in view of elevation, so far as environmental circumstances are not favorable for growing of wild rice, such as desert situated in a plateau. Such case was also found in south area of Ranchi, from there topographical configuration changed to Deccan plateau. No wild rice was found in the northern area 2 miles north to Canadian Dam. It may be due to the gradual going down in view of the temperature. Secondly, because wild rice migrates as companion plant of cultivated rice in most cases, tribe of people seems to be the limiting factor for the migration of wild rice in this case. When the tribe migrating to new locality is not fond of rice cultivation, the migration of wild rice may not be occurred, even if environmental circumstances in new locality are permissible for the growing of wild rice. In New Guinea, such cases have practically been found. Rice cultivation in west New Guinea is almost limited to the regions, where Indonesian people are living. Papuan people are not dedicated to rice cultivation (3). The migration of cultivated rice, including companion plant, *i.e.*, wild rice, seems to have been introduced by a people, who can cultivate rice and fond of it in the Ganga Plains. Lastly, soil conditions seem to be one of the most serious factors of disturbance for migration of wild rice. For example, migration may be disturbed on the way in some area, in the one where soil showed alkaline character, as mentioned in the previous chapter (II–1–viii). It is probable that adaptively ecotypic differentiation of wild rice to alkaline soil has not been occurred by any mutation up to now.

vi) Conclusion …… In summary of consideration on the migration of wild rice in view of large scale, the following conclusions may be drawn, basing on the several factors mentioned above. Migrations of wild rice in large scale was occurred from north to south localities, through the taking over a portion of the role by water, plant, animal and human being. Populations of wild rice had been, at first, continuously spreaded all over the Ganga Plains, following the invation from Nepal or *vice versa*. After that, the migration was disturbed in Deccan plateau and remarkable savannah, and further migration occurred only in east coast of India, to the vicinity of Orissa State and northern Madras State. The migration proceeded to west direction, such as Madhya Pradesh or Mysore State.

(2) Throughout this sub-chapter, the words "artificial migration" was used to signify a tendency toward more or less definite scale migration occasioned by animate objects, *i.e.*, animals and human beings, under the certain favorable environmental conditions in India.

i) Bird or buffaloes walked in and out the pond or swamp. Native people work in pond for collection water-caltrop or a kind of pond-snail as food materials, which were found at Shahiahampur and Santi Niketan (Fig. 7), respectively, and at other lot of localities. Because seeds of wild rice showed remarkably shedding behaviour at the pre-maturing and maturing stages, the seeds may be brought forward to other places by animals or native people in such cases, by being attached to them,

ii) People carry some things by the cart on the road. Seeds of wild rice shedded may be attached to it.

iii) Artificial irrigations for the paddy field and upland field using some cans or canoes are practised in several localities, such as Samastipur, Rajgir, Darbhanga (Fig. 28) and others. As mentioned above, the seeds of wild rice showed remarkably shedding behaviour, so that they float on the water and flow away in rivers or canals over the long distances. They may easily spread their habitat, owing to such artificial irrigation method.

iv) Along the main road connected the river, there are many washing-places for cart or car. Owing the same reasons mentioned above, the seeds of wild rice may be carried away by cart or car over the relatively long distances.

(3) Populations of wild rice were continuously found during long dimensions, such as areas of Arrah, Sasaram, Balrampur, Nirsa, Asansol, Raniganj, Rasulpur, but were interrupted in the long distances in other cases. In the areas, in those where wild rice was continuously growing over the long distances, population seems to be certainly domiciliated there in some extent. In this sub-chapter, back-ground factors of "domiciliation" of wild rice in the respective locality will be discussed.

i) As shown in the previous chapter (II-2-vi), the plenty of swamp, pond and paddy field, where cultivated and wild rice were growing, were adjacent to a graveyard, stupa or ruin of kings and rulers. Such constitutions of them were found at Lauriya (W 7 in Table 1 and Fig. 10), Kushinagar (W 18, Fig. 13), Srabasti (W 24, Fig. 33), Koshambi (W 34, Fig. 34), Nalanda (W 38, Fig. 36) and others. It was presumable that king or ruler had established castles or temples in an eminence and on a locality commanding a good view (Figs. 31, 34 and 35), which has been noted as a quite necessary stipulation for establishing and keeping their administrations at the respective locality. It would be a matter of course that the larger was population size of the native people, the larger became the scale of paddy field or swamp in accordance with the respective case. In the process of domiciliation of population of wild rice, it may sufficiently be true that the longer was the period governed by each king or ruler, the more stable was the population of the wild rice.

Even if castle or ruin has been distroyed in the greater part of it, configuration of castle or ruin, paddy field and swamp would be sufficiently assumed their original constitutions. Such case was found at Koshambi (Fig. 34). If the same tribe of people in the view of speciology has been domiciliated in its place after king or ruler has been overthrown, the population of wild rice may be continuously kept in its original territory.

ii) Population of wild rice were found, in general, near old village but not within old village or city. In other words, population of wild rice could not be domiciliated in the city, in which numerous disturbances were made by the people. Several cases of disturbance were ascertained during this trip to be smog, cutting off, animal husbandary, building house, constructing road and others. Two exceptional cases, however, were found. Populations of wild rice were found even near Hoogly City and in the road-side swamp, situated between large road and steam power plant (W 41). In the latter case, the air in these areas was exceedingly sick very much with fumes, coiling up from a chimney. It is very interesting on the genetic back-ground of its population, whether wild rice growing there has still differentiation-possibility or had already been driven on to the deadlock on the evolutional viewpoint.

On the other hand, population of wild rice was not found in the locality very far from the village. In conclusive sense, population of wild rice could stably be domiciliated in suburbs of the village but not so near or so far from the village. However, it is remaining as an interesting problem, whether this domiciliating pattern mentioned just above will be noted as locality specific characteristic or not; because the populations of wild rice have been frequently found in gardens, front or under a native house in North Borneo, Brunei and Sarawak (6).

iii) It is naturally assumed that domiciliation of population of wild rice was easily established, when the plant, including seed, leaf or under-ground part of it, was constantly used by the native people. It was said that the seeds of wild rice were collected and used as food materials by the poor people, who was living near Asansol, Raniganj and others. On the other hand, the seeds of wild rice growing in pond near Lauriya (W 7, Fig. 10) and Srabasti (W 24) were collected by boat and were sold at market. In these cases, the seed of wild rice excited higher bidding than that of the ordinary cultivated rice, *O. sativa*. The former was generally used for some festival and said to have a very sweet taste.

In some cases, the seeds and/or leaves have been used as some medicine, *i.e.*, hemostatics or stopping of abortion. Some similar methods have been found in the other countries, *i.e.*, in Brunei, Borneo, the base and lower part of culms of wild rice, *O. officinalis*, are cut off and boiled, after that their diffusates are used for curing malaria (6). Such case may be found also in the Ganga Plains, and is practically recorded in Kumta, south-west India.

When the wild rice has been used, at least, some part of it by the native people for some meanings mentioned above, the population of wild rice would be easily domiciliated not only as the "true" wild grass but also as "useful" grass in the connection to the native people.

V. Considerations on the origin of rice

Though, of course, the conclusive discussions and hypotheses would be drawn, basing on the extensively analyzed data, which may be obtained after several experiments made with the use of materials collected during this trip and from other countries, the appreciable considerations were reported here, basing on the experiment obtained up to this time.

In this chapter, the problems concerning the origin of cultivated rice will be briefly discussed in the order of the following subjects; primitive cultivated rice, putative ancestor of *O. sativa*, and primary and secondary centres.

(1) Primitive or native varieties of cultivated rice have generally a tendency to decrease from year to year in every localities of the Ganga Plains. New varieties, so-called high yielding varieties, are to be brougt forth out of the native varieties. However, the primitive varieties were cultivated in many places, because these varieties have the following merits on the practical cultivation, *i.e.*, stable production through the respective year, needlessness of manure and insecticide or fungicide, with no help of the proceeded techniques in the teeth of low yieldings. On the other hand, cultivation of new varieties showed unstable production year by year in accordance with the respective environmental conditions, and were practically enforced to use considerable amount of manure, insecticide or fungicide, and proceeded techniques, especially advanced irrigation systems. Recently, SHARMA *et al.* proposed a project for the systematic collection of the current and primi-

tive cultivars of rice from the north-east parts of India (15). In the present trip, the many primitive varieties had also been collected. These characteristics are being measured now and would be published in the separate article.

(2) A number of hypotheses regarding the putative ancestors of *O. sativa* have already been published (13, 14, 16 and others). CHANG (1964) had summarized these hypotheses (1) and mentioned that the question of the putative progenitor of *O. sativa* is to be fixed into the three hypotheses as follows; *O. sativa* f. *spontanea*, *O. perennis* and *O. officinalis*. The last one is considered not to be concerned in the putative ancestor of *O. sativa*, because *O. officinalis* might have been originated in Borneo or its adjacent islands, judging from several morphological and physiological characters (4). On the former two species, the conclusive issues would be published in the future papers after analyses made in detail, using the materials collected in the present trip and other countries.

(3) Archaeological evidence found in India dates the antiquity of rice to 1,000 B. C. According to several reports, rice cultivation probably began about ten thousand years ago. After WATT (16) and others, origin of *O. sativa* is fixed to be the area embracing south Asia, south-east Asia and China. CHOU (2) and others held that China is one of the primary centres of the origin and that differentiation of the *japonica* varieties took place in China. On the other hand, KATAYAMA (5) held that Sikkim might be one of the differentiation centres of *O. sativa* into *japonica* and *indica*, judging from diallel crosses using several strains collected in Sikkim and other countries. RAMIAH *et al.* (12) stated that cultivated rice had been originated in south India, and *japonica* type must have been developed later from *indica* type. Though this has been looked upon as complex symptom, it may become clear after analyses made in detail by using materials collected in the present trip.

(4) South India, for example, Jeypore and Cuttack tracts, may be looked upon as secondary centres, though very large populations of wild rice are found now, basing on several characters mentioned in the previous papers (9, 10). On the other hand, the Ganga Plains may be regarded as a primary centre over the large areas. This hypothesis will be clarified by the detailed experiments made by using new and old materials.

VI. Summary

During the trip from October 28 to December 8 in the Ganga Plains, *i.e.*, West Bengal, Bihar and Uttar Pradesh, many populations of wild rice species, *i.e.*, *Oryza sativa* var. *spontanea* ROSCHEV. and *Oryza perennis* MOENCH, and of natural hybrids were observed and forty two strains of wild species and three of natural hybrids were collected. Extensive considerations on the distribution and evolution of the rice were discussed. The main points were summarized as follows :

1) Distribution of wild rice were found in very large areas, and it was presumable that northern limit and western limit of the wild rice in the Ganga Plains were 29° N, 79°E and 27°N, 78° 10′E, respectively. Preventing factors of collection during this trip were discussed in view of the trip route, road position, flood damage, changing habitats by inanimate, animate objects and men, time lag of the maturing stage and soil condition. Limiting factors of natural distribution of wild rice were discussed in the view of water depth, population size, topographical constitution, flow of

river, annual rainfall and temperature.

2) Relationships between cultivated and wild rice species were discussed in view of natural hybrid, sympatric or allopatric growth of them, plant height, flowering order, flowering time, configuration of paddy field, and others. It will be noticeable that, in general, the wild rice appeared not to be a weed plant for the cultivated rice in the Ganga Plains.

3) Migrations of wild rice in the Ganga Plains were considered on the aspects of natural migration, artificial migration and domiciliation. The first former one was considered from the viewpoint of river, companion plant, tribe and road and topographical condition. Very large river might not be looked upon as a carrier of wild rice, but middle- and small-scaled rivers might be regarded as a carrier of wild rice. Migration occurred from north to south and continued all over the Ganga Plains, and after that, proceeded to east coast of India. The main migration route of wild rice from west Nepal to the Ganga Plains or *vice versa* may be assumed to be the following two routes : Lumbini → Nandangarh → Motihari → Muzaffarpur → Vaishali → Patna or *vice versa*, and Jalkundi → Srabasti → Balrampur → Gonda → Faizabad, Basti and Gorakhpur or *vice versa*. On the domiciliation of wild rice, the castle or temple, village constitution and usage by people should be extensively discussed. The following facts may be noticeable. King or ruler had established castle in an eminence, commanding a good view, which has been looked upon as a very necessary stipulation. Swamp, pond and paddy field, where cultivated and wild rice are growing, were adjacent to such castle or temple. It was assumed that the longer was the governing-period under each king or ruler in ancient time, the more stable was the population of the wild rice.

4) The origin of rice was considered in view of the primitive cultivated rice, putative ancestor of *O. sativa*, putative centre of *O. sativa*, and primary and secondary centres of it. The Ganga Plains may be looked upon as a primary centre and south India, *i.e.*, Jeypore and Cuttack tracts as secondary centres, respectively.

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Explanation of figures in plates

Figs. 5-23. Natural habitats of wild rice. Species names, dates of collection and localities were shown in Table 1. **5** : W 2, **6** : W 3, **7** : W 4, **8** : W 5, **9** : W 6, **10** : W 7, **11** : W 9, **12** : W 10, **13** : W 18, **14**: W 21, **15** : W 25, **16** : W 28, **17** : W 29, **18**: W 31, **19** : W 36, **20** : W 39, **21**: near Lohardaga, Ranchi, **22** : W 40, **23** : near Bhadrakh, Cuttack.

Figs. 24-36. Natural habitats concerned in text were arranged, following the date of the trip. **24** : road constitution near Santi Niketan, Oct. 28, **25** : canal near Santi Niketan, Oct. 29, **26**: plateau near Bhagalpur, Oct. 30, **27** : savannah near Bhagalgur, Oct. 30, **28** : irrigation method near Darbhanga, Nov. 1, **29** : floating rice near Motihari, Nov. 3, **30** : small canal near Vaishali, Nov. 5, **31**: stupa and its vicinity near Vaishali, Nov. 5, **32**: flood damage near Dohrighat, Nov. 9, **33**: view of Rapti River from Maheto Stupa, Nov. 12, **34** : ruin of Koshambi, Nov. 21, **35** : view of Sarnath, Nov. 22, **36** : savannah near Nalanda, Nov. 24.


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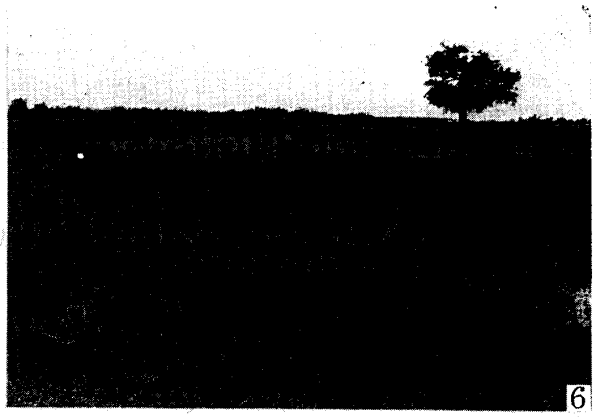
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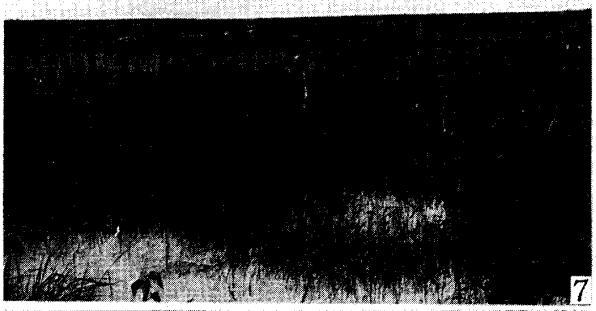
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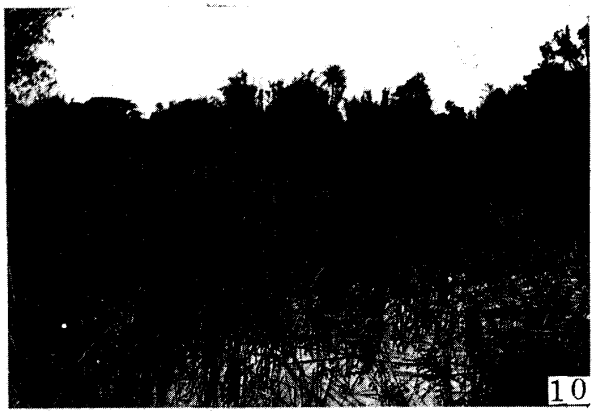
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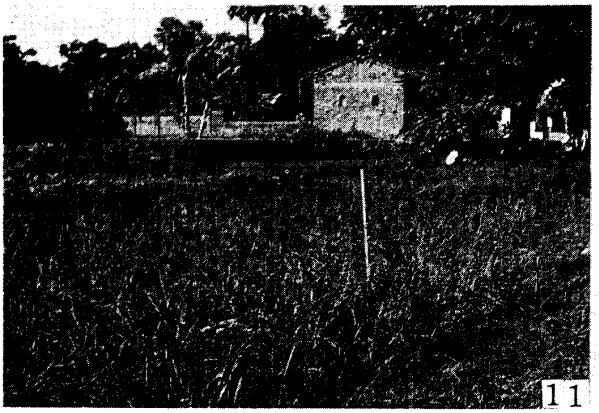
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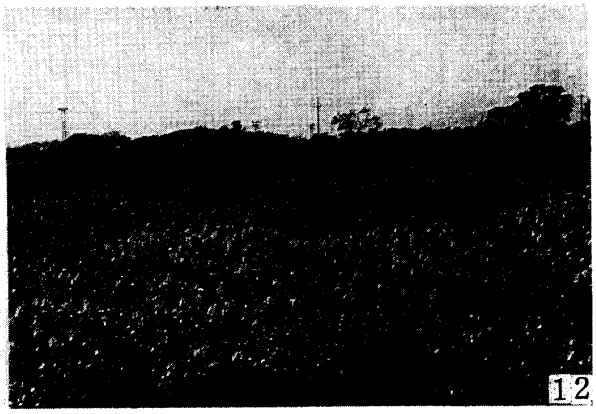
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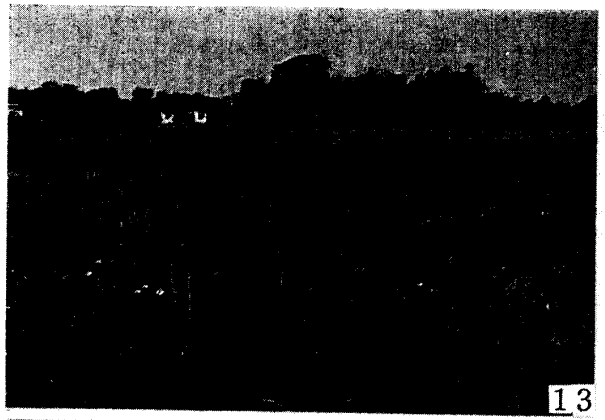
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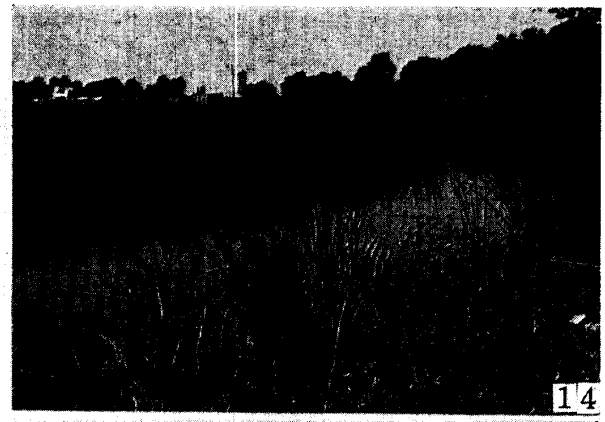
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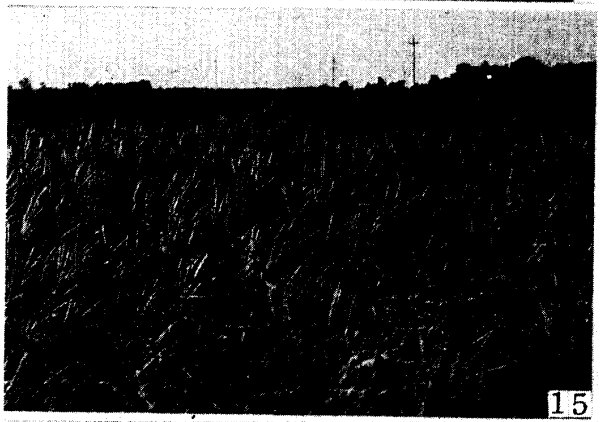
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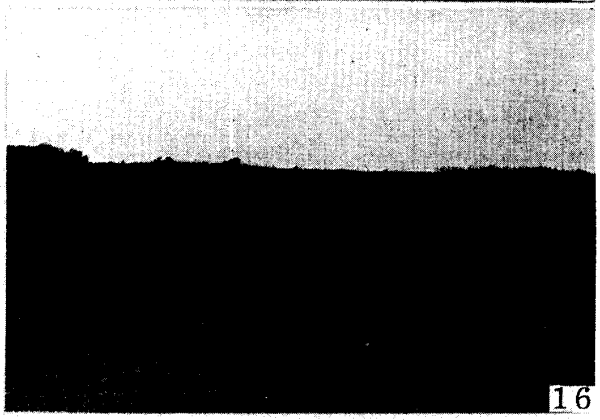
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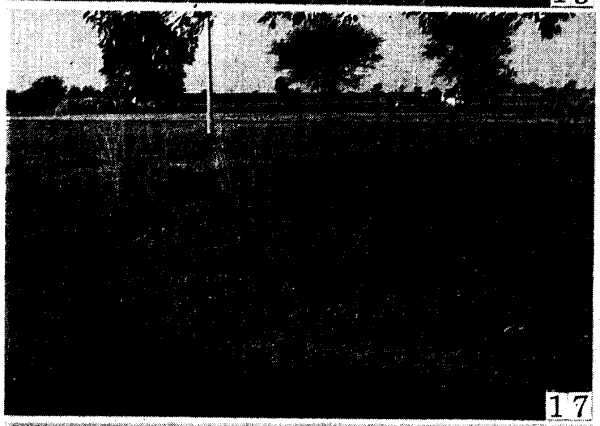
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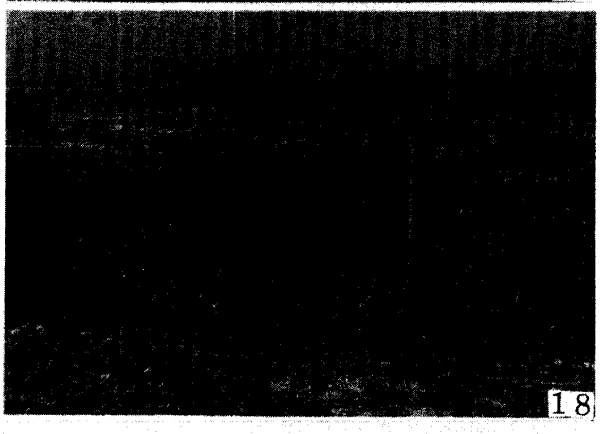
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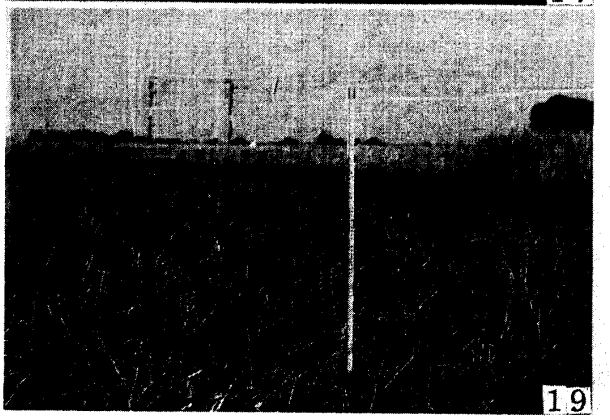
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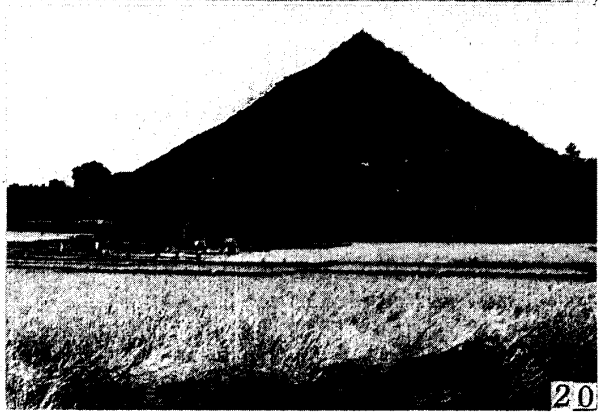
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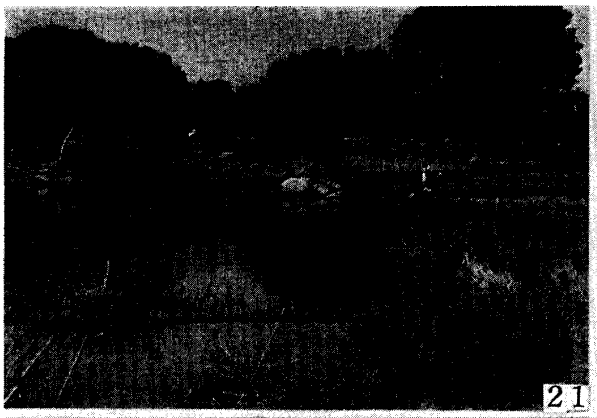
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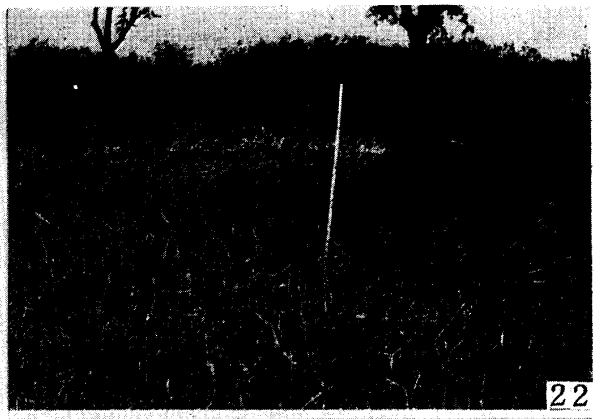
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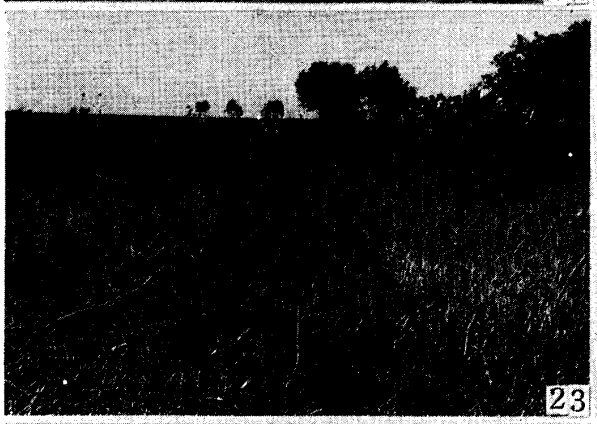
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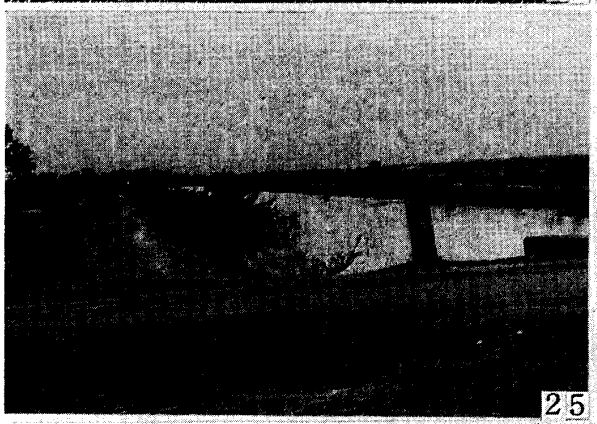
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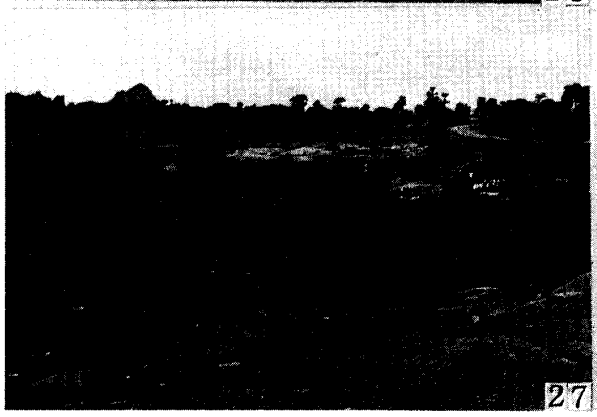
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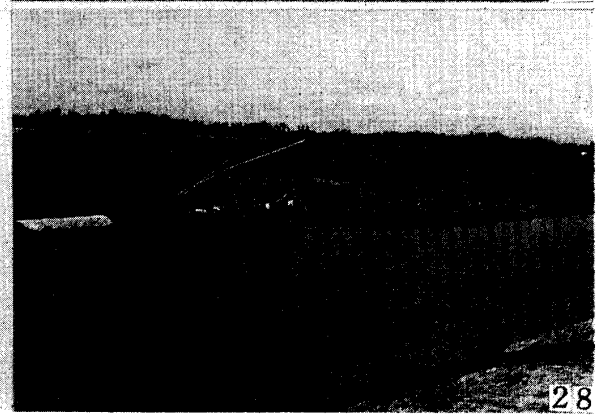
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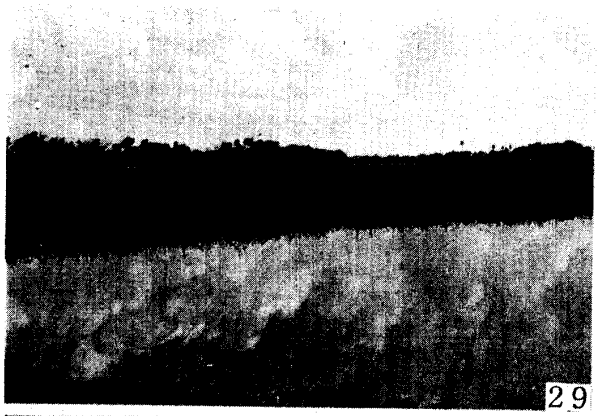
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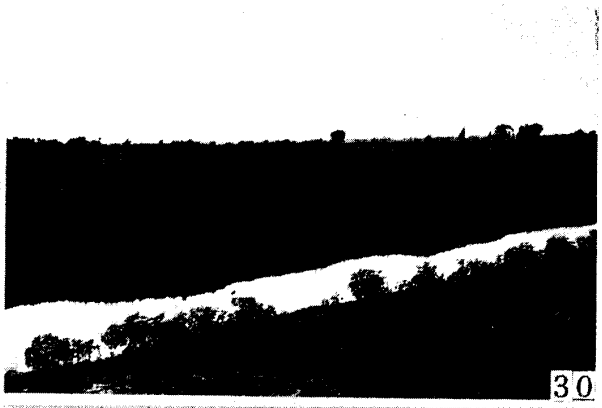
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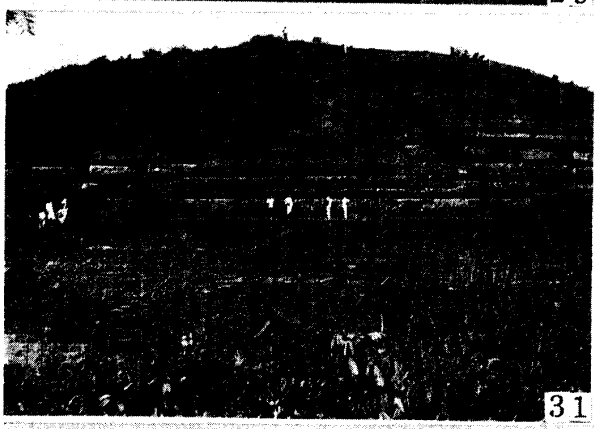
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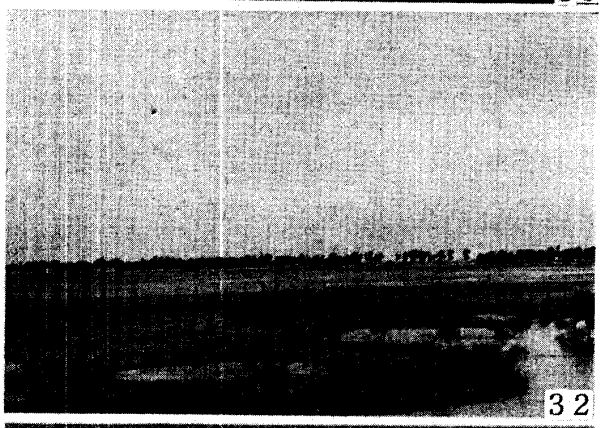
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