Effect of Agrometeorological Factors on the Yield of Rice

by

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ABSTRACT

This study is to find out the effect of agrometeorological factors on the growth and the yield of Tainung NO.67 paddy rice by a stepwise regression on the date obtained from ''Rice Yield Prediction Experiment'' carry out in Taoyuan, Taichung, and Kaohsiung DAIS during 1985-1989.

According to the results, the higher mean temperature during the transplanting stage and maximum tillering stage benefits the growth of the rice during the first crop in the northern Taiwan; but the high wind speed during the booting stage and mature stage of the second crop adversely affect plant height, spikelet number and fertility rate, consequently lower the yield. As for the central Taiwan, the higher rainfall during the maximum tillering stage at the first crop can increase number of tillers, but higher relative humidity during the booting stage can adversely affect the growth of stem, while the fertility rate and the yield is positively correlated with the sunshine duration and wind speed during the harvesting stage; the plant height at the second crop during the maximum tillering stage is affected by the maximum wind speed, the fertility rate, 1,000 grains weight and the yield is negative correlated with the relative humidity. The number of ears during the maximum tillering stage and the mature stage at the first and second crop in the southern Taiwan is positively correlated with the sunshine duration.

From the relation among the climate factors, the yield component factors and the yield, we can find out that the yield at the first crop in the northern Taiwan has a significant negative correlation with the rainfall before the harvesting stage, while the yield at the second crop is affected by the maximum wind speed, the greater the mean maximum wind speed, the lower the fertility rate, and consequently the lower the yield. As for the central Taiwan, fertility rate is the key factor affecting the yield during both the first and the second crops, the higher the sunshine duration before the harvesting stage, the higher the yield at the first crop; the higher the relative humidity before the harvesting stage, the lower the firtility rate, and consequently the lower yield at the second crop. For the southern Taiwan, the number of ears is the main factor affecting the yield, the longer the sunshine duration after the transplanting stage as well as the lower maximum temperature at the maximum tillering stage the higher the number of tillers, and consequently the higher the yield at the first crop; the higher the maximum temperature and relative humidity at the maximum tillering stage, the greater the number of tillers, and consequently the higher the yield at the second crop.

INTRODUCTION

Rice is the most important cereal crop in Taiwan, as rice consumption occupies 70% of the total cereal consumption in Taiwan today. With a total sown area of about 477,000 hectares, i.e., aboout 40% of the total sown area for crops in Taiwan, there are about 470,000 rice farms, which is about 65% of the total number of farms in Taiwan. From these figures, we can see that rice production is very important in Taiwan agriculture, and the yield of rice plays a very important role in availability of food, all general consumers, and fluctuation of material price, etc. Hence, predict on the yield of rice is very important in Taiwan.

Generally the yield of rice throughout Taiwan is estimated and predicted by the Taiwan Provincial Food Bureau by means of sampling upon harvesting. However, sampling is done during harvesting and there is a great difference in time of harvesting between the northern Taiwan and southern Taiwan, planting of rice seedling is completed in the central and southern Taiwan before sampling works are done. Hence, data from such sampling is too late for using as reference for making decision on food administration, and the government needs to have data about yield in each production season before harvesting as reference for its decision making in order to adjust supply condition of rice in Taiwan.

The yield of rice not only decided by its inherent nature but mainly by the environmental factor-climate and soil conditions, while there is a considerable cross reaction between the environment factor and the inherent nature. Therefore, the yield of paddy rice has a close and complicated relation with the climate, and it is known that climate factor does not affect yield directly, but it affects the yield component of rice, and consequently affect the yield(Wu,1979).

For years, there have been some studies on predict the yield of different crops with climate factors, among them the following studies are related to the yield of rice: Murata(1964), Yoshida and Parao (1976), Munakata (1976), Oldeman, et al. (1987), Kuo (1980), Ho (1980), Sheng (1983) and Chang (1985). As there are differences in climate, species, inherent nature and cross reaction with climate factors, there are different predication models suggest in these studies.

Upon the effort of the Central Weather Bureau, there has been a sound weather investigation and forecast system in Taiwan. There has been already a good foundation for processing of climate data with computer system. Recently, a 3-day agricultural weather forecast is given daily. Climate data is collected for related study to minimize loss due to climate disaster, and as reference for prediction of yield, which is applied by the government in determination of agricultural policy.

The purpose of this study is to use the data collected from ''Rice Yield Prediction Experiment'' and to find out the effect of agrometeorological factors on the yield of rice.

MATERIAL AND METHOD

Material

The data used in this study includes the yield of paddy rice in three experimental fields located at Taoyuan, Taichung and Kaohsiung District Agricultural Improvement Station respectively, covering a period from 1985 to 1989, totalling 10 crop seasons in five years. The species of the paddy rice is Tainung No. 67, and climate data used was collected by the weather observation station at each station.

RCBD was applied for the field design: Four replication 10 rows per plot. The length of each row is 3 meters, spacing 30 x 15 cm. A fertilizer of $N:P:K_2O$ = 35:60:35 kg/ha was applied during the growing stage.

Rice growing phase was divided into 5 stages: 1. Transplanting stage; 2. Maximum tillering stage; 3. Booting Stage; 4. Heading Stage; and 5. Harvesting Stage. In addition to recording of height of the plant and number of tillers, panicle number, spikelet number per panicle, fertility rate, and 1,000 grains weight as well as the yields were checked and recorded.

On climate factor, the mean maximum temperature (°C, HT), mean minimum temperature (°C, LT), summation of mean temperature (°C, MT), mean of differation of days temperature (°C, DT), sunshine duration (Hr, SD), summation precipitation(mm, p), mean relative humidity (%, RH), summation mean wind speed (m/sec, WS) and summation maximum wind speed (m/sec, MWS) during each phase were observed and recorded.

Method

Correlation analysis is applied to analyze the relation between the climate variable (X) and rice characters (Y) in order to determine the major climate factors which affect the yield and yield components.

Stepwise regression procedure (Drapper and Smith, 1981) is applied to find out a regression model between the yield and the yield component in order to find out the most important yield component factor affecting the yield, and the major climate factors affecting the yield component.

RESULT

Relation between growth of paddy rice and climate factors

Please refer to Tables 1 throuth 3 for the main correlation coefficient between plant height, number of tillers and the respective climate factors during the different growing stages of rice. The relation between agricultural properties/yield component/ultimate yield and the respective climate factors is described below.

For rice planting in the northern Taiwan, as shown in Table 1, the maximum temperature and difference of days temperature during the transplanting stage and maximum tillering stage during the first crop have significant positive correlation with the plant height (r = 0.926, r = 0.764). The number of tillers during the maximum tillering stage is positively correlated with the mean maximum temperature (r = 0.913). Apparently, the high temperature at the initial stage benefits the growth of rice in the northern Taiwan. After the maximum tillering stage (late April), temperature is raising, the temperature factors are no more to be the most important facter that affect the gorwth. The sunshine duration during the booting stage is positively correlated with the plant height (r = 0.853), while the summation of mean temperature has a significant negative correlation with the panicle number (r = -0.960). In the second crop of northern Taiwan, the plant height is negatively correlated with the mean maximum temperature, the plant height at maximum tillering stage has a positive correlation with the relative humidity, while number of tillers is positively correlated with the mean maximum temperature. However, during the early booting stage (after mid-October), the strong wind from the prevailing northeaster affects stem elongation and tillers number. As shown in Table 1, during the booting stage and heading stage, the plant height and the number of tillers have a significant negative correlation with the wind speed. The panicle number and the fertility rate during the harvesting stage are significantly negatively correlated with the wind speed (r = -0.917, r = 0.943). During the second crop, temperature and sunshine duration fall down gradually after the booting stage. Because of the lower sunshine duration, photosynthesis can not provide the plant with sufficient carbonhydrates for grain filling, hence the sunshine duration affects the 1,000 grains weight (r = 0.962).

For rice planting in the central Taiwan, as shown in Table 2, the plant height during the first crop is negatively correlated with the mean wind speed at the transplanting stage (r = -0.938). The number of tillers during maximum tillering stage is positive correlated with the sunshine duration and mean precipitation (r = 0.865, r = 0.888). The plant height and the number of tillers during the booting stage are negatively correlated with relative humidity (r = -0.846). During the harvesting stage, the yield is positive correlation with the mean wind speed (r = 0.823), but the plant height and the panicle number are negatively correlated with the maximum wind speed and mean wind speed (r = -0.756, r = -0.825). The fertility rate is positively correlated with sunshine duration (r = 0.872), while the 1,000 grains weight is negatively correlated with the mean precipitation (r = -0.765). During the second crop the plant height has a negative correlation with the maximum wind speed, at transplant stage the number of tillers is positively related to differation of days temperature during the maximum tillering stage. During the harvesting stage, the plant height is negatively correlated with the precipitation(r = -0.966), the panicle number is negative correlated with the sunshine duration (r = -0.835), the fertility rate, the 1,000 grains weight, and the yield are significantly correlated with the relative humidity (r = 0.891, r = -0.935, r = 0.858).

As for rice planting in the southern Taiwan, during the maximum tillering stage, the plant height has a negative correlation with the maximum wind speed (r = -0.928), and the number of tillers is positively correlated with the sunshine duration (r = 0.968, see Table 3) at the first crop. During the harvesting stage, the plant height and the panicle number as well as yield are positively correlated with the sunshine duration(r = 0.951, r = 0.938, r = 0.864), the spiketed number is negatively correlate to the mean minimum temperature(r = -0.956), and the 1,000 grains weight is positively correlated with the mean precipitation($r = 0.768$). As for rice planting in the second crop, the plant height is positively correlated with the sunshine duration ($r = 0.836$). During the booting stage, the number of tillers is negatively correlated with the minimum temperature ($r = -0.950$), but positively correlated to the mean precipitation ($r = 0.850$). During the harvesting stage, the yield and the panicle number are negative correlated with the mean precipitation ($r = -0.901$, $r = -0.883$), the plant height and the 1,000 grains weight are negatively correlated with the sunshine duration and relative humidity respectively ($r = -0.949$, $r = -0.897$).

The ultimate product of rice panicle is the yield of grains. Rich nutrition does not garrent high yield. Similarly, the number, the spikelete number per panicle, the fertility rate, and the 1,000 grains weight are the factors affecting the yield. The simple correlation of the yield and the yield component factors, and the correlation coefficient and decision coefficient by component regression procedure are listed in Table 4 and 5. The result indicated that except no yield component factor has any significant effect to the yield during the first crop in the northern Taiwan, the fertility rate is the most important which effect the yield during the first and second crops in the central Taiwan as well as the yield during the second crop in the northern Taiwan. The number of panicle is the most significant factor that effect the yield during the first and second crops in the southern Taiwan. The climate factors which affect the fertility rate are start after the booting stage, and the panicle number depends on the climate at the maximum tillering stage, booting stage and heading stage. Hence stepwise regression is done on the climate factors from different growth stage for the fertility rate compare with panicle numbers. In northern Taiwan, the most important factor which affect yield of second crop is fertility rate, the regression coefficient and contribution coefficient by using stepwise and path analysis are 0.63 and 0.32. In central Taiwan, the fertility rate is the main yield component which affect the yield of rice on first and second crops. The regression coefficient for the yield predication model are 0.7 for first and second crops, and the contribution coefficient for the selected yield component are 0.62 and 0.61 for the yield of first and second crops respectively. In southern Taiwan, the panicle number is the most important yield component factor. The regression coefficient for the main factor are 0.68 and 0.65 for the yield of first and second crops, and the contribution coefficient for the selected yield component are 0.27 and 0.53 for the yield of first and second crops. The result of stepwise regression is shown in Table 6. In the second crop of the northern Taiwan, the yield is affected by the fertility rate, while the fertility rate is affected by the mean maximum wind speed during the harvesting stage ($R^2 = 0.89$, $r = -0.94$). At the first crop of central Taiwan, the sunshine duration during the harvesting stage has the biggest effect on the fertility rate ($R^2 = 0.76$, $r = -0.87$). At the second crop in the central Taiwan, the relative humidity during the harvesting stage has the biggest effect on the fertility rate ($R^2 = 0.79$, $r = -0.89$). As for the yield during the first and second crops in the southern Taiwan, the sunshine duration is the main factor affecting the panicle number and the number of tillers ($R^2 = 0.81$, $r = 0.90$) at the first crop, but the mean maximum temperature is the most important factor affecting the generation of the panicle ($R^2 = 0.78$, $r = 0.88$)at the second crop.

DISCUSSION

The yield of rice is affected by its heredity nature, planting skill, soil conditions, climate and environment. Other human factors, such as quantity of fertilizer applied, water management, pests and diseases control, etc. do have some considerable effect to the yield too. Therefore, for study on the relation between the yield and the climate conditions, it is preferable to observe and collect data on the same experimental field with the same species and planting methods over a prolonged period of time. With such a premises, this study analyzes data collected by the "Rice Yield Prediction Experiment" to review the relation between the yield of paddy rice and the climate factors as a reference for prediction the yield of rice in the future.

To the paddy rice, climate factors are not affecting the yield directly, but its effect to different stages of the rice growing and then affects different yield component and consequently affects the gross yield indirectly (Wu, 1979). Therefore, by finding out the effect of each climate factor on the rice growth and the respective yield component factors, and then determine the most important climate factors which effect the yield is a reasonable and feasibly method. However, the climate factor is changing every minute, and such change, more or less, will affect the growth and the yield. Therefore, selection of some major influence factors among the numerous climate factors is a very difficult statistical task.

At the first crop in the northern Taiwan, none of the yield component factor is significant correlation with the yield. The climate factor rainfall during the harvesting stage is significant correlate with yield (R^2 = 0.86, r = -0.929), mainly because the rainfall during the rainy season in the spring (plum rains) could result in lodging of the rice plants, and con-sequently affect the yield. However, at the second crop, the plant height, number of tillers, number of grains and the fertility rate have a significant negation correlation with the mean wind speed and maximum wind speed respectively. According to the data available, the mean wind speed and the maximum wind speed at the second crop in the northern Taiwan reach 10 m/sec which is much higher than other parts of Taiwan. Fan (1980) stated in his report that the prevailing northeaster in the northern Taiwan after October each year significantly decreases the yield of corn. The strong wind also accelerates vaporization, and consequently reduces moisture content in the leaves, reduces photosynthesis, and seriously damage on the growing mechanism of the paddy rice (Yang and Chu, 1984). Hence, the northeaster is a key factor affecting the yield of rice in the northern Taiwan during the second crop. The northeaster do lower fertility rate and spikelet number, and consequently reduces the yield. Shorter sunshine duration after the booting stage would reduce photosynthesis, and hence nutrition for the growth of grains is not sufficient. Therefore, the sunshine duration has significantly correlated to the grain filling ability (r = 0.962).

In the central Taiwan, the yield of rice at the first crop has a positive correlation with the mean wind speed (ave/1.8 m/sec). The wind during harvesting stage, (i,e., around June) is very gentle, and such gentle wind can promote exchange of gas in leaves, and con-sequently promote photosynthesis to increase the yield (Yang and Chu, 1984). To the yield components, the fertility rate is the most important. The fertility rate greatly depends on the sunshine duration (R^2 = -0.76, r = 0.87), hence the longer sunshine duration and gentle wind during the first crop in the central Taiwan promote photosynthesis and increase the yield. At the second crop, the yield, 1,000 grains weight and fertility rate are negatively correlated with the relative humidity significantly, the key factor affecting the yield is the fertility rate. Therefore, the yield of rice mainly depends on the relative humidity for the second crop in the central Taiwan.

Generally, the relative humidity is up to 100% during night-time, the high temperature (generally above 25°C) in the field would easily bring pests and diseases. According to Tsai, the high relative humidity and the high temperature are the main causes of rice blast, particularly in Changhua, a county located at the central Taiwan. According the investigation from 1978-1986 the rice panicle blast disease infection area average around 3636 ha in central Taiwan area which is a major factor effect the yield of rice.

As for the southern Taiwan, the yield, panicle number, and the plant height are positively correlated with the sunshine duration during the harvesting stage at the first crop. Apparently, the longer the sunshine duration, the quicker the growth and the higher the yield. During the first crop in the southern Taiwan, the number of cloudy or rainy days is very few, the sunshine duration is correlated to the transplanting stage. The later the transplanting date, the higher the yield. Furthermore, the yield depends mainly on the panicle number while is significant correlated with the sunshine duration during the maximum tillering stage ($R^2 = 0.81$, $r = 0.9$). Such fact is consistent with the above decuction. The yield and panicle number during the second crop in the southern Taiwan are negatively correlated with the mean precipitation at harvest stage, which means that rainfall during the harvesting stage can affect the yield. The panicle number is also a decisive factor of the yield, while the panicle number depends on growing condition during the maximum tillering stage, the booting stage, and the heading stage. During the maximum tillering stage, the longer the sunshine duration, the greater the number of tillers. During the booting stage, the number of tillers is negatively related to the mean minimum temperature ($r = -0.950$). Such a finding is consistent with Chin's conclusion (1878): The high temperature would limit the number of tillers during the stem elongation, and the lower yield at the second planting season is caused by the lower number of tillers.

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Table 1. Correlation coefficient between growth of paddy rice and climate factors in the northern Taiwan.

Crops	Climate Factors	Growth Period I	II		III		IV		V					
		Plant height	Plant height	Tiller number	Plant height	Tiller number	Plant height	Tiller number	Plant height	Panicle number	Spikelet number	Fertility rate	1000 G.W.	Yield
I	HT.	0.926**	0.430	0.913**	0.054	0.286	-0.232	-0.850*	0.555	0.395	0.169	-0.469	0.043	0.241
	LT.	0.246	0.676	0.714	0.631	-0.193	0.273	-0.668	0.331	-0.171	-0.820*	-0.932**	0.571	-0.440
	MT.	0.787*	0.648	0.833*	0.364	-0.269	0.044	-0.960**	0.514	0.163	0.513	-0.787*	-0.230	-0.079
	DT.	0.764*	-0.592	-0.137	-0.849*	-0.108	-0.411	-0.110	0.340	0.624	-0.471	0.207	0.538	0.582
	SD.	0.769*	0.435	0.207	0.319	-0.873*	0.853*	-0.271	0.527	0.198	0.472	-0.750	-0.200	-0.032
	P.	-0.697	-0.515	-0.425	0.141	0.300	-0.668	0.604	-0.460	-0.263	0.347	-0.545	0.078	-0.929*
	RH.	0.045	0.007	0.066	0.109	0.974*	-0.275	0.611	-0.397	0.073	0.105	0.091	-0.663	-0.275
	WS.	0.153	-0.649	-0.898**	0.207	-0.956*	0.608	-0.619	-0.126	0.191	-0.400	0.072	0.907*	-0.073
	MWS.	-0.106	-0.512	-0.850*	0.221	-0.878	0.172	-0.859*	0.359	-0.670	0.397	-0.396	0.247	-0.090
II	MT.	-0.808*	0.226	0.897**	0.580	-0.011	-0.126	-0.188	0.079	-0.828*	0.550	0.105	0.493	-0.086
	LT.	0.740	0.616	0.070	0.446	-0.296	0.095	-0.043	0.534	-0.374	0.836*	0.085	-0.095	-0.054
	MT.	-0.693	-0.398	0.854*	0.548	0.195	-0.067	-0.097	0.297	-0.660	0.715	0.095	0.239	-0.079
	DT.	-0.800*	0.159	0.804*	0.018	-0.532	-0.166	-0.161	-0.655	-0.758*	-0.353	0.041	0.915**	0.057
	SD.	-0.487	-0.834*	-0.308	0.355	-0.445	-0.550	-0.661	-0.569	-0.709	-0.235	0.268	0.962**	0.000
	P.	0.229	0.471	0.667	-0.335	-0.078	-0.023	-0.544	-0.554	0.560	0.042	-0.268	-0.924**	0.173
	RH.	0.623	0.886*	-0.215	0.668	0.309	0.587	-0.207	0.941**	0.444	0.754*	0.344	-0.600	0.346
	WS.	0.555	-0.424	-0.363	-0.954**	0.843*	-0.921*	-0.848*	-0.621	-0.917**	0.060	-0.280	0.595	-0.668
	MWS.	0.595	0.011	-0.269	-0.627	-0.071	-0.233	-0.225	-0.316	0.112	-0.288	-0.943**	-0.591	-0.663

* : denote significant at 0.05 probability levels.

** : denote significant at 0.01 probability levels.

Table 2. Correlation coefficient between growth of paddy rice and climate factors in the central Taiwan.

Crops	Climate Factors	I Plant height	II Plant height	II Tiller number	III Plant height	III Tiller number	IV Plant height	IV Tiller number	V Plant height	Panicle number	Spikelet number	Fertility rate	1000 G.W.	Yield
		Growth Period												
I	HT.	-0.393	-0.400	-0.131	0.553	-0.275	-0.481	0.160	-0.425	-0.607	-0.110	0.727	0.459	0.622
	LT.	-0.274	-0.356	-0.679	0.365	-0.686	-0.378	-0.139	-0.272	-0.626	0.160	0.429	0.278	0.497
	MT.	-0.409	-0.370	-0.398	0.454	-0.493	-0.474	0.068	-0.336	-0.611	0.003	0.599	0.367	0.568
	DT.	-0.082	-0.071	0.828*	0.764*	0.570	-0.494	0.413	-0.550	-0.167	-0.477	0.701	0.486	0.216
	SD.	-0.419	-0.110	-0.865*	0.271	0.337	-0.370	0.112	-0.448	-0.143	-0.577	0.872*	0.639	0.534
	P.	0.419	0.110	0.888*	-0.487	-0.615	-0.364	-0.714	0.608	0.282	0.363	-0.789*	-0.765*	-0.428
	RH.	-0.258	-0.614	-0.828*	-0.846*	-0.406	0.465	-0.276	0.338	0.028	0.553	0.557	-0.124	-0.093
	WS.	-0.938**	0.614	0.281	0.715	0.537	0.427	0.630	0.436	0.413	-0.825*	0.634	0.114	0.823*
	MWS.	-0.917**	0.664	0.606	0.810*	0.036	0.004	0.500	-0.440	-0.756*	0.313	0.376	0.348	0.367
II	HT.	-0.031	-0.581	0.300	-0.169	0.411	0.620	0.009	0.815*	-0.436	0.560	-0.308	-0.743	-0.279
	LT.	-0.323	-0.143	-0.731	0.135	0.244	0.560	0.125	0.672	-0.260	0.420	-0.216	-0.656	-0.175
	MT.	-0.176	-0.486	-0.354	0.024	0.324	0.622	0.061	0.749	-0.325	0.481	-0.257	-0.701	-0.234
	DT.	0.339	-0.212	0.825*	-0.457	-0.079	-0.115	-0.689	0.260	-0.424	0.288	-0.219	-0.059	-0.318
	SD.	-0.175	-0.632	0.019	-0.189	-0.087	0.003	0.025	0.156	-0.835*	0.300	-0.363	-0.463	0.141
	P.	0.766*	0.244	0.177	0.330	-0.062	-0.335	-0.125	-0.966**	0.388	-0.598	0.359	0.664	0.593
	RH.	0.408	0.710	-0.714	0.345	-0.575	-0.312	-0.523	0.702	-0.454	-0.259	-0.891*	-0.935**	-0.858*
	WS.	0.390	-0.060	-0.477	0.375	-0.042	-0.529	-0.370	0.472	0.320	-0.391	-0.390	-0.382	-0.784*
	MWS.	0.605	-0.942**	0.506	0.091	0.458	-0.545	-0.055	-0.124	0.427	-0.320	0.114	-0.059	0.151

* : denote significance at 0.05 probability levels.

** : denote significance at 0.01 probability levels.

Table 3. Correlation coefficient between growth of paddy rice and climate factors in the southern Taiwan.

Crops	Climate Factors	Growth Period I: Plant height	II: Plant height	II: Tiller number	III: Plant height	III: Tiller number	IV: Plant height	IV: Tiller number	V: Plant height	Panicle number	Spikelet number	Fertility rate	1000 G.W.	Yield
I	HT.	0.676	0.762*	0.106	-0.679	-0.698	-0.266	-0.200	0.634	0.590	-0.812*	0.296	0.146	0.070
	LT.	0.673	0.479	-0.111	0.093	-0.350	-0 564	0.096	0.346	0.379	-0.956**	0.567	0.435	-0.081
	MT.	0.717	0.680	0.006	-0.454	-0.728	-0.498	0.016	0.540	0.530	-0.901**	0.442	0.304	0.029
	DT.	-0.511	0.640	0.354	-0.638	-0.377	0.777*	-0.390	0.652	0.512	0.039	-0.382	-0.471	0.271
	SD.	-0.827*	0.793*	0.968*	-0.612	-0.396	-0.381	0.651	0.951**	0.938**	0.165	0.289	-0.284	0.864*
	P.	-0.848*	0.198	-0.135	0.722	0.361	-0.267	0.590	-0.548	-0.459	-0.325	0.331	0.768*	-0.327
	RH.	0.293	-0.374	-0.329	0.555	0.472	0.162	-0.232	-0.671	-0.536	0.081	0.324	0.433	-0.234
	WS.	0.336	0.517	0.526	0.004	-0.198	-0.532	0.520	0.344	0.214	0.082	-0.268	0.631	0.391
	MWS.	-0.431	-0.928**	-0.532	-0.253	0.101	0.339	-0.280	-0.410	-0.230	0.433	0.419	-0.255	0.059
II	HT.	0.909**	0.847	-0.014	-0.272	-0.737	-0.739	0.497	-0.784*	-0.251	-0.143	0.462	0.133	-0.741
	LT.	0.393	0.794*	0.493	-0.090	-0.950**	-0.755*	0.722	-0.389	-0.477	-0.090	0.405	0.541	-0.749
	MT.	0.801*	0.901**	0.056	-0.204	-0.881*	-0.769*	0.588	-0.610	-0.369	-0.115	0.467	0.371	-0.770*
	DT.	0.932**	-0.042	0.081	-0.269	-0.283	-0.662	0.203	-0.208	0.534	-0.006	-0.175	-0.774	0.454
	SD.	0.835*	-0.103	0.836*	0.696	0.593	-0.745	0.214	-0.949**	0.329	0.498	-0.092	-0.313	-0.062
	P.	-0.634	0.010	-0.715	0.035	0.850*	0.084	-0.424	0.102	-0.883*	-0.588	0.290	0.384	-0.901*
	RH.	-0.778*	-0.460	-0.768*	-0.997**	-0.141	0.575	-0.479	-0.340	-0.248	-0.456	-0.254	-0.897**	-0.334
	WS.	0.694	0.485	-0.647	0.438	0.313	-0.236	-0.334	-0.324	0.243	0.717	0.106	0.649	0.094
	MWS.	-0.549	0.181	0.515	-0.148	0.280	-0.145	0.592	0.658	0.121	-0.348	-0.200	-0.393	0.447

* : denote significance at 0.05 probability levels.

** : denote significance at 0.01 probability levels.

Table 4. Correlation coefficient among the yield and yield component factors.

Location and crops	Plant Height	Panicle number	Spikelet number	Fertility rate	1,000 G.W.
1st crop, Northern Taiwan	0.647	0.038	-0.260	0.403	0.054
2nd crop, Northern Taiwan	0.629	0.341	0.158	0.791*	0.150
1st crop, Central Taiwan	-0.002	-0.167	-0.461	0.836*	0.532
2nd crop, Central Taiwan	-0.696	0.319	0.278	0.834*	0.758
1st crop, Southern Taiwan	0.790	0.826*	0.361	0.435	0.006
2nd crop, Southern Taiwan	0.240	0.808*	0.658	-0.321	0.071

* : denote significance at 0.05 probability levels.

Table 5. Regression coefficient and prediction model for the yield and the selected predictor yield component factor.

Location and crops	Parameter	Plant Height	Panicle number	Spikelet number	Fertility rate	1,000 G.W.	R^2	Path coefficient	Contribution
2nd Season, Northern Taiwan	826.9				42.39		0.63	0.40	0.32
1st Season, Central Taiwan	-742.9				81.75		0.70	0.74	0.62
2nd Season, Central Taiwan	-3692.6				93.76		0.70	0.73	0.61
1st Season, Southern Taiwan	3508.1		235.2				0.68	0.33	0.27
2nd Season, Southern Taiwan	-2633.2		543.4				0.65	0.80	0.53

Note: R^2 for the 1st crop in northern Taiwan is too low and does not reach the 5% significant level.

Table 6. Regression coefficient for the agrometeorological Factors and selected yield component.

Location and crops	Yield component	Climate Factors	R^2	r
2nd Season, Northern Taiwan	Fertility rate	M.W. in stage V	0.89	-0.94
1st Season, Central Taiwan	Fertility rate	S.D. in stage V	0.76	0.87
2nd Season,Central Taiwan	Fertility rate	R.H. in stage V	0.79	-0.89
1st Season, Southern Taiwan	Panicle number	S.D. in stage II	0.81	0.90
2nd Season, Southern Taiwan	Panicle number	M.T. in stage III	0.78	-0.88