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A survey of environmental stresses on crop fields as shown by changes in the structure of weed communities

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Abstract. This work aims at learning about the impact of environmental changes on crop fields in Taiwan as reflected by changes in the structure of weed communities. Weed communities were investigated on the assumption that the plants sprouting from buried seeds in soil samples represent the potential vegetation which would occur when a field was denuded and left without weeding for a few months. A part of the coastal area of Taoyuan County suffers from a complex of stresses, comprising saline wind from the sea owing to the destruction of windbreak forests, acid rains, and squalls of sulfur dioxide emitted by Linkow Power Plant. Weed communities in rice fields in the stress area showed higher density and lower equitability of species than those under normal conditions. This trend of change is comparable to that observed in copper-polluted rice fields in Japan. On the other hand, soil samples from abandoned fields near a copper smelter showed a pronounced reduction of weed density, some being completely barren.

The crop fields around Matou Town, Tainan County, planted with two rice crops a year, planted to sugar cane continually, and under the Chianan rotation system (two rice crops, a cane crop, and several upland crops in three years) were also observed by the same method. Rotation was found to have reduced the density and number of species of weeds, leaving equitability unchanged. The effect of crop shifting on weed communities was thus found to differ markedly from that of stresses due to pollution.

Key words: Crop rotation; Environmental stress; Pollution; Species equitability; Weed community.

Introduction

A spoonful of soil contains hundreds of plant seeds. A part of the seeds germinate when the soil is watered properly in a receptacle. The plants sprouting from the seed pool represent the potential vegetation that would occur when the field is denuded and left without weeding for a few months (Morishima and Oka 1980; Oka, 1984). In crop fields, it is difficult to take records of weed vegetation since weeding is made frequently. Therefore, an observation of plants occurring from soil samples would be a good method of surveying weed communities. Weed communities may sharply respond to environmental conditions by changing their structure. The changes may be regarded as reflecting the biotic environment that is affected by physicochemical environmental conditions.

The agricultural environment in Taiwan is changing as the result of environmental pollution and extensive use of herbicides and pesticides.

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The present study was projected to assess the biotic impact of such environmental changes as reflected by changes in the structure of weed communities. The results of some preliminary work conducted in 1986 are reported in this paper. The data show the effects of stress conditions on weed communities causing certain directional changes.

Materials and Methods

Soil samples, each consisting of surface soils (to a 3 cm depth) taken from several spots in a field and weighing about 1 kg, were collected from different sites in three districts, as follows:

1) The coastal area of Luchu Hsiang, Taoyuan County. Three rice fields were arbitrarily chosen as sampling sites. This area is subjected to saline wind from the sea due to destruction of the wind-break forest of *Casuarina equisetifola* and temporal acid rains, and suffers from low yields of the second (summer) crop rice, as will be mentioned later. As the control, soil samples were taken from rice fields in the inland side of three rural municipalities (Hsiang), Luchu, Shinwu and Pate

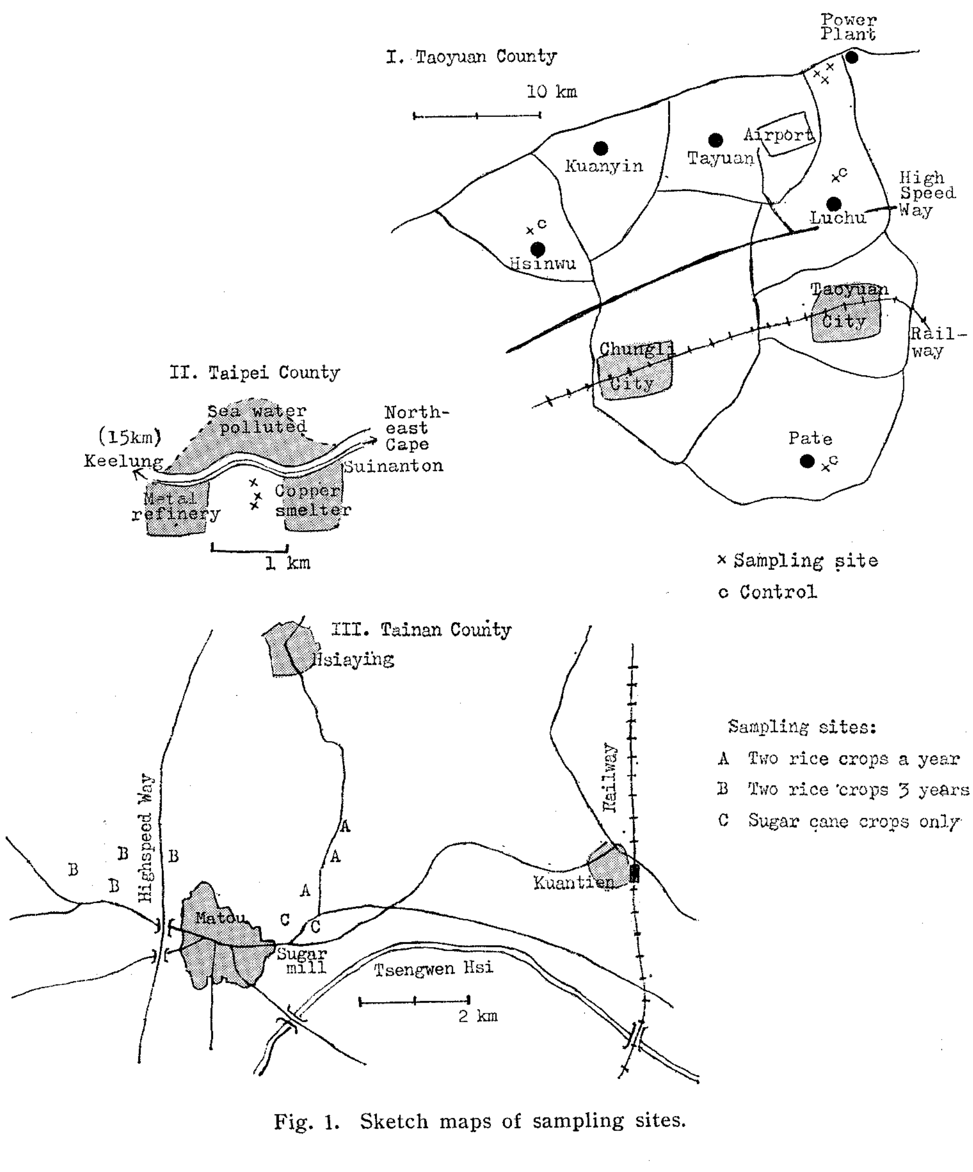

Fig. 1. Sketch maps of sampling sites.

(all in Taoyuan County; Fig. 1). Sampling was made in winter (February 18) and in summer (July 23).

2) Abandoned fields on a hill near a copper smelter (Taiwan Metal Co.), about 15 km east of Keelung along the coast (Fig. 1). Soil samples were taken from three sites on April 12.

3) Fields under different cropping systems around Matou Town, Tainan County: (A) rice fields planted with two rice crops and a vegetable crop a year, (B) fields under the Chianan rotation system, planted with two crops of rice, a sugarcane crop and several upland crops in three years in accordance with the schedule of irrigation, and (C) upland fields planted to sugar cane continually. Soil samples were taken in winter (January 23) and in summer (July 17).

On visiting the sampling sites, weed vegetation was recorded briefly if some remain without weeding. The soil samples were sun-dried, pulverized, and put in small plastic trays (17.9×10.3 cm$=184$ cm^2, 4 cm deep, with small holes on the bottom), each with two replications. The small trays were placed in larger trays filled with water, and were left in a glass-house. The soils in trays were kept moist for 3 (summer) to 4 (winter) months until most of the plants sprouting from buried seeds either flowered or attained a size so that they could be identified. Then the plants were classified into species and their numbers were counted.

As a measure to assess the structure of weed communities, species diversity was evaluated by the information content as given by Shannon-Wiener function,

$$H' = -\sum p_i \ln p_i,$$

where p_i stands for the proportion of plants of i-th species to the total plant number. Then, equitability was estimated as H'/H'_{max}, where $H'_{max}=\ln$ (no. of species) (Krebs, 1978, p. 456).

The total number of plants which would occur per unit area (m^2), or total weed density was estimated from the plant number per sample in two trays. The significance of differences in these values due to environmental conditions was tested either by analysis of variance or by t-test.

To examine whether or not the distribution of species differs according to environmental conditions, the data on the number of plants of different species were subjected to analysis of variance after being converted into $\log_{10}(n+1)$. For this, species occurring relatively frequently (relative frequency $>11\%$) only were used.

Results and Discussion

A. The effects of environmental pollution

1. *Weed communities in the coastal area of Luchu Hsiang*

This area is known to be subjected to a complex of environmental stresses, as mentioned. According to an observation by the Taoyuan District Agricultural Improvement Station (unpubl.), the soil pH value in this area is about 4.5, lower than that in normal area by about 1.0, on account of acid rains. However, this was not confirmed in the soil samples collected by the author, as the pH values ranged from 4.5 to 5.5 similarly as those from control fields.

The weeds sprouting from soil samples taken from this area and control sites comprised 9 grass, 8 sedge, and 28 dicot species, mostly being annuals. The weed communities obtained from this area differed from the control in that the total density was higher and the equitability of species was lower. Species diversity (H′) was also lower in the stress area than in the control, but the difference did not reach the 5% level of significance (Table 1).

This pattern of changes is nearly the same as that observed in Japan for copper-polluted rice fields, reported by Morishima and Oka (1977, 1980), although the pollutants concerned are quite different. The high density of weeds in the stress area is due to the domination of certain species.

Table 1. *Structure of weed communities compared between rice fields under stress and normal conditions in Taoyuan County*

Condition	Season	No. of samples	Density (No./m²)	No. of species	H′	Equitability H′/H′max
Stress	Winter	3	9,736	12.0	1.13	0.457
	Summer	3	3,435	7.7	1.29	0.512
	Mean		6,585	9.8	1.11	0.484
Normal	Winter	3	3,390	8.7	1.50	0.699
	Summer	3	1,148	8.0	1.53	0.751
	Mean		2,269	8.3	1.52	0.725
Difference:						
Winter-Summer			*	ns	ns	ns
Stress-Normal			*	ns	ns	*

* Significant at 5% level. ns: Not significant.

Table 2. *Trend of distribution of major weed species (relative frequency >20%) in stress and normal rice fields*

Abundance trend	Species	Relative freq. (%)	Density ratio*
Increasing under stress	***Cyperus difformis*** L.	77	60
	Ludwigia epilobioides Maxim.	46	45
	Echinochloa crus-galli Beauv. (w)	38	153
	Eclipta prostrata L. (w)	31	90
	Fimbristylis miliacea Vahl. (s)	31	6
	Wahlenbergia gracilis A. DC. (s)	23	—
Decreasing under stress	***Monochoria vaginalis*** Pr.	31	1/7
	Lindernia procumbens Philcox	23	—
	Stellaria aquatica Scop.	23	—
	Gnaphalium affine D. Don. (w)	31	1/20
Nearly unaffected	***Hedyotis diffusa*** Willd.	77	4
	Rotala indica Koene.	38	1/2
	Vandellia ciliata Yamaz.	31	1/4
	Centipeda minima Braun. (w)	23	4
	Vandellia antipoda Yamaz. (s)	23	3

* Stress/Normal density ratio, — showing infinite or zero.
(w), (s): Abundant in winter and summer samples, respectively.

The species increasing and decreasing in the stress area as compared with the control sites are listed in Table 2, excluding infrequent species. *Cyperus difformis*, although commonly distributed in many places, was particularly abundant in the stress area, its density in the stress area being 60 times as high as that in the control. Similarly, five other species showed an increase in the stress area. On the other hand, *Monochoria vaginalis* and three other species showed a decrease in the stress area.

It is somewhat awkward, however, to test the statistical significance of the increase or decrease in density of different species. In Table 2, the increasing or decreasing species were nominated when their density ratio exceeded 5 times. With 23 species occurring twice or more in 12 samples, the data for plant number per sample, converted into $\log_{10}(n+1)$, were subjected to analysis of variance (Table 3a). The results showed that the interaction between species and stress vs. normal condition, representing the differential increase or decrease of certain species, was significant, and that the least significant density ratio would be 2.4 times.

It is not more than a matter of conjecture why certain species has increased in the stress condition, increasing the total weed density. In view of nearly random association of weed species (Oka, 1984), their interaction would be in the state of diffused competition, and the lognormal distribution of species suggests that various effects on them are multiplicative (Oka and Liu, 1984). All the weed species are subjected to habitat disturbance due to cultivation and weeding, while they would be adapted to the condition and balanced mutually to maintain an equitability among them. Yet, when an additional stress comes about, their balance would be affected resulting in domination of certain species tolerant to the stress. The decline of equitability would bring about an increase in total density, in the same manner as the house fly outbreaks when other fly species decline.

The similarly in the pattern of community changes found between the Luchu rice fields under stresses and the copper-polluted rice fields in Japan suggests that, as Woodwell (1970) has pointed out, "change in natural ecosystems caused by many different types of disturbances are similar and predictable". Probably, the biotic environment is affected by different kinds of pollutants to bring about similar changes. The data thus indicate the presence of certain stress conditions in the problematic area, although the nature of the stress is not specified. The true character of the stress conditions, remaining unsettled, will be discussed later.

2. *Samples from abandoned fields near a copper smelter*

The sampling sites are on a seaside hill about one kilometer distant from both a copper smelter (east) and a metal refinery (west), where east wind prevails (cf. Fig. 1). This place would suffer from not only air pollution (SO_2) but also the fallout of dusts containing heavy metals. The hill has a plant cover consisting of some shrub and fern species which would be tolerant to the pollution, as this area enjoys much rainfall. Perennial grasses like *Miscanthus sinensis* and *Imperata*

Table 3. *Analysis of variance of plant number in $\log_{10}$ $(n+1)$ for testing difference in species distribution*

a. Stress vs. normal rice fields in Taoyuan County, for 23 species occurring twice or more among 12 samples

Source of variation	d. f.	Mean square
Species	22	0.5377**
Stress : Normall	1	0.0026
Winter : Summer	1	1.2670*
Interaction	1	0.0007
Species x		
Stress : Normal	22	0.4935**
Winter : Summer	22	0.2767
Residual	206	0.2101
LSD (5%, for interactions with species)		0.374 (2.4 times in ratio)

b. Fields with different cropping systems around Matou, for 19 species occurring 3 times or more among 27 samples

Interactions with species	d. f.	Mean square
Winter : Summer	18	0.1676**
Rice : Cane : Rotation	36	0.0886*
Rice : Cane	18	0.1028*
(Rice + Cane): Rotation	18	0.0743
Residual	36	0.0414
LSD (5%)		0.2895 (2 times in ratio)

*,** Significant at 5% and 1% levels, respectively.

Table 4. *Soil analysis, existing vegetation, and plants sprouting from soil samples taken at three sites near a copper smelter, about 15 km east of Keelung*

Site	pH[a]	Metals (ppm)[b]			Vegetation observed	Plants sprouting (No./m^2)
		Cu	Zn	Cd		
1	5.9	188	198	0.14	Close to a house and weeded	Ga-1 54 Da-63 54 Fern-3 190
2	4.1	184	15	trace	Perennial grasses: Gp-2, Gp-3, Gp-5; Fern-1 & Fern-2	Sa-3 136
3	3.8	76	0.8	trace	None, surrounded by Gp-5	None

[a] H_2O (1 : 1) [b] 0.1 N HCl soluble metals

Gp-2: *Cynodon dactylon* Pers.
Gp-3: *Imperata cylindrica* Beauv.
Gp-5: *Miscanthus floridulus* Warb.
Ga-1: *Digitaria ciliaris* Koel.
Sa-3: *Fimbristylis aestivalis* Vahl.
Da-63: *Vandellia crustacea* (L.) Benth.
Fern-1: *Nephrolepis hirsutula* Pr.
Fern-2: *Histiopteris incisa* J. Sm.
Fern-3: *Microlepia strigosa* (Thunb.) Pr.

cylindrica and perennial ferns like *Histiopteris incisa* grow vigorously. In this respect, this place differs from the valley and hill-side of Asio copper mine in Japan which are almost barren.

The three sampling sites were close to each other, sites 1 (highest) and 2 being 30 m apart, and 2 and 3 only 20 m apart. Yet, the pH and metal contents in the soil differed much, indicating that soil pollution is mosaic (Table 4). The reason for this remains unknown.

Site 1 was a waste land nearby a house, slanted and partly shaded by trees. Site 2 was an abandoned field with a vegetation of grass and fern species. Site 3 was also a small field cultivated in the past, but there was no plant growing. The field was surrounded by clumps of *Miscanthus floridulus*. The soil samples from sites 1 and 2 produced some plants, but their density was exceedingly low (Table 4). The soil from site 3 sprouted no plant as if the soil had been sterilized. The present author has not seen such completely barren soil previously.

It may be suggested that a moderate degree of stress brings about the dominance of certain weed species, decline of equitability, and an increase of total weed density, but a stronger stress reduces the surviving plants and buried seeds also.

3. *Effects of crop rotation on weed communities*

Crop rotation is highly developed in the central and southern parts of Taiwan. Where sufficient irrigation water is available, two crops of rice are grown in the first (winter) and second (summer) crop seasons, and a upland crop is raised in the interval between the second and first rice crops. In an about 150,000 ha area extending over Tainan County and a part of Chiayi County, however, water supply is controlled by the Chianan Irrigation Corporation. The fields are divided into three blocks each conducting a three-year rotation system with a different time schedule. The standard rotation schedule is as follows: The first year starts with some upland crop. In June to July, water is supplied and rice is planted as a summer crop. After the harvest of rice in October to November, sugar cane is planted, which will be harvested in the winter of second to third year. Then, some upland crop will be planted, and rice is grown in the summer of the third year. Thus, two rice crops, a sugarcane crop, and several upland crops are rotated in the period of three years.

Water comes from the well-known dam-lake at Usantou which takes water from the Tsengwen Hsi. The construction of the dam, and trunk and branch canals for irrigation and for drainage, exceeding 20,000 km in total length, was completed in 1930. Before that, this area suffered from drought and had little agricultural production. Until 1972, rice crop was limited to once in three years. Since the irrigation capacity was increased by the construction of the Tsengwen Dam in 1973, two rice crops have been raised in three years. Recently, sugar cane tends to decrease as replaced by other upland crops.

Around Matou Town, as mentioned, fields with three different cropping systems are found in proximity, having the same climatic and edaphic conditions, namely, A) planted with two rice crops and a vegetable crop a year, B) under the three-year rotation system, and C) planted to sugar cane continually (Fig. 1).

Among the plants sprouting from soil samples taken in this area, 7 grass, 7 sedge and 17 dicot species were identified, most of which were annuals. The weed communities obtained from the three kinds of fields differed significantly in total density (A>B; $\frac{1}{2}$(A+C)>B) and in number of species (A>B; C>B), but did not differ in species diversity (H′) and equitability (Table 5). The three-year rotation of upland crops and rice has reduced the total density of weeds and weed species also. Possibly, species which were less adapted to the frequently changing conditions were suppressed. But, the equitability of species was not modified by rotation.

The pressure of weeding on weed communities would have been intensified with the extensive use of herbicides. The kind and application method of herbicides differ according to crops, farm management, and farmer's choice. Therefore, the density of buried seeds could be affected differently by herbicide applications. Nevertheless, certain differences in weed communities were found between the fields under the rotation system and those with single crops. This suggests that crop rotation serves as a controlling agent against agrestal weeds.

In general, the winter samples showed higher

Table 5. *Structure of weed communities compared between fields with different cropping systems, at Matou, Tainan County*

Cropping system	Season	No. of samples	Density (No./m^2)	No. of species	H′	Equitability H′/H′$_{max}$
2 rice crops a year	Winter	3	2,007	11.0	1.77	0.76
	Summer	5	1,079	9.8	1.74	0.78
	Mean		1,485	10.3	1.75	0.77
Sugar cane sole crops	Winter	3	1,320	9.7	1.71	0.78
	Summer	4	702	9.0	1.81	0.84
	Mean		1,123	9.3	1.76	0.81
Chianan rotation system	Winter	4	780	6.5	1.60	0.79
	Summer	8	482	5.1	1.50	0.83
	Mean		581	5.2	1.54	0.82
Difference:						
Winter-Summer			ns	ns	ns	ns
Rice-Cane			ns	ns	ns	ns
Rice-Rotation			**	**	ns	ns
Cane-Rotation			ns	*	ns	ns
$\frac{1}{2}$(Rice+Cane)-Rotation			**	**	ns	ns

*,** Significant at 5% and 1% levels, respectively.

Table 6. *Trend of distribution of major weed species (relative frequency >15%) in the rice, sugar cane and rotated fields*

Abundance trend	Species	Relative freq. (%)
1. Common in all fields	*Cyperus difformis* L.	78
	Lindernia procumbens Philcox	52
	Portulaca oleracea L.	52
	Fimbristylis miliacea Vahl. (s)	30
	Stellaria aquatica Scop. (w)	19
2. Mainly in rice fields	*Vandellia antipoda* Yamaz.	30
3. Mainly in cane fields	*Cyperus iria* L.	22
4. Mainly in rice & rotated fields	*Chenopodium serotinum* L.	26
5. Mainly in cane & rotated fields	*Echinochloa colonum* Link.	22
	Leptochloa chinensis Nees	22
6. Mainly in rotated fields	*Ammannia baccifera* L.	19
7. Common in both rice & cane fields, but rare in rotated fields	*Eleusine indica* Gaertn.	37
	Rorippa indica Hiern. (s)	19
	Hedyotis diffusa Willd. (s)	15

(s), (w) Abundant in summer and winter samples, respectively.

total density than the summer samples, in the same manner as was found in the samples from Taoyuan County. However, the difference was smaller in magnitude than that observed in Taoyuan samples, and was significant only in the rice fields (A; $P \doteqdot 0.05$). The data for rice fields in Table 5 and those for control fields in Taoyuan County in Table 1 may be compared, even though Matou is about 300 km south of Taoyuan. This comparison shows that the Matou rice fields have a lower total weed density than the Taoyuan control rice fields, in the winter samples. At Matou, the rice fields are drained and planted to a vegetable crop in early winter, whereas in Taoyuan, the rice fields are planted to two rice crops only. The higher total density of weeds in Taoyuan than in Matou may serve as a support of the view that rotation reduces weeds.

The abundance of relatively frequently occurring species was compared among the fields with different cropping systems (Table 6). *Cyperus difformis* and a few other species (group 1) were commonly abundant in all kinds of fields, indicating that they had a wide adaptability. A few species were abundant either in rice (group 2) or in sugar-cane fields (group 3), and some others were abundant either in rice and rotated fields (group 4) or in sugar cane and rotated fields (group 5). *Ammannia baccifera* was abundant in rotated fields only (group 6). *Eleusine indica* and two other species occurring in summer were abundant in both rice and cane fields, but were rare in rotated fields (group 7). Probably, within these species, ecotypes adapted to lowland and upland conditions would be differentiated.

The results of analysis of variance for interactions between weed species and the three cropping systems are given in Table 3b. This is based on the mean number of plants for each cropping system in each season, converted into $\log_{10}(n+1)$, since the number of samples differed much according to cropping systems and seasons, making the two-way classification non-authogonal and due estimation of interaction variances difficult when the plant numbers in individual samples were used for computation. The results showed that the difference in abundance of species according to cropping systems, as well as that between winter and summer samples, were significant when the residual interactions were taken as error. The least significant density ratio was estimated to be about two times, although 5 times or more were considered to deserve to be noted in Table 6.

It may be worthy to note that the comparison between fields under rotation and single cropping has shown a quite different pattern from that obtained by the comparison between fields under stress and normal conditions in Taoyuan County. Rotation decreased total weed density and number of species, while stress increased total weed density and decreased equitability of species.

4. *Considerations on the nature of stress conditions in the coastal area of Taoyuan County*

The problematic area covers at least three Hsians or rural municipalities, Luchu (coastal part), Tayuan and Kanying, which are on the lee side of Linkou Power Plant when the north-east monsoon prevails in autumn to winter. The power plant began operation in 1969, and the windbreak forests of *Casuarina equisetifola* began to deteriorate in 1970. The yield of the second (summer) crop rice showed a decreasing trend starting in 1971.

The mean yield of the first (winter) crop rice in Tayuan and Kanying municipalities (Hsiang; cf. Fig. 1) for 1970 to 1978 showed an increase over that for 1960 to 1969 as the result of improvement in variety and cultural technique, but the mean yield of the second (summer) crop rice for 1970 to 1978 was lower than that for 1960 to 1969 (Table 7). Not only the second crop mean yield decreased, but also its standard deviation for annual fluctuation increased, indicating that the second crop yield became unstable. In Luchu Hsiang in which the coastal part only was affected, the yield records for 1981-1982 showed that the rice fields in the coastal part gave a lower yield than those in the normal inland part in the second crop season (Table 7).

The direction of wind in this area is largely east-north-east in September through March, and it is various in April to August. The reduction of the second crop rice yield suggests that the direction of prevailing wind has a bearing on this problem. Strong wind from the sea carries salinity and damages rice crops. In addition to this, according to the direction and velocity of wind, the coastal area will be exposed to squalls of sulfur dioxide, emitted at a rate of about 150 ton/day (estimated from fuel consumption). There may also be acid rains (Dr. T. Taniyama, Mie University, Japan, personal communication). However, the existing conditions have not been monitored systematically, so far as the author knows.

Along the coast, there was a belt of windbreak

Table 7. *Mean and standard error of rice yield (kg/ha) in the coastal area of Taoyuan County*

Hsiang[a]	Season	1960-1969	1970-1978	Trend
Tayuan	Winter	2,906±249	3,276±176	Increase**
	Summer	2,808±105	2,459±470	Decrease*
Kanying	Winter	2,636±260	3,151±75	Increase**
	Summer	2,601±165	2,504±423	Decrease[ns]
		Inland (n=9)	Coastal (n=8)	
Luchu (1981-2)	Winter	5,129±561	4,585±651	Decrease[ns]
	Summer	3,789±752	3,083±578	Decrease*

[a] Village municipality; data from municipal offices.
*,** Significant at 5% and 1% levels, respectively.

forest planted aroung 1910, which was necessary for crop protection. The forest was destroyed at the end of the War (1944-1945), but was replanted and fully restored by 1956. However, the forest began to decline in 1970, and was nearly destroyed by 1975 in the said area. Attempts to reforest the *Casuarina* trees have then been unsuccessful. There are two opposing views as to the cause of the death of *Casuarina* trees, one assuming the effect of sulfur dioxide emitted by the power plant, and the other assuming the effect of other natural factors. This problem seems to remain indeterminate although the circumstantial evidence suggests that the first view is more plausible.

Possibly, conifers growing upright like *Pinus* and *Casuarina* are sensitive to chronic exposure to sulfur dioxide even though they tolerate saline wind (cf. Garsed and Rutter 1982). At the coast of Luchu Hsiang it is observed that even *Pandanus odoratissimus* is damaged although it is typically a plant of the sea coast in Taiwan.

Looking into this problem, Fang and Chen (1976) reported that the destruction of windbreaks can not be attributed to air pollution due to the power plant, because 1) the atmospheric concentration of sulfur dioxide in the problematic area was lower than that in Taipei City, 2) the injuries of the trees observed did not resemble that caused by exposure of the trees to the gas in experimental chambers, and 3) the tree leaves in the problematic area did not contain much sulfer dioxide. However, the concentration of sulfur dioxide in air was measured only once a month for six months, and wind direction on the day of measurement is not recorded. The dissimilarity in symptoms between the trees on the spot and in experiment will be the difference between chronic and acute injuries. For measuring absorption of sulfur dioxide by plants, the total amount of sulfur in the leaves should be determined. Therefore, the report by Fang and Chen (1976) does not disprove the role of the power-plant exhaust in the death of the trees. After the destruction of windbreak forest, the problematic area would be exposed to a complex of stress conditions as mentioned, resulting in changes even in the structure of weed communities.

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本研究以雜草社會結構之變化，探討臺灣之田間作物受環境改變或環境汚染之影響情形爲目的而進行之。所謂雜草社會調查係以土壤所埋藏之種子發芽而生長的植物，可表示該地區在數個月未除草時可見到之潛在性植生的假說下行之，所得結果爲：桃園縣沿海地區防風林遭受破壞、鹽霧、酸雨、二氧化硫等導致複雜之環境壓力（Stress）。遭受這種壓力地區之稻田，其雜草社會比正常地區呈現較高之個體密度與較低之種平衡性。此改變趨勢與日本銅汚染稻田之改變趨勢相同。另一方面，鍊銅廠附近廢棄農田所採之土壤樣品表現，其雜草密度顯著的降低，有些甚至沒有種子發芽。

臺南縣麻豆鎮附近，水稻田（一年栽植兩期水稻），嘉南水利輪作田（三年內植二次水稻，一次甘蔗及數次雜糧或蔬菜），連續栽植甘蔗田等，不同耕作方式之田區，亦以同樣之方法進行觀察。結果發現輪作區田間雜草之密度與種數顯著減少，種平衡性則無改變。如此可知輪作對雜草社會之效應與環境汚染壓力之效應，完全不同。

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