Agrometeorological Studies in Taiwan

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ABSTRACT

As located at Monsoon area, serious losses in agriculture production caused by meteorological disasters are not uncommon in Taiwan. Preventing yield and quality losses by studying the responses of agricultural crops to the climatic disasters, and hence to setup a total solution to reduce the loss and to stabilize the production is urgently needed.

Several agrometeorology-related research programs has been initiated since the accomplishment of implementation of meteorological observation network around this Island. Research program on the studies and utilization of agro-climatic resources in Taiwan area, funded jointly by the Council of Agriculture, Executive Yuan and Department of Agriculture and Forestry, Provincial Taiwan Government was started since 1989.

The agrometeorological research consists of 4 main parts including the studies on crop responses to agrometeorological factors, microclimatic application under protected agriculture conditions, agriculture disasters caused by unfavorable climatic conditions and measures for prevention, and the investigation, planning, and utilization of agrometeorological resources in Taiwan.

For extending the scope of study, not only the crops but also the livestock and fishery were included in this program. Major crops such as rice, corn, legumes, peanut, tea, pepper, orange, loquat, longan, mango, wax apple, water melon, potato, vegetables, and grasses were used as study materials in this program. For investigation of climatic disasters, the central, north, Yun-Chia-Nan, and eastern areas of Taiwan have been included. The climatic observations at plain and hilly areas were also covered in this survey.

Fruitful results have been shown from this study project. Basic information concerning the responses of crops to the climatic conditions have been obtained for future uses. For intensifying the research activity, the coordination of researchers in team work for special crop in solving production problems caused by climatic disasters have been emphasized. Research priority including biological responses to agrometeorological environments, protected culture improvement under various agrometeorological conditions, forecasting on the yield and quality losses caused by climatic disasters, and agrometeorological information and warning system has been set up as the research goal in the future.

As evidenced from the past research achievements, for effective application of agrometeorological findings from research for preventing the agriculture loss caused by climatic disasters and hence to stabilize agricultural production, more input in equipment and facilities for climatic observation and studies, more researchers joined from various disciplines, and more financial supports are still needed.

INTRODUCTION

The yield and/or quality losses of crops caused by climatic disasters are not uncommon in Taiwan (Hsu, 1989; Young and Chang, 1989). Flooding caused by heavy and long-last rainfall, and typhoon during crop growing seasons were two major climatic stresses to crops. For example, a total of 198,560 and 451,114 hectares of crop lands were damaged by these two climatic disasters respectively during the period of 1987-1991. The crop value losses caused by flooding and typhoon were as high as 5.9 and 15.0 billion New Taiwan Dollars, respectively (PDAF, 1991). To understand the responses of crops to climatic stresses, and the measures for preventing yield and/or quality losses, studies on the crop responses to climatic changes are most concerned by the crop research scientists in Taiwan. However, the well-organized, high-cooperated, and systematic studies on the relationships between climate factors and crop production, crop responses to agrometeorological environments, and some other agrometeorology-related studies were initiated in 1989 after the complete installation of observatory network around the Island.

For enhancing the agrometeorological studies in research quality and for better coordination in research, the Evaluation and Advisory Committee for Agrometeorological Research (EACAR), consists of professors from universities and specialists from Council of Agriculture, Provincial Department of Agriculture and Forestry, and Central Weather Bureau has been formed in 1991.

In this paper, the agrometeorological research activities and achievements in the investigation of agricultural disasters caused by meteorological factors and utilization of climatic resources in Taiwan conducted by the agricultural research and experiment institutions and universities under the coordination of the Provincial Department of Agriculture and Forestry (PDAF) for the past three years will be briefly introduced.

SYSTEM OF AGROMETEOROLOGICAL RESEARCH

Based on the results of thoroughly discussions of senior scientists, specialists and professors majored in agrometeorology, four major research directions in agrometeorological studies including the categories of agrometeorological biology studies, microclimate application

under protected agriculture conditions, agrometeorological disasters, and planning and utilization of agrometeorological resources were formed. Research proposals submitted should meet one of these four categories for approval.

For ensuring the best research results, strictly procedures for evaluation on the application of agrometeorological research have been set up by PDAF. Researchers proposed the research proposal based on their own interests, economic importance of crop and climatic factors, and discipline under the four categories. After the primary approval from their own institute, the proposal could be submitted to the EACAR for primary evaluation. After passing and revising from the EACAR meeting, the detailed research proposal should sent to the coordinators of belonged category for further revising. Finally the revised proposal should re-submit to EACAR for final revision and re-evaluation. After final revision and approved by the EACAR, then the financial supports can be applied.

Source for financial supports usually comes from the National Science Council (NSC), Council of Agriculture (COA), or Provincial Taiwan Government (PTG). However, the major financial grants came from the Council of Agriculture. A total of 56 million dollars for research projects and 25 million dollars for equipments from COA has been used to support the research activity in the program of investigation of agricultural disasters caused by meteorological factors and the utilization of climatic resources in Taiwan during FY 1989-1993 (Table 1). Except for grants from COA, other routine research activities and work in agrometeorological studies and observation such as yield responses of rice to agrometeorological factors, and maintenance of observation facilities were financial supported annually by the budget of Provincial Taiwan Government. Usually, two-year grants can be obtained for short-term studies while grants for long-term studies can be as long as six years.

Long-term observations and researches in term work for the studies on the effects of climatic factors on the growth, development, and yield of important crops are more emphasized.

Evaluation and discussion on the research results for each project were conducted twice a year. Final and detailed report must be submitted and presented during the meeting of EACAR. Publication of research findings is highly-encouraged.

ACTIVITIES AND ACHIEVEMENTS IN AGROMETEOROLOGICAL RESEARCH

Before the complete of installation of agrometeorological observation network in agricultural research institutions, researches on the effects of climatic factors on the responses of crop were scattered in various field. For example, research on the yield response of rice to the climatic factors was included into the rice research projects. After the setting up of observation network, all the agrometeorology-related studies were organized, concentrated and

Table 1. Grants from Council of Agriculture for agrometeorological studies in the investigation of agricultural disasters caused by agrometeorological factors and utilization of climatic resources in Taiwan from FY 1989 to FY 1993.

Fiscal Year	Grants for Projects	Grants for Equipments	Total Grant
1989	8,000,000	5,000,000	13,000,000
1990	12,000,000	5,000,000	17,000,000
1991	12,000,000	5,000,000	17,000,000
1992	12,000,000	5,000,000	17,000,000
1993	12,000,000	5,000,000	17,000,000
Total	56,000,000	25,000,000	81,000,000

initiated under team-work and coordination conditions.

Investigation on agriculture disasters caused by unfavorable meteorological factors and studies on the utilization of climatic resources in Taiwan sponsored by the Council of Agriculture is one of the major research program carried out by the agricultural experiment institutions and universities. About 9 institutions were involved in this research including the Central Weather Bureau (CWB), National Pingtung Polytechnic Institute, Taiwan Agricultural Research Institute (TARI), Taiwan Livestock Research Institute (TLRI), Taiwan Fishery Research Institute (TFRI), Soil and Water Conservation Bureau, Taiwan Tea Improvement Station, Taiwan Seed and Seedling Improvement Station, and Taoyuan, Taichung, Tainan, Kaohsiung, Taitung, and Hualien District Agricultural Improvement Stations.

A total of 23 projects have been carried out during the fiscal year of 1989-1991. In which, 11 projects belonged to agrometeorological biology studies (Category 1), 2 projects belonged to the studies on microclimatic application under protected agriculture conditions (Category 2), 7 projects belonged to the studies on the agriculture disasters caused by unfavorable climatic conditions and measures for prevention (Category 3),and 3 projects belonged to the investigation, planning, and utilization of agrometeorological resources (Category 4). In fiscal year of 1992, a total of 26 projects were involved in which 18, 2, and 6 projects belonged to Category 1, 2, and 3, respectively. About 26 projects including 16, 3, 5, and 2 projects belonged to Category 1, 2, 3, and 4, respectively will be carried out in the fiscal year of 1994 (Table 2). Besides, the budgets from Provincial Taiwan Government also supported 22 agrometeorological research projects in fiscal year of 1993. About 14 projects will be supported in fiscal year of 1994. It showed that more researches on the microclimatic application under protected agriculture conditions (Category 2) and investigation, planning, and utilization of

Table 2. Number of projects supported by COA in agrometeorological research in the investigation of agricultural disasters caused by agrometeorological factors and utilization of climatic resources in Taiwan from FY 1989 to FY 1994.

Fiscal Year	Research Category				Total
	1	2	3	4	
1989-1991	11	2	7	3	23
1992	18	2	6	0	26
1993	6	2	11	1	20
1994	16	3	5	2	26
Total	41	9	29	6	95

agrometeorological resources (Category 4) are still required.

Researchers and workers were not emphasized before the initiation of agrometeorological research and the formation of Evaluation and Advisory Committee for Agrometeorological Research . Now the level of researcher was increased. Several researcher with doctorate or master degree, majored in plant physiology, environment physiology, crop science, and meteorology were involved in agrometeorological studies (Table 3). However, for better quality in agrometeorological researches the well-trained personnel are still needed.

Table 3. Personnel involved in agrometeorological research

Fiscal Year	Doctorate	Master	Bachelor and Others	Others
1989-1991	12	10	22	44
1992	16	17	31	64

As for agricultural disasters caused by unfavorable climatic factors such as air temperature, wind, evaporation, solar radiation, relative humidity have been studied. In FY 1992 and 1993 about 52.2 and 76.9% of research projects, respectively were focused on the studies on the crop responses to all the climatic factors. Other factors are only slightly studied (Table 4).

If classified research projects based on target crops, it showed that about 25.7% of

researches were focused on the responses of grain (rice and corn and vegetable crops) to climatic factors. Also, the fruit trees which occupied about 22.8% of total researches were the second important targets in agrometeorological studies during FY 1989-1991. More researches concentrated on rice, fruit and vegetable crops might be due to their economic importance in production and vulnerabilities of these crops to the unfavorable climatic conditions. Other targets such as legumes, special crops, forage grass, flower crops, and fishery were quite few in number in agrometeorological researches (Table 5).

Table 4. Climatic factors studied by agrometeorological research

Climatic factotor	Number of research projects	
	FY 1989-91	FY 1992
All factors	12	20
Precipitation	1	1.5
Solar radiation	1	0
Temperature	1	0.5
Wind	2	2
Others	6	3
Total	23	26

Several significant results have been obtained from agrometeorological research in the investigation of agricultural disasters caused unfavorable climatic conditions and utilization of climatic resources in Taiwan.

Low air temperature occurred during the winter season in central part of Taiwan. Predicting the occurrence of low temperature by using relative humidity data recorded at previous day was not significant (Chi, et al., 1992).

Rice yield in second crop could be increased as high as 38.0 to 65.2% when it was protected by windbreak trees in northern Taiwan (Lin and Chen, 1991). Higher rice yield might obtained when protected by windbreak trees within its effective range of 2H (Lin, 1992). Low air temperature (less than 20°C) during heading period reduce rice fertility which then resulted in low grain yield in Chiayi, Yulin and Tainan areas (Yang, et al., 1991). Lower rice yield caused by lower solar radiation, lower lighting hours and excessive rainfall at late growing stage was conformed when rice was grown at Ilan and Hualien areas (Lee and Lin, 1991). Bacterial leaf blight with 53% of occurrence in rice due mainly to the excessive rainfall occurred in May (Huang, 1991). Also, rice sheath blight and stem maggot occurred when temperature and rela-

Table 5. Research targets used in agrometeorological studies during the FY 1989-1992

Target	Number of Research project	Percentage of total
Grain (rice, corn)	9	25.7
Legumes	2	5.7
Tea	2	5.7
Special crops	2	5.7
Fruit trees	8	22.8
Vegetable crops	9	25.7
Flower crops	1	2.9
Forage grass	1	2.9
Fishery	1	2.9
Total	35	100.0

tive humidity were high (Lin, 1991). Heading and maturing dates and yield for Tainung 67 rice could be predicted with high regression coefficients by fitting meteorological data into CERES-Rice model. Modification physiological parameters of rice might provide better prediction (Liang, et al., 1992). Grain quality of rice can also be affected by wind. Higher percentage of green grain and late-maturing were found when rices were grown under windy conditions (Young, et al., 1992). Solar radiation and rainfall affected the growth of mulberry. Carbohydrate, total sugar and starch content were decreased with the increasing of temperature and solar radiation. Rust in mulberry occurred under low temperature and high relative humidity conditions (Lin, et al., 1992).

Drought caused yield reduction of corn. Irrigation corn based on meteorological and soil data could prevent yield loss of corn (Tu, et al., 1991). However, the kernel weight of corn was reduced when grown in the soil where water potential was about -8.0 to -10 bars (Fang, et al., 1992). Air temperature affects growth, development, and yield of legumes. Positive correlations between cumulative therm time and yield of legumes have been found. Regression equations derived from these climatic factors can be used in prediction of yield for legumes grown at Pingtung areas (Huang, et al., 1991). Rust disease occurred in peanut and soybean when relative humidity grater than 90% and in temperature between 18 and 28°C (Chen, et al., 1991).

Fruit trees grown at slope land areas could be easily damaged by unfavorable climatic conditions. About 62.9% of trees were damaged by rainfall, 32.5% damaged by wind, 21.3% damaged by drought, 19.5% damaged by low temperature, and only 1.5% damaged by hot wind

(Hsu, et al., 1991). Falling of flowers in Washington navel orange trees occurred when temperature higher than 27°C and relative humidity lower than 77%. This disaster could be prevented by application of water or plant growth regulator such as GA (Ro and Su, 1991). Lower temperature (less than 10°C) and low solar radiation caused serious fruit falling loss (11.3 to 19.8%) of wax apple in winter season at Pingtung area (Kao, 1991). High air temperature, strong wind and low humidity caused by hot wind (foehn phenomena) occurred at Taitung area could damage 5.2 to 24.6% of yield and quality of loquat and sugary apple. The most susceptible stages for loquat were at flowering and green fruit stages. For sugary apple, hot wind occurred at flowering stage could result in 100% loss. Spraying chemicals such as Abion-C and water by sprinkler irrigation and protected fruit trees by windbreak trees might reduce the losses of these crops (Chiu, 1991, 1992). *Gymnosporangium haraeanum* in pearl and powder mildew and rust disease in grape occurred seriously when excessive rainfall happened. Fruit setting for mango at Yuging area was reduced when low temperature occurred in January and February (Lin, et al., 1992). Flowering in longan, one of important honey source plant, was enhanced by higher temperature. Honey production by bee was decreased with the increase of rainfall (Chang, et al., 1992). Citrus canker occurred in citrus when temperature greater than 20°C with continuous rainfall greater than 50 mm, high relative humidity (90%), and wind speed greater than 10 m/s.

In vegetable crops, The microenvironment conditions could be changed when bell pepper covered by different kinds of colored PE which then affected the growth, development, and yield of bell pepper (Young, 1991). The wind damages in bell pepper could be reduced when crops were covered by windbreak nets especially at young seedling stage in northern part of Taiwan (Shong, 1992). Nonwovens with high reflectance can also be used to increase soil temperature and hence to protect the growth of bell pepper (Young and Lee, 1992). Covering vegetables by simple plastic covering could protect high-hill crops from rain and low temperature damages (Hsu, 1991). Potato tuber rot, various in size, and split of tuber always occurred when grown under higher temperature conditions in the stage of tuber formation (Chen, et al., 1992). Nonwoven used as cover materials with higher transparency could protect vegetable crops from low temperature and pest insects damages (Kuo, 1992). Highest yield can be obtained when onion planting in November and October. Onion yield was positively associated with solar radiation but negatively correlated with total rainfall during the growing season (Huang, et al., 1992). Virus disease for water melons occurred at 20-31°C. Temperature lower than 20°C inhibited the virus disease. Powdery mildew, anthracnose, and black rot happened in water melon under high temperature and high relative humidity conditions (Chen, et al., 1992).

Microenvironment also changed by covering surface soil by various cover materials. Bahia grass could reduce soil surface temperature 10 to 14°C when air temperature was high. However, when air temperature was low, this cover grass could increase soil surface temperature as high as 1.4 to 2.8 C. Highest effects in increasing temperature was found for simple PE tunnel covering (Chang, et al., 1991).

For forage grass such as pangola grass, the evapotranspiration (ET) can be estimated based on meteorological data through the calculation. The estimated ET values were ranged from 2.2 mm/day when solar radiation was 250 ly/day to 3.9 mm/day when solar radiation was 430 ly/day (Hsu, 1991). Shortage in rainfall reduced the yield and quality of pangola grass. Irrigation based on climate conditions could increase the yield for 54.3% (Yu et al., 1992).

Study on relationship between climatic factors and tea showed that base temperature for tea was about 6.4°C for Chinhsin Wulong and 3.7°C for Tai Tea 12. Suitable planting area based on thermal index and rain-temperature quotient for Chinhsin Wulong were 140-200 and 7.5-15, respectively (Chen, et al., 1991). Also hot wind could also reduce 10 to 80% in tea yield and 10 to 50% in tea occurrence of hot wind might be the only measure to recover the losses (Chang and Wei, 1991). Tea grown at mountain area with sea level higher than 1500 m would result in low production even the climate conditions were favorable the quality of tea (Chen, 1992). Processing of tea was also affected by climatic factors such as temperature, relative humidity, and wind. Temperature of 23-26°C and relative humidity of 75-80% were good for wilting process of tea (Yuan and Lin, 1992). Growth and development of black pepper were mainly affected by temperature, solar radiation and rainfall. Sun burn in black pepper can be prevented by shading (Hsu, et al., 1992).

Oxygen content in fishery pond was also affected by climatic factors such as air temperature and water temperature. However oxygen content was not affected by air pressure (Hsieh et al., 1992).

CONCLUSION

Agriculture production in Taiwan is not so stable due to the unfavorable meteorological environment. For ensuring the safety in agriculture production more research activities are needed. Since the systematic and well-organized studies in agrometeorology is at the beginning stage more researchers are encouraged to join this research program. With better observation and measurement equipments, enough grants for research projects, and correct research direction, the success of agrometeorological studies can be expected in the near future.

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